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An AI-Integrated Safety Ecosystem and Predictive Vehicle Intelligence Platform for Women Motorcyclists

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Abstract: Women motorcyclists may face challenges related to personal safety, road emergencies, and unexpected vehicle failures. Existing solutions often address rider safety, vehicle monitoring, and emergency assistance separately. This paper proposes SheTorque, an AI-integrated safety ecosystem and predictive maintenance platform designed specifically for women motorcyclists. The system consists of five modules: Guardian Eye, ECU Data-Bridge, Smart Bike Vitals, Emergency Response Hub, and HerRide Tribe. Guardian Eye uses computer vision and vehicle tracking to identify persistent following behaviour in Single Ride and Group Ride modes. The ECU Data-Bridge aims to retrieve supported vehicle diagnostic information and explain diagnostic trouble codes in simple language. Smart Bike Vitals estimates fuel range and maintenance requirements using motorcycle details, odometer readings, and service records. The Emergency Response Hub supports crash detection, gesture-based SOS activation, and emergency location sharing. HerRide Tribe provides safe-location mapping and connectivity among women riders. The proposed platform integrates artificial intelligence, sensor-based monitoring, predictive analytics, and location-aware services to improve rider awareness and support timely assistance.

Index Terms: Artificial Intelligence, Women's Safety, Computer Vision, Motorcycle Safety, Vehicle Tracking, Predictive Maintenance, ECU Diagnostics, Crash Detection, Emergency Response, Sensor Fusion.

I. INTRODUCTION

Motorcycles are an important mode of transportation because they provide flexibility, affordability, and convenience for daily travel. For women motorcyclists, however, riding may involve additional concerns related to personal safety, unexpected road emergencies, vehicle breakdowns, and limited access to reliable assistance. Situations such as suspicious vehicle-following behaviour, accidents, fuel shortages, and sudden mechanical problems can affect a rider's confidence and travel experience. Therefore, an intelligent and integrated platform is needed to support personal safety, emergency response, and motorcycle maintenance.

Recent developments in Artificial Intelligence (AI), computer vision, machine learning, mobile computing, and sensor technology have created opportunities to develop intelligent transportation and rider-assistance systems. Computer vision techniques can detect and track vehicles, while machine learning can support data analysis and maintenance planning. Smartphone sensors can help identify unusual movement patterns that may indicate a possible accident, and location-based services can assist riders in finding nearby support facilities. However, the availability and reliability of these functions depend on the selected hardware, software, data sources, and op3erating conditions.

Existing safety and vehicle-monitoring solutions often concentrate on individual functions, such as location sharing, emergency alerts, vehicle diagnostics, or maintenance reminders. Managing these functions through separate applications may create inconvenience for riders. An integrated platform can bring these features together and provide a more convenient approach to motorcycle safety and vehicle management.

The proposed SheTorque system consists of five major modules. **Guardian Eye** uses computer vision and vehicle tracking to monitor surrounding vehicles and identify persistent following behaviour. It includes Single Ride Mode and Group Ride Mode, allowing the system to consider trusted group members when evaluating potential alerts. This feature is intended to identify unusual following patterns rather than conclusively determine a person's intentions. **ECU Data-Bridge** is designed to obtain available motorcycle diagnostic information through compatible vehicle interfaces and present diagnostic trouble codes in an understandable format. Its functionality depends on the motorcycle's supported communication protocol and accessible data.

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Smart Bike Vitals focuses on fuel estimation and maintenance planning by using rider-provided motorcycle details, fuel records, odometer readings, and service history. These inputs can help estimate remaining fuel range and indicate when maintenance may be required. **Emergency Response Hub** combines smartphone motion sensors, possible crash-detection logic, gesture-based SOS activation, and emergency location sharing to support timely assistance. **HerRide Tribe** provides a community-oriented platform with safe-location mapping, including verified support locations, and features that help women riders connect with other riders when needed.

The primary objective of SheTorque is to integrate personal safety assistance, vehicle monitoring, maintenance planning, and rider-community support within a single platform. The proposed system aims to improve situational awareness, reduce the inconvenience of managing separate services, and encourage proactive motorcycle maintenance. Its performance can be assessed through experiments involving vehicle-detection and tracking performance, false-alert frequency, crash-detection reliability, fuel-estimation error, diagnostic compatibility, and application usability.

The key contribution of this work is the design of an integrated, women-focused motorcycle assistance platform that combines computer vision, sensor-based monitoring, predictive analytics, vehicle diagnostics, and location-aware community services. Rather than treating these functions as independent applications, SheTorque proposes a unified framework for addressing multiple challenges experienced during motorcycle travel.

II. RELATED WORKS

Muhammad Shoaib Farooq et al. reviewed existing Internet of Things (IoT)-based systems developed to improve women's safety. The study examined different sensors, communication technologies, and machine learning methods used to identify potential threats and transmit emergency alerts. It highlighted the need for automatic alert generation with reduced human intervention and improved detection accuracy. This research supports the development of the Emergency Response Hub in mSheTorque, which aims to provide crash detection, SOS alerts, and emergency location sharing.

