TANAUAN CITY COLLEGE

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SMART RIDING HELMET FOR ANGKAS DRIVERS

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ENDORSEMENT FORM

In partial fulfillment of the requirements for the **Degree of Bachelor of Science in Computer Engineering,** this capstone project entitled **Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers** prepared and submitted **by Abigael S. Bucala, Heart Princess G. Gonzales, Chienkie V. Macasinag, Cristel Mae P. Olano, Stanford T. Vispo** is hereby recommended for oral examination.

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GRAMMARIAN CERTIFICATE

This is to certify that the thesis **Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers** prepared and submitted **Abigael S. Bucala, Heart Princess G. Gonzales, Chienkie V. Macasinag, Cristel Mae P. Olano, Stanford T. Vispo** whose research design is developmental, was subjected to Grammar Editing at Tanauan City College by undersigned.

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THE PROBLEM AND ITS BACKGROUND

Introduction

In the next few years, the number of motorcycle riders working for ride-hailing services such as Angkas is expected to continue increasing, especially in busy and fast-growing provinces like Batangas. As communities expand and traffic congestion worsens, many commuters now prefer motorcycles because they offer a quicker and more convenient way to travel. Motorcycle ride-hailing services have become an essential part of daily transportation for many Filipinos, providing a practical alternative to traditional public transport. Riders can navigate congested roads more easily, helping passengers arrive at their destinations faster. This growing dependence on motorcycle transport reflects how people today value speed, efficiency, and accessibility.

However, this rapid growth also brings major challenges, particularly when it comes to road safety. Motorcycle riders are among the most vulnerable road users because they lack the physical protection that cars provide. Even minor collisions can cause serious injuries. As more riders join platforms like Angkas, ensuring their safety and the safety of their passengers has become more important than ever. The progress of motorcycle-based transportation must be matched with strong efforts to reduce risks and protect those who rely on these services.

In the Philippines, motorcycle accidents remain a significant road safety concern. Many accidents are caused by preventable human errors, such as speeding, riding under the influence of alcohol, distracted driving, improper overtaking, and poor road awareness. According to the Philippine National Police Highway Patrol Group, around 87 percent of motorcycle crashes involve reckless behavior. In 2024, more than thirty-one thousand vehicular crashes were recorded nationwide, showing a notable increase from the previous year. Over a third of these incidents involved motorcycles, with Metro Manila alone reporting more than twenty-two thousand cases. These alarming numbers highlight the risks that come with motorcycle riding, especially for those who work long hours on the road.

For Angkas riders, the risks are even greater because their jobs require them to travel constantly through heavy traffic and stressful road conditions. Many riders feel pressured to complete more trips in order to increase their income, which can sometimes lead to unsafe driving habits. Although Angkas provides safety training and retraining for riders involved in accidents, the everyday realities of their work still expose them to fatigue and stressful situations. Many riders also use motorcycles and helmets that lack built-in safety features, making them even more vulnerable to accidents. Studies show that wearing a helmet can reduce the risk of death by 42 percent and serious head injury by nearly 70 percent. Enhancing the capabilities of helmets with smart technology could further protect riders from harm.

Because of these risks, there is an increasing need for innovations that promote rider safety without interfering with their daily routine. Smart helmets have emerged as a promising solution in many countries. By equipping helmets with sensors and communication systems, they can monitor the rider's condition, detect unsafe situations, and automatically send alerts during emergencies. Since helmets are already part of the rider's required gear, adding technology to them offers a practical approach to improving road safety.

This study proposes the development of a solar-powered smart helmet designed specifically for Angkas riders. The helmet includes two main safety features. The first is an alcohol detection sensor that checks whether the rider has consumed alcohol before riding. If alcohol is detected, the system can issue warnings or prevent the motorcycle from operating. This directly addresses one of the most common causes of accidents and supports Angkas' strict no-alcohol policy.

The second feature is a GPS-based emergency alert system. In the event of an accident or sudden impact, the helmet can automatically send the rider's location to emergency contacts or authorities. This is crucial because delayed medical response can worsen injuries. By sending immediate alerts, the system helps ensure that riders receive assistance as quickly as possible.

A unique feature of this project is the use of solar energy. Angkas riders spend long hours outdoors, making solar charging ideal for powering the helmet's components. Many riders do not have access to charging stations during work hours, so relying on electricity alone can be inconvenient. By using built-in solar panels, the helmet can recharge throughout the day, ensuring continuous functionality. This not only improves the reliability of the smart features but also supports environmental sustainability by reducing the need for electrical charging. Interviews and observations reveal why this project is necessary. According to the Basic Occupational Health and Safety division of Angkas Batangas

Objectives of the Study

The main purpose of this study is to design and develop a smart riding helmet equipped with solar-powered, alcohol detection and GPS-based emergency alert features for Angkas drivers. Specifically, this study aims to:

1. Develop a solar-powered helmet system that integrates sustainable energy to ensure continuous functionality of smart safety features without relying on external charging.
2. Design and integrate an alcohol detection system within the helmet that monitors the driver's breath in real-time, preventing impaired driving and promoting road safety.
3. Implement a GPS-based emergency alert mechanism that automatically sends the driver's location to emergency contacts or authorities in case of accidents or unusual conditions.
4. Integrate an audio recording system to record real-time sound during rides, providing evidence in the event of accidents and supporting driver accountability and safety monitoring.
5. Assess the system's performance in terms of accuracy, reliability, and efficiency in enhancing rider safety, in accordance with the ISO/IEC25010 quality model.

Significance of the Study

The creation of a solar-powered smart riding helmet with GPS-based emergency alert systems and alcohol detection holds profound importance for improving road safety, especially for motorcyclists using ride-hailing services

As a result of the study, the following will benefit:

The Angkas Drivers – This study will enhance safety for Angkas rivers by providing them with a helmet that can detect alcohol, prevent peration when intoxicated, and enable quick emergency response through GPS alerts. This will help reduce accidents, ensure responsible riding, and offer peace of mind while on the road.

The Passengers – Passengers will benefit from greater security, knowing that their driver's sobriety is checked before each ride and that emergency services can be quickly contacted if an accident occurs.

The Angkas Company – Angkas as a company will see improved reputation and passenger trust by investing in innovative driver-safety measures. The adoption of such technology aligns with industry safety standards and can support company policies on responsible service.

The Community and Road Safety Authorities –The study supports efforts to lower the incidence of road accidents and alcohol-related injuries in the community. It also provides authorities a tool to promote compliance with road safety regulations.

The Researchers – The project will encourage researchers to develop practical and sustainable technological solutions to real-world problems by integrating solar energy, sensor technology, and IoT for social benefit.

Future Researchers – This work serves as a reference and starting point for further innovations in the field of smart transportation and safety equipment, inspiring new studies and technological advancements.

Scope, Limitations and Delimitations of the Study

This section presents the scope, limitations, and delimitations of the study, which focuses on the development of a Solar-Powered Smart Riding Helmet with Alcohol Detection and a GPS-Based Emergency Alert System for Angkas drivers. It also examines how the device can improve driver safety and help prevent accidents. The study investigates the helmet's effectiveness in promoting safe driving while focusing on possible limitations and specific areas such as the helmet's features, performance, and impact on the safety of a given group of Angkas drivers.

Scope

The system was designed to develop a Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert System connected to a central monitoring system for Angkas drivers. The helmet is equipped with an MQ-3 alcohol sensor that measures the alcohol level in the rider's breath. When the rider exhales near the sensor, the system detects and calculates the alcohol concentration. If the detected level exceeds the set safety limit, the ESP32 microcontroller sends a signal to the connected monitoring system and triggers a warning alert to inform the rider and the authorities about the unsafe condition. This feature aims to minimize the number of road accidents caused by drunk driving. The helmet also integrates a GPS-based emergency alert system capable of detecting the rider's exact location. In the event of an accident or emergency, the helmet communicates with the central monitoring system to automatically send location coordinates to the rider's pre-registered emergency contacts via a wireless communication module. The entire setup is powered by a solar panel, which serves as a renewable and eco-friendly energy source to ensure continuous operation. This reduces the need for frequent charging and promotes energy sustainability.

Limitations

The MQ-3 alcohol sensor may produce inaccurate readings when affected by external factors such as cigarette smoke, perfume, air pollution, or other gases. The accuracy and speed of the GPS system depend on satellite connectivity, which can be affected by poor signal reception in tunnels, highrise areas, or during bad weather. The performance of the solar charging system is dependent on the availability of sunlight, which may decrease during cloudy, rainy, or nighttime conditions. The connection between the helmet and the system also relies on wireless signal stability, which can occasionally experience delays or interruptions. The prototype is designed specifically for motorcycle helmets, and only minor modifications could allow adaptation to other helmet types. Moreover, the system focuses mainly on alcohol detection, GPS tracking, and accident prevention. It does not include health-related monitoring such as fatigue, heartbeat, or drowsiness detection. Real-time internet-based tracking is also not included due to limited connectivity and resources.

Delimitations

The research focuses on Angkas drivers as the main users taking into account that safety risks are part of their daily operations and that they are exposed to road dangers. The setup is restricted to the monitoring of alcohol and speed levels, as well as to other non-heath and non-data-analytics functionalities. The over speed warning system only alerts the driver, as it only sends notifications, it does not even take control of the motorcycle nor does it limit its speed automatically. The solar panel used in the helmet is a small 5V unit which can only supply the internal electronic components and is not meant for charging any external device. The experimentations and evaluations will take place in controlled and pre-selected road settings, in this way the trials of the prototype will be consistent and safe. The research project does not involve large-scale implementation, commercial deployment, or certification for actual road use as it is solely for research and academic purposes..

Definition Of Terms

This section provides the definition of key terms used in this study to helpthe reader understand the technical language and concepts related to the development of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers. By establishing clear and precise meanings, this section minimizes confusion and enables a more accurate interpretation of the study's objectives, design, and outcomes.

Alcohol Detection- A process of identifying the presence of alcohol in a rider's breath or system. It serves as a preventive measure to reduce accidents by discouraging impaired driving and promoting responsible riding behavior.

