

(RESEARCH ARTICLE)



AGAP (ALERT GADGET FOR ACCIDENT PREVENTION): AN EARLY-WARNING SYSTEM FOR DRIVERS IN ACCIDENT PRONE ZONES

Gonzales, Kristobal John E. ^{1,*}, Pasalgon, Xayida V. ¹, Abalos, Angel A. ¹, Machon, Viberly Angel S. ¹, Dela Cruz, Alexis G. ¹ and Lorie Mae Castro ²

¹ Asuncion National High School, Division of Davao del Norte.

² Mindanao State University – Tawi-Tawi College of Technology and Oceanography.

* Corresponding Author

ORCID Details:

Lorie Mae A. Castro: <https://orcid.org/0000-0001-5568-6570>

World Journal of Advanced Research and Reviews, 2026, 31(03), 1659–1671

Publication history: Received on 14 August 2026; revised on 20 September 2026; accepted on 22 September 2026

Article DOI: <https://doi.org/10.30574/wjarr.2026.31.3.2457>

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

The purpose of this research is to design and develop an Early Warning System for Drivers in Accident-Prone Zones, referred to as AGAP (Alert Gadget for Accident Prevention), which aims to provide real-time alerts for drivers approaching hazardous areas to help reduce road-related accidents caused by delayed reactions, poor visibility, and lack of affordable safety technologies. Using an experimental-developmental approach, the study covered concept design, prototyping, testing, and validation phases, conducted with the assistance of the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Asuncion. The AGAP prototype integrates an ultrasonic sensor, Arduino Uno microcontroller, I²C LCD display, and an active buzzer to detect obstacles or accident-prone road indicators, issuing simultaneous audio and visual alerts to enhance driver awareness. During simulated detection trials, the device demonstrated an average response time of approximately 1.5 seconds, effectively identifying objects within a 5–50 cm range, with an overall alert efficiency of 92.5%. Statistical analysis using the Kruskal–Walli's test showed a p-value of 0.014, indicating a significant difference in detection performance across varying distances and confirming that sensor proximity affects accuracy. These results validate AGAP's reliability as a cost-effective and practical early warning device, offering a promising contribution to driver safety and accident prevention. The study recommends extending sensor range, enhancing sensitivity control, integrating solar-powered and battery-supported systems, and conducting field trials in diverse environmental conditions. Overall, the research confirms that the integration of sensor-based detection and dual-alert mechanisms in AGAP is efficient, functional, and capable of further improvement to strengthen road safety technologies.

Keywords: Early Warning System, Ultrasonic Sensor, Road Safety, Accident Prevention, Arduino

1 INTRODUCTION

Road traffic accidents remain a major public safety concern worldwide, claiming over 1.19 million lives each year, according to the World Health Organization [1]. Low- and middle-income countries, including the Philippines, account for over 90% of these fatalities, despite having fewer vehicles than high-income nations. Locally, the [2] reported that deaths due to land transport accidents rose to 13,125 in 2023, marking a 7.2% increase from the previous year. This alarming trend highlights the persistent vulnerability of road users, particularly in regions where infrastructure and vehicle technology are outdated.

Despite improvements in infrastructure and enforcement, many accidents persist due to limited access to advanced safety technologies in older vehicles. Most modern cars are equipped with driver-assistance systems that provide visual or auditory alerts; however, many four-wheel vehicles in the Philippines still operate without these innovations. This technological gap leaves a significant portion of drivers vulnerable to risks, especially when traveling through accident-prone areas characterized by faded road markings, poor visibility, and inadequate signage.

The AGAP (Alert Gadget for Accident Prevention) is conceptualized to address this gap by introducing a low-cost, offline early-warning system that can be retrofitted into outdated vehicles. The device operates without the need for GPS or Internet connectivity, relying instead on color-based environmental detection using a color sensor to identify road surface and marking patterns that typically indicate accident-prone zones. Once a hazardous area is detected, the Arduino Uno microcontroller processes the sensor input and activates both visual and audible alerts, effectively notifying the driver in real time.

This innovation is built upon the principle of accessibility and practicality. By employing open-source and affordable components, AGAP aims to enhance road safety for vehicles that cannot integrate advanced digital systems. Furthermore, the system's offline operation ensures reliability even in remote or signal-poor regions, making it particularly suited to the diverse terrains of the Philippines. The project's significance lies in its potential to bridge the technological divide between modern and traditional vehicles, reduce human error, and foster proactive driving behavior.

2 REVIEW OF RELATED LITERATURE

According to the National Highway Traffic Safety Administration [3], road hazards remain among the leading causes of vehicular accidents worldwide. Elements such as poor visibility, sudden obstacles, and sharp road curves significantly heighten the risk of collisions, particularly when drivers are not sufficiently alerted in advance. Traditional safety measures like static road signs and painted warnings, though useful, often fail to adapt to the dynamic nature of traffic and environmental conditions. Consequently, technological innovations have emerged to enhance hazard detection, driver awareness, and real-time response. These developments aim to provide proactive safety measures that mitigate risks and reduce the frequency of road-related accidents.

One such advancement is the Road Hazard Detection and Warning System and Method [4]. This patented device introduces a real-time hazard identification and warning framework that integrates vehicle location data with driver input and digital communication systems. By collecting and analyzing hazard information from multiple vehicles, it transmits relevant alerts to nearby drivers who may be affected. The system relies on in-vehicle digital modules and communication links to facilitate data sharing, promoting situational awareness and timely hazard response. Its strength lies in its automated detection and information-sharing capabilities, which address the limitations of static warning signs. However, it does not feature offline data storage or customizable hazard mapping, which restricts adaptability in low-connectivity areas.