SheTorque extends this safety approach by focusing on motorcycle riders and integrating vehicle-following analysis with emergency assistance [1].

Yashashree Mahale et al. conducted a systematic literature review of 94 research papers on artificial intelligence-based predictive maintenance in vehicles. The study examined machine learning, deep learning, explainable AI, vehicle diagnostics, maintenance scheduling, and remaining useful life prediction. It also discussed challenges involving data quality and the development of reliable predictive models. This work provides a foundation for the Smart Bike Vitals module of SheTorque, which aims to estimate fuel range and maintenance requirements using vehicle information and service records. The proposed platform can incorporate advanced predictive models when sufficient reliable data are available [2].

Isinka Joseph Chukwudi et al. investigated an ensemble deep learning approach for predicting vehicular engine health. Their research explores the use of deep learning and ensemble techniques for vehicle health monitoring and maintenance-related decision-making. Such approaches can help analyze vehicle-related data to identify possible engine health problems. This research is relevant to the ECU Data-Bridge and Smart Bike Vitals modules of SheTorque, which aim to use available diagnostic information to support vehicle monitoring and maintenance planning. However, the proposed SheTorque system will require separate testing to determine whether its available data can support reliable engine-health predictions [3].

Miar Mamdouh Khalil et al. proposed EF-StrongSORT, an enhanced multi-object tracking model designed to improve vehicle or object tracking under challenging visual conditions. The study addresses problems such as object occlusion, appearance changes, rapid movement, and maintaining consistent object identities across video frames. Reliable tracking is important for monitoring vehicles in road environments. This research supports the Guardian Eye module of SheTorque, which aims to detect and track surrounding vehicles and identify persistent following behaviour. The tracking results can contribute to potential safety alerts, although vehicle tracking alone cannot confirm suspicious intentions [4].

David Richard Tom Hax et al. proposed a hybrid deep learning architecture for recognizing dynamic hand gestures from video. The study addresses the difficulty of extracting meaningful features from gesture sequences and classifying gestures in realistic environments. The research demonstrates the relevance of deep learning approaches to gesture-based human-computer interaction. This work is related to the Emergency Response Hub of SheTorque, which proposes gesture-based SOS activation as an alternative emergency input method. The gesture-recognition feature must be evaluated under practical conditions to assess its accuracy and suitability for motorcycle safety applications [5].

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Tahir et al. proposed a vehicle detection and tracking framework using YOLOv8-Nano and OC-SORT, with counting accuracy above 95% on the Cityscapes dataset. It supports Guardian Eye, but it was evaluated on traffic scenes and not on a motorcycle-mounted camera [6].

Yunxiang Liu and Shujun Shen proposed a lightweight vehicle detection and tracking method based on YOLOv8n. They added an SCConv-based detection head, dual convolutional kernels, and the Focaler-EIoU loss, and embedded the BoT-SORT tracker. On the UA-DETRAC dataset, the model reduced parameters by about 36.5% at the cost of only 0.2% mAP@0.5. Its tracking results were better than those of DeepSORT and ByteTrack. This study is relevant to Guardian Eye, which needs a lightweight detector that can run on a smartphone. Its evaluation was on fixed traffic-surveillance data and not on rider-mounted camera footage [7].

Naresh et al. implemented a real-time YOLO-based system that detects, classifies, and counts vehicles in video. It supports the detection stage of Guardian Eye but does not analyse whether a vehicle keeps following a particular rider [8].
Mahbub Ul Islam Khan et al. applied machine learning to detect and classify faults in the connection between a three-phase inverter and the BLDC motor of an electric vehicle. They tuned several classifiers, including Decision Tree, Logistic Regression, XGBoost, AdaBoost, K-Nearest Neighbour, and a Voting Classifier, on healthy and faulty data. This study shows that data-driven fault classification can support vehicle reliability. It relates to the ECU Data-Bridge and Smart Bike Vitals modules of SheTorque, which present vehicle diagnostic information to the rider. The study addresses electric-vehicle electrical faults and not the diagnostic data of a conventional motorcycle ECU [9].

Kushvanth Chowdary Nagabhyru et al. proposed a hybrid reinforcement learning framework for fault detection in electric vehicles. It uses standard-deviation-based data preparation and feature extraction, and it reported 95.08% accuracy. The work shows how learning-based methods can improve the reliability of vehicle systems. It is related to the predictive-maintenance goals of SheTorque. Like the previous study, it targets electric vehicles, so its applicability to motorcycle ECU data would need to be tested [10].

Mansouri et al. reviewed deep learning-based fault diagnosis for photovoltaic systems. Although the domain is solar power, it shows the value of learned features for diagnostics, which is relevant to Smart Bike Vitals [11].

Islam et al. built a bike accident detection system using an MPU6050 sensor and GPS/GSM modules that messages hospitals, police, and family after a crash. It is closely related to the Emergency Response Hub, but SheTorque uses the smartphone's own sensors and not separate hardware [12].