Emergency Alert System - A safety feature that automatically sends notifications to emergency contacts or authorities when an accident is detected. In this study, it uses GPS to share the rider's location for faster response and medical assistance.

ESP32 - An open-source microcontroller board that acts as the central processor of the system. It features built-in Wi-Fi and Bluetooth connectivity, enabling wireless communication. TheESP32 interprets inputdata,executes programmed instructions, and controls system outputs, making it crucial for automating and connecting the smart helmet's functions.

Renewable Energy – Energy that comes from natural sources such as sunlight and is continuously replenished. The study uses solar energy as a renewable power source to operate the helmet sustainably and reduce energy costs.

Smart Helmet – A technologically advanced helmet that integrates safety and monitoring features such as alcohol detection and GPS-based alerts. It enhances rider protection by combining traditional headgear with smart technology.

Chapter 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents a comprehensive review of literature and studies related to the development of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers. The review focuses on key areas that support the conceptual and technical framework of the study, including solar-powered systems, alcohol detection technologies, GPS-based emergency alert mechanisms, and smart helmet innovations. By examining previous research and existing technologies, this chapter aims to establish the relevance, feasibility, and necessity of the proposed system in enhancing rider safety and promoting responsible driving practices.

Emergency Alert System

According to Sasirekha et al.introduced a Smart Helmet with Emergency Notification System (SHENS) designed to detect motorcycle accidents and immediately send GPS coordinates to emergency responders. The helmet integrates multiple sensors, such as accelerometers and impact sensors, to monitor motion and detect collisions. Upon detection, the system triggers a GSM module that transmits an SMS containing the accident's GPS coordinates to pre-registered emergency contacts. This system operates autonomously, ensuring that alerts are sent even when the driver is unconscious. The research highlights the crucial role of combining GPS tracking and GSM communication for quick and accurate location reporting. The SHENS model's simplicity and effectiveness demonstrate how similar technology could be applied in helmets used by Angkas drivers to ensure immediate assistance after a crash.[1]

According to Alsayaydeh et al.a comprehensive accident detection and alert system published in the International Journal of Advanced Computer Science and Applications (IJACSA). The system integrates accelerometer sensors, GPS, and GSM modules for real-time detection and reporting of accidents. One notable feature is the false alarm prevention mechanism, which includes a manual "cancel" button that allows the user to stop unnecessary alerts. The system architecture focuses on reliability, speed, and scalability. The researchers highlight that incorporating cloud technology and user-friendly interfaces can further enhance communication between the system, emergency services, and users. This design model can be effectively adapted to Angkas helmets, providing drivers with a smarter and safer riding experience through real-time monitoring and emergency coordination.[2]

A study by Rao et al. a vehicle accident alert system that uses an accelerometer to detect collisions and a GPS module to pinpoint the vehicle's exact location. Once a collision is detected, the system transmits the GPS coordinates via GSM SMS to registered contacts. The researchers stressthat automation eliminates the dependency on human action during emergencies, especially when victims are incapacitated. Moreover, their experiment proved that the GPS module provides accurate positioning with a small error margin, even in areas with weak signal coverage. This is especially relevant for Angkas drivers in the Philippines, who often operate in both urban and semi- rural environments. The study confirms the potential of combining sensor- based detection with GPS-enabled messaging to provide life-saving alerts within seconds.[3]

Similarly, Amin et al. proposed an Automatic GPS-Based Vehicle Alert and Emergency System that monitors vehicle movements and detects sudden stops or abnormal speed variations. When an accident is suspected, the system transmits the exact location to predefined contacts. Their findings highlighted that GPS and GSM integration is an effective and low-costsolution for real-time accident alerting.[4]

In another study, Varshini et al.combined alcohol detection, accident monitoring and gps tracking in their smart helmet for accident detection and alert using iot. the helmet automatically sends the rider’s live location to an emergency contact when a crash occurs. This system demonstrates how integrating multiple sensors with GPS enhances safety for motorcyclists.[5]

Pooja S. Ingle and N. B. Mapari developed a real-time accident detection and tracking system that integrates both GPS and GSM modules. Their system uses an accelerometer sensor to detect a sudden change in acceleration, which indicates a possible collision. Once an accident is detected, the GPS module retrieves the exact geographical coordinates, while the GSM module transmits an alert message containing the location to predefined emergency contacts. The researchers emphasize that manual reporting after a crash can be impossible if the driver is injured or unconscious, so automation is crucial. The prototype successfully transmitted accurate coordinates and achieved fast alert delivery. This study demonstrates that combining automated accident sensing with GPS-based alerts can provide critical assistance in time-sensitive road emergencies, a concept directly applicable to Angkas drivers who frequently travel through high-traffic zones. [6]

Dashora, Sudhagar, and Marietta proposed an Internet of Things (IoT)-based accident detection framework that leverages cloud technology, GPS, and GSM modules for real-time accident reporting. Their system collects data from accelerometers and gyroscopes to detect collisions. Once an accident occurs, the system sends GPS coordinates and relevant data to a cloud server, which can be accessed by emergency services or family members. The study's IoT framework demonstrates how large-scale accident monitoring can be achieved using existing mobile networks and low-cost hardware. The researchers highlight the advantage of IoT integration: it enables data storage, remote monitoring, and trend analysis, which could be valuable for companies managing large fleets, such as Angkas. For instance, Angkas could employ similar IoT-based systems to monitor driver safety, log incidents, and generate reports for safety analytics. [7]

In another study, Kaul, Mehta, Saha, and Chandra created an Accident Alert and Vehicle Tracking System that uses GPS data to detect and track vehicles after a crash. The system automatically detects an accident, identifies the location using a GPS module, and communicates the data via GSM to emergency services and nearby hospitals. The authors emphasized the importance of real-time vehicle tracking for reducing delays in rescue operations. Their design includes a microcontroller for processing sensor input, a GPS module for obtaining coordinates, and a GSM module for communication. They also integrated a web-based dashboard that allows authorities to track the location in real time. For Angkas operations, this framework could serve as a blueprint for integrating a centralized monitoring platform that tracks active drivers and instantly notifies support teams during emergencies, improving both safety and accountability. [8]

Another significant contribution by Mounika Jammula, Kiranmai D., and Divya R., titled Accident Alert and Vehicle Tracking System Using GPS and GSM. The researchers developed a system designed to send an automatic alert to emergency contacts whenever an accident is detected. The system architecture consists of a vibration sensor connected to a microcontroller that monitors sudden changes in motion. When an impact occurs, the microcontroller activates the GSM module to send an alert message containing GPS coordinates of the vehicle's location. The message is transmitted in real time, allowing rapid dispatch of assistance. [9]

Febi Ramadaniati conducted a study titled The Design of Accident Detection and Tracking Systems on Motorcycles, which focuses on creating a device capable of detecting motorcycle accidents and tracking the exact crash location. The system utilizes several key components: vibration and tilt sensors to detect impact or imbalance, a GPS module to capture real-time coordinates, and a GSM module to transmit emergency messages containing the location link. When the motorcycle experiences a collision, the sensors immediately activate the communication module to send the coordinates to the rider's emergency contacts. This allows family members or responders to locate the accident site accurately and quickly. The study evaluated the performance of the GPS module in various environments to test its accuracy and reliability. Results revealed that the system achieved an average positional error of only 2.97 meters, proving its suitability for real-time tracking. The research concluded that the integration of GPS and GSM modules significantly reduces response time and improves the chances of immediate rescue. This study is particularly relevant to Angkas drivers because it provides a tested model for real-time crash detection and emergency notification that can be adapted to motorcycle-based ride-hailing operations. Angkas drivers, who often navigate through congested urban streets, are vulnerable to minor collisions and sudden falls. The GPS-based alert mechanism demonstrated by Ramadaniati could be embedded into smart helmets or mobile devices to ensure that an emergency alert is sent automatically in case of an accident. Moreover, the precision of GPS tracking identified in this study supports the practicality of implementing similar technology in the Philippine context, where accurate location information is essential for emergency response units. [10]

Smart Helmet Systems

According to Gupta et al. investigated an IoT-based smart helmet that incorporated sensors for helmet detection and alcohol monitoring to prevent drunk driving. Their work emphasized the role of sensor integration in enhancing traffic safety by ensuring that riders adhere to safety protocols through automated system responses. [11]

According to Rahman and Das developed a smart helmet equipped with impact sensors and Bluetooth communication modules capable of automatically sending accident alerts to emergency contacts. Their results showed reduced emergency response time through real-time notifications, though they identified frequent battery charging as a key limitation, suggesting solar energy as a potential solution. [12]

A study by Patil et al. presented a smart helmet combining alcohol detection, drowsiness sensing, and GPS tracking, transmitting real-time alerts via Bluetooth and the internet. Their findings revealed that the system effectively reduced accidents caused by fatigue or intoxication, but its continuous battery dependency limited long-term operation, especially in heavy-traffic conditions. [13]

Kumar et al. designed a helmet featuring vibration sensors for accident detection and GPS/GSM modules for transmitting emergency alerts. The inclusion of an alcohol sensor allowed ignition prevention under unsafe conditions. While the system provided efficient real-time responses, the researchers noted its dependence on consistent power sources, motivating the integration of renewable energy such as solar charging. [14]

Singh et al. introduced The Smart Helmet System: Enhancing Rider Safety through IoT and Sensor Integration, which used an ESP32 microcontroller to manage sensors for helmet wearing, one-hand detection, alcohol sensing, and accident monitoring. The system prevented ignition when unsafe behaviors were detected and sent alerts via Telegram. However, high power consumption posed a challenge, especially for professional drivers operating for extended hours. [15]

According to Nair and George proposed SHelmet: An Intelligent Self-sustaining Multi-Sensors Smart Helmet for Bikers, integrating solar and kinetic energy harvesting mechanisms with various sensors such as accelerometers, alcohol gas, light, and temperature sensors. Their system demonstrated reduced battery dependency, though increased helmet weight and cost were cited as trade-offs. [16]