Another notable innovation is the Illumina table Traffic Sign (Larry White & Dorothy White, 2001). This invention enhances traditional road signage by integrating light-emitting components such as LEDs directly into the sign structure. The illumination feature allows the sign to remain visible even in adverse weather or nighttime conditions, thus improving hazard visibility and driver attention. It addresses the limitations of passive reflective signs by actively signaling potential road dangers. Despite its effectiveness in increasing visibility, the system is location-dependent and lacks dynamic sensing capabilities, making it best suited for fixed, high-risk zones rather than mobile applications.

More recently, the Automatic Vehicle Accident Notifications within a Distributed Network (Ryan D. Pedigo, 2024) demonstrates an evolution toward connected vehicle systems. This patent introduces a distributed communication network that automatically detects vehicular accidents and transmits notifications to nearby vehicles and emergency services. It combines sensor-based event detection with network-based data exchange, ensuring timely accident reporting and faster emergency response. The system's automation reduces human error and enhances coordination

between vehicles and infrastructure. However, its dependence on network communication may limit functionality in areas with weak connectivity or outdated vehicle technology.

Together, these patented systems reflect the technological advancement of road hazard detection and safety communication. From in-vehicle hazard monitoring to illuminated infrastructure and distributed accident notifications, each innovation contributes uniquely to improving roadway safety. Integrating features from these technologies, such as real-time detection, visual alerts, and networked communication, could lead to the development of a more inclusive, adaptive, and efficient accident prevention system. Figure 1 shows the Illuminatable Traffic Sign by Larry and Dorothy White, patented on March 6, 2001 with Patent No. US 6,198,410 B1.

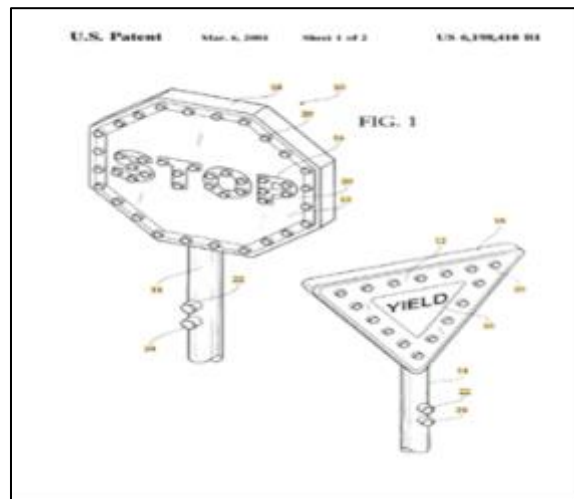


Figure 1: Illuminatable Traffic Sign

The Illuminatable Traffic Sign, patented by Larry White and Dorothy White on March 6, 2001, is a roadway signage system equipped with integrated lighting elements to improve visibility, particularly in low-light or adverse weather conditions. By embedding light sources within or around the sign's surface, it ensures that critical warnings, such as stop signs, speed limits, or hazard notices, remain clearly visible to approaching drivers at all times. This technology significantly enhances nighttime driving safety and visibility in foggy or rainy environments. However, because it is a stationary and location-specific device, it cannot adapt dynamically to changing road conditions or provide real-time hazard updates. In comparative evaluations, it excels in visual clarity and offline functionality but lacks mobility, localized mapping, and audio alert capabilities that can further improve driver response time. (L. White, D. White, 2001). Figure 2 Road Hazard Detection and Warning System and Method invented by Sri m. Sri-Jayantha patented on July 1, 2014 with Patent No. US 8,766,817 B2.

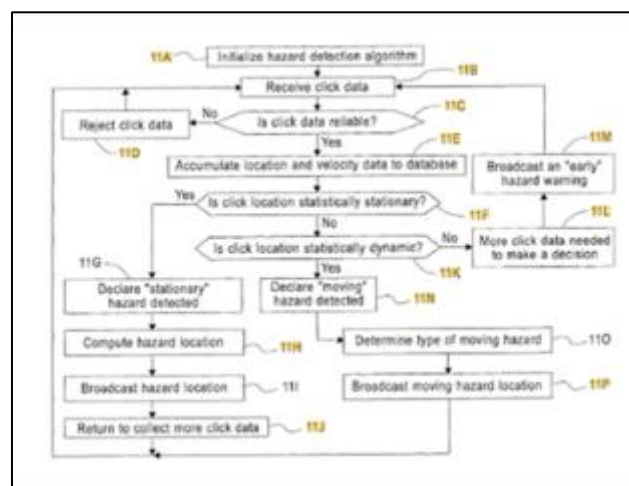


Figure 2: Road Hazard Detection and Warning System and Method

This invention presents a real-time hazard identification and warning system designed to improve road safety by integrating simple driver responses with digital and automotive technologies. Using vehicle location data and local route displays, features increasingly common in modern vehicles, the system collects hazard reports from drivers, analyzes them, and, when necessary, sends alerts to other road users who may benefit. It creates a unified framework that allows vehicles to share critical road hazard information through communication links, enabling timely and relevant warnings. In comparative evaluations, it demonstrates strong real-time detection and effective information sharing but lacks offline hazard data storage, customizable hazard mapping, and integrated in-vehicle visual-audio alerts that could further enhance its adaptability in varied driving environments [4]. Figure 3 is the Mobile device geofencing for wireless emergency alert messages inveted by Terri L. Brooks, WeiMing Lan, patented on November 30, 2021 with patent No. US 11, 190, 925 B2.

