

Development of automotive sensor-driven early warning device

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Abstract: This study presents key findings from the evaluation of an automotive warning device equipped with a blinker and alarm system. The objectives were to determine the sensitivity of the device in detecting incoming vehicles, assess the visibility of the warning light emitted under varying lighting conditions and distances, evaluate the sound clarity and effectiveness of the alarm at different distances, and gauge the acceptability of the device in terms of design, composition, safety, and operating performance. Controlled experiments were conducted to measure the sensitivity of the device in detecting incoming vehicles at varying distances. Visibility tests were carried out to evaluate the warning light's effectiveness under different lighting conditions and distances. The sound clarity and effectiveness of the alarm were assessed through experiments conducted at different distances. Findings revealed that the automotive warning device demonstrated high sensitivity in detecting incoming vehicles, ensuring reliable performance across varying distances. The warning light emitted by the device exhibited strong visibility under diverse lighting conditions and distances, enhancing its effectiveness as a visual alert system. Furthermore, the alarm system proved to be clear and effective in signaling approaching vehicles across different distances. Overall, the developmental automotive warning device with blinker and alarm system shows promising potential in enhancing road safety by providing timely alerts to drivers. Further refinement of the device's design and composition is recommended to enhance its aesthetic appeal and safety features. Continuous testing and optimization efforts are necessary to ensure consistent and reliable performance in real-world driving scenarios.

Keywords: Automated Early warning device, Road safety, Automotive device for safety, Road warning system

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INTRODUCTION

Modern cars are generally reliable, but unforeseen breakdowns or emergencies can still occur. Common situations include flat tires or running out of fuel. These incidents can happen anywhere, from deserted roads to busy highways. Regardless of location, utilizing an Early Warning Device (EWD) is crucial for safety.

The Philippines, though rich in resources, faces economic challenges due to natural disasters and human-caused damage. This can lead to fluctuations in basic commodity prices. However, this information is not directly relevant to the topic of EWDs.

The Land Transportation Office (LTO) of the Philippines mandates EWDs as a safety measure for emergency car stops. These highly visible neon-lit devices come in pairs: a red and a yellow triangle. When a car needs to stop, the red triangle is positioned about six meters behind the vehicle to warn approaching drivers of potential danger.

The yellow triangle is placed approximately six meters further back from the red one, creating a clear visual signal. This distance is particularly important on highways where cars travel faster. Additionally, EWDs should be positioned at a slight angle (five to ten degrees) away from the road surface. This angle optimizes light reflection from approaching vehicles, enhancing visibility.

EWDs not only alert drivers to your stopped car but also warn them of potential hazards you may have encountered, such as dead animals, accidents, or landslides. Using EWDs is

not just a legal requirement; it's a responsible action that prevents accidents caused by unexpected obstacles.

This research explores the development of a sensor-driven EWD for educational purposes. This project offers several benefits like integrating advanced automotive technologies into the curriculum exposes students and instructors to cutting-edge concepts relevant to the industry. Building the EWD allows students to apply theoretical knowledge in a real-world scenario, gaining hands-on experience in design, testing, and implementation. Studying these devices raises awareness of the importance of safety systems and their role in reducing accidents. The project can also inspire students to explore entrepreneurial ventures in the automotive technology sector, fostering innovation and creativity.

EWDs are a critical safety measure for all drivers. This research project complements these efforts by promoting safety awareness and potentially leading to the development of innovative automotive warning systems.

Statement of the problem

Generally, this study aimed to developed automotive sensor-driven early warning device.

Specifically, it sought to:

- 1) determine the sensitivity of the device in detecting incoming vehicles at varying distances;
- 2) determine the visibility of the warning light of the device during day and night at varying distances;
- 3) determine the sound audibility of the device at varying distances and
- 4) determine the acceptability of the device in terms of design, composition, safety, and operating performance.

LITERATURE REVIEW

Early warning system

There are some definitions regarding Early Warning System (EWS) that are applied to explain lots of actions of individuals, groups, and/or governments (Saadeldin et al., 2014). The EWS is a set of systems for its notification about the occurrence of natural events or the other forms. It can be in the form of disasters or other natural phenomena or in the form of several traffic incidents that occurred lately. Traffic of highways or roads causes such accidents which have occurred frequently in the last decades. One of them is due to the presence of the blind zone. Communicating the blind area on the road curvature that has been observed from inside the vehicle is one of the effective functions of the Driver Assistance System that can help minimize traffic accidents, and fatal crashes on the road, and it has received unprecedented attention. The disastrous event in the Intercity Buses arose from the sharp curvature of the road whereby many passengers were injured or did not survive. However, they have a significant potential to improve roadway safety and traffic productivity (Najada and Mahgoub, 2016).

Linear regression models have been used to assess the relationship between road design features and accident rates. However, these models have limitations. They assume a linear relationship between variables, which may not always be the case for accident data. Additionally, accident rates are non-negative and discrete values, whereas linear regression models can produce negative or non-integer values.

Nilsson and Nilsson (2015) proposed Poisson regression models as an alternative. These models are better suited for count data, such as accident rates, and can account for

random and sporadic factors influencing accidents. However, even Poisson models can lead to over- or under-estimation of accident rates.

