MERATECH
Vol. 01, No. 1 (2025), pp. 54-60
ISSN: XXXX-XXXX

Designing a Vehicle Accident Detection Device for Two-Wheeled Vehicles Using Vibration Values and Tilt Angles Based on the Internet of Things (IoT) System

Moch. Irsyadul Ibat[1] | M. Ihwanudin[2*] | Muchammad Harly[3]

[1,2,3] Study Program of Automotive Engineering Technology, Faculty of Vocational Studies, Universitas Negeri Malang, Malang 65145, Indonesia

Corresponding Author: M. Ihwanudin (m.ihwanudin.fv@um.ac.id)

Received: 28-08-2025 | **Accepted:** 31-08-2025

Abstract

Traffic accidents in Indonesia have been increasing every year. To address and minimize the high number of traffic accidents, especially involving two-wheeled vehicles, a device is needed to warn drivers when an accident is about to occur. The purpose of this study is to develop an accident detection device utilizing Internet of Things (IoT) technology by observing the angle of inclination and vibration values of two-wheeled vehicles. The research method used is R&D Research and Development, which follows the Borg and Gall development model. This model includes: 1) Literature review, 2) Planning, 3) Design creation, 4) Limited testing, 5) Revision, 6) Testing and feasibility testing, 7) Final revision, and 8) Dissemination and implementation. The research results explain that to measure vehicle vibration values, the SW-420 sensor was used with vibration values determined by the researcher at 2,000 Hz, 10,000 Hz, 30,000 Hz, and 40,000 Hz. For measuring the tilt angle of the vehicle, the GY 521 MPU-6050 sensor was used with tilt angle values determined by the researcher at 10°, 30°, 45°, and 50°. In conclusion, the accident detection device operates normally under normal vehicle conditions, and the vehicle tilt angle range remains between 10° and 30°. Under normal vehicle conditions, the vibration sensor on the vehicle does not fall within the range of 6.016–8.120. Meanwhile, the accident detection device will immediately activate and send an automatic message via WhatsApp to the user when the vehicle's tilt angle is between 45° and 50°, indicating that the vehicle has fallen. Regarding vibration values, the accident detection device will send an automatic message via the user's WhatsApp when the vibration range is between 10,558 and 60,850, indicating that the vehicle has fallen.

Keywords: Internet of things, NodeMCU ESP8266, GY-521 MPU-6050, SW-420, GPS BN 220

1. INTRODUCTION

In this era of rapid technological development and globalization, there has been an increase in the number of privately owned vehicles. One of these is the motorcycle. Motorcycles have become one of the most used modes of land transportation among various segments of society. This is because motorcycles are practical and easy to use, making them an attractive option for people looking to purchase a vehicle due to their affordable price. Despite the availability of numerous public transportation facilities provided by the government, the demand for motorcycle purchases among the public continues to rise each year [1]. With the increasing number of motorcycle users in today's technologically advanced and modern era, there are some technologies that do not come with measures to mitigate the risk of accidents. The number of traffic accidents in Indonesia continues to rise each year [2]. According to data from the Indonesian National Police through the National Criminal Information Center (Pusiknas) of the Criminal Investigation Department, there were 134,867 traffic accidents reported from January to November 2023. During this period, there were 134,867 traffic accident cases, resulting in total material losses of Rp258.18 billion. Given the high accident rate, there is a significant risk of fatalities. Of the accidents that occurred, 77% involved motorcycles, with drivers aged 25-40 accounting for nearly 40%. This can be minimized by ensuring that the victim's family receives information and handles the accident case as quickly as possible. Currently, reports of traffic accidents are still done manually, where witnesses at the scene contact the authorities responsible for handling the accident case. This manual reporting process can result in delays in information reaching the victim's family. Therefore, with the availability of such data, there is a need for an accident detection system that can quickly send information about the accident location [3]. Therefore, there is a need to develop an accident detection device to address and minimize the high number of traffic accidents, particularly involving two-wheeled vehicles. A device is required that is built with a real-time system and is always ready to alert drivers when an accident occurs [4].