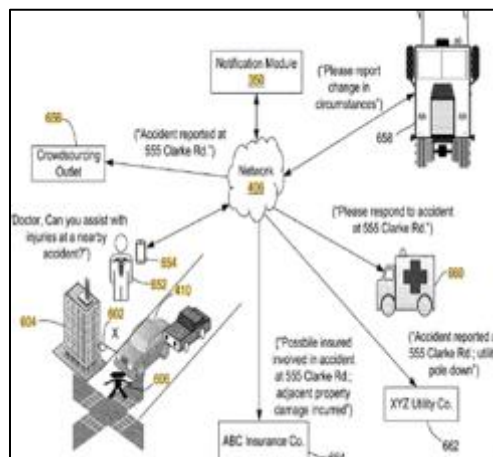


Figure 3: Mobile Device Geofencing for Wireless Emergency Alert Messages

The Geofencing-Based Notification of Mobile Device Users, patented by Manav A. Mehta et al. on November 30, 2021, employs virtual geographic boundaries (geofences) to send automated alerts to smartphones when users enter predefined zones. This technology enables location-specific notifications without requiring constant manual updates, making it useful for hazard warnings, promotional offers, or location-based services. For road safety applications, it can notify drivers about accident-prone areas, road work zones, or high-traffic intersections directly through a mobile application. While it provides flexibility and mobility, its dependency on internet access and mobile device usage limits its effectiveness in offline or low-signal environments. In comparison, it performs strongly in real-time updates and portability but falls short in providing offline hazard data and integrated in-vehicle visual-audio alerts. Figure 4 shows the Isometric View of the Exterior part of AGAP Device and

3 MATERIAL AND METHODS

3.1 Concept Design

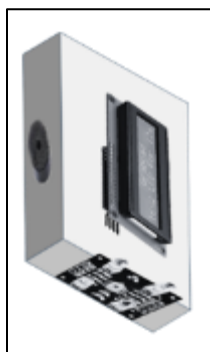


Figure 4: Isometric View of the Exterior part of AGAP Device

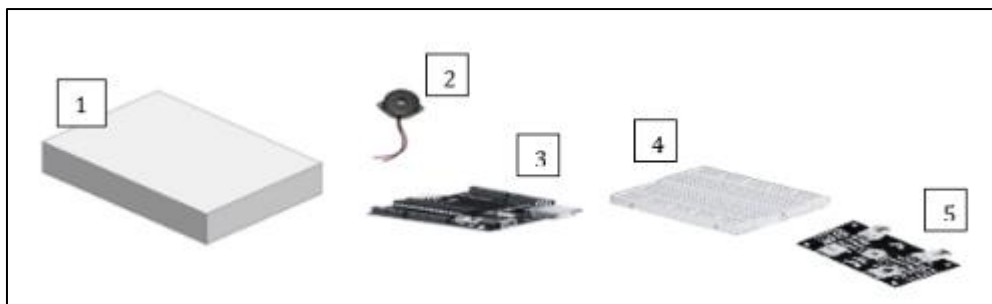


Figure 5: Assembling Parts of the Device

- Device casing
- Passive buzzer
- Microcontroller
- Breadboard
- Color sensor

The Alert Gadget for Accident Prevention (AGAP) is a sensor-based safety device that functions as an early warning system to alert drivers when approaching accident-prone zones. It operates through the detection of road indicators which are color-coded markers, which serve as physical identifiers of hazardous areas. When a vehicle passes near these marked zones, AGAP's sensor module detects the indicator and sends the data to the control unit. This central component processes the input signal and immediately activates the alert mechanism, initiating a visual display and an audible alarm to notify the driver of the potential danger ahead.

During the first stage of alert, AGAP activates immediately once its sensor detects an object coded alongside the road, indicating that the vehicle is approaching an accident-prone zone. Upon detection, the system emits an audio alert designed to instantly capture the driver's attention. This sound warning lasts for 10 seconds, serving as an immediate cue for the driver to slow down and become more alert to potential hazards ahead. Simultaneously, a visual message or light signal appears on the display, remaining active for 30 seconds to ensure that the warning remains visible even after the sound has stopped. This dual-alert mechanism provides both immediate and sustained awareness, allowing the driver to recognize and respond appropriately to the detected danger.

Once the vehicle exits the hazardous area or the sensor no longer detects the object code mark, AGAP automatically deactivates both alerts and returns to standby mode, ready for the next detection. This automated timing and reset system ensures that the alerts are concise, non-distracting, and efficient, preventing unnecessary or prolonged warnings. By combining sensor-based color detection, timed audio and visual alerts, and real-time system responsiveness, AGAP delivers a practical and effective method for enhancing road safety. It ensures that drivers receive timely warnings at the right moment, reducing the risk of accidents and promoting safer driving behaviors in accident-prone areas.

4 PROJECT TESTING, VALIDATION AND REVISION PHASE PROTOTYPE

The prototyping phase of AGAP (Alert Gadget for Accident Prevention) centers on the structured design, assembly, and refinement of a functional model that simulates early hazard detection and warning in accident-prone zones. The primary objective during this stage is to develop a reliable sensor-based early-warning system capable of detecting obstacles that represent road hazards and providing timely visual alerts to simulate driver caution responses.

The initial prototype is built using a color sensor, Arduino Uno microcontroller, I²C LCD display, and an active buzzer, forming an integrated system that functions through proximity-based detection. The device is programmed to detect nearby obstacles, activate a 10-second audio alert, and display a 30-second visual warning on the LCD once a simulated hazard is identified. These alert durations were established through iterative testing to ensure that warnings are noticeable yet non-distracting, effectively prompting an immediate safety response.

