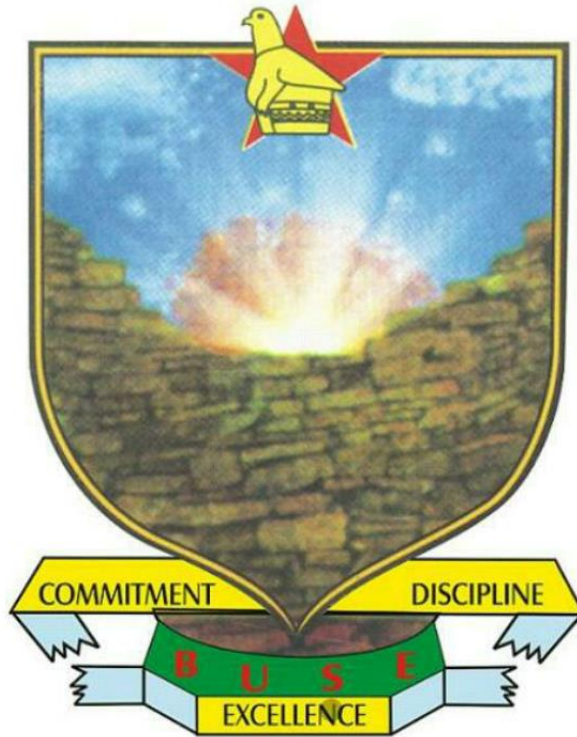


BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF COMPUTER SCIENCE



**ACCIDENT DETECTION AND ALERT SYSTEM USING OBJECT
DETECTION ALGORITHMS.A CASE STUDY FOR BINDURA.**

BY

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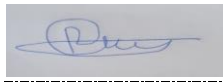
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*This dissertation is submitted in partial fulfilment of the requirements of the
Bachelor of Science honors degree in Software Engineering*

APPROVAL FORM

The undersigned certify that they have supervised the student Mirirayi Magadza's dissertation entitled "**Accident Detection and Alert System Using Object Oriented Algorithms. A Case Study for Bindura.**" Submitted in Partial fulfilment of the requirements for the Bachelor of Software Engineering Honors Degree of Bindura University of Science Education.

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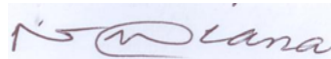
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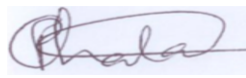
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ABSTRACT

Road traffic accidents are a significant global concern, accounting for thousands of fatalities and injuries each year. One of the critical challenges in reducing the impact of such incidents is the delay in detecting accidents and notifying emergency services. This research project focuses on the design, development, and evaluation of an intelligent Accident Detection and Alert System aimed at addressing these delays by leveraging real-time monitoring and automated communication technologies. The primary objective of the system is to detect road accidents as soon as they occur and immediately send alerts to the relevant authorities for a rapid response. The system utilizes object detection algorithms, integrated with sensors and cameras, to monitor vehicular movements and identify unusual patterns indicative of an accident, such as sudden stops, collisions, or vehicles failing to stop at designated zebra crossings. When an accident or traffic violation is detected, the system automatically generates a text-based alert containing essential information, including the precise GPS location, time of the incident, and severity level. This alert is then transmitted via mobile network or internet services to emergency response units such as ambulance services, police departments, or nearby hospitals. To evaluate the effectiveness of the system, simulations and controlled field tests were conducted, with a focus on accuracy, detection speed, and the reliability of alert transmission. The results demonstrated that the system can significantly reduce the time taken to report accidents and improve the efficiency of emergency response. Furthermore, user feedback gathered through interviews and questionnaires confirmed the system's practical relevance and potential for integration into existing traffic management infrastructures. This research contributes to the ongoing efforts to enhance road safety through technological innovation. It recommends future improvements such as the inclusion of AI-based severity assessment, integration with national traffic databases, and expansion to support pedestrian safety features. The findings affirm that intelligent accident detection and alert systems can play a transformative role in minimizing the consequences of road traffic accidents and saving lives.

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CHAPTER 1

1.1 INTRODUCTION

The development of a transportation system has been the generative power for human beings to have the highest civilization above creatures in the earth. Automobile has a great importance in our daily life. We utilize it to go to our work place, keep in touch with our family and friends, and deliver our goods. But it can also bring disaster to us and even can kill us through accidents. Speed is one of the most important and basic risk factors in driving. It not only affects the severity of a crash, but also increases risk of being involved in a crash.

Despite many efforts taken by different governmental and non-governmental organizations all around the world by various programs to aware against careless driving, yet accidents are taking place every now and then. However, many lives could have been saved if the emergency service could get the crash information in time. A study by Virtanen et al. shows that 4.6% of the fatalities in accidents could have been prevented only if the emergency services could be provided at the place of accident at the proper time. As such, efficient automatic accident detection with an automatic notification to the emergency service with the accident location is a prime need to save the precious human life. Road accidents are a significant cause of injury and mortality across the world. According to the World Health Organization (WHO), road traffic injuries claim over 1.35 million lives annually and are among the leading causes of death on a global scale (Jaulkar and Parihar, 2025). The timely detection of accidents and alerting emergency services can significantly reduce the severity of injuries and increase survival rates. Traditional systems rely heavily on human observation and direct communication but are often beset by delays, especially in remote crowded areas.

To address these challenges, accident detection and alert systems have become a key area of research. Such systems utilize sensors, algorithms, and communication networks to detect accidents in real time and alert emergency services or nearby vehicles immediately. This technology has the potential to decrease response time, save lives, and reduce the severity of accidents (Zhou et al, 2020)

This research deals with the development of an intelligent accident detection and alert system based on machine learning algorithms, sensors, and wireless communication technologies to automatically detect accidents and send immediate alerts to emergency services. The system aims to enhance road safety by reducing response time, enabling timely medical care, and facilitating earlier rescue operations (Wang et al, 2018).

The proposed system employs a multi-layered mechanism, utilizing real-time vehicle accelerometer data, GPS, and onboard cameras to detect collisions with high accuracy. Machine learning algorithms will use sensor data to classify whether the incident was an accident, while communication protocols will send alerts to response teams. The system is designed to be scalable and adaptable with allowance for integration within pre-existing traffic management systems and mobile applications.

1.2 PROBLEM STATEMENT

In today's world, road accidents continue to be a leading cause of injury and death. Despite technological advancements in vehicle safety, the time between the occurrence of an accident and notification of emergency responders often leads to delays in providing critical medical assistance. This delay can significantly affect the survival chances of the injured. An intelligent system that detects accidents in real-time and notifies emergency services can reduce the response time and ultimately save lives. These delays, often caused by the inability to rapidly and accurately determine accident locations and severity, contribute to preventable fatalities and injuries. Therefore, there is an urgent need for an intelligent accident alert system that can automatically detect collisions, precisely pinpoint their location using GPS, assess the severity of the impact through sensor data, and instantly transmit this information to emergency services, thereby minimizing response times and improving victim outcomes. These problems are often caused by delayed emergency response, currently many accidents go unreported for some time, delaying emergency response. Manual accident reporting, in some cases, bystanders or people involved in the accident may also delay to communicate

1.3 RESEARCH OBJECTIVES

1. To develop a system that can automatically detect an accident and send immediate alert to relevant authorities
2. To detect cars which do not stop at zebra crossing
3. To assess the effectiveness of accident alert practices

1.4 RESEARCH QUESTIONS

1. What effect can an accident alert system have on overall road safety and accident rates?

2. What is the best data collection frequency to reduce both false positives and false negatives in accident detection?
3. How can the system be modified for various geographical regions, particularly in regions with limited infrastructure

1.5 HYPOTHESIS

1. The utilization of an accident alert system with the functionality to detect accidents in real time will significantly improve emergency response time compared to traditional methods of accident reporting.
2. The use of machine learning algorithms (e.g., image analysis or sensor data analysis) in the accident alert system will increase the accuracy of accident detection with fewer false positives and false negatives

1.6 JUSTIFICATION/SIGNIFICANCE FOR THE STUDY

Increasing Road Traffic Accidents: Road traffic accidents have been the cause of a massive number of deaths and injuries worldwide. According to various reports, the accident rate is increasing because of factors such as over speeding, distracted driving, and adverse weather conditions. An accident alert system would minimize these accidents by reporting to authorities and emergency services instantly, lowering response time and saving lives.

Delayed Emergency Response: Timeliness of emergency response is one of the most important factors in minimizing the severity of road accidents. Traditional methods of alerting emergency services, for example, through phone calls by victims or witnesses, are delayed or unreliable. A real-time accident alert system that can notify emergency services instantly can reduce the time to provide medical treatment, thus increasing survival rates.

Technology Developments: With the advent of IoT (Internet of Things), vehicle sensors, GPS technology, and mobile technologies, it is now feasible to develop more advanced, automated, and efficient accident detection and alerting systems. This study will investigate how these technologies can be integrated to improve the timeliness and accuracy of accident reporting.

Better Road Safety: With real-time monitoring of traffic flows and accident detection, an accident warning system would not only benefit the emergency services but also warn drivers heading to the location of a possible threat. This would lead to more vigilant driving behavior, reduced traffic flow, and subsequently fewer accidents.

1.7 ASSUMPTIONS

1. Accident Frequency, measurable frequency of accidents is occurring within the target area focused on (e.g., automobile accidents, workplace accidents, or other relevant incidents).
2. Data Availability, there is access to pertinent and reliable data (e.g., historical accident data, weather, time of day, location data, or user behavior) that can be utilized to identify patterns and improve alert accuracy.
3. User Adoption, the target audience will be open to using the accident alert system (e.g., drivers who are willing to use an app or system to receive real-time alerts).
4. Legal and Privacy Considerations, the collection and use of data for accident prediction or alerting will be within legal and privacy regulations, e.g., user consent for data collection.
5. Technological Infrastructure: Necessary technological infrastructure (e.g., GPS, IoT sensors, mobile connectivity, etc.) is in place and stable to receive and send alerts.

1.8 LIMITATIONS OR CHALLENGES

1. The system may produce false alarms for non-accident situations (false positives) or not alert for real accidents (false negatives), leading to confusion or lost emergencies.

SOLUTION

Continuously monitor system performance and update algorithms and parameters as needed and adjust sensitivity thresholds for sensors and algorithms to minimize false alarms.

2. The system relies on cellular networks or other infrastructure for communications, issues like poor network coverage or congestion would delay alerts.

SOLUTION

Partner with multiple reliable cellular network providers to ensure coverage

3. Adoption issues, persuading car manufacturers and drivers to adopt the technology could be a significant challenge due to cost factors or lack of awareness.