2. METHOD

The research method used is RnD Research and Development, which refers to the Borg and Gall development model. This model refers to: 1) Literature study, 2) Planning, 3) Design creation, 4) Limited testing, 5) Revision, 6) Testing and feasibility testing, 7) Final revision, and 8) Dissemination and implementation. In this research method, several sensors and application software were used to support the development of this accident detection device.

In this study, a microcontroller in the form of NodeMCU ESP8266 was used, which has the function of processing various measurement data. NodeMCU ESP8266 is a microcontroller based on the ESP8266 chip equipped with built-in WiFi. Its functions include as the brain of an IoT system, it can receive input from sensors (temperature, humidity, light, etc.) and then process it. It controls actuators such as lights, LEDs, relays, motors, and other electronic devices. Internet connection (IoT) connects directly to a WiFi network to send/receive data to IoT platforms (Blynk, ThingsBoard, MQTT, Firebase). Prototyping & IoT application development is easy to program with Arduino IDE, PlatformIO, or Lua. Communication with other devices via protocols such as HTTP, MQTT, TCP/IP, or serial [5].

Here are the general specifications Main chip: ESP8266EX (32-bit RISC, Tensilica L106) Clock Speed: 80 MHz (can be overclocked up to 160 MHz) Memory: RAM: ±64 KB instructions + 96 KB data, Flash Memory: typically 4 MB (depending on the module) GPIO (General Purpose Input/Output): ±11 programmable pins Communication: UART, SPI, I²C, PWM, ADC (1 channel 10-bit) Operating Voltage: 3.3V (however, NodeMCU has an internal regulator so it can be powered by 5V via the USB port or Vin pin) Power Consumption: very low, ±80 mA on average, can enter deep sleep mode < 10 µA.

Figure 1. NodeMCU ESP 82660

The LM2596 is a DC-to-DC step-down (buck) converter IC used to lower high DC voltage to lower DC voltage with high efficiency. Main functions to provides stable voltage for microcontrollers (Arduino, ESP8266, ESP32, Raspberry Pi). Protects electronic devices from overvoltage. LM2596 also known as a step-down voltage regulator, is used to reduce the voltage from 12 V to 5 V, used in IoT systems, power banks, lithium batteries, LED drivers, chargers. DC input is supplied (e.g., 12V from an adapter or battery). The LM2596 IC reduces the voltage according to the setting (e.g., to 5V or 3.3V). The DC output is stable with a relatively large current (up to 3A). The output voltage can be adjusted using a potentiometer (on the LM2596 Adjustable module) [6].

Figure 2. LM 2596

The GY 521 MPU6050 sensor functions as a detector of changes in the tilt angle of a vehicle. The GY-521 is an MPU-6050 IC-based sensor module that functions to Measure acceleration (accelerometer) to detect linear motion on the X, Y, and Z axes. Measure angular velocity (gyroscope) to detect rotation or spin on 3 axes. Detecting orientation and position, which can be used to determine direction, tilt, and balance. Combining sensors (sensor fusion). The MPU-6050 has an internal Digital Motion Processor (DMP) to process accelerometer and gyroscope data, resulting in more stable data. Common applications, Robotics (maintaining robot balance, quadcopters, drones) Game controllers/joysticks, Navigation systems (Inertial Measurement Unit/IMU), Wearable devices (activity trackers, body movement), IoT motion monitoring [7].

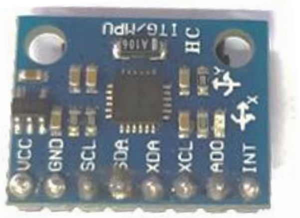

Figure 3. Sensor GY 521 MPU 6050

The SW-420 sensor plays a role in determining changes in vibration values in vehicles. he SW-420 sensor is a vibration sensor module that uses a vibration switch to detect vibrations or shocks. Main functions Detects vibrations/shocks when the module receives a sufficiently strong vibration, causing the output to change. Used as a security system in anti-theft alarms, earthquake alarms, machine vibration detection, etc. Machine/equipment monitoring detects vibrations from motors, fans, compressors, or industrial equipment. The automatic trigger can be used as an input for microcontrollers (Arduino, ESP8266, ESP32, etc.) to activate buzzers, lights, or other systems when vibrations are detected.