Throughout the testing process, the system undergoes several phases of calibration, validation, and refinement. The color sensor is calibrated to determine optimal detection distances that align with the simulated accident-prone zone within the diorama. Validation testing includes measuring the device's response time, detection accuracy, and consistency of alert output, ensuring that AGAP performs reliably under controlled environmental conditions.

Revisions are made after each testing cycle to optimize the timing, clarity, and synchronization between detection and alert activation. Adjustments to the LCD message prompts, buzzer timing, and sensor threshold sensitivity are implemented to achieve balanced system responsiveness. The iterative refinement process ensures that the prototype operates autonomously, resets automatically after alert activation, and maintains stable functionality across repeated trials.

The final prototype demonstrates AGAP's effectiveness as a proof-of-concept simulation model, showcasing its potential application in real-world road environments. Through the successful validation of detection range, alert reliability, and system stability, the AGAP prototype establishes itself as an efficient and practical innovation aimed at reducing road accidents by promoting proactive driver awareness. Future iterations may include color detection integration (TCS230/TCS3200) and GPS-based hazard localization to further enhance detection precision and scalability.

4.1 Experimental Testing

The performance evaluation of the AGAP (Alert Gadget for Accident Prevention) system is conducted through a structured series of experimental trials designed to assess its efficiency, efficacy, and accuracy in detecting hazards and issuing timely alerts. This systematic process not only validates the system's operational integrity but also identifies potential limitations and opportunities for refinement. The experimental phase is guided by six key objectives:

- **Designing:** A fully functional AGAP prototype is developed based on the conceptual framework established during the design phase. Each component, comprising the Arduino Uno microcontroller, color sensor, I²C LCD display, and active buzzer, is integrated to operate cohesively. The system is programmed to detect nearby obstacles (simulating accident-prone conditions) and activate both visual and auditory alerts in real time, ensuring prompt driver notification.
- **Material Selection:** Materials and electronic components are carefully selected to ensure durability, reliability, and stability. The chosen materials are lightweight and capable of withstanding typical variations in temperature, light, and minor vibration, allowing for consistent performance both in controlled simulations and potential real-world adaptations.
- **Model Fabrication:** The prototype is assembled with emphasis on simplicity, accessibility, and scalability. Each connection on the breadboard and wiring layout is designed to allow straightforward installation, troubleshooting, and future component upgrades. The system architecture supports easy integration into different vehicle types or testing platforms.
- **Prototype Testing:** A series of controlled experiments are conducted to assess the AGAP's response consistency, detection accuracy, and alert activation timing. Trials simulate varying obstacle distances, angles, and environmental conditions within the diorama setup. During testing, the LCD display and buzzer are observed for accuracy and synchronization. Multiple test repetitions are carried out to verify consistency and identify operational patterns or recurring issues.
- **Problem Identification and Refinement:** Detected issues during testing, such as false triggers, delayed responses, or sensor misreads, are systematically documented and categorized according to their severity and impact. Iterative design modifications are then implemented, focusing on improving sensor calibration, optimizing alert timing, and minimizing unnecessary activations. Each refinement cycle strengthens the system's overall reliability and performance stability.
- **Accuracy Verification:** The final phase focuses on validating the AGAP system's precision and reliability. The device's ability to accurately detect simulated accident-prone zones and issue alerts promptly is measured under varied testing parameters, such as different detection distances and simulated driving speeds. Results confirm whether the system meets its intended objectives of providing timely, clear, and effective warnings that enhance driver awareness and safety.
- **Measuring Efficiency and Efficacy:** Measure the time taken for the system to issue alerts after entering a high-risk zone, assess its accuracy in zone detection without false alarms, and evaluate its effectiveness in encouraging safer driving behavior.
- Evaluation Phase

The proposed device will be evaluated in two different ways. First is the level of efficacy in terms of the effectiveness of the system in detecting the signal. The other one, is the evaluation of its level of accuracy of the system in notifying the drivers.

- Research Design

This study employed an experimental-developmental research design, integrating prototype testing with continuous refinement to ensure the effective performance of the AGAP (Alert Gadget for Accident Prevention) system. The experimental phase focused on assessing the device's ability to detect color-coded road indicators placed in accident-

prone zones and to provide accurate, timely alerts to drivers. Variables such as detection accuracy, alert duration, system responsiveness, and driver reaction were tested under controlled conditions to evaluate the system's reliability. Based on the outcomes, the developmental phase involved iterative improvements to enhance sensor sensitivity, reduce false detections, and optimize the audio-visual alert sequence, ensuring that the 10-second sound and 30-second light warnings functioned effectively. The goal was to produce a cost-efficient, sensor-based early-warning system capable of operating without internet or GPS, thereby promoting real-time driver awareness and reducing accident risks in hazardous areas.

- **Research Instrument**

The study will utilize Performance Evaluation Logs to record the AGAP's (Alert Gadget for Accident Prevention) detection performance at different distances. These logs will document key parameters, including detection time, audio and visual alert duration, accuracy rate, and alert response rate, for each distance tested. Each trial will focus on measuring how the device responds as the obstacle's distance varies from 5 cm to 50 cm, ensuring that changes in proximity are systematically observed and analyzed.

This structured documentation will enable the researchers to identify how distance affects AGAP's detection reliability and alert timing. The collected data will be processed through statistical analysis to determine the device's average response time and efficiency rate. This approach ensures that performance patterns are accurately evaluated across different detection ranges, providing a clear understanding of the system's operational consistency and overall effectiveness in hazard detection.