Somnath R. Wategaonkar et al. developed an IoT-based accident detection and alert system with location tracking. The system detects accident-related sensor readings, finds the vehicle's position with a GPS module, and sends the coordinates to emergency responders. The authors argue that automatic alerts with live location can reduce emergency response time. This supports the alert and location-sharing function of the Emergency Response Hub. The system is built around dedicated hardware modules and is not designed specifically for motorcyclists [13].

Kumar et al. proposed an IoT-based smart vehicle accident detection system that informs the authorities and other concerned people. It is relevant to the alert function of SheTorque, but it is aimed at vehicles in general and not at women riders [14].

Manga et al. presented an IoT system that warns the driver when an obstacle is close and sends an alert if an accident occurs. It relates to the alert pipeline of the Emergency Response Hub but needs hardware installed in the vehicle [15].

Asani et al. presented AI-PaaS, an accident alert system that combines accident-sound detection with an MPU6050 motion sensor. It supports motion-based crash detection, and SheTorque adds a silent rider-initiated SOS and a safety-confirmation flow [16].

Ravichandran et al. proposed a helmet-mounted force-sensing resistor that sends an SOS when an impact crosses a threshold, analysed in simulation. It is related to the crash detection of SheTorque, which uses smartphone IMU data and not a helmet sensor [17].

Aditya Dubey et al. developed an Arduino-based smart helmet. It restricts ignition when the MQ3 sensor detects alcohol, and an IR sensor monitors eye closure to warn about fatigue. It also has rear LEDs for visibility, and an MPU6050 sensor, GPS module, and GSM module send the rider's location after a crash. The study shows that a single device can combine

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prevention and post-crash response. This relates to the combined safety approach of SheTorque. The helmet needs extra hardware and does not offer vehicle-following detection, diagnostics, or community features [18].

Mehadi Hassan Khan et al. proposed a sensor-integrated smart helmet for blind-spot protection. It uses an Arduino with GSM, GPS, and sensors to detect accidents and to examine the condition of the rider. This work shows interest in alerting riders to nearby hazards, which is related to the situational awareness aims of Guardian Eye. The helmet relies on dedicated sensors and not on camera-based vehicle tracking [19].

Anshul Soni et al. proposed a one-tap emergency response app. A single SOS button sends the user's location to the nearest hospital through Socket.io. The app shows the location on Google Maps, tracks the ambulance with GPS, and supports live video communication with WebRTC. This is related to the emergency location sharing of the Emergency Response Hub [20].

III.METHODOLOGY

The proposed SheTorque system follows a five-layer cyber-physical architecture that integrates computer vision, motorcycle diagnostics, smartphone sensors, cloud services, and a mobile application. The methodology focuses on proactive threat detection, vehicle health monitoring, crash detection, and emergency response for women motorcyclists. The system uses a smartphone as the primary processing and communication hub, supported by a rear-view camera, an OBD-II Bluetooth adapter, GPS, and built-in mobile sensors.

A. System Architecture

The system architecture of SheTorque consists of five layers: hardware and sensors, communication, software processing, database and cloud services, and user interface. These layers work together to integrate motorcycle safety monitoring, vehicle diagnostics, emergency response, and location-based services within a unified mobile application. The modular architecture allows each functional component to process its respective data while sharing relevant outputs with the overall system.

1) Hardware and Sensor Layer: This layer collects the information required for system operation. It includes a rear-mounted camera for capturing the road scene behind the motorcycle, the smartphone's inertial measurement unit (IMU) for detecting changes in acceleration and orientation, GPS for obtaining location coordinates, and a compatible OBD-II adapter for retrieving available motorcycle diagnostic data. The collected information serves as input for vehicle tracking, crash detection, vehicle monitoring, and emergency response functions.

2) Communication Layer: The communication layer enables data exchange between the hardware components, mobile application, and external services. Bluetooth Low Energy (BLE) or an appropriate Bluetooth communication interface can be used to connect the application to compatible vehicle diagnostic adapters. Internet connectivity supports cloud synchronization, location-related requests, and emergency notifications. The system should handle temporary connection failures and distinguish unavailable data from valid sensor or vehicle readings.

3) Software Processing Layer: This layer performs the main computational operations of the system. Video frames are processed by a vehicle detection model, such as YOLOv8-lite, while a multi-object tracking algorithm maintains vehicle identities across successive frames. Smartphone IMU readings are analyzed to identify possible crash events. Available ECU parameters are validated and processed for dashboard presentation, while vehicle records support fuel-range estimation and maintenance reminders. The processing layer also evaluates predefined alert conditions and prepares the corresponding notifications.

4) Database and Cloud Services Layer: Firebase Realtime Database can be used to store and synchronize selected application data, such as rider profiles, motorcycle details, maintenance records, and incident information, according to the implemented design. Google Maps SDK supports map visualization and location-based functionality. Cloud services can facilitate data access across supported application sessions and devices. Appropriate authentication, access control, and data protection measures are necessary when handling personal information, ride history, and emergency-contact details.