The radius of horizontal curves is a crucial element in road design that significantly impacts traffic safety. Smaller curve radii increase the likelihood of accidents due to limitations on vehicle stability. Studies by Zhang et al. (2020) and others have shown a correlation between sharper curves and higher accident rates.

Past research has explored the link between horizontal curve radius and accident rates. Researchers have calculated the average radius and curvature for different road categories and compared them to the average number of accidents within those categories. These studies support the notion that sharper curves contribute to a higher incidence of accidents.

The EWS made in this first stage is a model to obtain the minimum of the radius and the maximum allowed velocity on a gradient (sag or step)/curvature. These values are obtained as input to many parameters including road curvature data values, traveling speeds, traffic data analysis among others. This maximum permissible speed, therefore, becomes an important factor in the future to check whether an object that passes through the gradient/curvature is doing so at the right speed or whether it has to warn it to reduce its speed according to the permissible speed. In this built EWS model, as the speed data to be simulated in the application, it will automatically check with the application of the maximum speed from the calculations and geometry analysis results. It will also offer a safe sign or warning against the rate (Shen, et al., 2018).

Early warning devices are incredibly important to road users, including drivers, pedestrians, and cyclists, for several reasons in which early warning devices provide crucial alerts about potential hazards or dangers on the road, such as accidents, construction zones, or road closures. By alerting road users to these hazards in advance, they help prevent accidents, reduce the severity of collisions, and improve overall road safety. By providing early warnings, these devices allow road users to anticipate and prepare for potential hazards, enabling them to adjust their driving behavior accordingly. This can include reducing speed, changing lanes, or taking alternative routes to avoid dangerous situations. Early warning devices enhance situational awareness among road users by providing real-time information about changing road conditions, traffic patterns, and potential obstacles. This helps drivers make informed decisions and navigate safely through challenging environments. By alerting drivers to upcoming hazards or congestion, early warning devices help mitigate traffic disruptions and improve traffic flow. This contributes to smoother and more efficient transportation networks, reducing travel times and congestion-related delays for all road users. Early warning devices play a crucial role in facilitating emergency response efforts by alerting drivers to accidents, breakdowns, or other emergencies on the road.

METHODOLOGY

Research design

The researchers employed a developmental method of research to create an automotive sensorized early warning device. This approach involved combining and compacting various ideas and innovations into a single device to enhance the safety and precautionary measures for motorists. The research comprised controlled experiments to test the sensitivity of the device by varying the distances between the test vehicle and incoming vehicles, visibility testing under different lighting conditions to measure the device's performance during the day and at night, and sound clarity and effectiveness testing to evaluate how well the alarm could be heard at various distances. Additionally, an acceptability assessment was conducted with 30 evaluators using an evaluation sheet to gather feedback on the design aesthetics, materials

used, perceived safety, and overall performance of the device. This thorough methodology ensured that the device was rigorously tested and refined for optimal functionality.

Locale of the study and respondents

The study was conducted in various testing environments to simulate real-world conditions. These environments included controlled settings for sensitivity testing, as well as real-world scenarios for visibility and sound testing under different conditions such as daytime, nighttime, and varying weather. The acceptability assessment involved 30 randomly selected evaluators to ensure a diverse sample. The selection process adhered to safety regulations and ethical standards, involving participants from different backgrounds to capture a wide range of perspectives on the device's effectiveness and usability.

Research instruments

The research utilized several instruments to measure the effectiveness of the developed device. Sensors were employed to detect incoming vehicles and measure the device's response time and accuracy. Decibel meters were used to assess the sound clarity and effectiveness of the alarm. Luminance meters measured the visibility of the warning light under different lighting conditions. Structured questionnaires were designed by the researchers to gather detailed feedback from evaluators regarding the device's design, composition, safety, and operating performance. Additional tools and equipment used in the study included screwdrivers, iron soldering tools, electronic drills, LED lights, a flasher with a buzzer, and a PIR sensor, all essential for the construction and testing of the device.

Data analyses procedure

Data analysis for the study involved multiple parameters to ensure a comprehensive evaluation of the device's performance. Sensitivity testing was conducted through controlled experiments to measure the device's response time and accuracy in detecting incoming vehicles at various distances. Visibility testing under different lighting conditions involved measuring the brightness and clarity of the warning light using luminance meters. Sound clarity and effectiveness were assessed by placing decibel meters at different distances from the device and conducting subjective evaluations to gauge the perceived effectiveness of the alarm. The acceptability of the device was determined by analyzing feedback from 30 evaluators using a Five-Point Likert Scale, with scores ranging from "Very Acceptable" to "Not Acceptable." Binary numbers (1 and 0) were used to score the sensitivity, visibility, and audibility parameters. Statistical tools, such as the Mean, were employed to determine the measurements for multiple trials and to analyze the acceptability results of the device. This rigorous data analysis procedure ensured that the device met its intended purpose and provided accurate and reliable performance under various conditions.

