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A Comparative and Analytical Review of Iot-Enabled Smart Accidental Management Systems

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***Abstract*.** One of the most important issues that emerging nations are addressing is road accidents. It is important to develop smart accidental management systems with low cost and efforts to prevent accidents and causalities. The amalgamation of Intelligent Transportation Systems (ITS) and Information and Communications Technology (ICT) is expected to dramatically change how people experience driving by enabling cutting-edge traffic monitoring and incident detection strategies. This analysis focuses on various components of SAMS, such as sensor networks, communication protocols, data processing techniques, and decision-making algorithms. It examines how these components work together to create a connected infrastructure capable of detecting and responding to accidents promptly. The review highlights the role of data analytics in enhancing accident prediction and prevention. By processing and analyzing enormous real-time data from cameras, sensors, and other sources, IoT-driven SAMS can identify patterns and anomalies, allowing for proactive measures to avoid accidents in various settings, including transportation, industries, and public spaces.
Keywords: *SAMS, IoT, GSM, VANET, GPS*

1. INTRODUCTION

Many accidents are caused by driver drowsiness as a result of exhaustion, gruelling road conditions, and bad weather. Millions of people die in vehicle accidents globally each year. In general, road accidents are mainly caused by poor driving practises. Lane indiscipline, i.e., wrong-side driving, also led to accidents on the roads, accounting for a number of accidents, fatalities, and injuries. Jumping red lights, using a mobile, being drunk while driving, and failing to stop at stop signs all contributed to accidents and deaths.

Around 17–18% of all incidents, fatalities, and injuries were in the other category, which includes things like road conditions, car conditions, and so forth. There were also more accidents, deaths, and murders in 2019 compared to 2018 as a result of speeding, intoxicated driving, and running red lights while using a phone. In smart city areas, inefficient planning, a lack of sufficient facilities, and an increase in traffic are all challenges. A recent trend in intelligent transportation system research is the development of automatic event detection systems to detect instantaneous jamming, traffic congestion, and accidents on the roads that result in irreplaceable financial damages and human lives. Most modern automatic incident detection systems rely on fixed detectors to monitor occupancy, speed, and lane changes in traffic flow. Due to road maintenance, weather, short-range communication, line of sight, and driver driving patterns, errors in data collection may eventually lead to errors in processing as well. These systems were not suitable for urban environments because of the highly variable traffic density factor and were designed for motorways only.

Intelligent Transportation Systems (ITS) and Information and Communications Technology (ICT) have been merging at a great pace over the past ten years. This combination is expected to dramatically change how people experience driving by enabling cutting-edge traffic monitoring and incident detection. More specifically, to gather the data, sensors are embedded in the vehicles to enable vehicle-to-vehicle (V2V) communication between them, and roadside units (RSUs) may be installed on roadsides to enable V2I (vehicle-to-infrastructure) communication. The ITS systems utilise this information for the detection of incidents and disseminating notification tasks to suggest alternate routes to the drivers. The first hour following an accident is seen as the most essential, and the first 5 to 10 minutes are known as the "golden moment" for those who have been traumatized. As a result, AID, reporting, and prompt rescue service delivery contribute to a reduction in road-related injuries, fatalities, and other monetary losses. The road event detection systems need to be improved, which includes the usage of advanced sensors or detectors and consequently improving the corresponding algorithms of data processing. The video-based systems suffer from high latency in the event detection mechanisms. These systems collect data on traffic flow parameters using detectors, sensors, and other surveillance devices before designing algorithms for data processing to flag the occurrence of an event. Two key elements go into the design of AID for the systems: (1) data collection and (2) data analysis to identify trends in regular and incidental traffic flow to send out emergency notifications. People who report accidents worry about being wrongly accused and about being forced to testify in court because Indian legal processes are known for being drawn out.

The first hour after an accident is considered critical, and the first 5 to 10 minutes are referred to as the "golden moment" for individuals who have been traumatized. As a consequence, AID, reporting, and timely rescue service delivery help reduce road-related injuries, fatalities, and other monetary losses. The installation of advanced sensors and detectors and enhanced algorithms for data processing is part of a notable commitment to improving incident detection systems. In event detection techniques, both human and video-based systems suffer from substantial delays. These systems use sensors, detectors, and surveillance devices to collect data on traffic flow characteristics before developing algorithms for data-processing to recognize the occurrence of an event. The AID for the systems comprises the collection of data and then analyzing it to identify trends in regular and incidental traffic flow in order to send out emergency warnings. People who report accidents are concerned about being wrongfully charged and being forced to appear for trial in court. They were also concerned about being required to pay for the victim's medical care if they helped bring the victim to the hospital. As a result, there is a requirement for automatic accident notification and rescue preparation. This analytical review explores the advancements and challenges associated with Smart Accidental Management Systems (SAMS) that utilize IoT in accident prevention, detection, and response. This review also delves into recent research, case studies, and developments in this emerging field to evaluate the effectiveness and potential of such systems.

2. FUNCTIONALITIES OF SMART ACCIDENTAL MANAGEMENT SYSTEMS

Accidental management is a critical aspect of ensuring safety and preventing unwanted incidents in various environments, such as industrial settings, transportation, healthcare, and public spaces. The advent of smart technologies has brought forth innovative solutions to enhance accident prevention, detection, response, and overall safety. Smart Accidental Management Systems (SAMS) use advanced techniques like AI (Artificial Intelligence), IoT (Internet of Things), data analytics, and automation in order to create safer environments and minimise risks. The primary objective of Smart Accidental Management Systems is to proactively identify potential hazards, swiftly respond to emergencies, and continuously improve safety measures through data-driven insights.