5) User Interface Layer: The user interface provides a common access point for the system's features through the SheTorque mobile application. The dashboard presents available vehicle status information, safety alerts, maintenance reminders, location information, and emergency controls. Information is displayed according to its availability and source, with live diagnostic measurements distinguished from manually entered values and calculated estimates. The

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interface should also provide clear feedback about connection status, alert activation, and emergency-message dispatch.

System Data Flow: The system begins by collecting information from the camera, smartphone sensors, GPS, and compatible vehicle diagnostic interface. The communication layer transfers the available data to the relevant processing components. Each module analyzes its input and generates outputs, such as vehicle-tracking alerts, possible crash notifications, diagnostic information, or maintenance reminders. Selected information can then be synchronized with cloud services, while the mobile dashboard presents the results to the rider. This layered design supports modular development, easier testing, and future integration of additional safety and maintenance features.

system architecture consists of five layers: hardware and sensors, communication, software processing, database and cloud services, and user interface. The hardware layer includes a rear-mounted camera, smartphone inertial measurement unit (IMU), GPS, and a compatible OBD-II adapter. The communication layer supports Bluetooth Low Energy (BLE) for vehicle diagnostics and internet connectivity for cloud synchronization and emergency alerts. The software layer processes video, sensor readings, and vehicle telemetry. Firebase Realtime Database and Google Maps SDK support incident synchronization and location-based services, while the mobile dashboard presents vehicle status, safety alerts, and emergency controls.

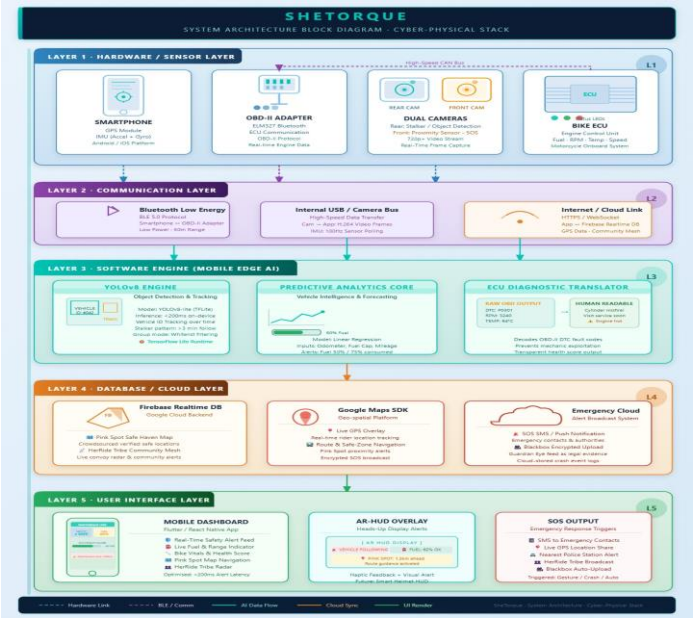


Fig 1. Five-layer system architecture of SheTorque.

B. Guardian Eye: AI-Based Vehicle Tracking

Guardian Eye is an AI-based vehicle monitoring module designed to improve situational awareness for women motorcyclists. It uses YOLOv8-lite for vehicle detection and EF-StrongSORT for multi-object tracking. A rear-facing camera captures the road scene behind the motorcycle, and the detection model processes successive video frames to identify surrounding vehicles. The model generates bounding boxes and confidence scores for detected vehicles, which provide the input for the subsequent tracking process.

The detected vehicles are passed to the EF-StrongSORT tracking algorithm, which assigns tracking identifiers and maintains vehicle trajectories across consecutive frames. The tracking module records vehicle positions and observation timestamps to monitor movement over time. This information helps the system estimate how long each vehicle remains visible behind the motorcycle. Factors such as temporary occlusion, missed detections, changing illumination, and traffic congestion may affect tracking continuity and identification accuracy.

The temporal persistence analysis component evaluates the tracking duration of each vehicle using its observation timestamps. When a tracked vehicle satisfies the predefined persistence threshold of more than 180 seconds, the system identifies the observation as a potential persistent-following event. A corresponding alert can be generated through the SheTorque mobile application, displaying available tracking information and the observation duration. In Single Ride Mode, the system monitors surrounding vehicles, whereas Group Ride Mode can use a suitable vehicle-recognition mechanism to distinguish registered group members and reduce unnecessary alerts during coordinated rides.

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The Guardian Eye module is designed to support continuous vehicle monitoring and timely notification. Its performance can be evaluated using detection precision, recall, tracking accuracy, identity-switch frequency, processing latency, and false-alert rate. Testing under different traffic and lighting conditions can help assess the reliability of the detection and tracking process. The system may also be improved by optimizing the detection model, handling temporary tracking interruptions, and adjusting the persistence threshold based on experimental observations.

The module processes tracking data continuously to identify vehicles that remain behind the motorcycle for an extended duration. Detection confidence and tracking continuity can help improve the reliability of the generated alerts. The system can be evaluated under different traffic conditions to measure detection accuracy, processing time, and false-alert frequency. These evaluations can help identify limitations and guide further improvements to the tracking mechanism.