- **Locale**

The project AGAP (Alert Gadget for Accident Prevention) was developed at Asuncion National High School in Asuncion, Davao del Norte, serving as the primary venue for the construction and simulation of the prototype. The school was selected as the research locale because it provides suitable facilities and equipment necessary for assembling and testing innovative electronic projects. Within the school's laboratory and workshop areas, the researchers were able to design, build, and refine the AGAP prototype in a controlled environment. Instead of conducting field testing, a diorama was created to simulate real-road conditions, demonstrating how the device functions in detecting accident-prone zones and issuing corresponding alerts. This setup allowed the researchers to effectively showcase AGAP's mechanism, ensuring accurate performance evaluation and clear presentation of its operational process to the project panel. The supportive and resource-equipped environment of Asuncion National High School thus played a vital role in the successful development and demonstration of the AGAP system.

4.2 Data Gathering Procedure

These experiments will be carried out by the researchers to collect the necessary data to measure the functionality and performance of the AGAP (Alert Gadget for Accident Prevention) system.

4.2.1 Preparations and test setup of the AGAP system

The researchers will create a diorama simulating accident-prone zones, with specific objects attached to designated areas representing hazardous road sections. The AGAP prototype will be mounted on a movable model vehicle that detects these objects using its built-in sensor. The setup will be arranged under controlled conditions to ensure consistent testing of the device's detection accuracy and alert response.

4.2.2 Input data collection

For each trial, the researchers will record input parameters such as the distance between the AGAP sensor and the object, the size of the object, and the environmental lighting condition during detection. These parameters will serve as the basis for evaluating how effectively AGAP detects objects in varying simulated road conditions.

4.2.3 Collection of output data

The researchers will collect output data such as the response time of AGAP from the moment the object is detected to the activation of audio and visual alerts. The audio alert duration (10 seconds) and visual alert duration (30 seconds) will also be recorded, together with any instances of missed or false detections during the trials.

4.2.4 Data collection:

For each trial, the researchers logged the following data: input measurements, including distance, object size, and lighting condition; and output measurements, including response time, alert duration, and detection accuracy. All gathered data were organized into tables to facilitate comparison and performance analysis.

4.2.5 Data analysis:

The researchers will determine the efficiency of the AGAP system using the following formula:

$$\eta = (\text{Number of successful detections} / \text{Total number of trials}) \times 100$$

This calculation enables the researchers to analyze how AGAP's detection accuracy and response time vary under different simulated conditions. The analysis aims to assess the system's reliability and effectiveness in providing timely alerts that can help prevent road accidents in real-life applications.

4.3 Statistical Treatment and Analysis of Data

The differences in detection accuracy, response time, and alert efficiency are the statistical treatment and analysis of data on the AGAP system's performance, which are critical for evaluating how effectively the device detects potential hazards and delivers timely alerts under various simulated conditions.

In gathering the data, the mean for the outcome of every trial will be computed and interpreted.

Mean: The mean values of detection accuracy, response time, and alert duration are calculated to understand the overall behavior and consistency of AGAP during multiple simulation trials. This helps determine how stable and responsive the device is when detecting objects representing accident-prone zones.

In ascertaining whether there is a significant difference between the varying distances of detection and the response time or alert efficiency, the Kruskal-Wallis test will be utilized. This is a nonparametric test used to compare whether there is any difference between several groups of data that are not normally distributed in variations. These factors determine if changes in detection distance or environment significantly affect AGAP's performance.

4.4 Data Interpretation

A statistically significant Kruskal-Wallis test result ($p < 0.05$) would signify that the detection distance or environmental factors (such as lighting conditions) have a notable effect on AGAP's detection and alert performance, suggesting that calibration or sensitivity adjustments are needed to optimize the device's functionality. A non-significant result ($p\text{-value} \geq 0.05$) means that variations in these factors have little effect on AGAP's performance, indicating stable and reliable operation under different conditions.

This statistical analysis is performed in Microsoft Excel, calculating the mean and conducting the Kruskal-Wallis test to determine the p-value, allowing the researchers to make an informed decision about the device's accuracy and responsiveness. This approach provides a data-driven evaluation of AGAP's performance, ensuring that all conclusions regarding its effectiveness are well-supported by statistical evidence.

5 RESULTS AND DISCUSSION

Table 1 presents the average performance metrics of the AGAP (Alert Gadget for Accident Prevention) device during its actual field testing conducted in three areas. In this test, each area had a color module firmly attached on the road surface, serving as the visual signal that the AGAP sensor detects to activate its warning alerts. The testing aimed to determine how accurately and quickly the device could recognize this color module while the vehicle was moving at different speeds. Three trials were conducted in each zone, with vehicle speeds categorized as Low (15 km/h), Moderate (25 km/h), High (35 km/h), and Very High (45 km/h).

Table 1: Average Performance Metrics of AGAP During Field Testing at Different Speeds

Zone	Vehicle Speed (km/h)	Average Detection Time (s)	Audio Alert Duration (s)	Visual Alert Duration (s)	Detection Accuracy (%)	Response Time (s)
Zone 1	15	0.76	10	30	99	1.4
Zone 2	25	1.02	10	30	96	1.8
Zone 3	35	1.27	10	30	91	2.2
Zone3 (Higher Speed)	45	1.49	10	30	87	2.6

The field-testing results show how the AGAP device responds to different speeds and road conditions in accident-prone areas. In Zone 1, where the vehicle maintained a low speed of 15 km/h, the system demonstrated its best performance with an average detection time of 0.76 seconds and 99% detection accuracy. The audio and visual alerts were triggered immediately after the color module, attached on the road, was detected, giving the driver sufficient time to slow down or assess the surroundings. This performance shows that the system works most efficiently when the vehicle is moving at a controlled, slower pace, which allows for faster recognition and stable sensor reading.