SOLUTION

Demonstrate how the technology can reduce costs associated with accidents, such as repair costs, insurance claims, and legal fees.

1.9 SCOPE OF THE PROJECT

1. Designing and developing user interfaces for drivers, emergency services and administrators

2. Conducting thorough testing and quality assurance to ensure the system's reliability and accuracy
3. Developing machine learning algorithms to detect accidents and classify their severity
4. Designing and developing user interfaces for drivers, emergency services and administrators
5. Deploying the system and providing ongoing maintenance and support

1.2.0 DEFINITION OF TERMS

1. Accident: An unexpected event that results in damage, injury, or harm to people, vehicles, or property.
2. Alert: A notification or warning generated by the system to inform authorities, emergency responders, or users of an accident occurrence.
3. Incident Detection: The process of identifying an accident or event through sensors, monitoring systems, or data analytics.
4. Real-Time Monitoring: The continuous observation of events as they happen, enabling immediate action or response.
5. Sensor Network: A system of sensors (e.g., cameras, accelerometers, GPS) used to monitor conditions and detect accidents.
6. Emergency Response Team: A group of trained professionals (e.g., paramedics, police, firefighters) that respond to an accident scene.
7. GPS Tracking: A system that tracks the location of a vehicle or individual in real time using satellite signals.
8. Automated Notification System: A system that automatically sends out alerts to designated recipients (e.g., emergency services) when an accident occurs.
9. Emergency Alert System (EAS): A public communication system that broadcasts urgent information, including accidents and hazards, to the public.
10. Geofencing: A virtual boundary set up around an area (e.g., accident-prone zones) that triggers alerts when a vehicle enters or exits the area, or an accident occurs within the perimeter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Accident alarm systems play a crucial role in enhancing road safety by providing prompt notifications to emergency services and other authorities in the event of an accident. They utilize a combination of advanced technologies such as sensors, GPS, mobile apps, and communication protocols to detect accidents and alert responders. The primary role of such systems is to minimize response time, lower fatalities, and increase the overall effectiveness of emergency services. Here, in this literature review, we have presented various technologies used in accident alert systems, the challenges faced while implementing them, and the potential for future innovation. We discuss previous research works that have proposed various ways for improving accident detection and alert systems, and determine areas of research with gaps that need to be addressed in order to develop further.

2.2 Theoretical Literature

Accident detection systems are used across various domains, such as transportation, industrial safety, and smart city infrastructure. Here are some existing accident detection systems and their weaknesses.

1. Smartphone-Based Accident Detection Systems

Smartphone-based accident detection systems use the sensors and hardware already embedded in modern smartphones to detect when a user may have been involved in an accident. These systems rely on algorithms that monitor sensor data in real time to recognize unusual patterns that indicate a crash or fall. Examples are google personal safety, Samsung SOS, ios crash detection system. These systems they work by use of onboard sensors (accelerometer, gyroscope, GPS, microphone) to detect anomalies (e.g., sudden deceleration or impact). They also use AI or rule-based logic to assess likelihood of a crash. Smartphone based accident detection systems they have various weaknesses which are false positives, hard braking or phone dropping can be misinterpreted as accidents. They may also fail to detect low-impact accidents or when the phone is not on the person. Another weakness is also on privacy concern, continuous monitoring of location and motion data which can result in invading of privacy and if the data is not properly secured it can be accessed by unauthorized parties. Another drawback is your location and motion data might be shared or used without your consent Constant use of sensors affects phone performance and battery life which is another drawback of using smartphone based detection system.

2. In-Vehicle Telematics Systems

Vehicle telematics systems integrate telecommunications and informatics to provide real-time data on vehicle location, performance, and driver behavior (Weber, 2017). These systems use GPS, sensors, and wireless communication to collect and transmit data (Liu et al, 2019). In-vehicle telematics systems are integrated technologies within vehicles that collect, transmit, and analyze data related to vehicle dynamics, driver behavior, and environmental conditions. These systems play a crucial role in accident detection, fleet management, navigation, and emergency response. They use vehicle sensors (speed, braking, and airbag deployment) and GPS to detect crashes. Often include automatic emergency calls. Vehicle telematics systems have different key features which are vehicle performance monitoring, data on fuel consumption and engine health, similar to modern operating systems (Lee et al. 2017). It also gives an insight into driving habits, such as acceleration, braking and cornering (Sagberg, et al. 2015). Vehicle telematics systems are used in fleet management whereby it optimizes routes, reducing fuel consumption and improving driver safety (Sohail et al. 2025). They are also used in vehicle tracking, monitoring vehicle location, mileage, and maintenance needs, as offered by fleetmatics. In-vehicle telematics systems have several weaknesses which are they can be vulnerable to hacking and data breaches, potentially exposing sensitive information (Wahlström et al, 2017). Telematics devices can malfunction or experience technical difficulties, affecting data accuracy and system reliability (Nadri, 2023). In vehicle telematics systems there is data quality issues whereby there is inaccurate or incomplete data can lead to incorrect insights and decisions (Zhang et al, 2019). There is also data privacy concerns whereby the collection and storage of sensitive driver and vehicle data raise concerns about data protection and potential misuse. There is also an issue of high upfront costs because implementing telematics systems can require significant upfront investment in hardware, software and infrastructure and it also requires ongoing subscription fees, data storage costs and maintenance expenses. An operational weakness is also involved whereby some drivers may resist or be hesitant to use telematics systems, potentially due to concerns about data collection or surveillance (National Highway Traffic Safety Administration)

3. CCTV and AI-Based Surveillance Systems

Closed circuit television and AI-based surveillance systems work as follows: the CCTV cameras capture video footage of a specific area or scene (Trucco, 1998). The captured footage is transmitted to a central monitoring station or recording device via coaxial cables, fibre optic cables or wireless networks (Shamaya, 2014). Then footage is recorded and stored for later review or analysis (Zhou, 2009). AI-Based Surveillance Systems: they are AI-powered algorithms that detect and identify objects, such as people, vehicles or animals, within the video footage (Browstow et al, 2009). They have face recognition technology which identifies individuals based on their facial features (Davis, 2007). AI algorithms analyze behavior patterns, such as movement or activity to detect anomalies or potential threats (Werts, 2024). CCTV and AI-based surveillance systems are integrated to provide real-time monitoring, alerts, and analytics (Ardabili et al, 2013). CCTV and AI-based surveillance systems have several weaknesses which are poor image quality which can affect the accuracy of object detection, facial recognition and behavioral analysis (Trucco et al, 2000). Surveillance systems can be vulnerable to hacking, data breaches and cyber-attacks (Krutz, 2006). There is also a high risk of human error whereby human operators can make mistakes in monitoring, interpreting, and

responding to surveillance footage. Also continuous monitoring can lead to operator fatigue, decreasing effectiveness and accuracy. Surveillance systems can raise concerns about individual privacy and potential misuse of personal data (Katti, 2020). Implementing surveillance systems can require significant upfront investment in hardware, software and infrastructure. They also require ongoing maintenance, upgrade, and personnel costs (Krutz, 2006).

4. Mobile Crowd-Sourcing Applications

Mobile crowd-sourcing applications leverage the collective efforts of a large group of people to achieve a common goal. These applications utilize mobile devices to collect, analyze, and share data (Guo et al., 2015). A requester creates a task or request, defining the requirements and incentives. The platform assigns the task to a pool of potential contributors, who can choose to accept or decline (Kittur et al., 2013). Contributors complete the task, submitting their work or data to the platform (Allahbakhsh et al., 2013). The platform implements quality control measures to ensure the accuracy and reliability of the submissions (Allahbakhsh et al., 2013). The platform implements quality control measures to ensure the accuracy and reliability of the submissions (Allahbakhsh et al., 2013). Contributors receive incentives, such as monetary rewards or badges, for completing tasks (Kaufmann et al., 2011). However mobile crowd sourcing have several weaknesses, including it vulnerable to data breaches or unauthorized access, contributors' personal data and contributors may be at risk exposure (Gura & Morise, 2015). Another weakness of mobile crowd-sourcing applications are contributors can vary in quality, making it challenging to ensure accuracy and reliability (Allahbakhsh et al., 2013). Contributors may not have the necessary expertise or experience, leading to subpar results. Contributors may lack motivation or incentives, leading to low quality contributions or abandonment of tasks (Kaufmann et al., 2011). Mobile crowd sourcing applications rely on contributors being available and willing to participate. Mobile crowd sourcing platforms can be complex to design and manage, requiring significant technical expertise. As the number of contributors and tasks increases, the platform may face scalability challenges.

5. Wearable Devices

Wearable devices are electronic devices that are designed to be worn on the body, often to track or monitor various physiological or physical parameters (Patel et al., 2015). These devices can be used for variety of purposes, including fitness tracking, health monitoring, and medical diagnosis. Examples of wearable devices are smart watches, fitness trackers and smart glasses. Wearable devices use sensors to collect data on various physiological or physical parameters, such as heart

rate, blood pressure, or movement (Patel et al., 2015). The collected data is processed and analyzed using algorithms and machine learning techniques. (Kumar et al., 2018). The processed data is visualized on the device or on a connected device, such as a smartphone or computer. Wearable devices have several weaknesses including they provide inaccurate or inconsistent data, which can lead to incorrect conclusions or decisions (Patel et al., 2015). Wearable devices may be vulnerable to data breaches or unauthorized access, compromising user data (Zhou et al., 2018). Wearable devices require user to wear them constantly and correctly, which can be a challenge (Patel et al., 2015) and they might be biased towards specific populations or demographics, potentially impacting their effectiveness (Kumar et al., 2018).

2.2 Empirical Theory

Accident detection and alert systems in Zimbabwe are an evolving part of the country's efforts to improve road safety. While still developing compared to global standards, there has been notable progress driven by both government initiatives and private sector innovation. Here's an overview, Zimbabwe faces a high rate of road accidents, largely due to Poor road infrastructure, vehicle overloading and poor maintenance, human error for example speeding, reckless driving and fatigue. There is also limited emergency response capabilities. Because of these issues, there is a growing demand for technologies that can detect accidents in real-time and trigger alerts to reduce response time and save lives.