Overall, Guardian Eye integrates computer vision and temporal tracking to provide an additional layer of road-safety awareness. By identifying vehicles that remain visible for an extended period, the module can help riders notice potentially unusual traffic patterns. However, persistent tracking alone cannot confirm

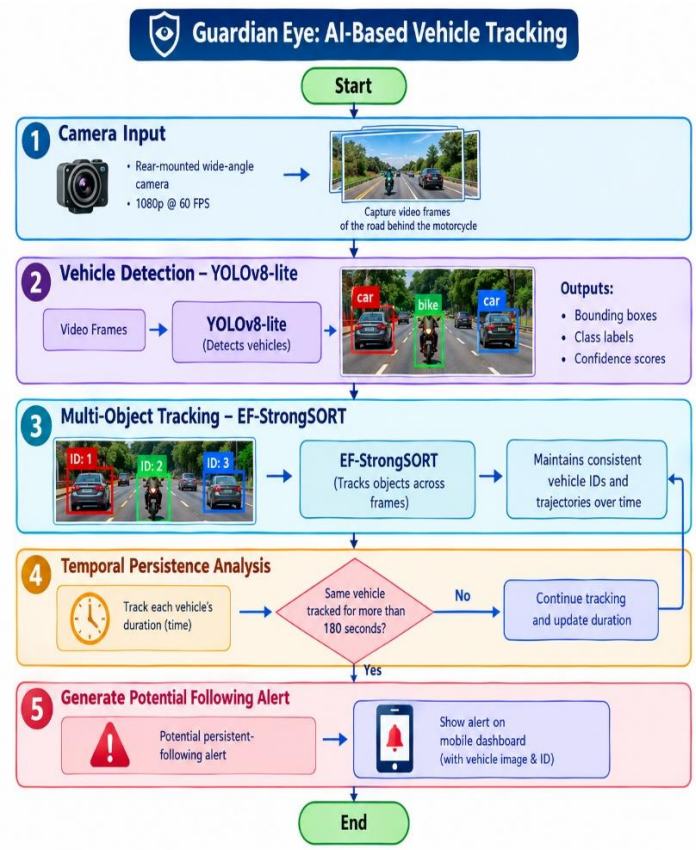


Fig 2. Guardian Eye vehicle tracking workflow.

C. Digital Garage: ECU Data Collection and Vehicle Monitoring

The Digital Garage module connects the SheTorque mobile application to a compatible motorcycle diagnostic interface through an OBD-II Bluetooth adapter, such as an ELM327-based adapter, where supported. The application retrieves available vehicle parameters, potentially including engine temperature, battery voltage, vehicle speed, fuel level, and diagnostic trouble codes (DTCs). The received information is presented on the SheTorque Hub dashboard to help riders understand their motorcycle's condition and monitor available vehicle data through a centralized interface.

The data collection process begins by establishing a communication link between the mobile application and the diagnostic adapter. Once the connection is established, the application requests supported vehicle parameters and processes the responses received from the electronic control unit (ECU). The retrieved values are checked for availability, validity, and consistency before being displayed. This validation process helps prevent unsupported, incomplete, or invalid readings from being presented as actual vehicle measurements. The application can also display connection status and data timestamps to indicate whether the information is current.

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The module provides diagnostic support by matching retrieved DTCs with an appropriate diagnostic reference database. The application displays the corresponding code and a simple explanation of the potential issue, helping riders understand the information before consulting a qualified technician. Where supported, diagnostic records can be stored for future reference and comparison. Reviewing recurring codes may help riders identify repeated warning conditions, although a diagnostic code alone does not always identify the exact cause of a mechanical or electrical problem.

The Digital Garage dashboard presents available vehicle parameters through status cards, indicators, and notifications. These may include engine-related information, electrical system readings, vehicle speed, and diagnostic warnings, depending on the motorcycle's capabilities. Service reminders can also be integrated with maintenance records to notify riders when a configured service interval is approaching. The application can periodically refresh available readings and notify the rider if the connection is interrupted. When communication fails, the system should indicate that the data may be outdated rather than continuing to display previous values as live measurements.

In addition, the module can organize diagnostic information into understandable categories, such as engine-related warnings, electrical issues, and general fault codes, when sufficient reference information is available. Maintaining a history of diagnostic readings, fault codes, and service notifications allows riders to review previous vehicle conditions and prepare relevant information before visiting a service centre. Basic error-handling mechanisms can manage communication failures, incomplete responses, unsupported parameters, and unavailable diagnostic information, improving the usability of the monitoring interface

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Furthermore, the Digital Garage module can support preventive maintenance by combining available diagnostic information with the motorcycle's recorded service history. By identifying repeated fault codes, changes in recorded vehicle parameters, and upcoming maintenance intervals, the system can provide timely reminders and help riders make informed maintenance decisions. A simple history view can allow users to compare previous and current records, making it easier to discuss recurring issues with service technicians. This feature aims to improve maintenance awareness, reduce the likelihood of overlooked service requirements, and support safer motorcycle use. However, any maintenance recommendations must be based on available vehicle data and reliable service guidelines, as the system cannot independently confirm every mechanical fault.