Rodriguez et al. designed a Smart Helmet for Accident Prevention and Alcoholic Detection system that verified both helmet wearing and sobriety ignition. The helmet effectively prevented risky riding behavior but faced limitations in continuous power availability and sensor reliability in adverse environments such as rain and dust exposure. [17]

A study by Fernandez et al. developed a Smart Helmet Prototype for Safety Riding and Alcohol Detection that included alcohol and drowsiness detection sensors, GPS tracking, and GSM-based accident alerts. Their prototype successfully detected unsafe riding conditions but required frequent recharging, reducing practicality for long-distance riders. [18]

In another study by Sinha et al. implemented a Smart Helmet for Alcohol and Drowsiness Detection using a Raspberry Pi controller with IR sensors, alcohol monitoring, and GPS tracking to observe rider behavior. Although effective in accident prevention, the study noted performance degradation and short battery life under tropical climates, suggesting the need for solar-based power solutions. [19]

According to Reyes and Tan presented a Smart Helmet System for Advanced Safety Using IoT, integrating infrared sensors for helmet wearing, accelerometers for accident detection, alcohol sensors, GPS, and GSM modules for alert notifications. The researchers observed high power consumption when all modules were active, limiting long-term usability. They recommended the inclusion of solar panels to support continuous safety monitoring for ride-hailing drivers such as Angkas operators. [20]

The Smart Helmet: Alcohol Detection and Sleep Alert design detects alcohol consumption using an MQ-3 sensor and monitors rider consciousness using heart-rate or similar sensors. When unsafe conditions are detected, alerts are generated, and in some models, the helmet restricts vehicle operation. However, the study reported reduced sensor accuracy in dim light and environmental interference due to humidity and temperature, as well as frequent battery usage. Incorporating solar energy storage in the proposed system helps sustain safety functions during low-light conditions and minimizes downtime due to charging. [21]

Finally, the Smart Helmet using IoT to Avoid Accidents project combined speed detection through a Hall-effect sensor, alcohol detection, and GPS/GSM modules to send alerts during unsafe events. While offering valuable preventive features, the design required regular recharging and faced delays in GPS/GSM communication in low-signal areas. Considering Angkas drivers' long hours and potential travel through areas with weak signals, the solar-powered system proposed in this study ensures longer operation time and may explore redundant alert methods for reliability during connectivity loss. [22]

Alcohol Detection Technologies

Alcohol consumption before driving remains a leading cause of road accidents worldwide. Semiconductor-based alcohol sensors, particularly the MQ-3, are widely utilized for detecting ethanol concentration in a person's breath. These sensors operate based on variations in electrical resistance when exposed to alcohol vapor, making them ideal for real-time detection. [23]

An alcohol detection system was also designed to prevent vehicle ignition when alcohol concentration exceeds a predefined limit, demonstrating how alcohol sensors can enhance safety by automatically controlling the vehicle's functionality. Nevertheless, such sensors are sensitive to environmental conditions, including temperature, humidity, and other volatile gases, which may affect accuracy. [24]

GPS and Emergency Alert Systems

The integration of Global Positioning System (GPS) and Global System for Mobile Communication (GSM) modules in smart safety systems allows for real-time monitoring and emergency notification. An IoT-based accident detection system was developed to transmit the exact coordinates of the rider to predefined emergency contacts through GSM when an accident occurs. The study proved that automatic alert systems improve the timeliness of medical response and rescue operations. [25]

Another study proposed a GPS and GSM-based vehicle monitoring system that tracks both the location and movement of the vehicle, emphasizing the role of these technologies in improving road safety and reducing post-accident response delays. However, GPS accuracy may decrease in areas with poor satellite coverage, such as tunnels or dense urban regions. [26]

Solar-Powered IoT Devices

The use of renewable energy, particularly solar power, in IoT-based applications has become an effective solution to power limitations. The implementation of solar energy in wearable safety devices provides a reliable and eco-friendly energy source while reducing dependency on traditional charging methods. [27]

A solar-powered IoT weather monitoring station was developed to operate efficiently in remote areas without external power supply, confirming that solar-powered systems can sustain low-energy IoT modules such as sensors, GPS, and microcontrollers. Integrating solar energy into wearable safety devices, such as helmets, enhances system reliability and ensures continuous operation even in outdoor conditions. [28]

ESP32-Based IoT Safety Systems

The ESP32 microcontroller has gained attention for its efficient power management, built-in Wi-Fi, and Bluetooth features, making it ideal for IoT-based safety and monitoring systems.

One study utilized the ESP32 to create a wireless health monitoring device that transmitted real-time sensor data to a mobile app, proving its efficiency for

IoT applications that require both communication and processing capabilities. [29]

In another study, the ESP32 microcontroller was used in a smart alcohol detection system that employed the MQ-3 sensor to identify intoxicated drivers and send alerts via IoT platforms. The researchers highlighted ESP32's role in simplifying data transmission while maintaining low energy consumption, demonstrating its suitability for portable safety devices such as smart helmets. [30]

In a study by S. Banerjee and L. Fernandez, an IoT-based motorcyclist safety helmet was implemented using ESP32 integrated with GPS and GSM modules. The system monitored the rider's head movement, alcohol level, and helmet-wearing status. If the helmet was not worn or alcohol was detected, the ESP32 sent warning notifications to the user's smartphone. Moreover, in case of accidents, it transmitted the exact geolocation to nearby hospitals. This study demonstrated the adaptability of ESP32 in multi-sensor integration for real-time vehicular safety. [31]

A. Rahman and T. Gupta introduced an IoT accident detection system that used an accelerometer and gyroscope sensor connected to ESP32 to monitor unusual vehicle movement. The system combined GPS tracking and cloud connectivity to store event data for post-accident analysis. By linking to Google Maps through a mobile app, responders could quickly identify accident locations. The research reinforced that ESP32's Wi-Fi and Bluetooth dual-mode functionality enables efficient transmission of emergency data across multiple networks. [32]

L. Chen and P. Nair presented an ESP32-powered safety helmet for industrial and vehicular applications, incorporating alcohol, gas, and temperature sensors. The ESP32 gathered continuous sensor readings and transmitted alerts through the Blynk IoT platform. Their system proved that ESP32's compatibility with cloud-based dashboards allows for remote safety supervision and historical data logging useful for accident investigation and driver behavior analysis. [33]

In an innovative approach, D. Johnson and H. Lee developed an ESP32-based driver monitoring system integrating heart rate, temperature, and motion sensors to assess driver fitness. Data collected by the ESP32 was sent to a cloud storage service via MQTT protocol, and abnormal readings triggered alerts to authorities. This study emphasized that combining biometric sensing with IoT enhances preventive safety, particularly when integrated into wearable devices like helmets. [34]

S. Torres et al. implemented an IoT smart helmet for bikers using ESP32, GSM, and GPS modules. Their system ensured that the motorcycle would not start unless the helmet was worn, and continuously monitored alcohol levels during operation. If intoxication was detected or an accident occurred, the ESP32 sent automated SMS alerts containing the biker's coordinates to emergency contacts. The system was validated through field testing, proving its reliability and real-time functionality in traffic environments. [35]

M. Alvarez and C. Park investigated a cloud-integrated road safety system that utilized multiple ESP32 nodes to monitor vehicle speed, proximity, and environmental hazards. Their architecture relied on the Thing Speak platform for real-time data analysis and event correlation. The researchers proposed that the same model could be applied to smart helmets for city-wide traffic safety monitoring, establishing a framework for IoT-based safety networks. [36]

Finally, P. Gomez and R. Singh proposed a machine learning-enhanced ESP32 IoT framework capable of detecting intoxication and drowsiness patterns based on sensor data. The system integrated GPS for location tracking and GSM for alert notifications. Their research suggested that AI-based processing on the ESP32 or its connected cloud server could predict unsafe driving behavior, moving IoT safety systems from reactive to predictive operation. [37]

Renewable Energy

K. V. Reddy and A. K. Singh provided a comprehensive survey of solar photovoltaic (PV) technologies, covering crystalline silicon and thin-film PV modules, power conditioning, maximum power point tracking (MPPT) algorithms,anddegradation/failuremodes.Theyhighlightedadvancementsin MPPT (e.g., perturb-and-observe, incremental conductance, and adaptive neural-network MPPT) that increase energy yield under partial shading and variable irradiance. The authors underscored the importance of thermal management and real-world reliability testing to extend module life and maintain safe operation in rooftop and utility-scale installations. [38]

L. Martínez et al. examined utility-scale wind energy developments, addressingturbineaerodynamics,bladematerials,andcontrolsystemsfor maximizing capture while minimizing structural fatigue. Their work emphasized condition monitoring and predictive maintenance using SCADA and vibration analysis to enhance safety and reduce downtime. The study also discussed grid code requirements for reactive power support and fault-ride-through capability, critical for reliable integration of large wind farms into power systems. [39]

H. Zhao and M. Kumar reviewed energy storage solutions required for high-penetration renewables, comparing electrochemical (lithium-ion, flow batteries), mechanical (pumped hydro, compressed air), and thermal storage. They concluded that storage selection depends on dispatch profile, cycle life, energy density, and safety characteristics (e.g., thermal runaway risk in batteries). The paper advocated hybrid storage strategies (fast-response batteries + long-duration storage) to meet both frequency regulation and seasonal balancing needs. [40]

According to Garcia et al. investigated the design and execution of solar-poweredwearabledevicesfortrafficsafety, specificallyhow photovoltaic cells can power integrated sensors in helmets. This is particularly relevant to Angkas drivers since it explores energy-efficient methods that might lessen dependency on batteries while potentially including alcohol detection andGPS warnings to improve rider safety in urban situations. [41]

According to Kim and Lee explored alcohol detection technologies in smart helmets and discovered that breathalyzer sensors embedded in headgear could reliably identify impairment levels in real time. The study focuses on applications for ride-hailing services such as Angkas, in which GPS-based warnings might be generated upon detection, enhancing emergencyresponse methods. [42]