Real-Time Monitoring and Detection: SAMS utilize a network of sensors, cameras, and other IoT devices to continuously monitor the environment. They can detect anomalies, abnormal behavior, or hazardous conditions that might lead to accidents.

- Data Collection and Analysis: After the data collection and processing, AI models and advanced algorithms are used to analyze these data in real-time. It is used to recognize trends, patterns, and potential risks, enabling proactive decision-making.
- Predictive Analytics: leveraging historical data and machine learning algorithms, SAMS can predict and forecast potential accidents or hazardous situations. This proactive approach allows for timely intervention and risk mitigation.
- Alerting and Emergency Response: When an unusual event or potential accident is detected, the system triggers immediate alerts and notifications to relevant personnel or emergency services. This prompt response enhances the chances of preventing accidents or minimising their impact.
- Preventive Measures: SAMS implements automated safety protocols, reminders, and safeguards to prevent accidents from occurring. These can include safety checklists, equipment shutdowns in unsafe conditions, and automated warning systems.
- Integration and Connectivity: Smart Accidental Management Systems can seamlessly integrate with existing safety infrastructure, such as fire alarms, access control systems, and emergency response mechanisms. Additionally, they can communicate with other smart devices and systems to enhance overall safety and coordination.
- Data Visualization and Reporting: SAMS provides user-friendly dashboards and data visualization tools to help users interpret data effectively. Comprehensive reporting features enable organizations to identify areas for improvement and implement targeted safety measures.
- Compliance and Regulatory Support: These systems assist organizations in complying with safety regulations and industry standards. They automate reporting processes, making it easier to demonstrate adherence to safety guidelines.
- Continuous Improvement and Learning: Smart Accidental Management Systems are designed to learn from past incidents and near-misses. By analyzing historical data, they enable organizations to continuously improve safety protocols and reduce the likelihood of similar accidents in the future.

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2. CLASSIFICATION OF SMART ACCIDENTAL MANAGEMENT SYSTEMS

Smart Accidental Management Systems revolutionize the way safety is managed in various domains. They bring intelligence and automation to accident prevention, detection, response, and analysis, ultimately leading to safer environments, reduced risks, and enhanced emergency preparedness. With the advancement of technology, these systems may become more complex and sophisticated. The broad classification of SAMS is given in figure 1.

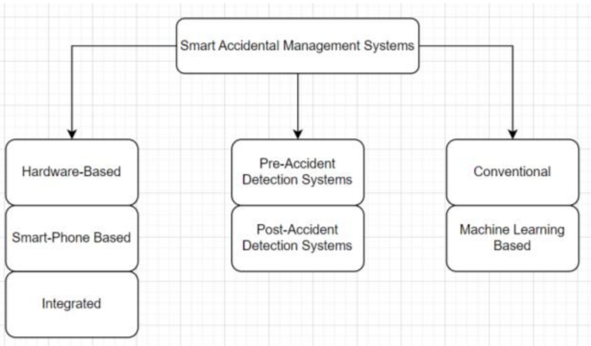

FIGURE 1. Classification of Smart Accidental Management Systems

3.1 Hardware Based SAMS

Various accident detection systems use a range of sensors to identify and report accidents. Typically, these sensors are installed externally on the vehicle. For instance, a microcontroller and vibration sensor-based vehicle prevention and detection system has been proposed by D. Bindu et al. [1]. The Atmel microcontroller AT89S52All is attached to all the peripherals, including the GPS module, GSM module, and sensors. These sensors sense events such as vibration, force, and acceleration and then invoke notifications to the emergency services regarding the predicted incidents. However, rescue operations are not well supported by these systems. Similarly, an accelerometer and GPS sensor based system using IoT has been proposed by A. Shaik et al. [2], which sends the collected information to the cloud. In the event of an accident, a message is dispatched to the victim's emergency contact numbers, providing details about the incident's severity and location and aiding the ambulance in reaching the scene promptly.

Another IoT-based system discussed by C. Nalini et al. [3] employs a GPS module, buzzer, and vibration sensor to sense the accident and thereafter make the alerts. Once an incident is detected, a buzzer is switched on for the prescribed time, and if it is not stopped during that timeframe, web services are used to send the notification to the emergency contacts. Likewise, C. Dashora et al. [4] introduced a similar system to the one used in [3]. However, one disadvantage of their approach is that after detecting an incident, the location is forwarded to the customer care department, which then involves human intervention by manually calling the nearby hospital. In contrast, a GPS module and crash sensor based automated system for incident detection and alerting has been presented by N. K. Karanam et al. [5]. One significant drawback of IoT-based systems is their costliness compared to Smartphone-based solutions. Nevertheless, the system's accuracy can be enhanced by integrating AI-based techniques.