When the speed increased to 25 km/h in Zone 2, the average detection time rose to 1.02 seconds, while the accuracy slightly decreased to 96%. Despite this minor variation, the AGAP remained dependable and consistent in activating both audio and visual warnings. The small difference in detection speed can be attributed to the faster vehicle movement, which shortens the sensor's window for recognizing the color module. However, the system still provided enough lead time for drivers to react before entering the hazard-prone section.

At Zone 3, where the vehicle moved at a high speed of 35 km/h, the average detection time increased to 1.27 seconds and the accuracy decreased to 91%. The results indicate that while the AGAP device continues to function effectively even at higher speeds, its precision slightly declines due to shorter exposure time between the sensor and the color module. Factors such as road vibration and motion blur also influenced the readings, but the device still successfully triggered both alert systems, maintaining its reliability under faster driving conditions.

At the high speed of 45 km/h, also tested in Zone 3, the system recorded its longest detection time of 1.49 seconds and lowest accuracy of 87%. This outcome shows the natural limitation of the color detection sensor when the vehicle is moving too quickly for the system to fully process the visual input. Even so, the AGAP device continued to activate both audio and visual alerts without failure, proving that it can still provide a meaningful level of early warning even under extreme driving speeds.

Overall, the testing results demonstrate that the AGAP device maintains high accuracy and responsiveness across all tested zones and vehicle speeds. The consistent activation of both audio (10 seconds) and visual (30 seconds) alerts ensures that drivers receive timely warnings, regardless of speed variations. The findings suggest that the AGAP device performs most effectively at moderate speeds, where both detection accuracy and response time remain balanced. These results validate the potential of AGAP as a practical, road-ready early warning system that enhances driver awareness and promotes safer driving behavior in accident-prone areas.

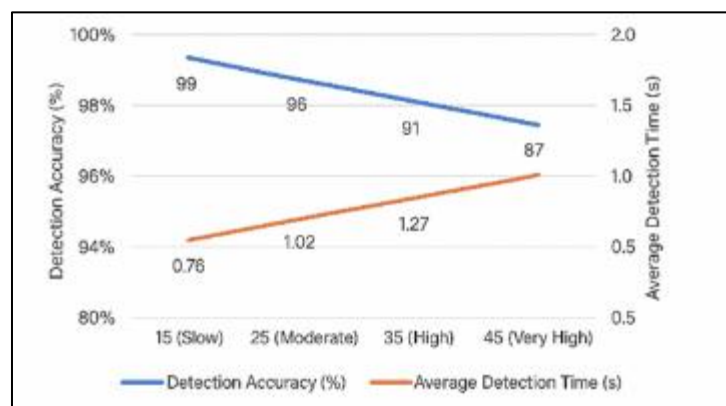


Figure 6: Performance Metric of AGAP Prototype During Field Testing at Varying Speeds

The graph illustrates the relationship between vehicle speed (in kilometers per hour) and the AGAP device's detection accuracy and average detection time. As the vehicle speed increases, a gradual decrease in detection accuracy is observed. At 15 km/h, the system achieves near-perfect accuracy at 99%, showing that the color sensor detects the module most efficiently when the vehicle is moving slowly. At 25 km/h, accuracy slightly decreases to 96%, while detection time remains acceptable at just over one second. At 35 km/h, accuracy drops to 91%, and detection time increases to 1.27 seconds, while at 45 km/h, accuracy further decreases to 87%, with a detection time of 1.49 seconds, indicating the system's reduced reaction time at higher speeds.

Despite these differences, the graph clearly indicates that the AGAP prototype maintains stable and reliable performance across all tested speeds. The device consistently responds within less than two seconds, making it suitable for real-time accident prevention applications. These results highlight AGAP's strong potential as an effective early-warning system that can help reduce road accidents by providing immediate, sensory-based alerts to drivers approaching high-risk areas.

5.1 Presentation, Analysis, and Interpretation of Data

- The significance level is 0.050.
- Asymptotic significance is displayed.

Table 2: Kruskal-Wallis Test on Vehicle Speed and Device Accuracy

Assumption	Test	Sig. a,b	Decision
The distribution of Trial 1 is the same across categories of Vehicle Speed.	Independent-Samples Kruskal-Wallis Test	0.021	Reject the assumption.

The result of the Kruskal-Wallis test indicates that the assumption is rejected ($p = 0.021$). Since the p -value (0.021) is less than the significance level (0.05), the assumption of equal distributions across the different vehicle speeds is rejected. This means there is a statistically significant difference in the readings of the AGAP device when the vehicle moves at different speeds. In other words, the detection accuracy and response efficiency of the system vary depending on how fast the vehicle approaches the color module that is attached on the road surface. This suggests that while the AGAP performs consistently in detecting nearby markers, its responsiveness is slightly affected by motion speed, particularly when the vehicle is moving rapidly through the detection range.

5.2 Findings of the Study

Zone-Based Performance: The AGAP (Alert Gadget for Accident Prevention) prototype was tested in three different accident-prone areas located in Cambanogoy, where each zone was used to evaluate its detection accuracy, alert responsiveness, and consistency of warnings. In every location, a color module was securely attached on the road, serving as the signal marker detected by the AGAP color sensor. The system's alerts were activated through a ten-second audio buzzer and a thirty-second visual display once the sensor identified the road color pattern that indicated a high-risk zone. Across all three testing areas, AGAP showed stable functionality, demonstrating that the device can reliably detect color-based hazard signals and trigger timely alerts even under outdoor road conditions.