A study by Thompson's research on GPS-enabled emergency systems in motorbikes revealed the usefulness of location-based notifications in shortening response times during accidents. For Angkas drivers, this may be integrated with solar-powered helmets to form a seamless, energy-autonomous system that alerts authorities or family members in crisis. [43]

Patel conducted a thorough evaluation of the integration of IoT and solar energy in personal protective equipment, such as helmets. The authors noted how such systems may include alcohol sensors and GPS for drivers in underdeveloped nations, such as those employing Angkas, to reduce the dangers of intoxicated driving and navigation mistakes.[44]

According to Rodriguez and Santosperformed a field study on smart helmets with many sensors, including alcohol detection, and discovered.Their research is relevant to Angkas in the Philippines since it includes GPS warnings driven by solar energy, which might reduce deaths in high-traffic zones.[45]

In a study focused on renewable energy in wearables, Chen assessed solar-powered GPS trackers for emergency services, pointing out its potential in motorcycle helmets in a research on renewable energy in wearables. This study emphasizes how flexible such technology is for Angkas drivers, where alcohol detection may be used as an accident avoidance strategy.[46]

The user adoption of smart safety equipment in transportation, namely helmets with GPS and alcohol incorporated, was investigated by Williams et al. According totheirresearch,solar-powered modelsmight bevery usefulfor Angkas drivers since they address power sustainability and allow for quick emergency notifications.[47]

In another study, Nguyen and Tran's comparative study of helmet-based safety solutions emphasized the advantages of integrating GPS and alcohol sensors in solar-powered systems. The study demonstrated that these solutions might improve driver responsibility and emergency response efficiency in ride-sharing situations such as Angkas. [48] A solar-powered smart helmet with built-in sensors for GPS tracking and alcohold etection was evaluated by Singhetal.as part of their prototype development study. The study demonstrated how it might prevent drunk driving and enable prompt notifications in emergency situations, underscoring its applicability for urban motorcycle taxi drivers, such those in Angkas.[49]

Last but not least, Lopez conducted a policy-focused study that examined regulatory frameworks for IoT devices in traffic safety, such as solar-powered helmets with GPS and alcohol capabilities. It talked about possible applications for Angkas drivers in the Philippines, promoting the use of these technologies to lower the number of accidents caused by drunk drivers and enhance general traffic safety. [50]

Synthesis

The reviewed literature and studies highlight significant advancements in the fields of road safety technology, renewable energy integration, and smart monitoring systems. The use of solar-powered technologies, such as photovoltaic panels and energy-efficient circuits, has proven effective in providing sustainable power sources for portable and wearable devices, reducing dependency on external charging. Studies on alcohol detection systems, particularly those utilizing gas sensors and microcontroller-based analysis, demonstrate promising results in accurately detecting alcohol levels in a driver’s breath, thereby preventing impaired driving and reducing road accidents.

Furthermore, the integration of GPS-based emergency alert mechanisms has greatly enhanced transportation safety by enabling real-time location tracking and automatic communication with emergency contacts or authorities during accidents. The development of microcontroller-based systems, such as Arduino and similar platforms, has expanded opportunities for building cost-effective, reliable, and customizable smart helmets. Additionally, research on wearable safety devices and Internet of Things (IoT) applications highlights innovations in real-time data transmission, driver monitoring, and intelligent response systems that contribute to safer road environments.

Despite these technological advancements, several challenges and gaps persist. Many existing smart helmets lack sustainable power solutions,making them dependent on frequent charging or external power sources. Similarly, some alcohol detection systems exhibit limitations in accuracy or response time, particularly in outdoor or moving environments. GPS alert mechanisms, while beneficial, are often not integrated seamlessly with other safety features, limiting their effectiveness in emergency response situations. Moreover, existing helmet designs may not prioritize comfort, affordability, or user-specific needs, especially for commercial motorcycle drivers such as Angkas riders.

Addressing these gaps, the present study proposes the design and implementation of a solar-powered smart riding helmet that integrates alcohol detection, GPS-based emergency alerts, and sustainable energy features to enhance rider safety and promote responsible.

Chapter 3

RESEARCH METHODOLOGY

This chapter presents the research design used by the researchers in planning, designing, developing, testing, deploying, and maintaining the system design of this research study. Research instruments and locales were also discussed in this section. It also includes the statistical treatment of data, planning stage, designing stage, and actual design of the system.

Theoretical Background

The integration of technology in everyday safety gear has seen significant advancements, particularly in the realm of personal protective equipment. The concept of a solar-powered smart riding helmet, designed specifically for Angkas drivers, combines several cutting-edge technologies solar energy harnessing, alcohol detection systems, and GPS-based emergency alerting. This chapter delves into the theoretical foundations that underpin these technologies, illustrating their relevance and application in enhancing rider safety and promoting responsible driving.

3.1 Solar Energy Utilization

Solar energy is one of the most abundant and sustainable resources available. The conversion of sunlight into electrical energy through photovoltaic cells provides a viable energy source for electronic devices. In the context of a riding helmet, solar panels can be seamlessly integrated into the outer shell, allowing for continuous charging of internal systems while the driver is on the move. This self-sustaining energy model not only reduces dependence on traditional power sources but also ensures that the helmet remains operational even in remote areas where conventional charging facilities may be absent. The efficiency of solar panels has improved significantly over the years, with current technologies achieving conversion efficiencies of up to 22%. This advancement makes it feasible to power multiple sensors and communication devices within the helmet, ensuring that essential safety features are always functional.

3.2 Alcohol Detection System

Alcohol detection technology plays a crucial role in promoting responsible driving behaviors. Modern alcohol detection systems, often referred to as breathalyzers, utilize sensors that can detect the presence of alcohol in a person’s breath. When integrated into a riding helmet, this technology can provide real-time assessments of the rider’s sobriety.

The operation of these systems typically involves a fuel cell or semiconductor sensor that reacts with alcohol molecules, producing an electrical signal proportional to the alcohol concentration. For the helmet, an embedded breathalyzer would trigger alerts and disable helmet functions if alcohol levels exceed legal limits. This feature aims to reduce the incidence of alcohol- related accidents among riders, fostering a culture of safety and responsibility.

3.3 GPS-Based Emergency Alert Systems

The incorporation of GPS technology into a riding helmet enhances the safety net for riders. GPS tracking can provide real-time location data, which is essential in emergency situations. In the event of an accident or if a rider is incapacitated, the helmet can automatically send alerts to emergency contacts or services, including precise location coordinates.

The effectiveness of GPS technology in emergency situations has been well documented, with studies indicating that timely response can significantly increase the survival rates of injured individuals. By equipping helmets with this capability, the proposed system not only aids in immediate assistance but also enhances the overall safety of riders operating in areas with high traffic density.

3.4 Integration and User Experience

The solar-powered smart helmet hinges on the integration of these technologies to create a cohesive user experience. The design must consider usability, comfort, and the seamless interaction of the helmet's features. User interface design will play a critical role. It should enable riders to easily access and understand the helmet's functions, including alcohol testing results and emergency alerts.

Furthermore, user acceptance of such advanced technology is vital for its success. Education and awareness campaigns can help familiarize riders with the benefits and functionalities of the helmet, ensuring higher adoption rates and ultimately contributing to safer riding practices. The solar-powered smart riding helmet with alcohol detection and GPS-based emergency alerts presents a promising solution to enhance the safety of Angkas drivers. By leveraging sustainable energy sources, promoting responsible behaviors, and utilizing advanced technologies for emergency response, this innovative helmet stands to significantly reduce risks associated with riding while improving overall road safety.

Theoretical Framework

The theoretical framework guiding the development of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers is grounded in the integration of sensor technology, automation, and real-time data communication to enhance safety and efficiency in motorcycle-based ride-hailing operations. The system is designed to ensure driver and passenger safety by continuously monitoring the driver’s alcohol level, detecting accidents, and providing an automated emergency response through GPS-based alerts powered by renewable solar energy.

This research applies the Human Safety and Monitoring Theory introduced by Reason (1990) in his book Human Error, which emphasizes the importance of continuous human performance monitoring and system feedback mechanisms to reduce risks and prevent accidents. According to Reason, integrating real-time detection and feedback tools into human-operated systems can significantly minimize hazardous events caused by fatigue, negligence, or impairment. This theoretical foundation aligns with the smart helmet's goal of ensuring driver fitness, enhancing awareness, and enabling immediate assistance in the event of an accident or emergency. [51]

According to Jain et al., excessive alcohol consumption impairs motor skills and reaction time, significantly increasing the risk of accidents. Monitoring parameters such as alcohol concentration, location, and impact detection is crucial in promoting road safety, particularly among commercial riders like Angkas drivers. Therefore, incorporating an alcohol sensor in the helmet provides a preventive measure ensuring that drivers are in a safe condition before operating their vehicles. Meanwhile, GPS and accelerometer sensors enable real-time tracking and emergency alert capabilities in case of crashes or sudden falls. [52]

Optimization of the design, development, and testing of the solar-powered smart helmet can be achieved by measuring key system parameters such as sensor accuracy, power efficiency, signal stability, and response time to ensure reliability and consistency in diverse riding environments. The assessment of these parameters ensures that the system performs its intended safety functions effectively. The inclusion of solar energy technology ensures sustainability and longer device usability, minimizing dependency on external power sources—an essential feature for Angkas drivers who operate for extended hours.

The theoretical framework is also informed by public health and safety theory, which emphasizes the importance of preventing alcohol-related injuries and fatalities. The integration of alcohol detection and emergency alert systems into personal protective equipment aligns with public health initiatives aimed at reducing the risks associated with alcohol-impaired driving. The theoretical framework assumes that the use of such technology will contribute to the overall safety of Angkas drivers and reduce the incidence of alcohol-related road accidents.

The design of the helmet system is guided by the theoretical framework of human-centered design, which prioritizes user needs, usability, and safety. This approach ensures that the helmet is not only technologically advanced but also intuitive and comfortable for the rider. The theoretical framework assumes that the integration of solar power, alcohol detection, and GPS-based emergency alerts will result in a user-friendly and effective system that enhances the overall user experience and promotes widespread adoption.