3.2 Smart-Phone Based SAMS

These systems employ smart phones and their sensors to detect and report road accidents. Zhao et al. [6] utilized a GPS data and accelerometer to recognize the incident locations. However, their strategy solely identifies the accidents without informing the rescue teams. An accident identification strategy has been presented by Reddy et al. [7] that utilizes a GPS module to identify the location of incidents and notifies hospitals through mobile messages. However, a limitation of their paper is its dependence on only one sensor. Consequently, the failure of that sensor will make the whole system non-functional, which may lead to an increased rate of false alarms. Hamid M. et al. [8] presented a system that uses Smartphones for notification if an accident is identified. This system uses speed, noise, and G-force values for the detection of the accident. The accelerometer and mobile sensor are employed in order to extract noise data and gravitational strength. A notification is sent to the control room after the detection of an accident. However, the false alarm rate may be raised when accidents happen at slow speeds because speed is primary factor used for accident detection.

Patel et al. [9] developed a system that uses an Android application for alerting when an accident is detected, relying on a GPS module and one accelerometer mobile sensor. Once an incident is detected, the rescue teams are informed via an already recorded voice message. Similarly, the disadvantage of this system is its dependence on a single sensor, which could lead to system failure if that malfunctions. An Android application was created by Isha Khot et al. [10] that utilize the GPS module and accelerometer sensor for the detection of accidents and alerting. The primary characteristic of this system is notifying nearby users regarding the location of the incident and rescue facilities. However, it also depends on a single sensor. One of the major disadvantages of Smartphone-based systems is their reliance on smart phones themselves. For effective functionality, the accident detection app must be installed by the users in their smart phones. Additionally, only the quality of the mobile sensor determines the accuracy of this system, and increased false accident detection may happen especially at slow speeds.

3.3 Integrated SAMS

Smart Accidental Management Systems (SAMS) integrate deep learning and IoT technologies for the detection of accidents and response. An integrated system utilizing an OBU (on-board unit) to detect and report the incidents has been proposed by Fogue et al. [11]. Various pieces of information, such as vehicle type, speed, and airbag status, are collected by the sensors, which are then forwarded to the cloud for analysis using machine learning techniques to predict accidents. A disadvantage of this approach is that OBU is not supported by all vehicles. A deep learning-based incident identification and emergency call system has been presented by R. Gokul et al. [12]. This system uses pre-installed cameras powered by Wi-Fi installed on highways to continuously monitor passing vehicles. Video analysis is performed by deep neural networks in the cloud, and then the nearby control room is notified about the incident.

Ghose et al. [13] use a system that classifies the incidents into two categories, non-accident and accident using CNN. Camera-recorded live video is sent to the server, where the used classifier classifies it into the respective categories. Their model was trained on a dataset created from YouTube videos, claiming 95% accuracy for accident detection but lacking rescue operation consideration. C. Wang et al. [14] use the already trained Yolo v3 model for vision-based detection of accidents and emergency services. This model is trained to detect accidents in various situations, like rainy or foggy conditions. The live video recorded by the cameras installed on the road is used by this system, which claims 92.5% accuracy with a false alarm rate of 7.5%. An IoT and machine learning-based incident identification and emergency services system has been presented by Akash Bhakat et al. [15]. Accident-related data is collected through an IoT kit and processed locally using fog computing instead of the cloud or server. However, the complexity and quality of the input video data may affect the accuracy of their machine learning approach.

Jae Gyeong Choi et al. [16] use audio and visual information from the dashboard for accident detection using ensemble deep learning. They used CNN and GRU (Gated Recurrent Unit) for the identification and classification of the accidents. The limitation of this system is that an accident may result in a damaged camera. As this method does not have any IoT modules, the false positive rate may increase. An automatic car accident detection technique using support vector machines (SVM) and CNN has been proposed by Hawzhin Hozhabr Pour et al. [17]. The model achieved 85% accuracy during testing, but this might not be sufficient for real-world applications.

Comi et al. [18] determine the main causes and patterns of road accidents by applying data mining approaches. They used various algorithms, such as Kohonen networks, k-means, decision trees, and neural networks, for analysis. Data mining techniques are applied by Li et al. [19] on the FARS Fatal Accident dataset to establish associations between accident causes and the environment. For association rule mining, the Apriori algorithm is used, and for creating clusters, k-means clustering is used. E. S. Part et al. [20] used path analysis to determine the relationship between a car's speed and collision frequency, finding a positive correlation. A deep learning model for forecasting road incidents using limited data has been proposed by G. Singh et al. [21], which may not be sufficient for training such models. In recent years, deep learning-based solutions have gained popularity across various sectors, including medical, agriculture, and transport. However, the lack of sufficient high-quality accident datasets is the main challenge for the researchers. Integrated road incident identification systems using cameras on highways depend heavily on camera quality and environmental conditions, which impact their accuracy. Pre-trained models can be used to address data scarcity and enhance accident detection accuracy.

3.4 Pre-Accident SAMS

In this section, various methods of accident identification and prevention have been explored proactively. The major objective of this module is to forecast the occurrence of an incident and alert the drivers to take precautionary measures. For forward collision detection, some systems have been developed using a range of sensors. On the other hand, other systems utilise VANETs to achieve a similar goal through different techniques and protocols. Communication between vehicles plays a crucial role in decreasing the probability of accidents on the roads by exchanging information that helps in avoiding collisions. Forward collision detection techniques are primarily used by Pre-Accident Identification systems. These methods utilise sensors like RADAR, LIDAR/LASER, or cameras to gauge the possibility of a forward impact [22]. The system analyses factors such as relative velocity, radius of curvature, detection range, and other parameters among the position of the vehicle and other related objects to avoid clashes. The real-time data from lidar, radar, sensors, and cameras enable the estimation of the range, angular information, and range rate of other automobiles and items in the vicinity of the concerned car.