Figure 4. Sensor SW-420

The BN 220 sensor functions as a detector of an object's location, in this case the coordinates of a vehicle. BN-220 is a GPS (Global Positioning System) module that functions to receive GNSS satellite signals (GPS, GLONASS, Galileo, BeiDou depending on firmware) and generate position, speed, altitude, and time data. Main functions to Determine geographical position (Latitude & Longitude). Measure movement speed. Calculating altitude. Providing accurate time (UTC time) from satellites. Used in Drones & quadcopters (navigation & RTH/Return to Home), Navigation robots, Vehicles (GPS tracking) IoT projects (location trackers, trip loggers, fleet monitoring) [8].

Figure 5. Sensor BN 220

Arduino IDE is used in program creation and code validation in the form of a text editor, after which the edited “sketch” will be saved in the internal Arduino file. Fonnte is used to send automatic messages that are directly connected to the user's WhatsApp. Thus, the Fonnte service functions as feedback by using WhatsApp to send messages automatically via API or webhook systems. DomaiNesia hosting is used to create a website for storing all data. The stored data includes location, images, and videos. The domaiNesia website can meet user needs with a payment system and has a usage period. Researchers use this website for a period of one year. Therefore, every year, it is necessary to renew the subscription to back up the previous data [9]. The Autodesk Inventor application is used for design creation. Design Creating 2D drawings and 3D models for buildings, machines, vehicles, products, etc. 3D Modeling Creating realistic 3D models that can be used for visualization, simulation, and manufacturing. Analyzing structural strength, fluid flow, forces, vibrations, and design performance prior to production. Technical Documentation Producing working drawings, technical specifications, and blueprints. Manufactring, Supporting CAM processes such as CNC machining, additive manufacturing (3D printing), and fabrication [10]. Animation & Visualization Creating animations, realistic renderings, and visual effects (especially with Autodesk Maya, 3ds Max). Collaboration & BIM (Building Information Modeling) Facilitating cross-disciplinary teamwork in construction and design projects. The Fritzing application is used for electrical circuit design. This electrical circuit is used to arrange the layout of the system to be used. It arranges the arrangement and placement of each research component, including GY 521 MPU-650 sensor, SW-420 vibration sensor, NodeMCU Wifi ESP 8266, and GPS BN 220 [11].

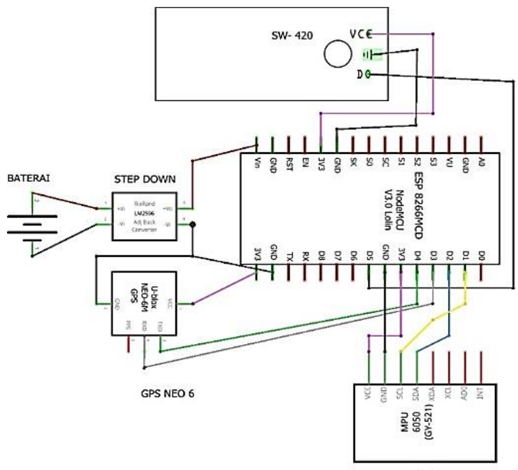

Figure 6. Schematic Circuit of Accident Detection Device

The schematic diagram of the accident detection device uses a 12V battery as the input voltage, which is stepped down to 5V. The stepped-down voltage serves as the input voltage for the NodeMCU ESP8266. The cable from the step-down converter can be connected to the Vin and GND pins on the NodeMCU ESP8266. In this study, the GY 521 MPU6050 sensor is used as an angle tilt detector. This sensor operates using MEMS and communicates with the microcontroller using a 3.3V input voltage on the VCC pin, with data communication via the SCL pin connected to D1 and the SDA pin connected to D2. The SW-420 sensor receives a 3.3 V voltage input through the VCC pin connected to the 3V3 pin, while data communication uses the D0 pin connected to the D5 pin. The NeoBlox 6M GPS sensor communicates with the microcontroller using the RX pin connected to the D3 pin and the TX pin connected to the D4 pin [12].