The solar-powered smart riding helmet with alcohol detection and GPS-based emergency alert system is built on a foundation of renewable energy technology, smart device engineering, alcohol detection science, GPS navigation, public health research, and human-centered design. These theoretical principles collectively support the development of a safe, sustainable, and innovative solution to enhance the safety of Angkas.

Conceptual Framework of the System

The solar-powered smart riding helmet with alcohol detection and GPS-based emergency alerts is built on ideas from renewable energy, smart device engineering, alcohol sensing technology, GPS navigation, public health, and human-centered design. Bringing these principles together allows the system to function smoothly, respond quickly in risky situations, and support safer and more responsible riding habits. Overall, this approach helps create a practical and sustainable solution that aims to protect and improve the safety of Angkas riders in their daily trips.

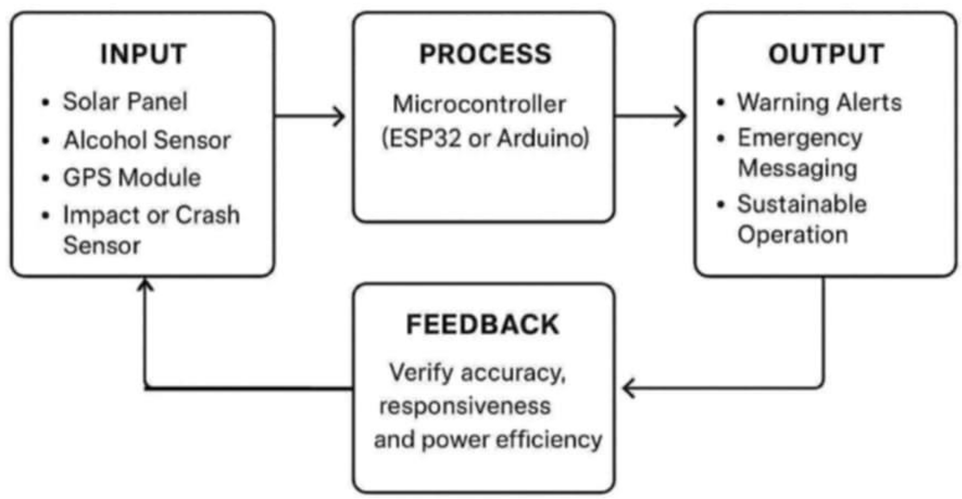

Figure 1. Conceptual Framework of the Design System

Input: The system starts with various input components that collect essential data for helmet operation. These include the solar panel, which supplies renewable energy to power the device; the alcohol sensor, which detects the rider's breath alcohol concentration; the GPS module, which tracks real-time location; and the impact or crash sensor, which monitors sudden shocks or collisions. These inputs serve as the foundation for safety monitoring and system activation.

Process: At the process stage, the microcontroller, ESP32, or Arduino receives and analyzes all incoming data from the sensors. It interprets alcohol levels, monitors for crash detection, and manages system functions. If alcohol is detected above the safe threshold, it triggers warning signals. In case of an accident, the microcontroller activates the GPS and GSM modules to send emergency alerts automatically. This processing ensures that all system decisions are made accurately and efficiently.

Output: The outputs are the visible and functional results of the system's operation. These include buzzer or LED alerts that warn the rider of alcohol detection and automatic GPS-based emergency messages sent to pre-registered contacts in case of an accident. The helmet also delivers continuous solar-powered performance, allowing sustainable use without frequent charging. These outputs directly enhance rider safety and promote responsible behavior.

Feedback: The feedback component ensures continuous system improvement and reliability. It monitors the performance of each module, especially the sensors and communication components, to verify accuracy and response time. Feedback data can be used to recalibrate the sensors, optimize power usage, and enhance the helmet's efficiency. This continuous evaluation process helps maintain the system's effectiveness, ensuring consistent safety and sustainability for Angkas riders.

Research Design

This research study utilizes a developmental research method to design, construct, and evaluate the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert System for Angkas Drivers. The researchers adopted an agile development model, composed of several key phases: requirement gathering and analysis, design, development, testing, deployment, and maintenance.

The agile framework's iterative and flexible approach allowed the researchers to continuously refine the system's design, hardware, and functionality. At each stage, adjustments were made based on testing outcomes, user feedback, and technical evaluations to ensure that the system effectively enhances safety and promotes responsible driving practices among Angkas drivers.

By using this developmental methodology, the researchers aimed to produce an innovative, user-centered, and sustainable solution that contributes to road safety, accident prevention, and emergency responsiveness through the integration of renewable energy and smart monitoring technology..

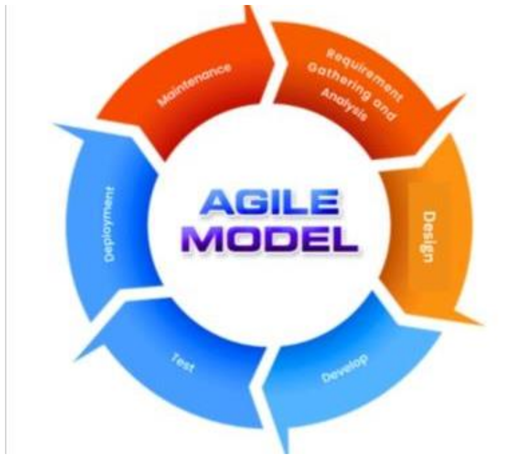

Figure 2. Agile Model

Requirement Gathering and Analysis Stage - In this stage, the researchers gathered all essential information required for developing the Solar-Powered Smart Riding Helmet aimed at improving road safety for Angkas drivers. The study began with consultations involving transportation safety experts, Angkas drivers, and road enforcement authorities. These initial consultations helped the researchers gain valuable insights into the current challenges faced by Angkas drivers, such as drunk driving, accident response delay, and helmet power limitations.

To further understand the specific needs and preferences of the target users, surveys and interviews were conducted. Particular attention was given to identifying helmet materials that ensure durability, comfort, and ventilation, while integrating the MQ-3 alcohol sensor, GPS module, ESP32 microcontroller, and solar panel for sustainable power.

In addition, the researchers conducted a thorough review of existing smart helmet technologies, alcohol detection systems, and GPS-based safety devices. They also assessed recent innovations in IoT (Internet of Things) and renewable energy integration. Furthermore, tools and instruments for measuring performance such as GPS tracking accuracy, alcohol detection response time, and solar efficiency tests were identified to evaluate the helmet's overall effectiveness.

Design Stage – In his stage, the researchers focused meticulously on designing the Solar-Powered Smart Riding Helmet, guided by the insights and data collected during the requirement analysis phase. Following interviews and surveys with Angkas drivers, the design phase commenced with careful consideration of the helmet's structure, materials, and intended safety functions.

The researchers began by selecting lightweight yet durable materials to ensure both comfort and protection for riders. Simultaneously, ergonomic considerations were made, focusing on proper head coverage, breathability, and visibility.

To validate the design, prototypes were produced and subjected to multiple tests involving Angkas drivers. These tests included alcohol detection trials, GPS signal accuracy tests, solar charging efficiency, and system connectivity checks. Feedback and performance data were collected across several trials to refine the design and ensure its effectiveness in reducing drunk-driving incidents and improving emergency response.

Development Stage - During this phase, the researchers focused on building the smart helmet system designed to enhance road safety. The process began with the careful selection of electronic components such as the MQ-3 alcohol sensor, GPS module, ESP32 microcontroller, and solar charging system. The internal wiring and circuitry were designed to integrate these components seamlessly while maintaining the helmet's comfort and safety.

The team wrote and integrated custom program codes that allowed the ESP32 to process alcohol readings, send alerts, and trigger the motor restriction mechanism when the alcohol level exceeded the safety limit. The GPS module was programmed to send real-time location coordinates to pre-registered emergency contacts during accidents or emergencies.

All hardware and software components were carefully embedded into the helmet's structure without affecting the rider's visibility or comfort. Once the system integration was complete, the program was uploaded to the ESP32 microcontroller, making the helmet fully operational and ready for testing.

Testing Stage - In this phase, the researchers assessed the helmet's overall performance and reliability. Tests were conducted to ensure that each feature—alcohol detection, GPS tracking, solar charging, and alert system—functioned accurately and efficiently.

The alcohol sensor was tested with varying levels of alcohol concentration to confirm its sensitivity and accuracy. The GPS module was tested in different outdoor conditions to evaluate signal stability and location precision. The solar panel underwent performance testing under varying light intensities to ensure sustainable charging. Durability tests were also performed to assess the helmet's resistance to heat, vibration, and moisture.

Real-world simulations involving Angkas drivers were conducted to evaluate how effectively the helmet could detect intoxication, send alerts, and operate using solar energy. The gathered data was analyzed to identify areas for improvement and optimize system responsiveness.

Deployment of the System - In this stage, the researchers ensured that the Solar-Powered Smart Riding Helmet was ready for real-world implementation. A small group of Angkas drivers were selected to use the helmet under real driving conditions. Educational sessions were conducted to train drivers on the proper use, maintenance, and purpose of the helmet.

A feedback mechanism was established to gather user experiences and identify any technical issues. The researchers also coordinated with local authorities and Angkas management to explore the potential of large-scale deployment.

Promotional efforts highlighted the helmet's role in accident prevention, environmental sustainability, and driver safety. Quality control procedures ensured that each unit maintained consistent performance before being distributed to users.

Maintenance - In this final stage, the Solar-Powered Smart Riding Helmet underwent regular inspection and maintenance to ensure long-term functionality. The hardware components—particularly the ESP32 microcontroller, alcohol sensor, GPS module, and solar panel—were tested periodically to detect any malfunctions or calibration issues.

Routine updates to the system software ensured compatibility and accuracy in real-time data transmission. Cleaning and safety checks were also performed to maintain helmet hygiene and prevent sensor obstruction.

The researchers continuously monitored system feedback to enhance performance and durability. The maintenance process ensured that the helmet remained reliable, sustainable, and effective in supporting safe and responsible driving practices among Angkas drivers..