In VANET, the cars are the mobile nodes. It is an application of MANET (Mobile Ad Hoc Network). In VANET, the hub can be a moving vehicle or a RSU, forming a decentralized system. It comprises a custom-designed topology and various medium access strategies for communication and coordination, enabling interactive communication among vehicles through a unique method [23]. Using Vehicle-to-Vehicle (V2V) communication in VANETs, cars can exchange and broadcast critical information like accident alerts and traffic conditions among other vehicles and within a specific region. In a VANET, a RF module is utilized for wireless V2V communication [24]. The Wave Station presents the common protocols, interfaces, and necessary engineering for VANET functionality. It organizes vehicles and facilitates data exchange among them through V2V communication, providing real-time updates on the state of the vehicles on the road. Wireless communication systems between vehicles are rapidly gaining popularity, with a focus on vehicle-to-vehicle (V2V) and infrastructure-to-vehicle communication systems. Figure 2 depicts vehicular-to-vehicular communication.

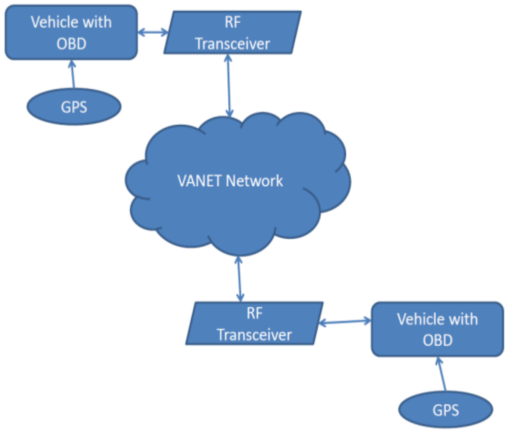

FIGURE 2. Vehicular to Vehicular Communication

CoMoSeF utilizes cell phones to replace substandard sensors, resulting in improved data dissemination speed. Its primary objective is to provide services for vehicles lacking a functioning CAN-Bus framework and information in a convenient and rapid manner. Drivers, fleet operators, vehicle manufacturers, and additional road users are the main beneficiaries of CoMoSeF. The implementation efforts of CoMoSeF will span across various countries worldwide, demonstrating its advantages and impact. The administration is expected to provide crucial weather information and crucial data for improving road safety. The main focus of CoMoSeF is on developing the backend applications, sensors, and street-side units and helping drivers make informed decisions. Cars will receive individualized information through data display-enabled intelligent street-side devices. The Human-Machine Interface (HMI) method employed for displaying and modifying driver messages also plays an important role. Furthermore, a diagnostic tool will be used to create a simulation framework, offering a comprehensive overview of the entire communication.

3.4 Post-Accident SAMS

This section discusses the various methods utilized to detect accidents and the alert systems used to inform rescue personnel about accidents. Various sensors are installed in cars to gather data about the direction of the accident and the position of the vehicle. A novel technique utilizing a gyroscope and accelerometer for identifying the various parameters such as collision, oscillation, and tension or high-speed compression has been proposed by Hari Sankar S et al. [25]. On the other hand, Norsuzila Ya'acob et al. [26] utilize a Piezoelectric sensor. The general workings of these systems are given in figure 3.

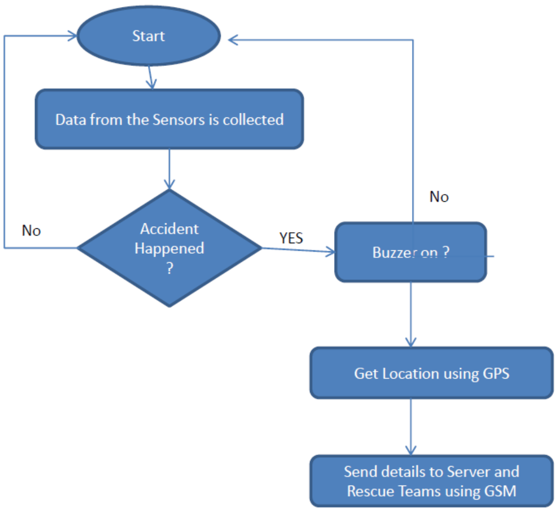

FIGURE 3. General workflow of Post-Accident SAMS

In [27], the authors assess the frequency of accidents using airbag sensors, vibration sensors, and biological sensors. The position of the accident is determined by installing GPRS/GPS modems [28–30]. Additionally, the automobile is equipped with a switch to detect sudden heart attacks and other life-threatening illnesses. The accident detection module utilizes advancements in GSM and GPS technologies. To ensure that the drivers are in good working order and that the safety belt is properly worn, corresponding devices are employed in the security empowerment module. In case of an accident, if vibrations exceeding the maximum level are observed by the vibration sensor, the GSM module is notified of this information, which then forwards the corresponding notification to the prescribed teams [31].

3.5 Conventional SAMS

The conventional approaches to accident detection and alerting systems use various types of information like vibration, pressure, accelerometers, shock sensors, RFID, IF, etc. for the detection tasks. Figure 4 below presents the list of various parameters/devices used conventionally to detect accidents, and thereafter alerting is done accordingly.