FINDINGS AND DISCUSSION

Sensitivity of developed automotivesensor-driven early warning devicein terms of detecting incoming vehicles at varying distances

The data shows that in three different conditions and set distances, the device was functioning and showing the mean of "1" which means the sensor was effective in detecting the moving vehicle that passed by alerting the user for their safety while repairing their vehicle. This result means that the sensor within the device effectively detected passing vehicles at that distance during the three (3) trials without a problem. The term "sensitive" here implies that the sensor was able to accurately detect the presence of passing vehicles and trigger the

warning system, which includes both a blinker and an alarm. The fact that the sensitivity was observed consistently across three trials suggests that the effectiveness of the warning device was not just a one-time occurrence but rather a reliable feature. This indicates that the device could be effective in providing warnings to drivers or pedestrians about approaching vehicles within a 10-meter range under the conditions tested. Overall, this result was promising as it demonstrates that the warning device has a sufficient detection range to provide timely alerts to users, enhancing safety by notifying them of approaching vehicles well in advance.

According to Yun and Lee (2014) using Pyroelectric infrared (PIR) sensors are widely used as a presence trigger. They developed data that can monitor people in different locations and their speed doesn't affect the detection. Their findings used in the development of this study become the baseline to use the sensor in moving or passing vehicles since they found out that PIR shows the raw data set captured from a single PIR sensor of each of modules could achieve more than 92% accuracy in classifying the direction and speed of movement, the distance interval and identifying subjects. This can also alert the users for safety and a given task was normally a warning device for both users and motorists passing by with a maximum of nine (10) meters radius. Moreover, when in times of rainy weather rain doesn't affect the ability of the sensor to detect moving objects and very effective and it was designed to be waterproof so that it can be used anywhere.

Visibility of developed automotive sensor-driven early warning device during day and night at varying distances

The data show that under three conditions such as day and night, the device was still visible and according to the data gathered, the blink was visible at a distance of up to 30 meters which can easily be seen by motorists when the user perform the troubleshooting in their vehicle. The blinker was deemed to be easily seen by the motorist rather than the normal warning device reflector and the device also performs much better during nighttime since reflectorized warning devices cannot be easily seen because of obstruction of rain and fog in their windshield. Since the blinker is operated by a rechargeable battery, if ever it discharges, the user can charge it easily using their vehicle or customized charging station. Furthermore, as the developed warning device's blinker was consistently visible up to a 30-meter distance in three trials, it indicates that the visual warning signal emitted by the device was sufficiently bright or conspicuous to be seen from that distance. This suggests that the warning system, specifically the blinker component, was effective in alerting nearby individuals or drivers about the presence of the device.

Moreover, the visibility was consistent across three trials reinforcing the reliability of the blinker's effectiveness in providing a visual warning signal. It implies that under the conditions tested, the blinker was reliably visible at distances of up to 30 meters, providing ample warning to nearby individuals or drivers. Overall, this result is positive as it demonstrates that the warning device's visual signal can effectively convey its presence to individuals in the vicinity, enhancing safety by alerting them to potential hazards or the presence of the device itself.

Sound audibility of developed automotive sensor-driven early warning device at varying distances

According to the data gathered while observing in different places, each condition includes multiple trials, and the finding indicates whether the device was audible (marked as "1") or not audible (marked as "0") in each trial. Three different locations have been selected for a tested scenario such as heavy flow of vehicles, moderate flow of vehicle, and normal flow of

vehicles, the device alarm was audible in a minimum of 3 meters to a maximum of 10 meters radius.

However, in a city with populated traffic, the warning device was audible at all distances tested (3 meters, 6 meters, and 10 meters). Similarly, in an urban area with normal traffic, the device was consistently audible across all distances. Even in a rural area with little traffic, where ambient noise levels might be lower, the device remained audible at all tested distances. Overall, these results suggest that the developed warning device with both blinker and alarm systems effectively maintains audibility across different environmental conditions and distances, making it a reliable safety feature for various settings. However, if the sound alarm was too loud it also affected the other motorists passing by so the researchers decided to retain the sound of the alarm so that it would not hamper the operation of another vehicle passing by.

Having a good sound or audible alarm at a far distance means that the alarm system was effective in alerting individuals or pedestrians even when they were located at a significant distance from the source of the alarm. This implies that a good audible alarm ensures that people can be warned of potential hazards or emergencies even if they are not close to the danger. This enhances overall safety by providing timely warnings. Moreover, an alarm system in the device that can be heard from far away provides early warning, allowing individuals to react and take appropriate action well in advance of the danger. This can be crucial in situations where quick evacuation or response is necessary. Accessibility was improved when alarms were audible over long distances.

People with hearing impairments or those working in noisy environments may still be able to perceive the alarm, increasing inclusivity and ensuring that everyone can respond to alerts. A good sound that carries over long distances indicates that the alarm system is effective even in challenging environments with background noise or obstacles that might obstruct sound transmission. By being audible over long distances, the alarm reduces response time, as individuals can quickly identify the location of the alarm and take appropriate action without delay. In summary, having a good sound or audible alarm at far distances is crucial for ensuring effective warning systems, enhancing safety, and facilitating prompt responses to emergencies or hazardous situations.