Research Locale

This study is being undertaken in Tanauan City, Batangas, where the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert will be evaluated. The research site was chosen because of its demographic variety, large volume of motorbike traffic, and diverse climatic circumstances, making it a suitable location for evaluating the impact of safety-enhancing technology on Angkas drivers.

Preliminary discussions with Tanauan City Traffic Management Office officials and local Angkas members verified that there are no extensively adopted or distributed smart helmets with alcohol detection or GPS emergency functions. This data reveals a large gap in accessible technology solutions for motorcycle riders confronting dangers such as impaired driving and roadside crises in the area.

The findings from both the Traffic Management Office and the localized survey emphasize the importance of introducing an innovative, solar-powered helmet solution that not only improves rider safety but also incorporates real-time alcohol detection and GPS-based emergency alerts via IoT technologies. Tanauan City's diverse environment, including its congested roads and known incidence of traffic accidents among motorcyclists, provides a practical and realistic setting for assessing the efficacy of the proposed device in real-world scenarios.

Statistical Treatment

I. Sensor-Based Smart Helmet Analysis

In this section, statistical analysis is used to evaluate the performance, reliability, and functionality of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers. The study focuses on analyzing sensor-based data gathered from the MQ-3 alcohol sensor, GPS module (Neo6M), SIM800L module, and accelerometer (MPU6050). Key metrics such as Accuracy, Precision, Recall, and System Response Time are employed to determine how effectively the smart helmet detects alcohol concentration, senses motion, and sends emergency alerts during critical riding conditions. These metrics help assess how well the system functions as a real-time safety device for Angkas drivers.

ISO/IEC 25010 Model

The ISO/IEC 25010 standard was applied to assess the system's overall quality across multiple characteristics, including Functional Suitability, Usability, Reliability, Security, Performance Efficiency, and Portability. These criteria ensure that the smart helmet operates effectively, safely, and reliably under real-world conditions.

A. Functionality Suitability Test

This test evaluates whether the helmet's sensors and modules perform their intended functions — detecting alcohol accurately, tracking the driver's location, and triggering emergency alerts when necessary.

A group of selected Angkas drivers participated in a functionality evaluation to validate the system's real-world effectiveness.

The functional performance Is calculated using the following formulas:

$$\text{Percentage} = \frac{\text{Raw Score}}{\text{Perfect Score}} \times 100$$

$$\bar{X} = \frac{\sum(X_i \times F_i)}{\sum F_i}$$

Where:

- X¯\bar{X}X¯=Mean performanc erating
- XiX_iXi = Value of each rating
- FiF_iFi = Frequency of responses minimal errors

Table 1. 4-Point Likert's Scale

NUMERICAL SCALE	WEIGHTED MEAN INTERVAL SCALE	MEAN DESCRIPTION EQUIVALENT
4	3.26 - 4.00	STRONGLY AGREE
3	2.51 - 3.25	AGREE
2	1.76 - 2.50	DISAGREE
1	1.00 - 1.75	STRONGLY DISAGREE

B. Usability

Usability testing focuses on how comfortable, intuitive, and easy to use, the helmet is for Angkas drivers during normal operation. Respondents were asked to rate the helmet's usability after hands-on trials involving the detection and alert functions.

Metrics include comfort, design ergonomics, interface simplicity, and user satisfaction. A high usability rating confirms that the helmet is suitable for daily use without causing distraction or discomfort.

C. **Reliability**

Reliability testing examines the consistency and durability of the smart helmet over extended operation. Trials included repeated alcohol detection tests, long-duration GPS tracking, and emergency alert activations.

Fault tolerance tests were conducted by intentionally disconnecting sensors, simulating low battery levels, and observing whether the system recovered automatically. The helmet’s stable performance under varying conditions validates its dependability for continuous rider use.

D. Security

Security testing ensures that all data transmitted via the SIM800L and stored in the microSD card are protected against unauthorized access. Encryption and authentication mechanisms were tested to ensure the confidentiality and integrity of GPS coordinates and alert messages.

Network communication was monitored using diagnostic tools to verify secure data transmission under the ISO/IEC 25010 Security criteria.

E. Performance Efficiency

. Performance efficiency measures how effectively the system uses power from the solar module and battery while maintaining fast response and stable operation. This includes testing the power consumption rate, alert sending delay, and data processing speed of the microcontroller (ESP32 or Arduino).

Stress tests simulated continuous data logging and multiple alerts to ensure sustained performance without overheating or lag.

F. Portability Test

Portability testing evaluates the helmet's adaptability across different weather, lighting, and network conditions. Tests were conducted under varying sunlight intensities and GPS signal strengths to verify stable performance. The helmet's lightweight and modular design ensure that it remains functional for various users and environmental setups..

Planning Stage

The researchers began by identifying the increasing number of road accidents caused by drunk driving, lack of emergency response, and inadequate safety equipment among motorcycle riders, particularly Angkas drivers. Motorcycle-related accidents are a major safety concern in the Philippines, often resulting in serious injuries or fatalities. Many of these incidents are associated with alcohol consumption, delayed emergency assistance, and the absence of intelligent safety systems.

To address these issues, the researchers proposed the development of a Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert System. This innovative helmet aims to enhance road safety, ensure immediate emergency response, and promote sustainable energy use through solar power. The system integrates alcohol detection, GPS tracking, and GSM communication modules to provide real-time monitoring and automated alerts.

The design process involved selecting reliable components capable of ensuring continuous operation, accurate sensing, and effective communication. Each module was chosen based on efficiency, compatibility, and safety. The main objective of this project is to reduce road accidents caused by drunk driving and provide timely assistance to Angkas drivers in emergencies.

Through this innovative approach, the researchers aim to produce a smart and sustainable helmet system that promotes safe driving practices and harnesses renewable energy for enhanced transportation safety.

Figure 3. ESP 32

The ESP32 microcontroller serves as the central processing unit of the helmet's electronics system. It handles data acquisition from the alcohol sensor, processes the rider's breath analysis, coordinates GPS location retrieval, and dispatches emergency alerts via GSM. Its dual-core architecture enables multitasking (sensor reading, communication, power management) while maintaining low power consumption. The embedded Wi-Fi and Bluetooth modules allow future integration or remote firmware updates. The module operates at 3.0–3.3 V, features a Tensilica LX6 dual-core processor clocked up to 240 MHz, and includes up to 520 KB SRAM and multiple interface peripherals (UART, SPI, I2C). [53

Figure 4. SIM800L GSM/GPRS Module

The SIM800L module provides the helmet's cellular communication capability, enabling SMS or data transmission of the rider's GPS coordinates and status alerts to pre-registered emergency contacts. When the alcohol sensor surpasses the safety threshold or an accident is detected, the module uses quad-band GSM (850/900/1800/1900 MHz) and GPRS data to send notifications. It operates in a 3.4 V–4.4 V supply range, supports AT command interfaces, and ensures global connectivity for riders [54].

Figure 5. MQ-3 Sensor

The MQ-3 alcohol sensor is the helmet's key component for detecting alcohol vapor in the rider's breath before engine ignition. It uses a SnO_2 (tin dioxide) semiconductor oxide layer whose conductivity increases in the presence of alcohol vapor. The sensor has high sensitivity to alcohol, is low cost, and is suitable for breath-alcohol detection, with a typical detection range of 0.05–10 mg/L alcohol concentration. The operating voltage is typically 5 V for the heater and detection circuit [55].

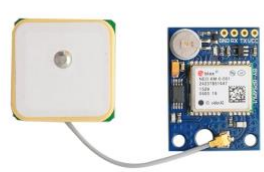

Figure 6. GPS Module (NEO-6M)

The NEO-6M GPS module provides accurate geographical positioning to facilitate emergency alerts for motorcycle riders. Upon detection of a crash or alcohol-induced impairment, the GPS module acquires satellite data to determine the rider’s latitude and longitude, which are then transmitted via the GSM module to pre-registered emergency contacts. The module supports 50 channels, has a cold-start time of approximately 27 s and a hot-start time as low as 1 s. It uses UART communication and is compatible with 3.3 V to 5 V supply voltages. With a horizontal position accuracy of approximately 2.5 m CEP (Circular Error Probability) under SBAS correction, it provides reliable localization even in dynamic driving environments [56].

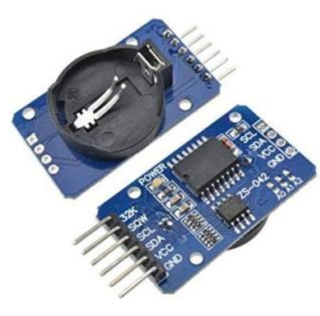

Figure 7. RTC Module (DS3231)

The DS3231 Real-Time Clock (RTC) module provides precise timekeeping for event logging in the helmet's system. Using an integrated temperature-compensated crystal oscillator (TCXO), it maintains accurate date and time even during power interruptions via its backup battery input. Time-stamps allow the system to correlate alcohol detection events, GPS alert transmissions, and system activations within a unified temporal framework. The DS3231 supports I²C communication with a 400 kHz bus, operates from 2.3 V to 5.5 V, and features an accuracy of ±2 ppm from 0 °C to +40 °C and ±3.5 ppm from -40 °C to +85 °C [57].

Figure 8. 18650 Li-Ion Battery (2200 mAh)

The 18650 lithium-ion cell serves as the primary energy storage for the helmet's electronics when solar input is insufficient — for example, during night rides or low-sunlight conditions. It provides a nominal voltage of 3.7 V and, according to the referenced datasheet, a typical capacity of 2600 mAh. Key characteristics include cylindrical dimensions (approximately 18.2 mm diameter × 65 mm length) and standard electrode voltage thresholds: full charge at ~4.2 V, cut-off discharge around ~2.5 V. The use of a protected 18650 cell ensures the system can maintain power for the microcontroller, sensors, GSM module, and GPS during extended use [58].