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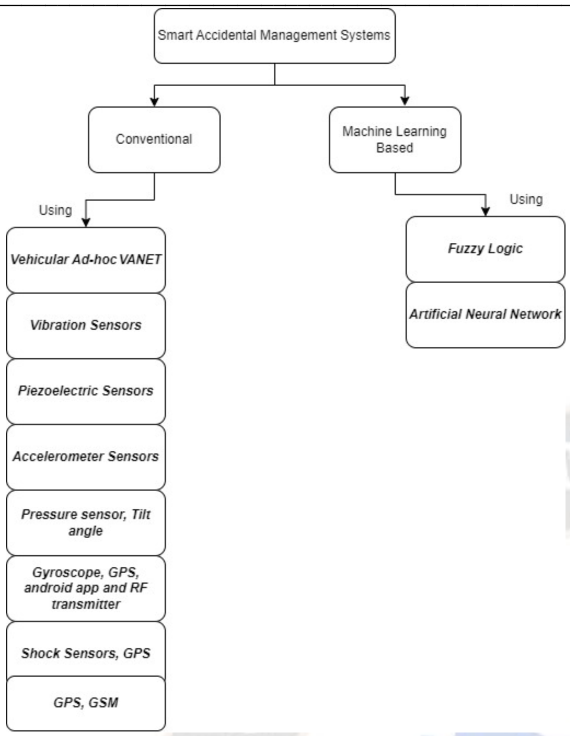

FIGURE 4. Conventional and ML-based SAMS

3.5.1 VANET-Based SAMS

Manuja M et al. [32] put forward a proposal concerning traffic congestion, attributing it to vehicle failures or accidents occurring in areas without network coverage. Their solution involves implementing a VANET-based system, where each moving vehicle acts as a node. An RF module is used to transmit the alert messages, which are received by other vehicles within its range. Once the message reaches a vehicle within the network area, it is forwarded to the base station. These alert messages are triggered by four types of events detected by different sensors, including a temperature sensor, a MEMS sensor, a flame sensor, and a piezoelectric sensor. The primary advantage of this system is its ability to swiftly identify vehicular mishaps and promptly notify rescue teams, providing them with the exact location of the incident. Additionally, a switch is integrated into the system, allowing the driver to halt the alert message transmission in the event of minor injuries or minimal damage. The system's controller processes the data taken from the sensors, and accident alert information is being sent to the RSU, which further dispatches the message to the rescue team. The vehicle's location is determined using WiFi and GPS technology. Unlike previous systems that relied on GSM modules and failed in no-network areas, this system ensures communication in both network and no network regions. It also offers the option to suspend message transmission in situations where serious damage has not occurred.

However, there are certain limitations and challenges that need to be considered and resolved in future work. VANETs face privacy and security concerns and also suffer from routing challenges due to their highly dynamic topology. In a related study, B. Shabir et al. [33] conducted an analytical study on congestion control strategies for VANETs. The network congestion in VANETs is prevented by three different congestion control techniques: reactive, proactive, and hybrid. Throughput and latency are the two vital parameters that need to be considered in network congestion control. The techniques they investigated fall into six major categories: prioritizing, CSMA/CA-based, rate-based, power-based, hybrid strategies, and clustering-based techniques.

In [34], the focus is on the critical problem of network congestion in VANETs, primarily caused by their highly dynamic topology. This congestion poses a significant challenge to applications relying on VANETs, particularly emergency services like rescue teams and ambulances, which heavily depend on timely communication for responding to road accidents, mishaps, security alerts, and other emergencies. VANETs serve various applications, both safety-related and non-safety-related. Safety applications are particularly crucial in preventing accidents by giving timely warnings to cars, but their effectiveness can be compromised due to network congestion. In VANETs, vehicles are considered mobile nodes, a subset of MANETs, and can be instrumental in Intelligent Transportation Systems (ITS) for enhancing road safety and convenience. The major concern with using VANETs is their highly dynamic topology, which leads to problems such as network congestion and frequent disconnections. To tackle these issues, multicast routing techniques in VANET protocols have been explored and their performance studied. The multicast routing techniques are categorized as reactive, proactive, and flooding. Multicast routing strategies are used in VANETs to deal with certain challenges like adaptability, loop avoidance, and network overhead in the context of a highly dynamic topology.

3.5.2 Vibration-Sensor Based SAMS

D.B. Tushara et al. [35] presented a microcontroller-based technique for the detection of accidents and reporting tasks. The system is designed with the aim of reducing the response time following an incident. The system also features an alert to a pre-configured number when an accident is detected. The detection of accidents is achieved through the use of a vibration sensor. However, the system is limited by its dependence on a single sensor, which increases the likelihood of generating incorrect output. Another drawback is that while the system generates an alert message upon detecting an accident, the location of the accident is not provided.

3.5.3 Accelerometer Sensors Based SAMS

Careless and rash driving are the main factors leading to accidents among bike riders. A proposed system uses helmets for accident identification and reporting. It utilizes various components such as processors, sensors, and cloud computing utilities. Upon accident detection, the system uses a cloud-based service to send relevant details to emergency contacts. GPS technology tracks the location of the car. The helmet is equipped with a tri-axial accelerometer, a microcontroller, and GPS. Continuous monitoring of the head and helmet orientation allows the system to calculate the probability of an accident. If the speed limit is crossed, an alert notification is transmitted to the control room. It is connected to the cloud server using a RESTful architecture with HTTP communication. Compared to other solutions, this system is cost-effective and ensures that text messages are sent continuously until an acknowledgement is received in case of an accident. However, there is a potential drawback, as false alarms may occur if the driver accidentally or intentionally removes the helmet. Moreover, the system requires additional storage and computational capabilities for communication with the cloud services.