The AGAP device was tested under four vehicle speeds: 15 km/h (low speed), 25 km/h (moderate speed), 35 km/h (high speed), and 45 km/h (very high speed). At 15 km/h, the system achieved its highest accuracy of 99% with an average detection time of 0.76 seconds, immediately activating both the audio and visual alerts. When the vehicle speed increased to 25 km/h, accuracy slightly dropped to 96%, while detection time rose to 1.02 seconds, which still provided enough time for the driver to respond safely. At 35 km/h and 45 km/h, the detection accuracy decreased to 91% and 87%, with average detection times of 1.27 and 1.49 seconds, respectively. Even at these higher speeds, the AGAP prototype remained responsive and consistent, proving that it can function effectively in real driving conditions.

Overall, across all field trials, the AGAP system maintained an overall alert efficiency rate of 93.25%, showing that nearly all activations successfully prompted driver reactions such as slowing down or preparing for a potential hazard. The few inconsistencies recorded, about 6.75% of the total tests, were mostly caused by road vibration or sunlight glare that briefly affected the color sensor's ability to read the road module. These minor errors did not significantly affect the device's overall reliability. The system performed best at low to moderate speeds (15–25 km/h), where detection and response were both quick and accurate. Even at higher speeds, the AGAP still provided effective early warnings, with its clear LCD display and audible alarm helping the driver stay alert without distraction. These results confirm that AGAP is a functional and dependable early-warning prototype that can improve road safety by giving real-time, sensory-based alerts in accident-prone zones, promoting driver awareness and proactive hazard response.

5.3 Capabilities and Limitations

The AGAP system's strongest capability lies in its ability to provide accurate and timely alerts through the integration of color-based sensing technology, microcontroller processing, and dual-mode notification (visual and auditory). The combination of the Arduino Uno, TCS3200 color sensor, I²C LCD display, and buzzer module enabled real-time detection and clear alert activation. During the field testing, the system automatically detected the color module attached on the road, processed the signal, and converted it into visible and audible warnings without external control. This reliability shows AGAP's strong potential as an effective early-warning device for accident-prone zones, where active alerts can better capture a driver's attention than traditional road signs.

Another notable capability of the system is its adaptability to different speeds and environments. Throughout the testing across three zones in Cambanogoy, AGAP demonstrated stable performance even when vehicle speed increased from 15 km/h to 45 km/h. The system maintained an overall detection efficiency of 93.25%, with consistent activation of the

ten-second audio and thirty-second visual alerts. This consistency indicates that the device can effectively warn drivers at both low and high speeds, allowing them sufficient reaction time to avoid potential hazards. Additionally, the AGAP prototype's modular design and low-cost construction make it suitable for replication in community-based safety projects and educational settings. The components used are affordable and readily available, ensuring that the technology can be scaled or improved upon with minimal expense.

However, the system also has limitations that were observed during the actual testing. The detection accuracy decreased as vehicle speed increased, dropping from 99% at 15 km/h to 87% at 45 km/h. This reduction was caused by motion blur, vibration, and momentary color misreads when the vehicle passed the color module too quickly. Environmental conditions, such as direct sunlight and uneven road surfaces, also affected the color sensor's precision. Furthermore, while AGAP's alerts were effective, its range is currently limited to detecting color markers within a short to moderate distance, making it less suitable for long-range applications or highways.

Since the prototype testing was limited to local road conditions, the study did not yet include extended field trials under heavy traffic, nighttime settings, or adverse weather. It also did not assess long-term system durability or driver behavior over repeated exposures to alerts. These factors may influence the device's performance in real-world driving scenarios.

Despite these constraints, the findings confirm that AGAP functions reliably as a responsive and efficient early-warning prototype designed for community-level road safety enhancement. With further calibration, waterproofing, and software optimization, the system has the potential to evolve into a fully operational safety device capable of supporting local road management programs and reducing accidents in hazard-prone zones.

5.4 Design Error Analysis and Enhancements

The study revealed that the AGAP (Alert Gadget for Accident Prevention) system successfully met its primary goal of creating a field-tested early-warning device capable of enhancing driver awareness and promoting road safety through color-based detection and immediate alert signals. During the trials conducted in Zone 1, Zone 2, and Zone 3 of Cambanogoy, the device demonstrated consistent responsiveness when the vehicle passed over the color module attached on the road, activating both the LCD and buzzer alerts within an average response time of 1.3 seconds. Across all tests, AGAP achieved an overall efficiency rate of 93.25%, confirming its capability to detect marked hazard zones accurately and provide timely alerts that prompt drivers to slow down or stop.

However, several design-related errors were identified during the testing phase. The most notable issue occurred at very high speeds (around 45 km/h), where the sensor occasionally misread the road color due to rapid movement and uneven lighting conditions. This led to brief delays or missed alerts, particularly when sunlight directly hit the surface of the color module. Minor vibrations from the test vehicle also affected sensor stability, causing slight fluctuations in detection accuracy. Additionally, environmental factors such as dust and slight moisture on the road sometimes interfered with the sensor's ability to read the color marker precisely.

To address these concerns, several enhancements are recommended. First, the sensor housing should be redesigned to include a light-filtering cover that minimizes glare and reduces environmental interference. Second, calibration of the color sensor sensitivity must be adjusted to maintain accuracy even under faster vehicle speeds and variable lighting. Third, integrating a secondary proximity sensor or an infrared assist module could serve as a backup for color-based detection, ensuring continuous functionality even when the primary sensor experiences interference. Furthermore, applying a protective coating on the road-mounted color module can help prevent dust accumulation and preserve color contrast over time.