General acceptability of the developed automotive sensor-driven early warning device in terms of design, composition, safety and operating performance

The data further shows that in terms of design, it got a Mean score of 4.96 which means that the design of the warning device was rated very acceptable. Respondents highly approve of the design aspects of the warning device, indicating that it effectively addresses considerations such as aesthetics, usability, and integration of features. A well-designed device enhances safety, usability, and user satisfaction. In terms of composition, it got a Mean score of 4.95 which means that the warning device was rated very acceptable. The composition aspects include materials, parts, and components used in the construction of the device. Respondents view the composition positively, indicating that it addresses considerations such as durability, serviceability, and flexibility, contributing to the device's overall effectiveness.

In terms of operating performance, it got a Mean score of 4.99 which means that the warning device was rated very acceptable. Operating performance encompasses aspects such as power source, ease of operation, visibility, rechargeability, and warning functionality. Respondents highly approve of the device's performance during operation, indicating reliability, usability, visibility, and effective warning capabilities.

In terms of safety, the Mean score was 4.97 which means that the warning devices were rated very acceptable. The safety aspects include protective covering, functional compartments, ease of operation with safety features, safeguarding during maintenance, and conformity to safety practices. Respondents highly approve of the safety features, indicating that the device effectively addresses considerations related to user safety and compliance with safety standards.

The Grand Mean has a mean score of 4.97 which was also verbally interpreted as Very Acceptable. The overall mean score reflects the high level of acceptability of the warning device across all aspects evaluated: design, composition, operating performance, and safety. This indicates strong confidence and approval from respondents regarding the device's overall effectiveness, usability, reliability, and safety. In summary, the data demonstrates that respondents highly approve of the development of the warning device across all evaluated aspects. The device is deemed very acceptable in terms of design, composition, operating performance, and safety. This suggests that the device effectively meets expectations and requirements in various key areas, contributing to its overall high acceptability and effectiveness in promoting safety and usability.

This conforms to the result of the study of Christopoulos and Wright (2013). Even there are typically no internal serviceable parts and breaking the factory seal generally results in jeopardizing the manufacturer's warranty. Because of issues inherent to the product design, historically the maintenance of electronic circuits by the end user has been limited to mechanical mounting, electrical wiring, and manual operation of the mechanism and is acceptable to the consumer.

Acceptability of developed automotive sensor-driven early warning device in terms of design

The findings showed that the overall acceptability of the device was "very acceptable" in terms of design with a mean score of 4.96. The mean ranges from 4.93 to 5.00. Of the five (5) statements, statement five (5) got the highest mean score of 5.0 which is interpreted as very acceptable "It requires safety features when trouble or undergoing repair of a vehicle occurs on the road." This statement received the highest possible score, indicating unanimous agreement among respondents regarding the importance of safety features in the design.

It suggests that respondents view safety as a paramount consideration and strongly endorse the inclusion of safety features in the device's design, followed by statements one (1) and four (4) with a mean score of 4.97 which means "very acceptable" on "It is anchored to the need for safety precautions when automobiles are on maintenance or undergoing repair." This statement indicates that the design of the warning device was closely aligned with the safety needs associated with vehicle maintenance and repair. Respondents rated this aspect very high, indicating strong approval of the device's focus on safety and statement #4 which was the "Parts and components contribute to the whole operation of the warning alarm system" which respondents highly approve of the design integration of various parts and components, indicating that they perceive these elements as effectively contributing to the overall operation of the warning alarm system.

This suggests that the design is perceived as cohesive and well-integrated. Statement two (2) and three (3) got a score of 4.93, which means "very acceptable" on "This resembles the concept of a typical/manual automotive warning device." Respondents find the design of the warning device to be highly acceptable, as it aligns well with the concept of traditional automotive warning devices. This suggests that the device's design was familiar and intuitive to users. and "The electronic parts operate automatically when other vehicles are approaching" This statement highlights the automation feature of the warning device, which

respondents view very favorably. The automatic operation of electronic parts in response to approaching vehicles is seen as a desirable and effective design element.

Moreover, this well-designed warning device offers several advantages such as it ensures that the warning device effectively communicates potential hazards or emergencies, thereby enhancing safety for both users and those around them. Clear signals and intuitive operation reduce the risk of accidents or misunderstandings. It also improved user experience and the design was user-friendly, making it easier for individuals to understand and operate. This results in a more positive user experience, reducing frustration and increasing compliance with safety protocols. It also increased effectiveness and is more likely to be noticed and heeded by individuals in its vicinity. This leads to quicker responses to potential dangers, minimizing the risk of accidents or injuries.

The device was also versatile and can be adapted to different environments and situations. Whether it's used in urban areas with heavy traffic or rural settings with fewer vehicles, a versatile design ensures that the device remains effective across various contexts. The product was also reliable and ensured that the warning device was robust and reliable, able to withstand environmental factors such as weather conditions or mechanical stress. This reliability is crucial in emergencies where the device must perform consistently. While investing in good design may require initial resources, it often results in long-term cost savings.