In a study by B.S. Anil et al. [36], they proposed a novel technique for the detection of clashes. Their technique uses flex and accelerometer sensors to detect accidents, and the position of the mishap is transmitted to the control room via a GSM modem. The transmitted data contains crucial information, including the accident position, time of occurrence, and vehicle number. Real-time video from an in-mount camera helps monitor the passengers' current situation. The system also monitors the speed of the car using the accelerometer and checks it against a pre-defined threshold value to detect accidents. While the presence of in-mount cameras aids in assessing accident severity and providing appropriate medical aid, it also leads to privacy issues due to the transmission of live video. R.K. Megalingam et al. presented another smart collision detection and rescue alert system [37]. This system is designed to be installed inside a vehicle, where an accelerometer sensor detects accidents. The microcontroller observes the sensor output, which interfaces with an RF (Radio Frequency) transmitter module to send information to rescue teams. Upon receiving the information, the rescue teams take the necessary steps to provide timely medical treatment.

3.5.4 Piezoelectric Sensors Based SAMS

Patil et al. [38] proposed a technique that detects accidents and promptly informs rescue teams and the nearby police station. GSM is employed in this system to send alerts and notifications to the emergency and rescue teams. By constantly tracking the car, the system can immediately notify rescue teams if an accident occurs. The system incorporates a GSM modem and GPS receiver along with the Renessa's microcontroller. The GSM is employed for sending an alert notification that includes the GPS-provided location as well. The main modules of this system comprise a GPS, GSM, and piezoelectric sensor. The system continuously tracks the location of the car, ensuring timely communication of the location in case of an accident. However, a significant drawback of this approach is the absence of a switch to cancel the transmission of the alert notifications in situations where no severe harm has occurred.

3.5.5 GPS, Gyroscope, RF transmitter and Android App based SAMS

Kumar et al. [39] presented an innovative solution for accident detection and reporting, completely eliminating the need for manual human intervention before or after an accident occurs. The system's main components include GPS, a Gyroscope, an Android application, and a Raspberry Pi. Additionally, the driver's blood group is also saved within the system. Upon detection of an accident, the rotation angle is measured by the Gyroscope installed in the vehicles, and if it is above the prescribed threshold value, a notification is immediately sent to an active server. Simultaneously, the server continuously feeds the information to the application installed in the ambulance. This application aids the ambulance in efficiently navigating to the site of the incident by utilizing Google Maps API to trace the path with the least traffic congestion. The ambulance periodically transmits an RF signal to avoid traffic congestion and further expedite the journey. Traffic lights in the area are equipped with RF receivers, and when they detect the signal, they promptly turn green, facilitating the ambulance's swift passage towards the accident site. Furthermore, the system sends an emergency message to the sufferer’s family, ensuring they are promptly informed about the incident. This comprehensive system aims to provide timely assistance to accident victims and enhance emergency response efficiency.

3.5.6 Tilt angle and Pressure Sensor based SAMS

An Android application-based solution for accident detection and reporting is introduced in [40]. The system employs various sensors to monitor the vehicle's status. An external pressure sensor is employed in order to measure the outer force observed by the car, while accelerometer sensors and GPS on the phone measure the tilt angles and the speed. The data from these sensors is transmitted to the phone via Bluetooth. The system detects accidents based on sudden changes in the speed of the vehicle and when tilt angle and pressure cross a pre-determined threshold value. To offer flexibility, a switch is included so that when false alarms and non-severe accidents occur, the driver may discontinue the transmission of emergency messages. However, the research acknowledges certain limitations. One limitation is that the force observed by the phone might not precisely match the force observed by the car. Additionally, smart phones have battery limitations, which could affect the system's continuous monitoring capabilities.

3.5.7 GPS and Shock Sensors based SAMS

Nasr et al. [41] introduced a technique that promptly informs the PSO (Public Safety Organization) when a mishap happens. The system employs a Shock Sensor to detect accident occurrences. Once the signal from the Shock Sensor is processed, the system transmits the geographic location to the PSO. This method is structured into different stages. The vehicles are registered, and an IoT gadget is mounted in the Vehicle Registration phase. After the device installation, the vehicle ID is given to the concerned individual at the PSO headquarters for registration in their database. The passenger registration phase involves registering passengers associated with the vehicle. In the PSO headquarters-based Accident Monitoring phase, the PSO headquarters continuously monitors accidents. The main modules of the system include a GPS, shock sensor, NFC reader, and cellular IoT. These devices exchange information with each other to detect accidents and promptly inform the PSO head office, providing the geographic location of the incident. When the shock sensor identifies an incident, a notification is transmitted via HTTP request along with the accident's site.