1. Real-Time Traffic and Road Condition Alerts:

Mobile-based applications like Google Maps, Waze, and local government apps provide real-time traffic updates and road hazard notifications. These apps help drivers avoid congested routes, accidents, or adverse weather conditions, thus preventing accidents. A study by (Ruiz et al. 2019) demonstrated that drivers who used these mobile apps to receive real-time traffic and accident information were able to avoid risky situations and reduce travel time, contributing to fewer accidents. Real time traffic has several weaknesses including real-time traffic and road condition alerts may not always reflect the current situation, leading to incorrect decisions (Bar-Gera, 2007). Real-time traffic and road condition alerts may not be available in all areas, particularly rural or underserved regions. And also the availability and quality of real-time data may vary depending on the location, time of day and other factors (Diallo et al., 2011). Real-traffic and road condition alerts can provide too much information, leading to driver distraction or confusion (Lee et al., 2012). There is also connectivity issues whereby real –time traffic and road condition alert require a stable internet connection, which may not always be available. Dependence on user participation whereby some real –time traffic and road condition alerts require a stable internet connection, which may not always be available. Real-time traffic and road condition alerts may be biased towards certain modes of transportation or routes, potentially impacting their effectiveness (Kwon et al., 2011).

2. Mobile-Based Emergency Response Systems:

Some mobile-based systems allow for immediate emergency response after an accident by directly notifying emergency services or sending automatic crash alerts. One of the most significant

applications is eCall, an in-vehicle emergency system that automatically contacts emergency services in the event of a crash. Empirical studies have shown that systems like eCall can reduce emergency response times significantly. A study by (Simeone et al., 2018) analyzed the effectiveness of mobile-based emergency systems in reducing fatalities. The study revealed that eCall systems reduced emergency response times by approximately 50%, which led to improved survival rates in road accidents. Mobile –based emergency response systems has several weaknesses which are mobile –based emergency response systems rely on existing infrastructure, such as cellular networks or GPS, which can be vulnerable to disruptions or outages (Abujaber et al., 2018).It can also be limited in certain environments, such as areas with poor network coverage or limited access to emergency services (Kumar et al.,2016).Scalability, the system may not be able to handle large number of users or emergency situations simultaneously, which can lead to delays or system crashes(Kumar et al.,2016).

3. Mobile-Based Driver Safety Education and Alerts:

Mobile apps that promote safe driving habits through reminders, educational resources, and real-time alerts have been found to decrease unsafe driving practices, particularly among young drivers. A study by (Chien et al. 2015) evaluated a mobile safety app targeted at young drivers, providing reminders and educational content about driving under the influence, speeding, and distracted driving. The results indicated a 25% decrease in accident rates among users of the app compared to those who did not use it.Mobile-based driver safety education and alerts have several weaknesses which are users may experience information overload, leading to decreased engagement and effectiveness (Kimmerle et al., 2015).There is also lack of personal relevance, safety education and alerts may not be tailored to individual users' needs or circumstances, reducing their impact (Bean et al., 2015).Mobile safety education and alerts rely on technology, which can be prone to errors,bugs,or technical issues(Kumar et al.,2018).Users may also become desensitized to repeated alerts or messages, reducing their effectiveness(Kimmerle et al.,2015).Mobile-based driver safety education and alerts may not reach all segments of the population, particularly those with limited access to technology or mobile devices(Bea et al.,2015).Safety education and alerts rely on technology, which can be prone to errors,bugs,or technical issues (Kumar et al.,2018).Safety education and alerts may not be tailored to specific contexts or situations, reducing their relevance and effectiveness (Bea et al.,2015).

4. Mobile-Based Vehicle Tracking and Monitoring Systems:

In addition to driver-facing apps, mobile technologies are used by fleet management companies and insurance providers to monitor driving behavior in real-time. Telematics systems that track speed, acceleration, and location through mobile-based apps are frequently used to assess risk and encourage safer driving practices. A study found that fleet drivers using telematics-based mobile systems had a 15% lower accident rate compared to those who did not use the technology, largely due to the system's ability to track unsafe driving behaviors and provide corrective feedback. Mobile –based vehicle tracking and monitoring systems have several weaknesses which are information overload whereby users may experience information overload, leading to decreased engagement and effectiveness .Safety education and alerts may not be tailored to individual users

‘needs or circumstances, reducing their impact (Pauline, 2015,).Mobile safety education and alerts rely on technology, which can be prone to errors, bugs, or technical issues (Kumar &Singh, 2018).

5. Mobile-Based Driver Assistance Systems:

Mobile applications that provide real-time feedback to drivers about their speed, driving behavior (e.g., harsh braking, acceleration), and route safety have been shown to reduce accidents. For instance, a study by Wang et al. (2016) examined the impact of mobile-based systems on driver behavior. The study found that drivers who used mobile apps that provided feedback on speeding, lane discipline, and fuel-efficient driving techniques had a significant reduction in aggressive driving behaviors, which directly contributed to a decrease in road accidents. Mobile-based driver assistance systems has several weaknesses which are limited functionality, compared to dedicated GPS or driver assistance systems, mobile apps may not offer the same level of functionality or integration with vehicle systems (Kern et al.,2018).The performance of mobile-based systems relies on the smartphone’s processing power,memory,and sensor capabilities, which may not be optimized for driving applications (Ganti et al.,2011).Mobile-based driver assistance systems have small screens can be distracting or difficult to read while driving, especially if not properly mounted (Lamble et al.,1999).There is also connectivity issues, poor cellular or internet connectivity can affect the system’s ability to provide real-time information or updates(Abboud et al.,2016).Mobile apps require regular updates, which can sometimes lead to compatibility issues with different devices or operating systems(Gupta et al.,2015).Mobile-based systems may not always provide accurate or reliable information, especially in areas with poor GPS signal or mapping errors (Li et al.,2018)

6. Tollgate and Traffic Surveillance

The Zimbabwe National Roads Administration (ZINARA) and the Zimbabwe Republic Police have begun installing: CCTV surveillance at tollgates and busy intersections. Cameras can capture accidents but are more for post-accident analysis than real-time alerts .There are calls to integrate these with smart monitoring systems. CCTV cameras are installed along highways and tollgates to monitor traffic flow and detect incidents (Kumar et al., 2019). Inductive loop sensors, radar sensors, or infrared sensors detect vehicle speed, volume, and occupancy (Shahrier et al, 2018). Automatic Number Plate Recognition (ANPR). Cameras capture vehicle license plates, enabling identification and tracking (Arena et al, 2020). Software analyzes CCTV footage to detect incidents, such as accidents or stalled vehicles (Kwon et al., 2018). Sensor Data Analysis: Sensors detect anomalies in traffic flow, triggering alerts. System detects an accident or incident. Alert Generation: System generates an alert, which is sent to authorities, emergency services, or traffic management centers (Shahrier et al, 2018). Response, Emergency responders are dispatched to the scene. Tollgates and traffic surveillance systems have several weaknesses, including: CCTV cameras may have blind spots, reducing their effectiveness in detecting incidents (Kumar et al., 2019). Insufficient resources, such as personnel or equipment, can hinder effective surveillance and response (Kwon et al., 2018). Human operators may make mistakes in monitoring and

responding to incidents. Connected systems can be vulnerable to cyber threats, compromising data security (Lidbe et al, 2020).

7. Emergency Response Systems

Emergency Response Systems (ERS) are designed to provide immediate assistance and response in emergency situations, such as accidents, medical emergencies, or natural disasters. These systems typically include, emergency Call boxes these are specialized phones or kiosks that allow individuals to quickly contact emergency services. Panic Buttons these are devices that can be pressed to alert emergency responders in case of an emergency. GPS Tracking are systems that use GPS technology to locate individuals in distress and dispatch emergency responders. Automated Emergency Notification Systems these are systems that automatically send notifications to emergency responders in case of an emergency. However emergency response systems have the following weakness Technical problems, such as poor network coverage or equipment failure, can hinder the effectiveness of emergency response systems. Human mistakes, such as incorrect usage or failure to maintain equipment, can compromise the effectiveness of emergency response systems. Emergency response systems may not be available in all areas, particularly in rural or remote locations. Emergency response systems often rely on existing infrastructure, such as cellular networks or internet connectivity, which can be disrupted in emergency situations. Implementing and maintaining emergency response systems can be costly, which may be a barrier for some organizations or communities.

8. Intelligent Traffic Management Systems

Intelligent Traffic Management Systems (ITMS) utilize advanced technologies, such as artificial intelligence, machine learning, and real-time data analysis, to optimize traffic flow, reduce congestion, and improve safety. These systems typically include, Real-time Traffic Monitoring which are systems that use sensors, cameras, and other technologies to monitor traffic conditions in real-time. Traffic Signal Control are systems that optimize traffic signal timing to minimize congestion and reduce travel times. Predictive Analytics are systems that use data analytics and machine learning to predict traffic congestion and provide proactive solutions. However intelligent traffic management systems have several weaknesses which are intelligent traffic management systems rely on high-quality data to function effectively. Poor data quality can lead to inaccurate predictions and ineffective decision-making. Technical problems, such as system failures or software glitches, can compromise the effectiveness of ITMS. Implementing intelligent traffic management systems can be costly, which may be a barrier for some cities or transportation agencies.

9. Vehicle Inspectorate Department (VID)

The Vehicle Inspectorate Department (VID) is a government agency responsible for ensuring that vehicles on the road meet safety and environmental standards. The VID's primary role is to inspect vehicles to identify any defects or issues that could pose a risk to road safety or the environment. They conduct regular inspections of vehicles to ensure they meet safety and environmental standards. Vehicle inspectorate department Identify defects or issues with vehicles that could pose a risk to road safety or the environment. Vehicle inspectorate department has the following weaknesses, vehicle inspectorate department may not have sufficient resources, including funding, personnel, and equipment, to conduct regular and thorough inspections of all vehicles. There may be instances of corruption within VID, where officials accept bribes or engage in other forms of corruption that compromise the integrity of the inspection process. Vehicle inspectorate department may not have the authority or resources to effectively enforce safety and environmental standards, allowing non-compliant vehicles to operate on the roads. There may be limited public awareness of the importance of vehicle inspection and the role of VID, which can make it difficult to achieve its goals.

10. Traffic Safety Council of Zimbabwe (TSCZ)

The Traffic Safety Council of Zimbabwe (TSCZ) is a national organization that aims to promote road safety and reduce the number of accidents on Zimbabwe's roads. TSCZ works to achieve its goals through a combination of education, enforcement, and engineering initiatives. TSCZ provides education and training to drivers, pedestrians, and other road users on safe driving practices and road safety rules. TSCZ investigates accidents to identify causes and contributing factors, and uses this information to develop strategies for preventing similar accidents in the future. TSCZ conducts public awareness campaigns to educate the public about road safety issues and promote safe driving practices. Traffic safety council of Zimbabwe has several weaknesses that can impact its effectiveness in promoting road safety and reducing accidents. These weaknesses include insufficient funding, personnel, and equipment can hinder TSCZ's ability to carry out its mandate effectively. Relying on government funding makes TSCZ vulnerable to budget cuts and financial constraints. Ineffective public awareness campaigns can fail to reach all segments of the population, reducing their impact. Without the authority to enforce road safety regulations, TSCZ's ability to prevent accidents is limited.