A well-designed warning device was less likely to require frequent maintenance or replacement, reducing overall operational costs. It also complies with the standards that meet regulatory requirements and industry standards. Compliance with these standards not only ensures legal obligations are met but also instills confidence in users regarding the device's quality and effectiveness. The device can set itself apart from competitors through innovative features or aesthetics. This differentiation can lead to a competitive advantage in the market and increased adoption by users.

Finally, the warning device extends beyond mere aesthetics. Such a design enhances safety, improves user experience, increases effectiveness, offers versatility and reliability, saves costs, ensures compliance with standards, and fosters innovation, ultimately contributing to better outcomes in terms of accident prevention and risk management.

Acceptability of developed automotivesensor-driven early warning devicein terms of composition

The results presentthe acceptability of the developed of automotive sensor-driven early warning device in terms of its composition, focusing on the materials, parts, and components used in its construction. Each statement represents a specific aspect of the composition of the warning device, and respondents provided ratings for each statement.

Data showed that the overall acceptability of the device was “very acceptable” in terms of composition with a mean score of 4.95. The mean ranges from 4.93 to 5.00. Out of the five (5) statements, statement three (3) got the highest mean score of 5.00 which is interpreted as very acceptable on “The device is flexible to any type of vehicle upon maintenance or undergoing repair while on the road.”

This statement received the highest possible score, suggesting unanimous agreement among respondents regarding the device's flexibility to accommodate various types of vehicles during maintenance or repair on the road. Flexibility was a desirable quality, as it ensured the device's applicability across different vehicle types and situations. followed by statement one (1) with a mean score of 4.90 which means “very acceptable” on “The materials are available locally.” Which respondents highly approve of the use of locally available materials in the composition of the warning device.

This indicates that the device's design takes into account accessibility to materials, potentially reducing production costs and logistical challenges. Statements two (2) and four (4) got a score of 4.97, which means “very acceptable” on “The parts of the product are serviceable” in which the high mean score indicates strong agreement among respondents regarding the serviceability of the warning device's parts. Serviceability ensures that components can be easily maintained, repaired, or replaced as needed, contributing to the device's longevity and reliability and “The parts and components are well-connected and attached for better operation while undergoing maintenance on the road” in which respondents highly rate the connectivity and attachment of parts and components in the warning device. Well-connected components contribute to the device's overall functionality and reliability, especially during maintenance or repair activities conducted on the road. Statement five (5) got the lowest mean score of 4.93 which means “very acceptable” on “Battery-operated LED light with sensor and translucent triangular body parts automatically operates when another vehicle is approaching.”

This statement highlights specific features of the warning device, including battery operation, LED lights, sensor technology, and translucent triangular body parts. Respondents view these features favorably, indicating that they contribute to the device's overall acceptability and effectiveness.

Acceptability of the developed automotive sensor-driven early warning device in terms of safety

The data shows that the overall acceptability of the device was “very acceptable” in terms of safety with a mean score of 4.97. The mean ranges from 4.97 to 5.00. Of the five (5) statements, statements three (3) and four (4) got the highest mean score of 5.00 which is interpreted as “very acceptable” on “The device can easily be operated with a safety features manual.” The ease of operation with a safety features manual receives the highest possible rating of very acceptable. This perfect score suggests that respondents unanimously agree on the importance of an easy-to-operate warning device, especially with the assistance of a safety features manual.

This feature ensures quick and effective utilization of the device, promoting safety and minimizing the risk of accidents. Likewise, “The product can be used for safeguarding while doing maintenance or repair of vehicles on the road.” This entails that the ability of the product to safeguard individuals during maintenance or repair activities on the road receives a very acceptable rating. This perfect score also indicates strong approval of the device's safety function, particularly its ability to protect users during potentially hazardous maintenance or repair tasks conducted on the road.

Statement #1 with the mean score of 4.90 which means “very acceptable”. This device is covered with fiber-acrylic plastic with epoxy primer painted wooden utility box or storage compartment for any weather condition upon operation.” Respondents find the use of fiber-acrylic plastic with epoxy primer painted wooden utility box or storage compartment for weather protection to be very acceptable. The high rating indicates strong approval of the protective covering, suggesting that respondents recognize its importance in ensuring the device's durability and resilience in different weather conditions. Statements two (2) and five (5) got the lowest mean score of 4.97, which means “very acceptable” on “It has a functional storage compartment area for safekeeping” and the presence of a functional storage compartment area for safekeeping receives a rating of very acceptable. The high mean score indicates unanimous agreement among respondents regarding the utility and importance of the storage compartment. This feature enhances organizational efficiency and reduces safety hazards by providing a designated space for essential items.

Likewise, Statement 5 conforms to occupational safety and health practices of automotive servicing and driving and is rated very acceptable. The high mean score indicates that respondents view conformity to safety practices favorably, recognizing the importance of meeting established safety standards and regulations in ensuring the device's effectiveness and reliability.

Acceptability of the developed automotive sensor-driven early warning device in terms of operating performance

The findings present the acceptability of the developed automotive sensor-driven early warning device in terms of its operating performance. The dataset summarizes respondents' ratings for various statements related to the performance of the warning device during operation. In Statement 2 the ease of operation and convenience, Statement 3 the visibility and attractiveness to drivers and Statement 4 the rechargeable in one hour for continuous use got the highest possible mean score of 5.00.