3.5.8 GSM and GPS based SAMS

The system utilizes a GPS receiver to continuously observe the speed of the car. The detection of the incident relies on the monitored speed, where the GPS compares the previously monitored speed with the current speed instantaneously by using a microcontroller unit. If the speed falls below a pre-defined threshold limit, the system identifies it as an accident. Additionally, the GPS module detects the geographic position of the vehicle. When an incident is identified, the system uses a GSM module to transmit a notification to the crisis management teams, notifying them about the incident. In [42], a solution is presented to determine the vehicle's position using an ARM microcontroller. To obtain the vehicle's position, the user sends an SMS to make a request for the same. The GSM module receives and acknowledges the request, and the Spartan processor processes the request. The processor then commands the GPS module to track the vehicle's position. The GPS module replies to the request with the position coordinates of the vehicle, including latitude and longitude values, that are sent back to the user. However, a weakness in the literature is noted, as external environmental factors may significantly impact the system's performance.

3.6 Machine Learning Based SAMS

The transportation system has a vital role in the everyday lives of human beings, providing numerous conveniences, though it also carries various associated risks. With road traffic accidents increasing each year, it is crucial to develop an effective mechanism to reduce their frequency. Crash prediction models have gained significant popularity, particularly for ensuring road safety on highways. Various models based on AI (Artificial Intelligence) and ML (Machine Learning) have been proposed for crash prediction, such as fuzzy logic, ANN (Artificial Neural Networks), SVM (Support Vector Machine), Genetic Programming, and Random Forest Classifiers. These models utilize real-time data, which is evaluated with already collected data on accidents, enabling the differentiation between normal situations and accidents. In the following discussion, some of the key strategies for prediction and detection of accidents in the ML/AI domain will be explored.

3.6.1 Fuzzy Logic Based SAMS

Alkandari et al. [43] presented a fuzzy logic based technique for the detection of accidents within the vicinity of traffic lights. The whole system contains the detection sub-system and the action sub-system. Based on the Webster Method with some modifications, the data from various zones is collected, as well as the frequency of cars in each lane and their respective speeds. Any disturbance in the normal traffic flow serves as a primary indicator of an accident's occurrence. The key components of this scheme involve crisp inputs/outputs, linguistic variables, fuzzy rules, and membership functions. Linguistic variables such as accident status, zone status, cross ratio, and section speed assist in identifying accident scenarios. The system generates the output by applying fuzzy rules to the linguistic inputs, leading to appropriate actions to enhance the flow of traffic. The outcomes demonstrate the model's capability to accurately detect accident situations.

A novel model for accident prediction utilizing fuzzy logic is proposed in [44]. As accidents are influenced by non-linear relationships between various factors, the use of fuzzy logic is deemed preferable. Contributing factors to road accidents include traffic conditions and human negligence, among others. The key inputs to the model include the road width, speed, frequency of cars in a lane, and surface condition of the road. Accident data used in the model was gathered from officials, focusing on roads with increasing accident occurrences in previous years to enhance the model's accuracy. In the model, fuzzy rules-based mapping of crisp inputs with the corresponding crisp outputs is carried out based on specific circumstances. The membership functions are used to define the input variables. Fuzzy variables are created by defining the membership functions for inputs and

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outputs, represented linguistically. Trapezoidal and Triangular functions are employed in this model. The obtained performance values demonstrate good accuracy in the prediction of accidents; however, various aspects such as weather conditions and road lighting were not considered in this study.

3.6.2 ANN and SVM Based SAMS

A system is proposed to detect accidents from the video recordings taken from CCTV cameras mounted on roads [45]. The video frames are fed into a CNN (Convolutional Neural Network) model, allowing it to differentiate between frames depicting accidents and non-accidents. To implement the system, a Raspberry Pi 3 B+ Model is used as a remote computer that has the capability of being positioned on the CCTV cameras. The system utilizes a Pi Camera for demonstration purposes to capture video data. To detect accidents, the Inception v3 model is utilized after being trained on two diverse sets of video data containing non-accident and accident frames. Inception v3 is a CNN model appropriate for object detection and image classification tasks. Both LSTM (Long Short-Term Memory) and CNN (layers) are used in the proposed model. The Inception v3 model is advantageous for extracting features from images through heterogeneous convolutions. The system is implemented on a Raspberry Pi using Keras, OpenCV, and Tensor Flow. Each frame of the video is processed, and it is predicted whether the frame depicts an accident or not. If the predicted information crosses a threshold limit of 60%, the GSM module is initiated by the Raspberry Pi and transmits a notification to the nearest hospitals, including the geographic details of the location. The performance parameters demonstrate the system's good accuracy with the trained data set, and it is also considered cost-effective. However, its constraint is that only severe accident data is utilized to train the model, potentially excluding moderate or minor accident scenarios from its coverage.

Pan and H. Wu [46] introduced a method for accident detection using mobile sensors and Support Vector machines (SVM). Their approach specifically targets accident detection on city roads, which are more susceptible to accidents due to the presence of various flow-disrupting elements such as bus stops, traffic signals, and other urban features. In contrast, motorways experience less traffic. The approach utilizes Vehicular Ad-Hoc Networks (VANETs), where each vehicle is equipped with mounted sensors that allow them to gather their own traffic data, including lane state, speed, identity, and location.

4. COMPARATIVE ANALYSIS

4.1 Characteristics and Limitations

In this study, several recent works have been studied thoroughly by considering various aspects. Every SAMS has its characteristics and limitations. Some of them are listed below in Table 1.