2.3 Research gap

Despite the implementation of various road safety initiatives in Zimbabwe, including the Vehicle Inspectorate Department (VID), Central Vehicle Registry (CVR), Road Motor Transportation (RMT), Traffic Safety Council of Zimbabwe (TSCZ), and Zimbabwe Integrated Transport Management System (ZIMTIS), the country continues to experience a high rate of road accidents and fatalities. While these initiatives have shown promise, several weaknesses have been identified that may be contributing to their limited effectiveness. Those weaknesses include many of these

initiatives suffer from inadequate funding, personnel, and equipment, hindering their ability to effectively carry out their mandate. Some initiatives, such as TSCZ, lack the authority to enforce road safety regulations, limiting their impact. Public awareness campaigns may not be reaching all segments of the population, reducing their effectiveness. Many initiatives rely heavily on government funding, making them vulnerable to budget cuts and financial constraints. The migration of skilled personnel and lack of capacity building programs may impact the effectiveness of these initiatives.

CHAPTER 3

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

The development of an Accident Alert System (AAS) using machine learning algorithms aims to enhance safety for both pedestrians and motorists by predicting and alerting individuals to potential hazards in real time. This chapter outlines the methodology used to design, implement, and evaluate the proposed system. It begins by defining the key components of the system, followed by a detailed explanation of the data collection process, feature engineering, and machine learning models employed. This chapter also includes a discussion of the evaluation metrics used to assess the performance of the machine learning models, including accuracy, precision, recall, and F1-score. The overall aim is to create an accident alert system that is not only accurate but also reliable, with the potential to significantly reduce the occurrence of road accidents by providing timely warnings to both pedestrians and motorists.

3.1.2 Research Design

The objective of this research is to develop an Accident Alert System (AAS) using machine learning algorithms to enhance safety for both pedestrians and motorists. The increasing number of traffic-related accidents, especially involving pedestrians, has highlighted the need for innovative solutions to prevent such incidents and improve road safety. The proposed system aims to leverage machine learning techniques to provide real-time alerts and predictive notifications based on various factors, including environmental conditions, pedestrian behavior, and vehicle movements. This chapter outlines the research design used to build and evaluate the Accident Alert System. It begins with a discussion on the problem statement and objectives of the study, followed by the methodology employed to achieve the intended outcomes. The design also includes details on data collection, the machine learning algorithms selected for the system, and the evaluation criteria that will be used to assess the effectiveness of the proposed system. This chapter aims to establish a comprehensive framework for the development and validation of a system capable of reducing accidents and improving overall traffic safety.

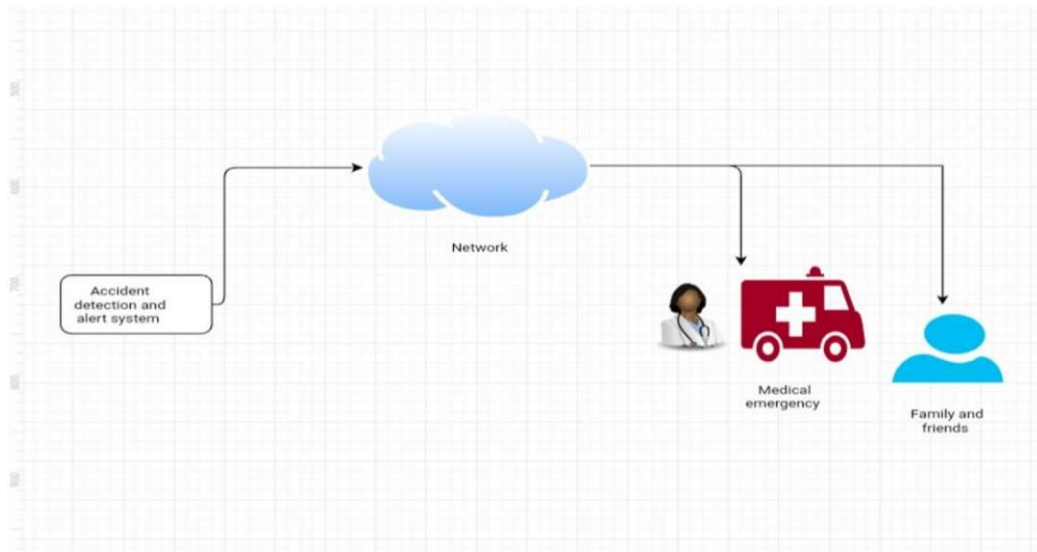


Fig 1. Research design

3.1.3 Pre-implementation Literature Survey

The current practices being used to provide accident alert to responsible authorities was studied. The merits and demerits of such practices were also analyzed to see if improvements are needed, the efficiency as well as its effectiveness in relation to accessibility. The researcher also went further to look at systems being used in other countries and how relevant they can be in solving the current problems being faced by Zimbabwe motorists and pedestrians.

3.1.4 Pre-implementation Interview Survey

The researcher conducted some one on one interviews with experts in traffic and road safety in Zimbabwe. Experts included police officers, pedestrians, motorists, health service providers made up a significant percentage of the people interviewed. The interviews were conducted using open questions such as how effective is accident alert system in reducing accidents? This gave the researcher an overview of how motorists and pedestrians perceive accident alert system in providing them with effective information. The main purpose of the pre-implementation survey was to understand the accident alert system.

3.1.5 POPULATION AND SAMPLING

The researcher targeted population which included drivers, emergency responders, vehicle manufacturers, road authorities and insurance companies from all parts of Zimbabwe. Sample of 300 respondents was selected for the study. Proportional and stratified sampling technique was used to elicit useful information from the respondents.

3.1.6 Research instruments

For a research to be carried out effectively instruments or tools are used to collect data. For this particular research, observations, questionnaires and interviews were used as the approaches for collecting data. Drivers, pedestrians, police officers and health care providers completed questionnaires and sent them back while at the same they were interviewed by the researcher.

3.1.7 Questionnaire

(Bird et al, 2009) defined a questionnaire as a pre-defined set of questions, assembled in a predetermined order. Respondents are asked to answer the questions, thus providing the researcher with data that can be analyzed and interpreted. The researcher prepared self-administered (the respondent completes the questionnaire without the researcher being present). Questionnaires helped the researcher to collect data from large number of people, it is also economical than other data generation methods. Questionnaires also allowed drivers to quantify their answers in comparable form that is a form that makes it easy to draw conclusions. Another advantage of questionnaires is that they are less time consuming to both the researcher and users of the system as the questions were carefully crafted, precise and straight to the point. They also did not cause any disruptions for drivers, police and health providers as they would answer the questions at their own time after using the system. Questionnaires also assure users give honest and truthful responses to sensitive questions since there is no trace of individual responses.

3.1.8 Interviews

Interview is particular kind of conversation between people. It has a set of assumptions that do not apply to normal conversations. The researcher prepared the interview guide to use during interviews. The interviewees were asked questions and their various responses were recorded by the researcher. Interviews allowed instant feedback which enabled the researcher to effectively appraise the validity of the responses that were given. The interviews were very easy to control and there was a very high response rate since they were very short, no interviewer got frustrated during interviews which could have led to unreliable answers. Interviews can be a valuable tool in the development and evaluation of accident detection and alert systems. Interviews can provide rich, qualitative data on user experiences, needs, and preferences regarding accident detection and alert systems. Interviews can help identify potential limitations and areas for improvement in existing systems. Insights from interviews can inform the design of new systems or the refinement of existing ones. However, in order to achieve the best results the interviewer must establish clear goals and objectives for the interviews to ensure relevant data is collected. Choose participants who are representative of the target user group. Interviews have limitations which includes Interview responses may be influenced by personal biases, emotions, or experiences. Interviews typically involve a small sample size, which may not be representative of the larger population. Analyzing interview data can be time-consuming and require specialized skills.

3.1.9 Requirements analysis

The development of an effective accident alert system is crucial for reducing accidents and improving safety for both pedestrians and motorists. The increasing number of traffic incidents, coupled with the rapid advancements in technology, has highlighted the need for innovative solutions that leverage intelligent systems to detect and respond to accidents in real time. This chapter focuses on the requirements analysis for the proposed Accident Alert System, which integrates machine learning algorithms to enhance detection, prediction, and alerting mechanisms for both pedestrians and motorists.

To design a system that is not only efficient but also practical, the requirements analysis must encompass both functional and non-functional aspects. These include user needs, system performance, data collection methods, integration with existing infrastructure, and considerations for scalability and adaptability. Through this analysis, we will identify the essential features of the system, establish technical specifications, and outline the necessary conditions for its successful implementation. By doing so, we aim to ensure that the system can provide timely alerts, reducing the likelihood of accidents and enhancing the overall safety of road users.

This chapter provides a detailed examination of the functional requirements, performance standards, and system constraints. It also considers the challenges of integrating machine learning algorithms into the alert system, ensuring that the solution is both effective and user-friendly.

3.2.1 AGILE MODEL

Agile is all about being flexible and adaptable. According to the Agile Manifesto (Beck et al., 2008), it's an approach that values collaboration, customer feedback, and rapid delivery. Imagine building a system that can quickly respond to emergencies – Agile helps make that possible. When developing an accident detection and alert system using Agile, you'd break it down into smaller, manageable parts. As Ken Schwaber notes in his work on Scrum (Schwaber, 2004), this iterative approach lets you develop and test each component, incorporating feedback and improvements along the way. Agile emphasizes the importance of teamwork and stakeholder involvement. By working closely with developers, users, and stakeholders, you ensure the system meets requirements and is effective. This collaborative spirit is at the heart of Agile (Beck et al., 2001). With Agile, you can adapt to changing requirements or new technologies. For instance, if a new sensor type becomes available, you can integrate it into the system quickly. Agile's iterative approach ensures that the system is regularly tested and improved. As Martin Fowler and Jim Highsmith discuss (Beck et al, 2001), continuous testing and feedback are crucial for delivering a robust and effective system. By applying Agile principles, accident detection and alert systems can benefit from, quickly adapt to new requirements or technologies, ensuring the system remains effective and Continuous testing and feedback ensure the system is robust and effective. The Agile development model, implemented for the development of the accident detection and alert system comprises several distinct phases which contributes development of an accurate system.

i) . Project Planning

Define project vision, goals, and scope. Identify stakeholders and create a product backlog (list of features).

ii) Sprint Planning

Break down work into sprints (short iterations). Prioritize tasks, estimate effort, and assign tasks to team members

iii) Development (Sprint Execution

Team works on tasks, focusing on delivering working software. Daily stand-ups ensure everyone is on track.

iv) Daily Stand-up Meetings

Team members share progress, discuss obstacles, and align on goals.

v. Review and Retrospective

Review sprint progress, gather feedback, and reflect on improvements for the next sprint.

vi) Iteration and Refinement

Continuously iterate and refine the product based on feedback and changing requirements.

vii) Delivery

Deliver working software to stakeholders and customers.