The availability and accuracy of individual parameters depend on the motorcycle's ECU, communication protocol, diagnostic interface, and adapter compatibility. Some motorcycles require manufacturer-specific adapters or communication protocols, while certain parameters may not be accessible through a standard OBD-II connection. For example, fuel level and battery voltage are not guaranteed to be available on every motorcycle through an ELM327 adapter. Therefore, the application should clearly distinguish live ECU readings from manually entered information and calculated estimates. The module can be evaluated using connection success rate, data retrieval time, parameter validity, diagnostic-code interpretation accuracy, and dashboard update reliability. Overall, Digital Garage is intended to improve vehicle monitoring and maintenance awareness, rather than replace professional vehicle inspection or diagnostics.

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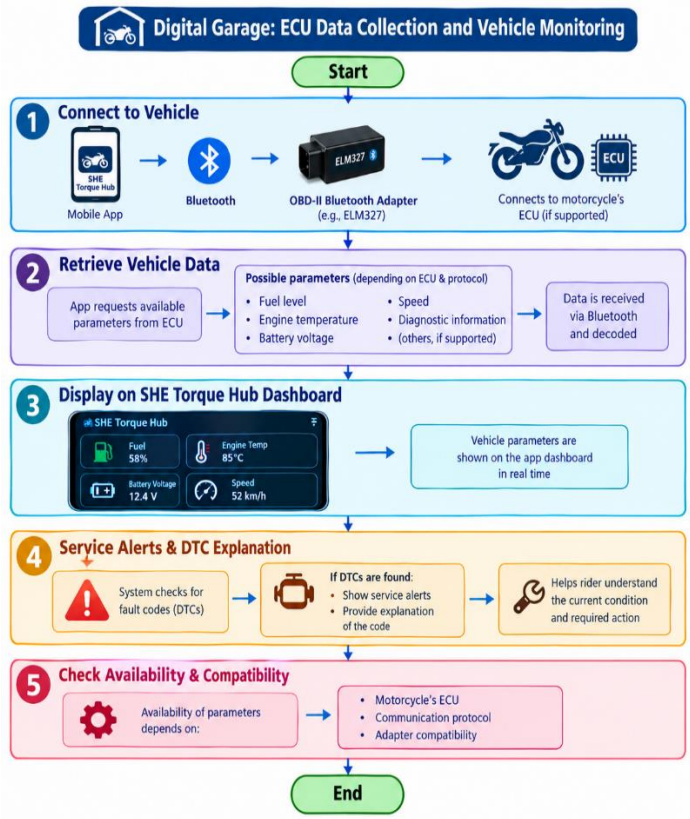


Fig 3. Digital Garage ECU data collection and vehicle monitoring workflow.

D. Sensor Fusion Hub: Crash Detection

The crash-detection pipeline uses smartphone inertial measurement unit (IMU) data, including accelerometer and gyroscope readings, to identify sudden impacts and unusual orientation changes. Sensor readings are continuously evaluated against predefined thresholds and contextual conditions to distinguish potential crash events from normal riding activities. The accelerometer measures changes in acceleration, while the gyroscope captures rotational movement and angular velocity. Combining these measurements provides a more comprehensive understanding of the motorcycle rider's motion than relying on a single sensor parameter.

The detection process begins with continuous sensor-data acquisition and preprocessing. The collected readings are checked for invalid values and processed to reduce noise and unwanted fluctuations. The system then calculates relevant motion features, such as acceleration magnitude, angular velocity, and changes in orientation over a short observation period. These features are compared with predefined thresholds to identify abnormal movement patterns that may indicate a collision, sudden fall, or loss of balance. The thresholds and observation duration must be calibrated and validated through testing to achieve suitable detection performance.

When a sudden impact or significant motion change is detected, the system evaluates additional contextual information before classifying the event as a potential crash. This step helps reduce false alarms caused by sudden braking, road bumps, sharp turns, or accidental smartphone movement. Instead of depending on one isolated sensor reading, the system can consider multiple sensor features and their temporal relationship. However, these conditions indicate a possible crash rather than confirming that an accident has occurred.

After detecting a potential crash, the application can initiate an emergency countdown that allows the rider to cancel the alert if the event was triggered incorrectly. If the countdown expires without cancellation, the system prepares an emergency notification containing available incident details, the event timestamp, and the rider's location when location access is available. The notification can then be sent to predefined emergency contacts. The application should also display the delivery status and indicate whether the alert was successfully transmitted. This process is intended to reduce the delay between possible crash detection and communication with emergency contacts.

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The Sensor Fusion Hub can also maintain a record of detected events, including timestamps and selected sensor readings, to support subsequent analysis and system improvement. Such records can help developers examine false-positive detections, missed events, and variations in sensor behaviour under different riding conditions. The system may be evaluated using detection accuracy, precision, recall, false-positive rate, missed-crash rate, and emergency-alert delivery time. These metrics provide a structured way to assess both the reliability of the detection pipeline and the effectiveness of its emergency-response process.