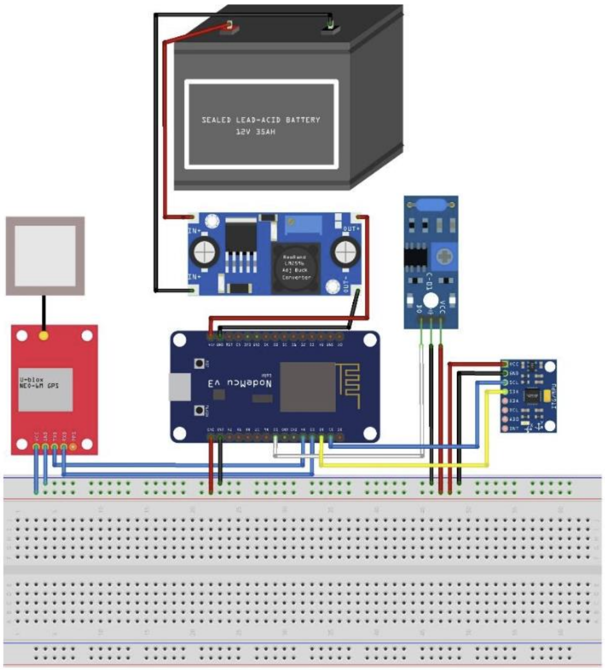

Figure 7. Sistem Wiring Design

The research was conducted on the installation shown in the figure 7. The battery supplies power to the NodeMCU ESP8266 microcontroller, which is then used to activate the SW-420 vibration sensor, BN 22O GPS, and GY-521 MPU 6050. The SW-420 vibration sensor detects vibrations using a metal float that vibrates in a tube with two electrodes when it receives a vibration/shock. In this study, vibration values were taken from flat, bumpy, and falling road conditions. The GY-521 MPU 6050 sensor detects the angle of inclination from the x and y axes. In this study, the -x and +x axes of the vehicle were used. The x-axis is called the Roll mode, which works by rotating the x-axis to move M1 and M3 up and down so that the roll angle changes. In this study, tilt angles of 10°, 30°, 35°, 45°, and 50° from the ground were used. A programmed microcontroller controls the sensor's performance. When a two-wheeled vehicle experiences an accident and the vibration sensor exceeds the specified limit, it will activate the tilt angle reading on the GY-521 MPU-6050 sensor [13]. The microcontroller will send information that the vehicle has experienced an accident via the ESP-8266 connected to the internet from the web server to send a notification to a smartphone in the form of the accident location [14].

3. RESULTS AND DISCUSSION

The results of the research conducted on testing accident detection devices on two-wheeled vehicles show that several devices were created based on the data collected. The devices were tested according to predetermined variables. During the testing process, vehicle tests were conducted using tilt angles of 10°, 30°, 45°, and 50°, as well as vibration values of 2,000 Hz, 10,000 Hz, 30,000 Hz, and 40,000 Hz.