Figure 9. MT3608 Boost Converter

The MT3608 boost converter is used in the helmet's power system to step up battery voltage (or solar panel output) to the required voltage levels for sensors and modules when lower-voltage sources are available. With an input range of 2 V to 24 V and an adjustable output up to 28 V, this converter supports efficient power delivery while maintaining a compact form factor. It features a fixed switching frequency of 1.2 MHz, an integrated 80 mΩ MOSFET, and can reach efficiencies up to ~93% [59].

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Figure 10. TP4056 Solar Charging Module

The TP4056 module is responsible for managing the charging of the Li-ion battery within the helmet’s system, sourced from the solar panel. It provides constant-current/constant-voltage regulation, typically supports 4.5 V–5.5 V input, and up to 1 A charging current. The module includes overcharge protection, temperature monitoring, and ensures safe, reliable battery management for wearable applications like this smart helmet [60].

Figure 11. Solar Panel

The 5 V solar panel works by converting sunlight into electrical energy. It absorbs energy from the sun and converts it into direct current (DC) electricity that can power small devices or charge batteries. The 5 V solar panel is lightweight, efficient, and eco-friendly, making it ideal for portable or wearable projects like smart helmets. It provides a renewable source of energy that helps reduce reliance on non-renewable electricity. The solar panel is important because it allows the device to operate even without being plugged into a power outlet, ensuring sustainability and reliability [61].

Figure 12. HTML, JS, CSS

HTML, CSS, and JavaScript are fundamental technologies for web development, each serving distinct yet complementary roles. HTML (Hypertext Markup Language) forms the backbone of any web page by defining its structure and content. It specifies elements such as headings, paragraphs, and images, and serves as the foundation for organizing and displaying information. However, on its own, HTML provides a static layout that lacks visual appeal.

CSS (Cascading Style Sheets) enhances the visual presentation of HTML elements, adding styles like color schemes, fonts, and layout designs, making the website visually engaging. While HTML focuses on structure and CSS on aesthetics, JavaScript introduces interactivity by enabling dynamic behaviors on web pages. This includes functionalities such as form validation, animations, and data updates without needing to refresh the page.

Together, these technologies enable the creation of rich, interactive, and user-friendly websites. Their integration, however, demands careful attention to ensure cohesive and efficient design, particularly in more complex projects where maintaining clarity and usability is essential [62].

Design Stage

A. Block Diagram

In this section, the researchers present a block diagram to illustrate the functioning and workflow of the system, providing insights into the seamless interaction and collaboration of its components.

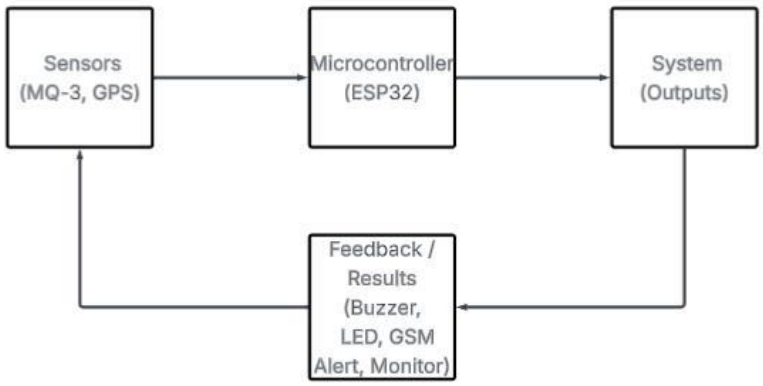

Figure 13. Block diagram

The figure illustrates the system flow of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert System. The process begins with the sensors—specifically the MQ-3 Alcohol Sensor and the GPS Module—which collect input data, such as alcohol concentration and the rider's location. These inputs are transmitted to the ESP32 Microcontroller, serving as the main processing unit of the system.

The microcontroller analyzes the sensor data and determines whether an unsafe condition, such as alcohol detection or an accident, has occurred. Based on the processed data, it activates the appropriate system outputs, such as sending an alert signal or disabling the vehicle ignition.

The resulting actions are reflected through the feedback and results components, which include a buzzer, LED indicator, GSM module (for sending emergency SMS alerts), and monitor. These outputs provide real-time notifications and visual indicators to both the rider and emergency contacts. The feedback loop ensures that the sensors and system continuously monitor and respond to the rider's condition, enhancing safety and reliability during operation.

B. Data Flow Diagram

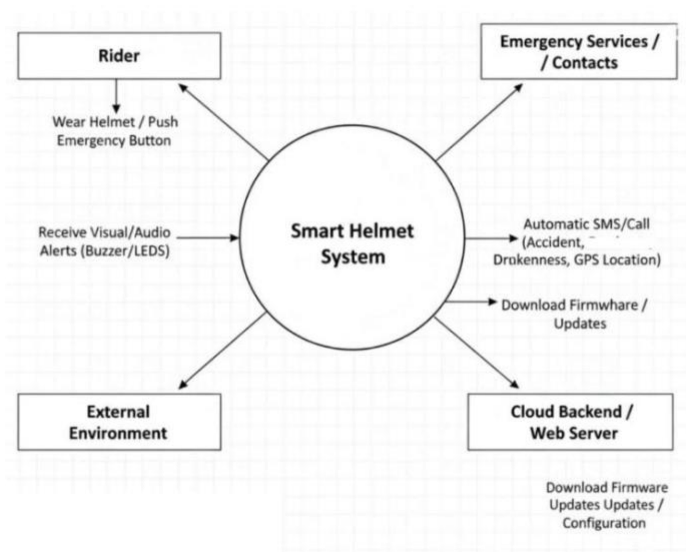

Figure 14. Data Flow Diagram

The Solar-Powered Smart Riding Helmet System is designed to enhance rider safety by integrating alcohol detection and data communication technologies. At the core of the system is an MQ-3 alcohol sensor, which continuously monitors the rider's breath for traces of alcohol. When alcohol is detected, the sensor sends this data to the central helmet system.

From there, the information is processed and distributed across multiple outputs. It is displayed on a monitor for immediate visual feedback, stored in a database for record-keeping, and transmitted to a web-based system for remote monitoring and analysis. Additionally, the data is relayed to an ESP32 microcontroller, which serves as the system’s processing hub, coordinating the flow of information and triggering appropriate responses.

This integrated approach ensures that alcohol detection is not only immediate but also actionable, supporting both real-time alerts and long-term safety tracking.

C. System flowchart

Figure 15. System Flowchart

This illustrates the safety and alert system built around the ESP32 microcontroller, designed to provide real-time monitoring and emergency response capabilities for riders. The process begins with the initialization of the ESP32, which powers on all connected sensors and communication modules, including GSM and GPS. The system first checks alcohol levels using the MQ-3 sensor. If the detected level exceeds a predefined threshold, it immediately alerts the rider through a buzzer or LED warning. If no alcohol is detected, the system proceeds to assess solar power input. When sunlight is available, it charges the battery and switches to battery power to maintain energy efficiency. In the absence of solar input, the system prepares to send an emergency alert via the SIM800L module. Next, it checks for signs of an accident. If an accident is detected, the system retrieves the GPS location and sends an SMS alert to designated contacts, while also updating a web-based system for remote monitoring. If no accident is found, the system still logs data to the web-based platform for continuous tracking. This comprehensive flow ensures that the helmet system remains vigilant, energy-efficient, and responsive to both environmental and safety-related triggers.

D. Hardware connection

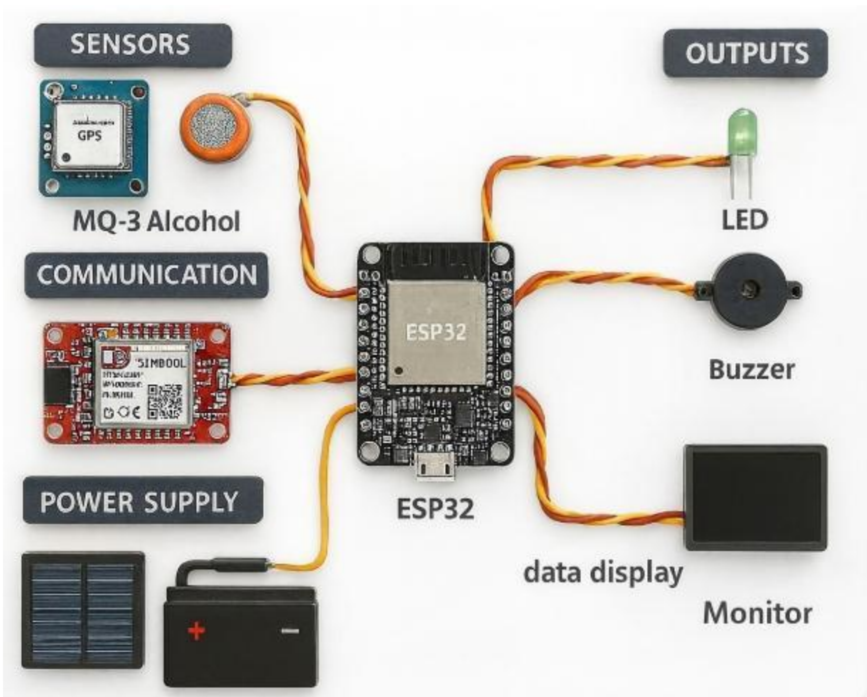

Figure 16. Hardware Connection

This GPS and alcohol detection-based alert system is built around the ESP32microcontroller,serving asthecentralhubforprocessingand control. Itintegratestwo key sensors: the NEO 6M GPS module for real-time location tracking and the MQ-3 alcohol sensor for monitoring alcohol levels. Whenthe alcohol sensor detects a level above the set threshold, the ESP32 triggers alerts through both visual and audible outputs—specifically an LED and a buzzer. These alerts are labeled as “alert” and “audible alert” respectively in the system. For communication, the SIM800L GSM module is used to send emergency messages or notifications, ensuring that critical data reaches remote systems or contacts. The system is powered by a solar.