Furthermore, the ease of operation and convenience of the warning device receives the highest possible rating of very acceptable. This perfect score indicates unanimous agreement among respondents regarding the ease of operation and convenience of the device. A user-friendly design and straightforward operation enhance usability and user satisfaction, promoting effective use of the device. The visibility and attractiveness of the warning device to drivers are rated very acceptable.

This perfect score suggests that respondents highly value the device's visibility and attractiveness, indicating that it effectively catches the attention of drivers and encourages compliance with safety warnings. An attractive design can also enhance the device's visibility in various environmental conditions. The ability of the device to recharge in one hour for continuous use is rated very acceptable. This perfect score indicates strong approval of the device's quick recharge capability, allowing for uninterrupted operation. Rapid recharging ensures minimal downtime, enhancing the device's reliability and usability in emergencies.

Statement 1, which was equipped with a 12v DC Battery has a mean score of 4.97 which was also verbally interpreted as "Very Acceptable" The inclusion of a 12v DC battery for operating the device is rated very acceptable. The high mean score suggests strong approval of the choice of power source for the device. A 12v DC battery is commonly available and provides sufficient power for the device's operation, ensuring reliability and convenience for users. Lastly, Statement 5 in which the device can alarm before the vehicle passes also got a Mean score of 4.97 this means that the device's ability to alarm to warn the owner/mechanic before the vehicle passes was rated very acceptable. The high mean score suggests that respondents view the device's warning function favorably. Providing warning alerts users to potential hazards or approaching vehicles, allowing them to take timely action to prevent accidents or injuries.

The grand mean score of 4.99 verbally interpreted as Very Acceptable reflects the high level of acceptability of the warning device's operating performance across all statements. This suggests that respondents overwhelmingly perceive the device's performance positively, indicating strong confidence in its reliability, usability, visibility, rechargeability, and warning capabilities. In summary, the operating performance of the warning device, with all statements receiving a very high mean. This indicates that the device effectively meets performance expectations in terms of power source, ease of operation, visibility, rechargeability, and warning functionality, contributing to its overall high acceptability and effectiveness during operation.

CONCLUSIONS AND RECOMMENDATION

Based on the findings from the development of the automotive sensor-driven early warning device, several conclusions were drawn. The controlled experiments conducted at varying distances provided valuable insights into the device's sensitivity. It was observed that the device effectively detected incoming vehicles from different distances and angles, indicating its capability to alert users to potential road hazards accurately. Additionally, the evaluation of the warning light's visibility under various lighting conditions and distances demonstrated its effectiveness. The warning light remained visible even in low-light or adverse weather conditions, ensuring that nearby drivers could easily detect the presence of the vehicle and take appropriate actions.

Furthermore, the assessment of the alarm sound at different distances revealed its clarity and effectiveness. The alarm sound was found to be loud, clear, and distinguishable from background noise, effectively warning nearby individuals of potential hazards and prompting them to respond accordingly. The acceptability assessment, which covered various aspects such as design, composition, safety, and operating performance, also yielded positive results. The positive ratings and feedback from respondents indicated that the device met user expectations and requirements in these areas. Users found the device to be well-designed, composed of quality materials, safe to use, and highly effective in its operating performance. These conclusions underscore the device's potential as a reliable and user-friendly early warning system for automotive safety.

Based on the conclusions and findings of the study on the development of automotive sensor-driven early warning devices, several recommendations have been drawn. The developed device is primarily designed to help car owners secure a warning system equipped with a distance sensor to alert both the motorist and nearby individuals. It is also recommended for automotive students, mechanics, technicians, trainees, hobbyists, and enthusiasts. By engaging with this technology, these groups can enhance their understanding and potentially contribute to the advancement of the device, creating opportunities for collaboration with the automotive industry.

Further research and development should focus on optimizing the device into IoT versions that integrate with smartphone applications, improving its sensitivity, visibility, and sound audibility. This includes refining its design, composition, operating performance, and safety to better meet the diverse needs and preferences of automotive technicians. Educational institutions and the automotive industry should incorporate information about these devices into their curricula and workshops. Raising awareness about the benefits of these devices can facilitate patent applications and commercialization, fostering greater adoption of sustainable automotive practices among both emerging and established automotive technicians and instructors.