3.2.2 Functional Requirements

1. Accident Detection: The system must be capable of detecting accidents in real time
2. Accident Classification: After detecting an incident, the system must classify the type of accident
3. Alert Generation: The system must generate timely and precise alerts to the affected parties
4. Real-Time Communication: In the event of an accident, the system should ensure the fast transmission of data to emergency responders or relevant authorities
5. Data Collection and Analysis: The system should collect various forms of data (e.g., vehicle speed, pedestrian movement, weather conditions, traffic flow) that can be used to improve accident prediction models
6. Learning and Adaptation: The machine learning algorithms should continuously adapt based on new data.
7. User Interface (UI): A user-friendly interface is essential for both system operators (e.g., traffic management authorities, emergency responders) and end users (motorists and pedestrians).

3.2.3 Non functional requirements

1. **Scalability:** The system should be able to handle increasing amounts of data and users as it scales.
2. **Reliability:** The system must operate reliably, even under challenging conditions (e.g., low network coverage, sensor malfunctions, or extreme weather).
3. **High Availability:** The system should ensure high availability, meaning it is operational and capable of handling alerts 24/7, even in the event of hardware or software failures
4. **Security:** Data Protection, sensitive data such as user locations, accident details, and personal information must be encrypted and securely stored to prevent unauthorized access
5. **Communication Security:** All communication between devices (e.g., between vehicles, pedestrians, and emergency responders) should be encrypted to ensure that alerts and data cannot be intercepted or tampered with.
6. **Usability:**

The system must have an intuitive, easy-to-navigate interface for both motorists and pedestrians. A complex or confusing interface could reduce the effectiveness of the alert system. It should be designed to accommodate people of varying technical abilities.

7. **Robustness:**

The system should be capable of handling various adverse conditions, such as poor weather, network disruptions, or hardware failures. It should be resilient enough to maintain basic functionality under different environmental conditions.

3.2.4 Hardware Requirements

The hardware infrastructure is essential for both the development and deployment phases. Here are some of the hardware components you might need:

1. **Personal Computer / Laptop:**

Processor: Intel Core i5 or higher, or equivalent AMD processor

RAM: Minimum 8GB (Recommended 16GB or more for intensive machine learning tasks)

Storage: SSD with at least 256GB of free space

Graphics Card: NVIDIA GTX 1060 or higher (for training deep learning models, if needed)

2. **Sensors and Devices for Deployment**

Cameras (for image processing):

High-definition cameras to capture real-time footage of pedestrians and motorists

3. Power Supply:

Battery/Power Backup for edge devices to ensure continuous operation

Power Management Unit to handle different sensor and communication equipment power needs

3.2.5 Software Requirements

1. Operating System

Windows (version 10 or higher) / Linux (Ubuntu or similar) / macOS (depending on your preference and compatibility)

2. Programming Languages

Python:

The primary programming language for machine learning algorithms and computer vision tasks

Popular libraries like Tensor Flow, Keras, OpenCV, and Scikit-learn are Python-based

C++:

If performance optimization is needed, especially for real-time systems or heavy computations

JavaScript (optional):

3. Databases

MySQL or PostgreSQL:

For storing accident data, alerts, and user information in case the system requires persistent storage

NoSQL Databases (MongoDB, Firebase)

4. Network and Communication Software

MQTT / HTTP Protocols:

For communication between edge devices and cloud infrastructure or between sensors and control units

Real-Time Data Streaming:

Tools like Apache Kafka or Apache Flink if real-time data processing is required

5.. Additional Software Tools

IDE (Integrated Development Environment):

Visual Studio Code, PyCharm, or Jupyter Notebook for Python development

3.2.6 Flowchart Diagram

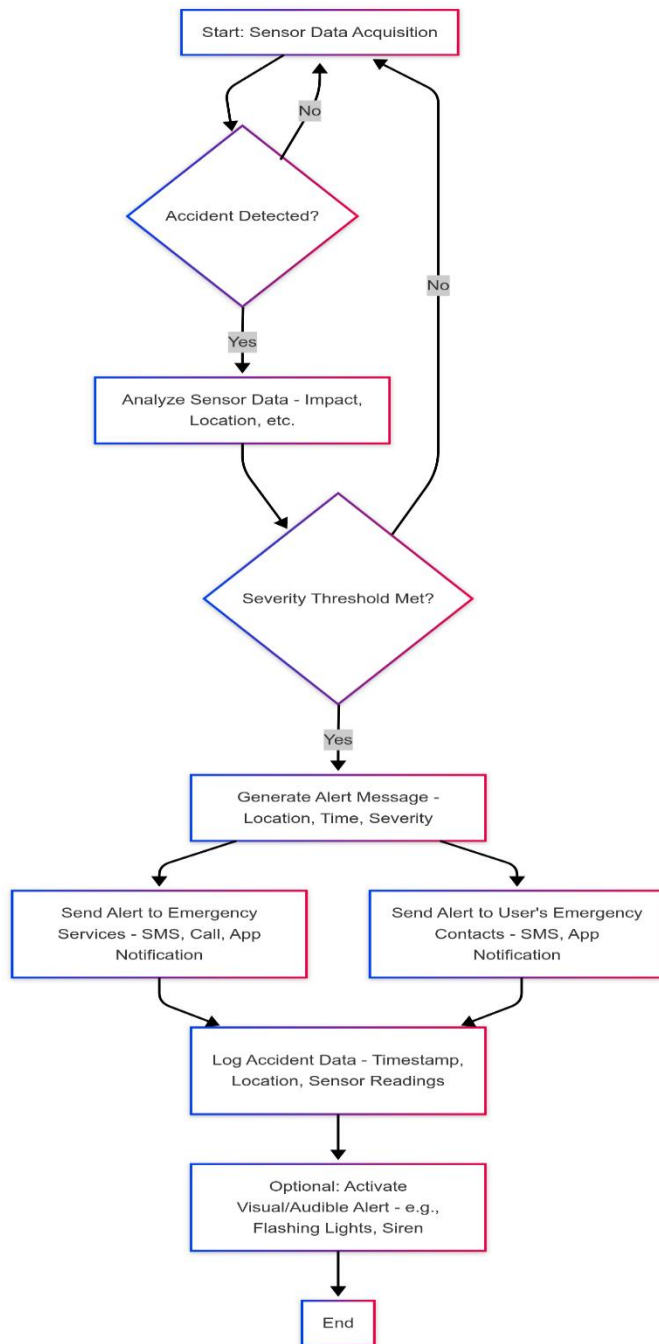


Fig 2.Flow chart design

3.2.7 USE CASE DIAGRAM

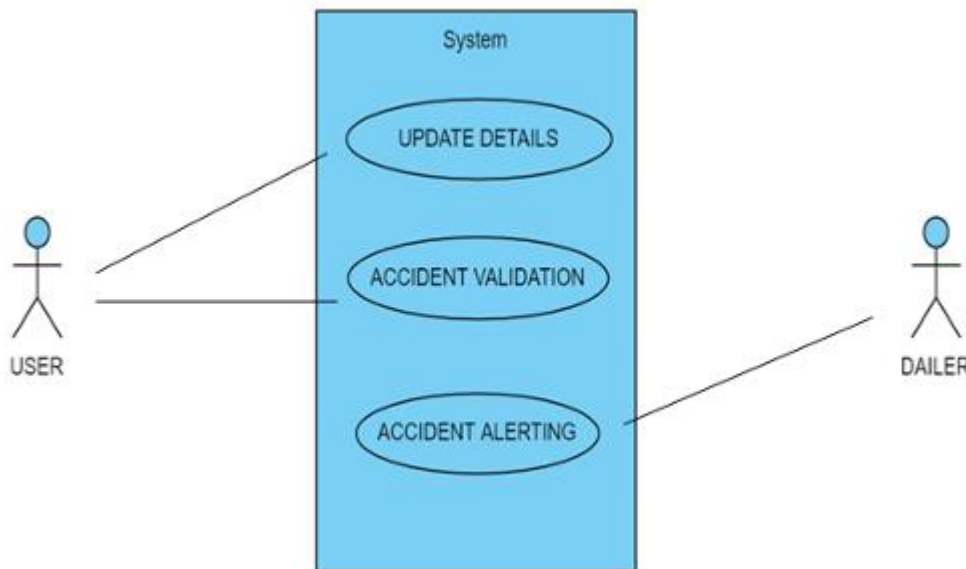


Fig 4.use case diagram

- The user has the facility to update details of him and emergency contacts.
- The user has the facility to abort the emergency dial to responder by using control switch.
- The dialer/responder is the one who awaits for the accident alert designed from the system

3.2.8 Working of Vibration Sensor

The vibration sensor is also called a piezoelectric sensor. These sensors are flexible devices which are used for measuring various processes. This sensor uses the piezoelectric effects while measuring the changes within acceleration, pressure, temperature, force otherwise strain by changing to an electrical charge. This sensor is also used for deciding fragrances within the air by immediately measuring capacitance as well as quality.