3.1. Vibration Accuracy Data Results

The vibration value accuracy data consists of the difference in sensor readings from the ranges of 2,000 Hz, 10,000 Hz, 30,000 Hz, and 40,000 Hz, along with the accuracy and status of the readings indicating whether the motorcycle was in a fallen or safe condition [11] [12]. Description: Vibration 2,000: Driving on a flat road, Vibration 10,000: Driving over a speed bump, Vibration 30,000: Getting hit, Vibration 40,000: Vehicle being dropped. The results of the vibration value testing are shown in the table below:

Table 1. Vibration Value Data Results

Testing	Vibration Values and Event Settings			
	2.000	**10.000**	**30.000**	**40.000**
1	2102	10370	30120	40142
2	2212	10214	30183	40194
3	2085	10687	30448	40171
4	2039	10473	30264	40274
5	2295	10212	30316	40157
6	2156	10589	30244	40198
7	2174	10185	30263	40219
8	2173	10462	30387	40201
9	2190	10268	30294	40283
10	2093	10179	30228	40272
Average value	**2151.9**	**10363.9**	**30274.7**	**40211.1**

3.2. Angle Accuracy Data Results

The angle accuracy data consists of the difference in sensor readings from the range of 10°, 30°, 45°, and 50°, accompanied by the accuracy and status of the readings when the motorcycle is falling or safe. Event Setting Description: 10°: Vehicle at standard 1, 30°: Vehicle at standards 2 and 1, 45°: Vehicle is between falling and not falling, 50°: Vehicle is dropped the vehicle angle test results can be seen in the table below:

Table 2. Angle of Inclination Data Results

Testing	Angle of Inclination			
	10°	**30°**	**45°**	**50°**
1	11	29	43	78
2	9	29	49	61
3	9	29	44	89
4	10	36	44	77
5	7	30	44	55
6	8	27	43	89
7	10	29	44	89
8	7	29	47	77
9	11	29	47	80
10	11	29	49	51
Average value	**9.3**	**29.6**	**45.5**	**74.6**

The non-uniformity in hardness measurements (ranging from 36.64 to 39.24 HRA across different points) indicates potential microstructural inhomogeneities in the material. This variability is consistent with the work of those who observed that the presence of pearlite colonies and ferrite grain size variations can lead to hardness fluctuations in annealed low-carbon steels. However, our results showed better consistency compared to possibly due to better temperature control during our annealing process. When compared to previous studies, our findings at 750°C show a less dramatic hardness reduction than those reported for similar holding times [15]. This difference may be attributed to variations in initial microstructure or cooling rates. The work suggested that slower cooling rates after annealing could lead to slightly higher hardness values, which might explain our observations.

3.3. Discussion of the Accident Detection Device

This IoT-based accident detection device considers ease of driving. Real-time reporting makes it easier for families to receive information. It also makes it easier for relevant parties to rescue accident victims. This detection device has a GPS program that allows riders to access their two-wheeled vehicles wherever they are. This device can also address and minimize the high number of traffic accidents involving two-wheeled vehicle drivers. Therefore, this device is designed to be real-time and always on standby to warn drivers when an accident occurs. The process of sending location signals will help in determining the location of the accident and immediately preparing the appropriate response to deal with fatalities. This allows for collaboration with medical personnel to determine the severity of the accident through the signals sent and to provide treatment as quickly as possible. The design of this IoT-based accident detection device considers the ease of use in vehicles. The use of lightweight components allows for easy installation without affecting the overall performance of the vehicle. In addition, low power consumption ensures that the system can operate without placing an additional burden on the vehicle's electrical system. The design of this system considers the placement of sensors and sensor cables. It is known that SW 420 requires precise vibration values. Vibrations in two-wheeled vehicles are also very difficult to predict due to road conditions that are often less than ideal. The placement of these components must be appropriate, considering several other components, such as GPS or

MPU. GPS itself is difficult to detect or receive signals. Meanwhile, MPU itself is too sensitive to tilt. Therefore, the device is made as flexible as possible so that other components can function properly [16].