E. Schematic Diagram

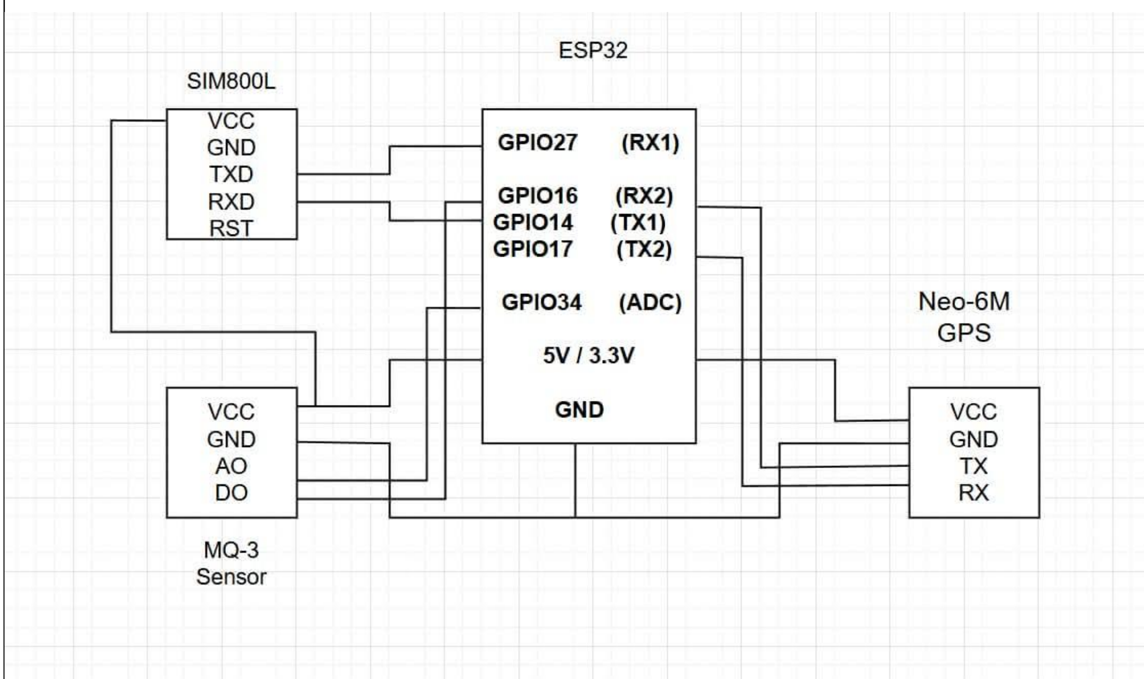

Figure 17. Schematic Diagram

This schematic illustrates the wiring configuration for a smart safety system that combines alcohol detection and GPS tracking using an ESP32 microcontroller. At the heart of the setup is the MQ-3 alcohol sensor, which connects to the ESP32 via its analog output (A0) and digital output (D0), wired to pins 36 and

39 respectively. The sensor is powered through the ESP32's 3.3V and GND pins. For GSM communication, the SIM800L module is integrated, with its RXD and TXD pins connected to ESP32 pins 17 and 16, enabling data transmission. The module's VCC and GND are linked to an external power source and ground, while its RST pin is tied to a push button for manual resets. Location tracking is handled by the Neo-6M GPS module, which connects its RX and TX pins to ESP32 pins 4 and 2, and draws power from the 3.3V and GND lines. The ESP32 serves as the central processor, coordinating inputs from the sensors and managing communication tasks, ensuring seamless integration of alcohol detection, GPS tracking, and emergency alert functionalities.

Proposed Design

In this section, the researchers elaborate on the actual system design, presenting a detailed illustration of the Solar-Powered Smart Riding Helmet with Alcohol Detection and GPS-Based Emergency Alert for Angkas Drivers. This section complements the statistical treatment by visually and structurally describing how the components—such as the MQ-3 alcohol sensor, MPU6050 accelerometer, GPS Neo-6M, SIM800L module, solar power unit, and microcontroller—interact to achieve the system's intended functionality.

The design representation aims to provide a clear and comprehensive understanding of the system's operation, particularly how sensor data are collected, processed, and transmitted to ensure real-time alcohol detection and automatic emergency alerting. By integrating both the statistical evaluation and system architecture, the study establishes a cohesive link between quantitative performance analysis and the functional implementation of the smart helmet, demonstrating its effectiveness as a reliable safety innovation for Angkas drivers.

A. Proposed Device Design

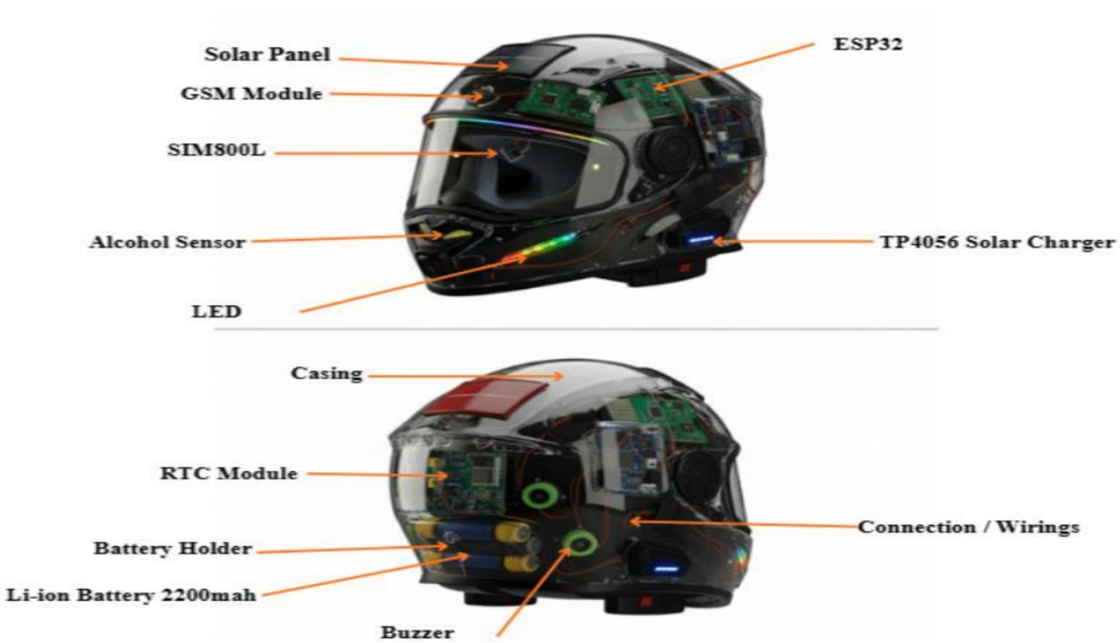

Figure 18. Proposed Device Design

This part, presents an understandable visual representation of the primary features and structure of the actual system, along with a simple design concept.

Figure 19. Proposed Design Front View

The front side of the design doesn't have any distinct features and remainsunadorned and has length of 48 cm.

Figure 20. Proposed Design Back View

The back side of the design does not have any distinct features and remains unadorned.

Figure 21. Proposed Design Right View

On the right side of the device the charging port is placed serving as the entry point for charging the internal battery.

Application UI Design

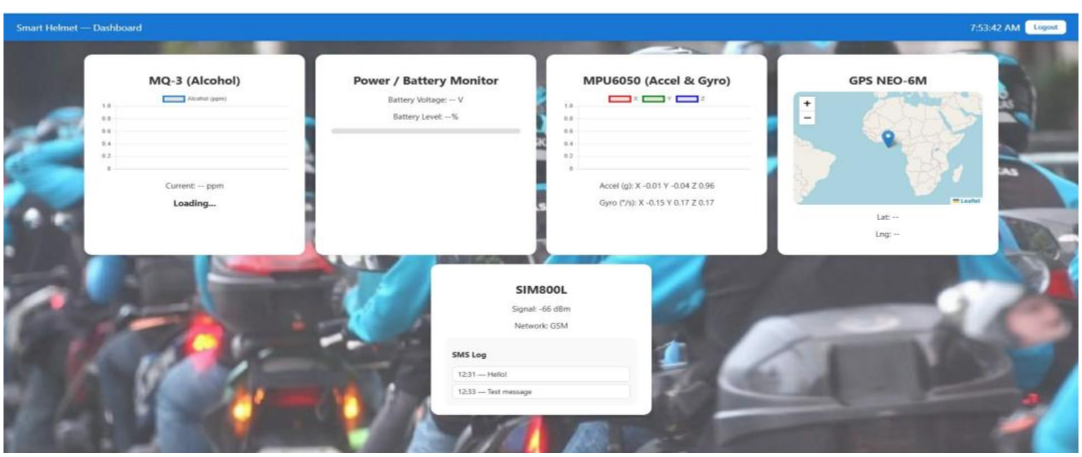

Figure 22. Dashboard

The Smart Helmet Dashboard serves as the primary user interface for monitoring and managing the system's real-time operations. It provides clear visual indicators showing the current status of key components such as the MQ-3 alcohol sensor, power and battery monitor, MPU6050 accelerometer and gyroscope, GPS NEO-6M module, and SIM800L communication system. Each module's data is displayed on separate panels to ensure organized and efficient tracking of helmet performance.

The alcohol sensor section measures the rider's breath alcohol concentration, which helps determine if it is safe to operate a motorcycle. The power and battery monitor displays the battery voltage and percentage level, ensuring sufficient energy for continuous operation. The MPU6050 panel shows acceleration and angular movement values that can detect sudden impacts or possible accidents. The GPS module provides real-time location coordinates on an interactive map, while the SIM800L panel displays signal strength and logs text messages sent during emergency alerts.

BILLING OF MATERIALS

ITEM	ESTIMATED COST
ESP 32	₱ 259
Micro SD Card Module	₱ 75
MQ 3 sensor	₱ 85
TRIPLE AXIS ACCELEROMETER	₱ 175
MICRO USB	₱ 21
SIM800L	₱ 230
LI-ION BATTERY (2200mA)	₱ 100
SOLAR PANEL 5V	₱ 100
MT 3608 Boost Converter	₱ 45
TP4056 Solar Charging Module	₱ 80
DS3231RTCMODULE	₱140
TOTAL	₱1. 310

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