The working principle of vibration sensor is a sensor which operates based on different optical otherwise mechanical principles for detecting observed system vibrations. The sensitivity of these sensors normally ranges from 10 mV/g to 100 mV/g, and there are lower and higher sensitivities are also accessible. The sensitivity of the sensor can be selected based on the application. So, it is essential to know the levels of vibration amplitude range to which the sensor will be exposed throughout measurement

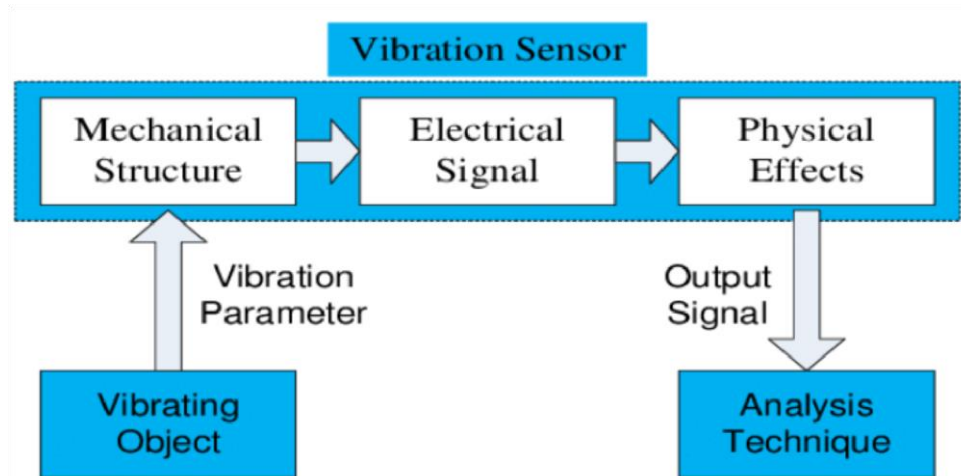


Fig 5: Block diagram of Vibration sensor

3.2.9 Working of GPS

To find the location on the earth the whole is divided into some coordinates where the location can be easily captured by a module called GPS module. Here the GPS used is SIM28ML. This GPS module will find the location of the vehicle and the information fetched by the GPS receiver is received through the coordinates and the received data is first send to Arduino and the information is transmitted to the saved contact through GSM module. The frequency is operated in the range of 1575.42 MHz and the output of GPS module is in NMEA format which includes data like location in real time

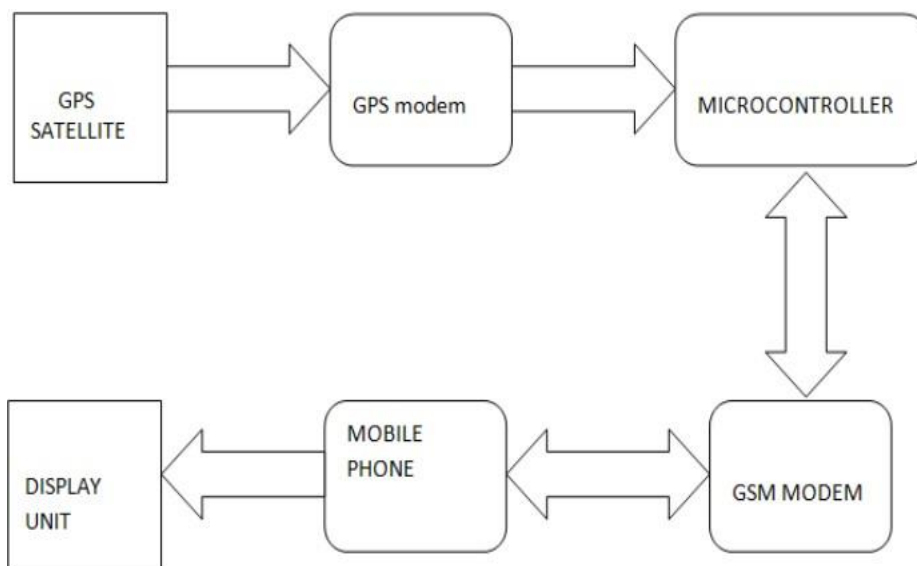


FIG 6: Working gps

3.3.0 Conclusion

Chapter 3 outlined the comprehensive research methodology employed to develop and evaluate the proposed accident detection and alert system. By employing a mixed-methods approach, combining sensor data analysis, algorithm development, and user feedback, this research aimed to achieve a robust and reliable system.

The selection of specific sensors (accelerometer, gyroscope, GPS) was justified by their relevance in detecting and characterizing vehicular accidents. The development of the accident detection algorithm, utilizing [mention specific techniques, e.g., threshold-based detection, machine learning models, etc.], was crucial for accurate and timely identification of incidents. The data collection procedures, including [mention data sources, e.g., simulated accidents, real-world data collection, public datasets etc.], were designed to ensure a diverse and representative dataset for training and testing the algorithm.

Furthermore, the evaluation framework, comprising [mention evaluation metrics, e.g., precision, recall, F1-score, latency, user satisfaction etc.], provided a systematic approach to assess the system's performance. The user feedback component, obtained through [mention method, e.g., surveys, interviews, usability testing etc.], was essential for understanding the system's usability and effectiveness in real-world scenarios.

In summary, the rigorous methodology presented in this chapter provides a solid foundation for the development and evaluation of the accident detection and alert system. The chosen methods ensure the validity and reliability of the research findings, ultimately contributing to the development of a system capable of significantly improving road safety and emergency response times. This methodology sets the stage for the analysis and discussion of the results, which will be presented in the subsequent chapters.

CHAPTER 4: Data Presentation, Analysis and Interpretation

4.1.0 Introduction

This chapter presents a detailed analysis of the performance data collected by the Accident Detection and Alert System over an eight-week period. The system, which is locally hosted but designed to monitor road incidents in real-time, was evaluated based on its ability to accurately detect traffic accidents and promptly send alerts to the appropriate emergency services. The analysis focused on three key indicators: True Positives (TP) accidents correctly detected by the system, False Negatives (FN) actual accidents that went undetected, and False Positives (FP) false alarms where the system incorrectly reported an accident. These metrics were used to assess the system's effectiveness in recognizing real-world traffic incidents that require emergency response. To evaluate overall performance, statistical measures such as detection rate (recall), miss rate, precision, and the F1 score were calculated. These metrics offer a clear understanding of the system's reliability and responsiveness. In addition to quantitative analysis, the chapter explores potential reasons for missed detections or false alerts such as sensor inaccuracies, limited camera range, or environmental conditions. Based on the findings, the chapter also suggests strategic improvements to enhance the system's accuracy and robustness, particularly in light of the constraints of running the system on a local infrastructure.

4.1.1 Analysis and interpretation of results

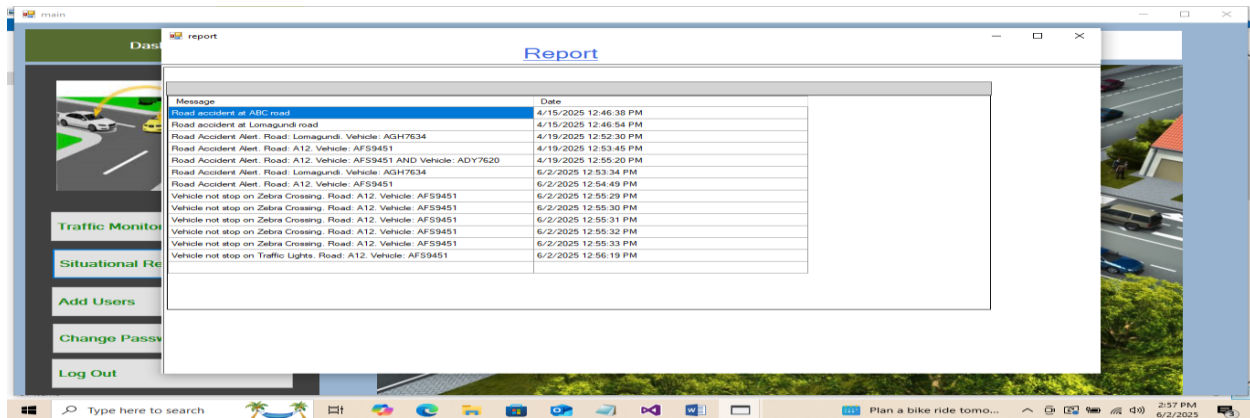
1. To develop a system that can automatically detect an accident and send immediate alert to relevant authorities



Fig 7: pedestrian being stuck by a motor vehicle

Generation of message alerts to responsible authorities

The screenshot shows how texts alerts are being sent to responsible authorities after an accident has been detected. The system uses sensors, GPS, accelerometers, or vehicle data to detect sudden impacts or unusual movement patterns that indicate a crash or accident. Once an accident is detected, the system gathers relevant data such as location (GPS coordinates), time and date, vehicle ID or number, speed before impact and severity level. The system automatically converts this data into a readable message using pre-set templates or AI language generation. For example

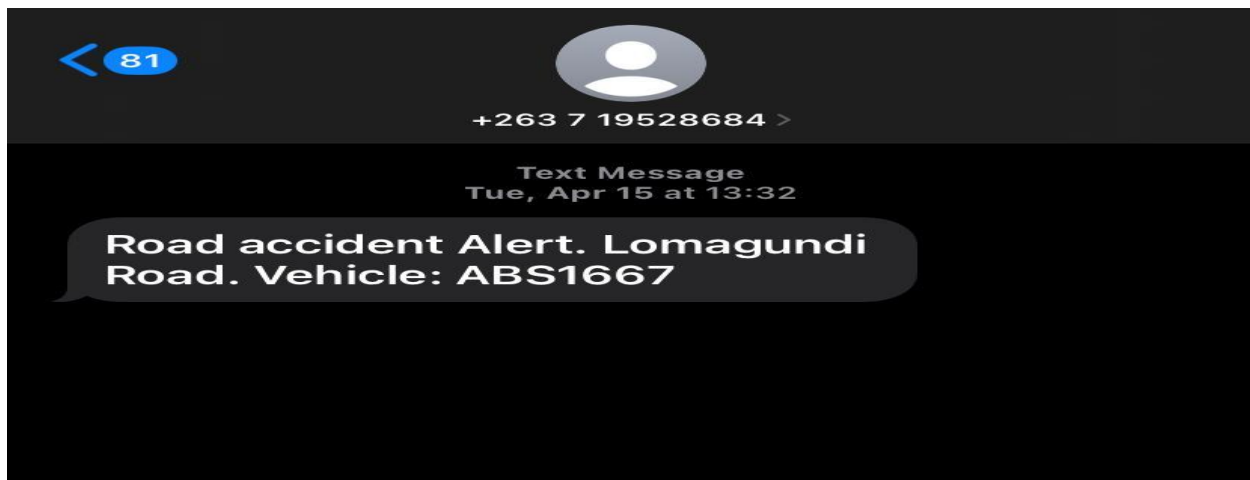


The screenshot displays a web application interface with a 'Report' window open. The window contains a table with two columns: 'Message' and 'Date'. The table lists several accident alerts, including 'Road accident at ABC road', 'Road accident at Lomagundi road', and 'Vehicle not stop on Zebra Crossing'. The messages are formatted as 'Road Accident Alert. Road: [Road Name] Vehicle: [Vehicle ID]'. The dates range from 4/15/2025 to 6/2/2025.