The result of designing this accident detection device shows that accident notifications are very important because they can help medical personnel respond to accidents. This system design has a 12V DC current from the battery that goes to the components. Accident detection devices are very useful for quickly conveying information. This system design has a 12V DC current. The 12V current from the battery is reduced to 5V in a 12V battery step-down. The reduced voltage becomes the voltage input for the NodeMCU ESP8266. The cable from the step-down can be connected to the Vin and GND pins on the NodeMCU ESP8266. This study uses a GY 521 MPU6050 sensor as an angle tilt detector. This sensor operates using MEMS and communicates with the microcontroller using a 3.3 V input voltage on the VCC pin and data communication using the SCL pin connected to D1, and the SDA pin connected to D2. The SW-420 sensor receives a 3.3 V input voltage through the VCC pin connected to the 3V3 pin, while data communication uses the D0 pin connected to the D5 pin. The BN 220 GPS sensor communicates with the microcontroller using the RX pin connected to the D3 pin and the TX pin connected to the D4 pin.

With this accident notification system, it can be implemented in vehicles through a series of tests on the system circuit. The creation of an accident notification system for motorcycles. This accident notification system can be implemented in vehicles through a series of tests on the system circuit. The results obtained show that the accident detector can run according to plan and function properly. The ESP8266 module can be directly connected and integrated with the WhatsApp device. From the test results, the message delivery delay time was 10 seconds to send the accident signal, and the serial monitoring of the vibration value and tilt value or MPU can be seen directly [17].

The results of the accident detection device indicate that the device can accurately read the vehicle's condition. The accident detection device will immediately activate and send an automatic message to the user's WhatsApp connection when the vehicle's tilt angle reaches 45° to 50°, indicating that the vehicle has fallen. Regarding vibration values, the accident detection device will send an automatic message [18]. via the user's WhatsApp within a vibration range of 10,558 to 60,850, indicating that the vehicle has fallen. Test results for the detection device on the vehicle were obtained under normal vehicle conditions and when the vehicle was not overturned, with the vehicle's tilt angle ranging from 10° to 30°. Under normal vehicle conditions, the vibration sensor on the vehicle when it was not overturned recorded a range of 6,016 to 8,120.

4. CONCLUSION

This IoT-based accident detection device considers the ease of driving. Real-time reporting makes it easier for family members to receive information. This also makes it easier for relevant parties to rescue accident victims. This detection device has a GPS program that allows riders to access their two-wheeled vehicles wherever they are. This device can also address and minimize the high incidence of traffic accidents involving two-wheeled vehicles. Therefore, this device is designed to operate in real time and is always ready to alert drivers if an accident occurs. The process of sending location signals can help determine the exact location of the accident and immediately prepare appropriate measures to handle fatalities. This enables collaboration with medical personnel to determine the severity of the accident through the transmitted signals and to provide prompt medical attention. Recommendations In future research, the device could be developed with a high-integrity and comprehensive system, utilizing vibration sensors and GPS that directly read and display values within a specific range.

REFERENCES

[1] V. Goud, "Vehicle Accident Automatic Detection and Remote Alarm Device," *International Journal of Reconfigurable and Embedded Systems (IJRES)*, vol. 1, no. 2, 2012, doi: 10.11591/ijres.v1.i2.pp49-54.
[2] M. K. J. Al Mukhaini and K. Al Harthy, "A Proposal for an Advanced Smart System of Vehicle Accidents Detection," *Journal of Student Research*, 2020, doi: 10.47611/jsr.vi.959.
[3] C. Dashora, P. E. Sudhagar, and J. Marietta, "IoT Based Framework for the Detection of Vehicle Accident," *Cluster Computing*, vol. 23, no. 2, 2020, doi: 10.1007/s10586-019-02989-z.
[4] N. Pathik, R. K. Gupta, Y. Sahu, A. Sharma, M. Masud, and M. Baz, "AI Enabled Accident Detection and Alert System Using IoT and Deep Learning for Smart Cities," *Sustainability (Switzerland)*, vol. 14, no. 13, 2022, doi: 10.3390/su14137701.
[5] M. Balfaqih, S. A. Alharbi, M. Alzain, F. Alqurashi, and S. Almilad, "An Accident Detection and Classification System Using Internet of Things and Machine Learning Towards Smart City," *Sustainability (Switzerland)*, vol. 14, no. 1, 2022, doi: 10.3390/su14010210.
[6] R. A. Jangle, S. S. Girpunje, and G. M. Thorat, "An IoT Based Vehicle Accident Detection and Alert System," *Turkish Journal of Computer and Mathematics Education*, vol. 12, no. 7, 2021.
[7] J. A. J. Alsayaydeh, M. F. Bin Yusof, M. A. A. Bin Abdillah, A. J. A. Al-Gburi, S. G. Herawan, and A. Oliinyk, "Enhancing Vehicle Safety: A Comprehensive Accident Detection and Alert System," *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 11, 2023, doi: 10.14569/IJACSA.2023.0141104.
[8] R. Kumar, A. Tomar, and M. Lal, "Enhancing Vehicle Safety: Automated Accident Detection and Emergency Alert System," *Journal of Universal Computer Science*, no. June 2023.