REFERENCES

- Ahangari, S.; Jeihani, M.; Ardeshiri, A.; Rahman, M.M. (2021). Dehzangi, A. Enhancing the Performance of a Model to Predict Driving Distraction with the Random Forest Classifier. *Transp. Res. Record*
- Ahn, A. (2022). What's the meaning of the modified device? Retrieved from <https://elsmar.com/elsmarqualityforum/threads/whats-the-meaning-of-the-modified-device.84276/>
- Bidinger, C., Bogenberger, K, (2017). Early warning system for emergency vehicles to prevent rear-end collisions using radar sensors of current driver assistance systems. *International Conference on Intelligent Transport System in Theory and Practice, Mobil TUM*. 1-15
- Chee, F.P., Angelor, S.F., Asmahani, A., and Dayou, J. (2018). An Intelligent Safety Warning and Alert System (ISWAS) for automobile vehicle. *ASM Science Journal* 11(3):7-17

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- Cheng, L.L.; Liu, Z.G.; Bi, M.Y. (2018). Automobile Safety Starting System with Anti-Alcohol Driving Based on Platform Arduino. *J. Automotive Safety Energy*
- Fan, X., Shen, J., and Zhuo, T. (2020). Research on the Sensor-Based Automotive Interior Safety Alarm System. *Journal of Physics Conference Series* 1631(1):012165; DOI:10.1088/1742-6596/1631/1/012165
- Gross, J. (2013). "Who Made That Turn Signal?". *The New York Times Magazine*.
- Guo, J., Luo, Y., and Li, K. (2017). Adaptive neural-network sliding mode cascade architecture of longitudinal tracking control for unmanned vehicles; *Nonlinear Dynamics* 87(4); DOI:10.1007/s11071-016-3206-2
- He, Y.; Liu, Z. A (2021). Feature Fusion Method to Improve the Driving Obstacle Detection under Foggy Weather. *IEEE Trans. Transp. Electrification*.
- Hein, W., Torres, H., Arryo, Z., Quezada, V., Arriagada, D., Valenzuela, A., Gutierrez, S.M. and Bedregal, P. (2019). An Acceptability Study Of A Personal Portable Device Storing Critical Health Information To Ensure Treatment Continuity Of Home-Dwelling Older Adults In Case Of A Disaster. Published 8 November 2019 Volume 2019:13 Pages 1941—1949 DOI <https://doi.org/10.2147/PPA.S218232>
- Hongwei, Cui, (2014). Research on Vehicle Safety Warning System Based on Data Fusion. *Journal of Applied Sciences*, 14: 2837-2842. DOI:10.3923/jas.2014.2837.2842 <https://scialert.net/abstract/?doi=jas.2014.2837.2842>
- Jiao, P.P.; Zhang, Y.J.; and Sun, B. (2020). Effect of Intervention Mode on Avoidance of Pedestrians by Right-Turning Vehicles. *China Journal Highway Transportation*
- Khan, F., Hossain, N., Jannat, J., Maksudur, S.M., Rahman, A., Iqbal, J., Billah, M., and Chowdhury, M.A. (2024). Advances of composite materials in automobile applications – A review. Department of Mechanical Engineering, IUBAT-International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh. *Journal of Engineering Research*
- Kondo, T., Kato, T., and Tsuda, K. (2023). The influence of sound on the attractiveness of automobile from a bird's eye view of perceived attractiveness. *Procedia Computer Science* Volume 225; <https://doi.org/10.1016/j.procs.2023.10.170>
- Kriswardhana, W., Hasanuddin, A., Palestine, I.M. (2020). Modeling the road traffic accident rate and road geometric parameters relationship. *AIP Conference Proceeding*, 2278: 020003. <https://doi.org/10.1063/5.0014530>
- Leonaviciene, T.; Pukalskas, S.; Pumputis, V.; Kulesiene, E.; Zuraulis, V. (2020). Investigation of Factors That Have Affected the Outcomes of Road Traffic Accidents on Lithuanian Roads. *Balt. Journal Road Bridge Engineering*
- Li, Y., Ma, D., Zhu, M., Zeng, Z. and Wang, Y. (2018). Identification of significant factors in fatal-injury highway crashes using genetic algorithm and neural network. *Accident Analysis & Prevention*. Volume 111, School of Information and Electronics, Beijing Institute of Technology, Beijing 100081, PR China. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA 98195, USA. Institute of Marine information science and technology, Zhejiang University, Zhoushan 316021, PR China and Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, PR China
- Lin, Y.Y., Hsiung, P.A. (2017). An early warning system for predicting driver fatigue. 2017 IEEE International Conference on Consumer Electronics – Taiwan (ICCE-TW). <https://dx.doi.org/10.1109/icce-china.2017.7991106>
- Lord, D., Qin, X., Geedipally, S.R. (2021). Identification of hazardous sites. *Highway Safety Analytics and Modeling*. Science Direct, 259-297. <https://doi.org/10.1016/B978-0-12-816818-9.00001-9>
- LTO Memorandum Circular No. Rtl-Mc-02412, March 22, 2002; Installation Of Early Warning Devices On Motor Vehicles
- Ma, Y., Xu, J., Gao, C., Mu, M., Guangxun, E. and Gu, C. (2022). Review of Research on Road Traffic Operation Risk Prevention and Control. School of Highway, Chang'an University, Xi'an 710064, China;
- Shandong Hi-Speed Group Co., Ltd., Jinan 250098, China; *International Journal of Environmental Research Public Health* 2022, 19(19), 12115; <https://doi.org/10.3390/ijerph191912115>