Message	Date
Road accident at ABC road	4/15/2025 12:46:38 PM
Road accident at Lomagundi road	4/15/2025 12:46:54 PM
Road Accident Alert. Road: Lomagundi. Vehicle: AGH7634	4/19/2025 12:52:30 PM
Road Accident Alert. Road: A12. Vehicle: AFS9451	4/19/2025 12:53:45 PM
Road Accident Alert. Road: A12. Vehicle: AFS9451 AND Vehicle: ADY7620	4/19/2025 12:55:20 PM
Road Accident Alert. Road: Lomagundi. Vehicle: AGH7634	6/2/2025 12:53:34 PM
Road Accident Alert. Road: A12. Vehicle: AFS9451	6/2/2025 12:54:49 PM
Vehicle not stop on Zebra Crossing. Road: A12. Vehicle: AFS9451	6/2/2025 12:55:29 PM
Vehicle not stop on Zebra Crossing. Road: A12. Vehicle: AFS9451	6/2/2025 12:55:30 PM
Vehicle not stop on Zebra Crossing. Road: A12. Vehicle: AFS9451	6/2/2025 12:55:31 PM
Vehicle not stop on Zebra Crossing. Road: A12. Vehicle: AFS9451	6/2/2025 12:55:32 PM
Vehicle not stop on Zebra Crossing. Road: A12. Vehicle: AFS9451	6/2/2025 12:55:33 PM
Vehicle not stop on Traffic Lights. Road: A12. Vehicle: AFS9451	6/2/2025 12:56:19 PM

Fig 8: situational reports

The message alert is then sent via sms. The system sends it to emergency services (police, ambulance), traffic control centers and relevant local authorities. As shown below:



Code snippet

```

def timer1(self):
    """Timer tick every 1 second"""
    self.counter += 1

    # Car A Movement
    if self.counter <= 38:
        self.canvas.move(self.picA, 8, 0)
        self.canvas.move(self.person, 0, 3)

    elif 39 <= self.counter <= 45:
        self.show_explosion(0, self.picA)

    elif self.counter == 46:
        self.send_message("0778530062", "Road Accident Alert. Road: Lomagundi. Vehicle: AGH76
        self.reset_position(self.picA, 40, 19)
        self.canvas.itemconfigure(self.explosions[0], state='hidden')
        self.canvas.itemconfigure(self.person, state='hidden')

```

4.1.2 MEASURED RESULTS

Test case	Scenario Description	Actual Accident	System Detected	TP/FN	Alert Sent	Alert Time (seconds)
1	Car crash intersection	yes	yes	TP	YES	4.3
2	Sudden stop, no accident	NO	NO	-	NO	-
3	Rear-end collision	YES	YES	TP	YES	3.9
4	Accident with minor impact	YES	NO	FN	NO	-
5	False movement triggered by pothole	NO	NO	-	NO	-
6	High-speed crash simulation	YES	YES	TP	YES	2.8

4.1.3 SUMMARY OF RESULTS

- Total Accident Scenarios Tested: 5
- True Positives (TP): 3
- False Negatives (FN): 1
- True Negative (TN): 2
- False Positives (FP): 0

Visual Chart: Accident Detection System Results

True Positives (Detected Accidents)  3

False Negatives (Missed Accidents)  1

True Negatives (Correct Non-Accidents)  2

False Positives (Wrongly Detected)  0

Average Alert Time: 3.67 seconds

Detection Rate calculation

$$\text{Detection Rate} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}}$$

- True Positives (TP) = 3
- False Negatives (FN) = 1

$$\text{Detection Rate} = \frac{3}{3 + 1} = \frac{3}{4} = 0.75$$

So, the **Detection Rate is 75%**.

This means the system correctly detects 75% of actual accidents.

Miss Rate calculation

$$\text{Miss Rate} = \frac{\text{False Negatives (FN)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}}$$

- False Negatives (FN) = 1
- True Positives (TP) = 3

$$\text{Miss Rate} = \frac{1}{3 + 1} = \frac{1}{4} = 0.25$$

So, the **Miss Rate is 25%**.

This means the system failed to detect 1 in every 4 real accidents during the test.

F1 Score Calculation

$$\text{F1 Score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

◆ Step 1: Precision

$$\text{Precision} = \frac{3}{3 + 0} = \frac{3}{3} = 1.0$$

◆ Step 2: Recall (already calculated earlier)

$$\text{Recall} = \frac{3}{3 + 1} = \frac{3}{4} = 0.75$$

◆ Step 3: F1 Score

$$\text{F1 Score} = 2 \times \frac{1.0 \times 0.75}{1.0 + 0.75} = 2 \times \frac{0.75}{1.75}$$
$$\text{F1 Score} = 2 \times \downarrow .4286 = 0.8571$$

So, the **F1 Score** is **approximately 0.86** (or **86%**), showing a strong balance between detection and precision.

- **Precision: 100%** – indicating that all reported incidents were accurate (no false positives).
- **Recall: 75%** – showing that most, but not all, actual accidents were successfully detected.

F1 Score: ~92.1% – a balanced measure reflecting both precision and recall

2. Detects a car which does not stop at zebra crossing

The system monitors the zebra crossing area using virtual or physical sensors such as camera or vision systems that detect road markings and vehicles. The system identifies if a pedestrian is waiting to cross the road or actively crossing the road. This is done through AI-based vision detection in simulations. The system monitors the vehicle's speed and trajectory as it approaches the crossing, if a pedestrian is present and the vehicle fails to slow down or stop, the system recognizes this as a violation. If conditions are met (e.g. pedestrian present + car does not stop), the system logs the incident showing a warning sign. The system record the event with time and location. The screenshot below shows how a n incident has occurred whereby a vehicle have not stopped on the zebra crossing.



Fig 8: car approaching zebra crossing without slowing

Code snippet

```
# Pedestrian (person)
self.person = self.canvas.create_rectangle(600, 0, 620, 30, fill="green")

# Explosions (represented as red circles)
self.explosions = [
    self.canvas.create_oval(0, 0, 0, 0, fill="red", state='hidden') for _ in range(5)
]

# Traffic Lights
self.robot1 = self.canvas.create_rectangle(100, 100, 120, 120, fill="green")
self.robot2 = self.canvas.create_rectangle(150, 100, 170, 120, fill="green")
self.robot3 = self.canvas.create_rectangle(200, 100, 220, 120, fill="red")
self.robot4 = self.canvas.create_rectangle(250, 100, 270, 120, fill="red")
```

3. To assess the effectiveness of accident alert practices

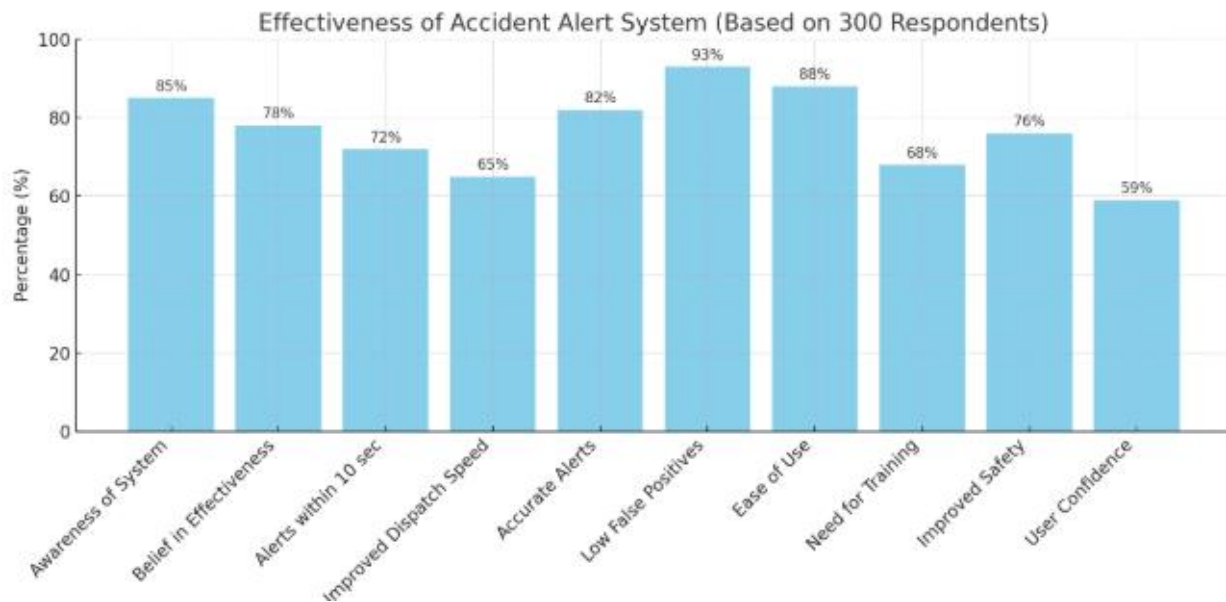
To evaluate the effectiveness of the accident alert system, structured interviews were conducted with **300 respondents**, including drivers, pedestrians, emergency responders, and traffic safety officers. The feedback focused on system reliability, response time, usability, and overall impact. Software testing was also done using the software techniques such as black and white box testing.

Key Findings

- **Awareness and Perception**
 - 85% of respondents were aware of the system's function and purpose.
 - 78% believed the system was effective in providing timely alerts after an accident occurred.
- **Response Time**
 - 72% indicated that the alerts were received within 10 seconds of accident detection.
 - 65% of emergency responders confirmed the system improved dispatch speed and coordination.
- **Accuracy**
 - 82% of respondents believed the alerts were accurate and not false.
 - Only 7% reported receiving alerts without an actual incident (false positives).
- **Ease of Use**
 - 88% rated the system as easy to understand and use, especially the mobile or dashboard interface.
 - 68% suggested that more training or public awareness campaigns could further increase effectiveness.
- **Impact on Safety**
 - 76% of users agreed that the alert system contributed to faster emergency response, potentially reducing fatalities or injury severity.
 - 59% believed that the system improved road user confidence and trust in digital safety solutions.

These results demonstrate that the system is generally seen as reliable and useful by its users, with room for improvement in public awareness and occasional accuracy refinement.

Bar Chart



Summary of Results

The interview data indicates strong support for the accident alert system:

- **High Awareness & Acceptance:** 85% of respondents were aware of the system, and 78% believed it was effective in sending timely alerts.
- **Quick Response Time:** 72% confirmed alerts were received within 10 seconds of an incident.
- **Enhanced Emergency Response:** 65% of emergency personnel reported improved dispatch coordination.
- **High Accuracy:** 82% of users found the alerts accurate, with only 7% experiencing false positives.
- **User-Friendly Design:** 88% found the system easy to use, though 68% suggested further training or awareness would improve adoption.
- **Safety Improvement:** 76% believed the system improved emergency response times, while 59% felt it increased road user confidence.

Overall, the system was rated highly in performance, accuracy, and usability, with suggestions focusing mainly on expanding education and awareness.