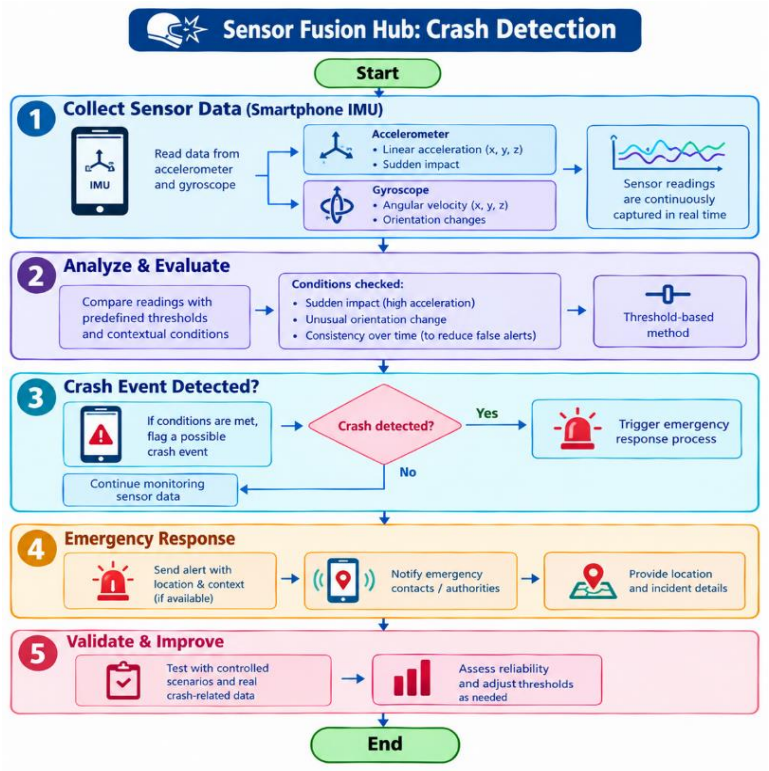


Fig 4. Sensor Fusion Hub crash detection workflow.

E. Silent SOS: Proximity Sensor-Based Activation

Although the initial proposal considered MediaPipe-based hand gesture recognition, the presentation describes a proximity-sensor-based approach selected for implementation because it offers a simple, battery-efficient input method that does not depend on camera lighting. The application monitors the smartphone proximity sensor and detects a sustained near-state for three continuous seconds. This duration acts as an activation condition to reduce unintended triggers caused by brief sensor obstruction or accidental contact. Rate-of-change discrimination and inertial measurement unit (IMU) context are used to improve activation reliability by considering changes in proximity readings alongside the device's movement patterns.

The emergency activation process begins by continuously monitoring the proximity sensor while the relevant application functionality is active. When the sensor reports a near-state, the application starts a three-second observation interval. If the near-state remains continuous for the entire interval and the additional validation conditions are satisfied, the system identifies a potential SOS activation. If the sensor returns to its normal state before the interval finishes, the activation timer is reset. This approach provides a straightforward input mechanism that can be used without requiring the rider to interact with the smartphone screen during an emergency. However, sensor availability and behaviour may differ between smartphone models, and the activation method must be tested under realistic riding conditions.

After a valid activation is detected, the application provides haptic feedback to inform the rider that the SOS process has started. The system can then initiate the emergency-response workflow, including obtaining the device's available location and preparing an SOS message for configured emergency contacts. The message may contain the rider's emergency status, timestamp, and location information when available. Location tracking can support the sharing of updated coordinates where the required permissions and application capabilities are available. However, successful location retrieval and message transmission depend on GPS availability, network connectivity, operating-system restrictions, and the implementation of the messaging service.

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To reduce accidental emergency notifications, the application can incorporate a safety confirmation flow that allows the rider to cancel an unintended activation before the message is sent. A cancellation or resolution mechanism also allows the rider to indicate that assistance is no longer required after an alert has been initiated. The application should distinguish between an alert that has been triggered, an alert that has been sent, and an alert that has been successfully delivered, where delivery information is available. This distinction improves transparency and prevents the interface from implying that emergency contacts have received a message when transmission has not been confirmed.

The Smart SOS module can maintain an event history containing activation timestamps, location availability, and notification status to support testing and subsequent performance analysis. Evaluation can measure activation response time, false-trigger frequency, successful message-transmission rate, location retrieval time, and cancellation reliability. Testing should include normal smartphone handling, repeated sensor obstruction, simulated emergency activation, changes in device orientation, and varying network conditions. These tests can help identify weaknesses in the activation logic and improve the consistency of emergency notifications.

Despite its advantages, proximity-based activation has limitations because the proximity sensor is generally designed to detect nearby objects rather than recognize specific emergency gestures. Its behaviour may depend on the sensor's physical location, device design, screen state, and whether the sensor is accessible during riding. Similarly, background execution restrictions and location permissions may affect continuous monitoring and location sharing. Therefore, the proximity-based method should be treated as an accessible emergency-trigger mechanism rather than a guaranteed crash or distress detector. Further development should focus on device compatibility, reliable background operation, secure handling of emergency-contact information, and comprehensive testing under realistic riding conditions.