TABLE 1. Characteristics and Limitations of some SAMSs

Reference	Characteristics	Limitations
Bansal B.N. et. al. [47]	- Less costly sensors and easy availability of vibration sensor - Small in size -Faster communication with MQTT protocol and Wi-Fi technology. -Vibration sensor value is published to Adafruit platform every 2 seconds.	- Ill maintained roads and speed breakers led to false alarms.
Gomathy C. K. [48]	-GPS is used to determine the exact location.	-System becomes costlier due to GSM. - Slower communication with GSM.
Suryakala N.R.G. et al. [49]	-Monitoring of speed of the vehicle. - Varying Mobile numbers.	- Sending of data isn’t secure -Not suitable in poor network environment. -Costlier system - Speed breakers and ill maintained roads led to false alarms

R. K. Kodali et. al. [50]	-Simple system	-Costly Accelerometer - Speed breakers and ill maintained roads led to false alarms -LOSANT platform is comparatively slower than Adafruit IO
Manuja M et al. [32]	-Faster and Quicker Process -Additional information regarding the vehicle is received using the additional sensors. -Reliable and Fast	-Costly
Swetha B. et al. [51]	-Reliable system	-Cost of the system enhanced due to use of the additional sensor. -Ultrasonic sensor can be avoided -Nonfunctional in remote areas.
Reddy V.S. et al. [52]	-More Reliable as both GSM and Wi-Fi have been utilized. -Camera Module enhances the usefulness of the system.	-Controller is costly

4.2 Analysis in terms of Cost and Accuracy

The comparative analysis of the various Accident detection and alerting systems based on their costs, accuracy, False Positive Rate, Automatic Reporting and Switch to Terminate False Alarm is summarized in Table 2, where their performance is analyzed in terms of Low, Medium, and High .

TABLE 2. Comparative Study of some GSM based Systems

Reference	Cost	Accuracy	False Positive Rate	Switch to Terminate False Alarm	Automatic Reporting
Chandran et al. [53]	High	Medium	Medium	No	Yes
Rao et al. [53]	Medium	Low	High	No	Yes
Nanda et al. [55]	High	Medium	Low	No	Yes
Manuja M et al. [32]	High	High	Low	Yes	Yes
Faiz et al. [40]	Medium	Medium	High	Yes	Yes
Ahmed et al. [56]	Low	Low	High	No	No
Amin et al. [31]	Medium	Low	High	-	Yes
Ghosh et al. [18]	High	High	Low	-	Yes
Berade et al. [51]	Medium	Medium	Low	No	Yes
Priyanka C et al. [57]	Medium	Low	High	No	Yes
Anil et al. [36]	Medium	Medium	Medium	No	Yes
Tushara et al. [58]	Low	Low	High	No	Yes
Nasr et al. [41]	Medium	Low	High	No	Yes
Patil et al. [59]	Medium	Low	High	No	Yes

4.3 Analysis in terms of various parameters used in different SAMSs

A comparative summary of various parameters used by the researchers in different accident detection and alerting systems is summarized in Table 3, which depicts that the Smart Accidental Management Systems use more than one parameter to make the prediction and detection.

TABLE 3. Comparative study of various parameters used in different research works

Reference	GPS	Accelerometer	Temperature	Seat Belt	Pressure	Vibration	RFID	Alcohol
Chandran et al. [53]	Yes	Yes	-	-	-	-	-	-
Rao et al. [54]	-	Yes	-	-	-	-	-	Yes
Nanda et al. [55]	Yes	Yes	-	-	Yes	Yes	Yes	Yes
Manuja M et al. [32]	Yes	-	Yes	-	-	Yes	-	-
Faiz et al. [40]	Yes	Yes	Yes	-	-	-	-	-
Ahmed et al. [56]	-	Yes	Yes	-	-	-	-	-
Amin et al. [31]	Yes	-	-	-	-	-	-	-
Berade et al. [51]	-	-	-	Yes	-	-	-	Yes
Priyanka C et al. [57]	Yes	Yes	-	-	Yes	-	-	Yes
Anil et al. [36]	Yes	Yes	-	-	-	-	-	-
Tushara et al. [58]	-	-	-	-	-	Yes	-	-
Nasr et al. [41]	Yes	-	-	-	-	-	-	-
Patil et al. [59]	Yes	-		-	Yes	-	-	-

5. CONCLUSION

The review of smart accidental management systems reveals a diverse range of innovative solutions aimed at enhancing accident detection, reporting, and response mechanisms. Various approaches have been presented, each leveraging different technologies such as sensors, GPS, GSM, IoT, Machine Learning, and Artificial Intelligence to improve road safety and emergency assistance. Some of the reviewed systems use helmets equipped with sensors and cloud-based services to detect accidents and promptly notify emergency contacts. Others focus on in-vehicle sensors and communication modules to send accident-related information to rescue teams. Additionally, certain systems utilize video footage from CCTV cameras and advanced algorithms to identify accidents on highways. It also highlights the importance of accurate accident prediction models with the adoption of techniques like fuzzy logic and Convolutional Neural Networks. These models help anticipate potential accident scenarios and improve traffic flow management. While the reviewed systems demonstrate promising results, there are still some limitations that need to be addressed. These include potential false alarms, privacy concerns with live video feed transmission, and the need for better consideration of various environmental factors affecting system performance. Overall, the ongoing research and advancements in smart accidental management systems offer great promise in reducing accident frequencies, enhancing emergency response times, and ultimately saving lives on the roads. Future efforts should focus on addressing the identified limitations, exploring more robust technologies, and conducting real-world testing to ensure the systems' effectiveness and reliability.

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