- Najada, H.A., Mahgoub, I. (2016). Anticipation and alert system of congestion and accidents in VANET using Big Data analysis for Intelligent Transportation Systems. 2016 IEEE Symposium Series on Computational Intelligence (SSCI). <https://dx.doi.org/10.1109/ssci.2016.785009>
- Nguyen-Phuoc, D.Q., Phuong, Tran, A.T., De Gruyter, C., Kim, I., and Su, D. (2019). Turn signal use among car drivers and motorcyclists at intersections: a case study of Da Nang, Vietnam. *Accident Analysis & Prevention* 128:25 – 31. DOI:10.1016/j.aap.2019.03.012
- Nilsson, P., Nilsson, S. (2015). Application of poisson regression on traffic safety. Master Thesis of SCI School of Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden
- Ning, F., Cong, W., Qui, J., Wei, J., and Wang, S. (2015). Additive manufacturing of carbon fiber reinforced thermoplastic composites using fused deposition modeling. Department of Industrial Engineering, Texas Tech University, Lubbock, TX 79409, USA. *Composites Part B: Engineering*. Volume 80
- Philtoyota.com (2023). Early Warning Device For Cars Every Driver Must Know Retrieved from <https://philtoyota.com/stories/early-warning-device-for-cars-every-driver-must-know-str87>
- Rolison, J.J., Regev, S., Moutari, S., Feeney, A. (2018). What are the factors that contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. *Accident Analysis and Prevention*, 115(2018): 11-24. <https://doi.org/10.1016/j.aap.2018.02.025>
- Saadeldin, M., Mazen, S., Ezzat, E., Zaher, H. (2014). Using a Multi-Criteria Approach in Early Warning Information Systems (MCEWIS). In *New Perspectives in Information Systems and Technologies*, 1: 399-410. <https://dx.doi.org/10.1007/978-3-319-05951-8>
- Salifu, S., Desai, S., Ogunbiyi, O. and Mwale, K. (2022). Recent development in the additive manufacturing of polymer-based composites for automotive structures—a review. *The International Journal of Advanced Manufacturing Technology* Aims and scope Submit manuscript. Volume 119, pages 6877–6891
- Shen, B., Zhang, Z., Liu, H., Li, S., Zhao, L. (2018). Research on a conflict early warning system based on the active safety concept. *Journal of Advanced Transportation*. 2018(Article ID 8372108): 1-11. <https://dx.doi.org/10.1155/2018/8372108>
- Stam, D., Cignini, F., Domenichini, L., Alessandrini, A. (2018). ARTS for last-mile transport designing and integrating into cities. In *Implementing Automated Road Transport Systems in Urban Settings*, 17-80. <https://dx.doi.org/10.1016/b978-0-12-812993-7.00002-4>
- Szmelter-Jarosz, A. (2017). The Importance of Automotive Industry in Shaping Habitants Mobility in Future Cities. *Zeszyty Naukowe Uniwersytetu Gdańskiego Ekonomika Transportu i Logistyka* 71 DOI:10.5604/01.3001.0010.5733. University of Gdansk
- Technical Committee on Geometric Design. (2018). *The Green Book: A Policy on Geometric Design of Highways and Streets*, 7th ed. Washington, DC: American Association of State Highway and Transportation Officials (AASHTO).
- Trachenko, K.; Monserrat, B.; Pickard, C. J.; Brazhkin, V. V. (2020). "Speed of sound from fundamental physical constants". *Science Advances*. 6 (41): eabc8662. arXiv:2004.04818. Bibcode:2020SciA....6.8662T. doi:10.1126/sciadv.abc8662. PMC 7546695. PMID 33036979.
- Wang, C.; Song, D.B.; Fu, R.; Guo, Y.J.; Xu, Y.X. (2018). Identification of Lane Change Safety Characteristic of Large Commercial Bus on Expressway. *China Journal Highway Transportation*
- Wang, J.Q.; Huang, H.Y.; Li, Y.; Zhou, H.C.; Liu, J.X.; Xu, Q. (2019). Driving Risk Assessment Based on Naturalistic Driving Study and Driver Attitude Questionnaire Analysis. *Accid. Anal. Prev.*
- Williams, J.B. (2017). *The Electronics Revolution: Inventing the Future*. Springer. pp. 245 & 249. ISBN 9783319490885.
- Yun, J. and S. Lee (2014). Human Movement Detection and Identification Using Pyroelectric Infrared Sensors doi: 10.3390/s140508057; PMID: PMC4063065; PMID: 24803195 Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4063065/>
- Zhang Y S, Zhang M J, Fan J X, Liu Q Q and You Z (2017). Automobile alarm system for prevent children from lefting in the automobile based on STM32F103 Internal Combustion Engine & Parts 12 132-133.

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Zhang, Y., Zou, Y., Wu, L., Tang, J., Abid, M.M. (2020). Exploring the application of the linear Poisson autoregressive model for analyzing the dynamic impact of traffic laws on fatal traffic accident frequency. *Journal of Advanced Transportation*, (Article ID 8854068): 1–9. <https://dx.doi.org/10.1155/2020/8854068>

Zhu, B.; Piao, Q.; Zhao, J.; Wu, J.; and Deng, W.W. (2016). Vehicle Longitudinal Collision Warning Strategy Based on Road Adhesive Coefficient Estimation. *Automotive Engineering*