[9] B. Rani, R. Praveen Sam, and G. R. Kamatam, "A Review on Vehicle Tracking and Accident Detection System Using Accelerometer," *International Journal of Applied Engineering Research*, vol. 13, no. 11, 2018, doi: 10.37622/ijaer/13.11.2018.9215-9217.

[10] A. Mateen, M. Z. Hanif, N. Khatri, S. Lee, and S. Y. Nam, "Smart Roads for Autonomous Accident Detection and Warnings," *Sensors*, vol. 22, no. 6, 2022, doi: 10.3390/s22062077.

[11] V. Saritha, S. L. Chandana, U. S. B. K. Mahalaxmi, D. Shamia, P. Chawla, and A. Chaturvedi, "An Intelligent Sensing and Detection System for Accident Preventions in Four-Wheeler Vehicles," *Materials Today: Proceedings*, vol. 80, 2023, doi: 10.1016/j.matpr.2021.05.353.

[12] N. Kumar, D. Acharya, and D. Lohani, "An IoT-Based Vehicle Accident Detection and Classification System Using Sensor Fusion," *IEEE Internet of Things Journal*, vol. 8, no. 2, 2021, doi: 10.1109/JIOT.2020.3008896.

[13] A. Vangala, B. Bera, S. Saha, A. K. Das, N. Kumar, and Y. Park, "Blockchain-Enabled Certificate-Based Authentication for Vehicle Accident Detection and Notification in Intelligent Transportation Systems," *IEEE Sensors Journal*, vol. 21, no. 14, 2021, doi: 10.1109/JSEN.2020.3009382.

[14] M. I. Basheer Ahmed, et al., "A Real-Time Computer Vision Based Approach to Detection and Classification of Traffic Incidents," *Big Data and Cognitive Computing*, vol. 7, no. 1, 2023, doi: 10.3390/bdcc7010022.

[15] D. Tian, C. Zhang, X. Duan, and X. Wang, "An Automatic Car Accident Detection Method Based on Cooperative Vehicle Infrastructure Systems," *IEEE Access*, vol. 7, 2019, doi: 10.1109/ACCESS.2019.2939532.

[16] U. Alvi, M. A. K. Khattak, B. Shabir, A. W. Malik, and S. R. Muhammad, "A Comprehensive Study on IoT Based Accident Detection Systems for Smart Vehicles," *IEEE Access*, vol. 8, 2020, doi: 10.1109/ACCESS.2020.3006887.

[17] P. Josephinshermila, S. Sharon Priya, K. Malarvizhi, R. Hegde, S. Gokul Pran, and B. Veerasamy, "Accident Detection Using Automotive Smart Black-Box Based," *Measurement: Sensors*, vol. 27, 2023, doi: 10.1016/j.measen.2023.100721.

[18] W. J. Chang, L. B. Chen, and K. Y. Su, "DeepCrash: A Deep Learning-Based Internet of Vehicles System for Head-On and Single-Vehicle Accident Detection With Emergency Notification," *IEEE Access*, vol. 7, 2019, doi: 10.1109/ACCESS.2019.2946468.