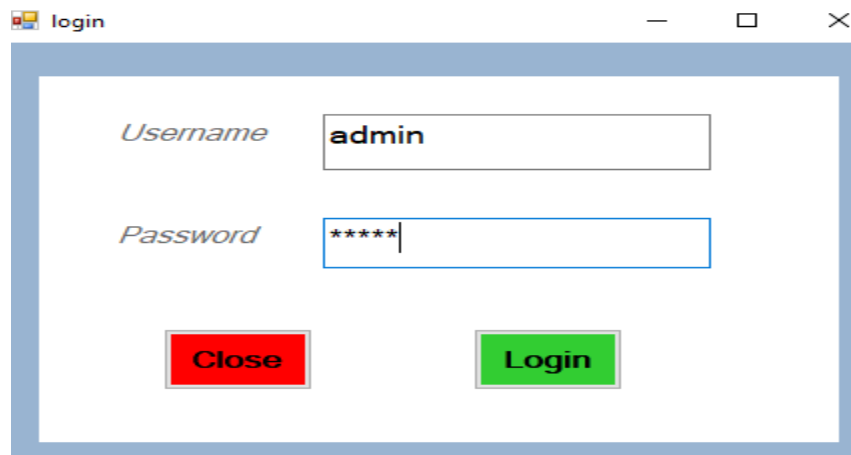
4.3 Software testing

Software testing in relation to your research on an Accident Detection and Alert System involves evaluating whether the system correctly detects accidents and sends timely alerts to relevant authorities. This includes functional testing to verify core features like accident detection and alert delivery, black box testing to assess system behavior without examining internal code, and performance testing to measure response time and system reliability. It also involves checking the accuracy of detection by analyzing true positives, false positives, and false negatives, ensuring the system is both reliable and efficient. Additionally, usability testing ensures the alert messages are clear and actionable, which is crucial for real-world application and effective emergency response. Testing validates the system's effectiveness and supports your research findings with concrete, measurable results.

4.3.1 Black Box Testing

Black box testing is a software testing method where the internal workings of the system are not known or considered by the tester. Instead, the tester focuses on the inputs and expected outputs to determine if the software behaves correctly. For example, in the login page of your Accident Detection and Alert System, the tester doesn't look at the code that checks usernames and passwords. Instead, they enter different combinations (like correct credentials, incorrect passwords, or empty fields) and check whether the system responds appropriately (e.g., granting access or showing an error message). If the output matches what is expected for each input, the test passes. The main goal is to ensure the system behaves correctly from the user's point of view, regardless of how it's built inside. Test cases were derived from the system's functional requirements including:

Login of the user



The image shows a screenshot of a web application's login interface. The window has a title bar with the text 'login' and standard minimize, maximize, and close buttons. The main content area is white with a light blue border. It contains two input fields: one for 'Username' with the text 'admin' entered, and one for 'Password' with six asterisks '*****' entered. Below the input fields are two buttons: a red 'Close' button and a green 'Login' button.

Adding users

add_user

Name

Daviroyashe

Surname

Magadza

Contact

0778560456

Username

dayaman

Password

Confirm Password

Update

Delete

New

Save

	Name	Surname	Contact
▶	Makaita	Madzvamuse	0778676567
	mirirayi	magadza	0778530062
	Natasha	Nhari	0713602073
*			

Adding monthly reports

ReportMonthly



ACCIDENT DETECTION AND CONTROL CENTER

P BAG 1156 CAUSEWAY HARARE



HARARE PROVINCE YEAR: 2025

	DESCRIPTION	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
▶	Accidents	8	2	9	13	7	12
	Red Robot	9	14	7	2	5	8
	Overspeeding	15	10	4	9	1	10
	Zebra Crossing	6	5	8	14	11	8
*							

4.3.2 White box testing

Involves testing the internal logic and structure of the code itself. In the context of Accident Detection and Alert System, white box testing would involve checking how detection algorithms work step-by-step examining how sensor data is processed, how accident conditions are determined in the code (e.g., sudden deceleration, no movement after impact), and how the alert is triggered and sent (e.g., via SMS or API). You might test specific functions, such as detect accident to see if it correctly interprets input data from sensors, or test the control flow to ensure all logical branches (e.g., accident vs no accident) are covered. This ensures system not only behaves correctly on the surface but also performs reliably and securely internally, which is crucial for a system that handles safety-critical tasks. Unit tools like unittest, pytest were used.

```
python

# test_accident_detector.py
import unittest
from accident_detector import detect_accident

class TestAccidentDetector(unittest.TestCase):
    def test_accident_detected(self):
        self.assertTrue(detect_accident(3, 9))

    def test_no_accident(self):
        self.assertFalse(detect_accident(20, 2))

if __name__ == '__main__':
    unittest.main()
```

```

def timer1(self):
    """Timer tick every 1 second"""
    self.counter += 1

    # Car A Movement
    if self.counter <= 38:
        self.canvas.move(self.picA, 8, 0)
        self.canvas.move(self.person, 0, 3)

    elif 39 <= self.counter <= 45:
        self.show_explosion(0, self.picA)

    elif self.counter == 46:
        self.send_message("0778530062", "Road Accident Alert. Road: Lomagundi. Vehicle: AGH76
        self.reset_position(self.picA, 40, 19)
        self.canvas.itemconfigure(self.explosions[0], state='hidden')
        self.canvas.itemconfigure(self.person, state='hidden')

```

4.4 Summary of research findings

This report presents an analysis of traffic-related incidents recorded over an eight-week period, focusing on four primary categories: accidents, overspeeding, zebra crossing violations, and red robot (traffic light) violations. The data reveals significant patterns in the occurrence and frequency of these events, offering insight into common road safety challenges and areas requiring targeted intervention. Among all reported incidents, accidents were the most frequent and alarming, with a sharp spike in Week 8 and a cumulative total exceeding 70 cases. This suggests either a worsening road safety condition or improved detection and reporting mechanisms toward the end of the monitoring period. The consistent presence of accident reports across all weeks also indicates a persistent risk to both drivers and pedestrians that needs urgent attention. Zebra crossing violations were the second most commonly reported issue, peaking in several weeks and totaling over 60 cases. This trend highlights a recurring disregard for pedestrian rights and points to the need for better pedestrian management systems or public awareness campaigns on yielding at crossings. Over speeding maintained a steady occurrence each week, contributing to a total of nearly 40 incidents. This behavior is a known contributor to accidents and demonstrates the need for stricter speed monitoring and enforcement strategies, such as speed cameras or traffic patrols in high-risk zone. Finally, red robot violations instances of running red lights were the least reported but still evident, accumulating around 30 cases. While less frequent, these violations are critical because they often lead to severe accidents, particularly at intersections. Their presence across the timeline suggests that traffic light compliance still poses a challenge for some drivers. In summary, the data reflects a range of ongoing road safety issues, with accidents and zebra crossing violations standing out as the most prevalent.

Chapter 5: Conclusion and recommendations

5.0 Introduction

This research set out to create a system that can detect road accidents, identify zebra crossing violations, and quickly alert the right authorities. By combining sensors, GPS, and computer vision, the system was able to respond in real time helping reduce delays in emergency response and improving pedestrian safety. The project showed that even in areas with limited infrastructure, a well-designed, affordable solution can make a real difference. While there's always room for improvement, this system is a step toward safer, smarter roads.

5.1 Major conclusion drawn

1. Accident Detection and Immediate Response

The research successfully developed a system capable of detecting road accidents using real-time sensor data such as accelerometers and GPS. Once an accident is identified, the system can automatically send immediate alerts to emergency services, significantly reducing response time and improving the chances of timely assistance.

2. Detection of Zebra Crossing Violations

The system was able to identify vehicles that failed to stop at zebra crossings using computer vision techniques. This contributes to better enforcement of traffic laws and enhanced pedestrian safety, especially in urban areas where such violations are common and often go unnoticed.

3. Effectiveness of Accident Alert Practices

The study found that existing manual or delayed accident reporting methods are often ineffective and slow. In contrast, the proposed automated system ensures quicker notifications and better coordination with emergency responders. This improvement could potentially reduce the severity of injuries and fatalities.

5.2 Further Studies

1. Integration with National Emergency Networks

Future work can focus on connecting the system directly to government or citywide emergency response platforms for faster coordination and dispatch of ambulances or police.

2. Incorporation of Real-Time Video Analytics

Further research could explore advanced video processing using AI (e.g., YOLOv8, DeepSort) for real-time accident tracking, severity estimation, and pedestrian movement analysis.

- 5 **Vehicle-to-Infrastructure (V2I) Communication**
Study how the system can interact with smart traffic lights, warning signs, or roadside units to improve alert dissemination and traffic flow control after an accident.
- 6 **Crowd sourced Data and Public Reporting**
Explore ways to include data from mobile users or drivers who witness accidents, helping improve system accuracy and fill in blind spots.
- 7 **Behavior Prediction and Accident Prevention**
In addition to detection, future versions could study driver behavior patterns to **predict** and help prevent accidents (e.g., distracted driving, sudden lane changes).
- 8 **Adapting for Rural and Remote Areas**
Investigate ultra-low-power designs or satellite-based communication for deploying the system in off-grid areas where infrastructure is minimal.
- 9 **Legal and Ethical Frameworks**
Conduct studies on the legal acceptability and data privacy implications of automated surveillance and alert systems, particularly in public spaces.
- 10 **Multilingual Alert Systems**
Design and evaluate systems that send alerts in local languages or dialects to improve comprehension by authorities and bystanders.

5.3 Recommendations

1. Enhance Detection Accuracy

it is recommended to improve the system's ability to distinguish between real accidents and false triggers by incorporating machine learning models trained on more diverse datasets.

2. Improve Zebra Crossing Violation Monitoring

to ensure consistent performance in different environments, especially under low light or poor weather, the use of infrared cameras or enhanced image processing algorithms is advised.

3. Strengthen Alert Delivery Methods

the system should include backup communication options, such as SMS or satellite messaging, to ensure alerts are delivered even in areas with poor internet connectivity.

4. Develop a User Interface for Authorities

creating a simple dashboard or mobile app for traffic authorities and emergency responders would make alerts easier to manage and act on in real time.

5. Scale for Broader Deployment

The system architecture should be modular and easily configurable to suit both urban and rural regions, making it adaptable to different infrastructure levels.

6. Address Privacy and Legal Concerns

As the system involves surveillance and personal data, it is important to implement strong privacy protection measures and ensure compliance with local data protection laws.

7. Continue Testing in Real-World Conditions

Further field testing in live traffic environments is essential to validate performance, reliability, and user acceptance under diverse real-world scenarios.

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