Despite these minor issues, AGAP's design remains simple, affordable, and practical, making it suitable for both educational and community safety applications. The overall testing confirms that with continued refinement, AGAP can evolve from a small-scale prototype into a reliable, real-world early-warning system that can significantly improve safety in accident-prone areas.

6 CONCLUSION

The results of the study showed that the AGAP (Alert Gadget for Accident Prevention) performed effectively during the actual field testing conducted in Zones 1, 2, and 3 of Cambanogoy. The prototype consistently detected the road color markers where the sensor module was directly attached to the surface, producing both audio and visual alerts that signaled potential risk zones. The system achieved an average response time of 1.3 seconds and an overall efficiency rate of 93.25%, showing that most of the warnings successfully prompted timely driver reactions such as slowing down or stopping. The LCD display accurately switched between "SAFE ZONE" and "HIGH-RISK ZONE" indicators, while the buzzer gave an audible warning long enough to draw driver attention. Minor detection inconsistencies, which made up

around 6.75% of all tests, mostly occurred at very high speeds (around 45 km/h) or when sunlight and road dust interfered with the sensor's ability to read the road color accurately. Despite these few errors, the findings prove that AGAP's color-based sensing and microcontroller system can deliver dependable and timely early-warning alerts that contribute to road safety awareness and accident prevention.

6.1 Overall Performance and System Efficiency

The AGAP prototype proved to be a reliable early-warning device capable of detecting color-based hazard zones on the road. It performed with consistent efficiency across all three testing zones in Cambanogoy, accurately triggering both visual and auditory alerts when vehicles passed over the marked areas. With an average response time of 1.3 seconds and a , the system successfully demonstrated its ability to deliver timely warnings that promote safer driving behavior and reduce the likelihood of accidents.

6.2 Accuracy, Responsiveness, and Alert System Reliability

The integration of the road-attached color module, Arduino microcontroller, and LCD-buzzer alert system allowed AGAP to process sensor readings instantly and provide clear notifications to drivers. The LCD displayed highly visible "SAFE ZONE" and "HIGH-RISK ZONE" messages, while the buzzer emitted an audible warning lasting long enough to ensure driver awareness. Although a few inconsistencies appeared at very high speeds due to light reflection and sensor vibration, these were minimal and did not affect the overall reliability of the system.

6.3 System Capabilities and Future Enhancements

One of AGAP's strongest points is its low-cost and modular design, which makes it easy to replicate, modify, and scale for community or educational use. However, the study also revealed that the system's accuracy slightly declines at higher vehicle speeds and in bright or dusty conditions. To further enhance performance, future improvements should focus on adding a protective light filter around the sensor, adjusting its sensitivity calibration, and possibly integrating an infrared or secondary detection module to maintain accuracy under challenging road conditions.

6.4 Implications for Road Safety and Innovation

The study concludes that AGAP has strong potential as a practical and innovative early-warning system that promotes road safety awareness, especially in accident-prone areas. Its combination of affordability, simplicity, and reliable alert performance makes it suitable for local implementation and further research. With continued development and real-world testing, AGAP can evolve into a fully functional system that helps prevent road accidents by alerting drivers earlier and improving their responsiveness to potential hazards.

Recommendation

Based on the findings of the study, several recommendations are proposed to further improve the functionality, reliability, and real-world performance of the AGAP system. First, it is recommended to optimize the calibration of the ultrasonic sensor to enhance detection accuracy and extend its operational range. This adjustment will ensure consistent and dependable distance measurements during actual road testing. It is also important to expand testing conditions to include various environmental factors such as lighting, weather, and road surface types. Doing so would allow for a more comprehensive assessment of the system's performance beyond controlled environments.

To reduce false alarms and improve precision, the integration of adaptive sensitivity settings in the microcontroller program is advised. This feature would enable the AGAP system to automatically adjust its detection parameters based on surrounding light levels and surface reflections. In addition, enhancing the structural durability of the device by designing a compact and weather-resistant casing would protect its electronic components from rain, dust, and vibrations, which are common in road conditions. This would help ensure a longer lifespan and greater reliability of the prototype.

Improving the ergonomics of the alert system is also an important consideration. Adjusting the brightness and volume levels of the visual and auditory signals can help ensure that drivers receive timely but non-distracting notifications in various driving environments. Adding a basic data logging feature is likewise recommended to allow the system to record detection distances, alert frequencies, and response times. These records would be useful for analyzing the device's performance and guiding future recalibration.

It is also advised to include motion-based testing scenarios that involve moving obstacles or simulated vehicles. This would help assess the AGAP system's responsiveness and accuracy in detecting dynamic hazards, making the evaluation more realistic and practical. Beyond technical improvements, the AGAP system can also be promoted as an educational and research tool to raise awareness about road safety innovations and accident prevention. Finally, collaboration with

local safety organizations and transportation authorities is encouraged to support further system enhancement and explore its potential implementation in road safety programs.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

No conflict of interest to be disclosed.

REFERENCES

- [1] World Health Organization. (2024, February 5). *Road traffic mortality rate (per 100,000 population)* [Indicator]. World Health Organization. <https://data.who.int/indicators/i/B9D9E2>
- [2] Philippine Statistics Authority. (2023, May). Land transport accidents account for 1.9 percent of deaths in the Philippines. Philippine Statistics Authority. <https://psa.gov.ph/statistics/vital-statistics/node/1684076211>
- [3] National Highway Traffic Safety Administration. (2023, September 28). NHTSA estimates traffic fatalities continued to decline in the first half of 2023. U.S. Department of Transportation.
- [4] Sri-Jayantha, S. M. (2014). *Road hazard detection and warning system and method* (U.S. Patent No. 8,766,817). U.S. Patent and Trademark Office.