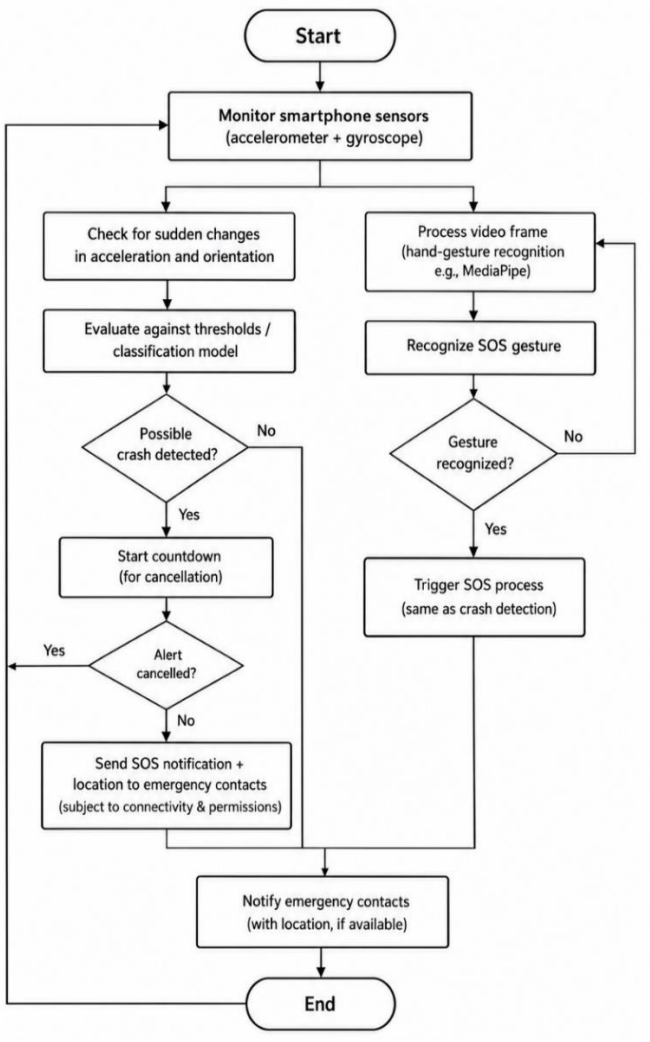


Fig 5. Combined crash detection and SOS activation flowchart.

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F. Mobile Application and Cloud Integration

The SheTorque mobile application provides the primary interface between the rider and the proposed safety ecosystem. It includes rider sign-in, motorcycle registration, the SHE Torque Hub dashboard, vehicle monitoring, service alerts, navigation, and emergency controls. The application brings together information from the Digital Garage, Sensor Fusion Hub, and Smart SOS modules to present relevant vehicle information, safety notifications, and emergency options through a unified interface. This integrated design aims to reduce the need for riders to switch between separate applications when accessing essential safety and vehicle-monitoring functions.

Firebase Realtime Database is proposed for incident logging and data synchronization between the mobile application and the cloud. Subject to the implemented database structure and access rules, the system can store incident details, event timestamps, notification status, and selected vehicle-monitoring records. Synchronization allows supported information to be accessed and updated across connected application sessions. Appropriate data validation and access controls should be applied to maintain data consistency and prevent unauthorized access to sensitive rider information. Where network connectivity is unavailable, the application should communicate synchronization failures clearly and handle pending records according to the implemented data-management strategy.

Google Maps SDK supports location display and the integration of location-based services within the application. It can be used to display the rider's available location, present navigation information, and identify nearby safe locations or assistance points when suitable location and place data are available. During an emergency, the application can attempt to obtain the current coordinates and include them in an SOS notification. The accuracy and availability of these functions depend on location permissions, GPS conditions, internet connectivity, and the selected mapping services. The interface should indicate when a location is unavailable or may be outdated rather than presenting uncertain information as current.

The application combines outputs from independent detection and monitoring pipelines to generate context-relevant notifications. For example, a potential crash detected by the Sensor Fusion Hub can initiate the emergency-response workflow, while a valid proximity-based SOS activation can trigger the Smart SOS process. Vehicle diagnostic information from the Digital Garage can be presented alongside service reminders and warning indicators. This modular architecture allows individual functions to be developed and tested separately while maintaining a common interface for the rider. Clear notification categories, timestamps, and status indicators can help users distinguish vehicle warnings from emergency alerts and general application messages.

Security and privacy are important considerations because the application may process personal details, vehicle information, location coordinates, and emergency-contact data. Authentication should be combined with appropriate database security rules and permission checks so that users can access only the information they are authorized to view or modify. Location collection should be limited to the functionality required by the application and handled transparently through the relevant operating-system permissions. Sensitive records should be protected during transmission and storage using suitable security measures, and access to incident history should be restricted to authorized users and services.

The integration process must also account for mobile operating-system restrictions, background execution limits, sensor availability, network interruptions, and battery consumption. Continuous sensor monitoring, repeated location requests, and frequent cloud synchronization may increase power usage if they are not managed carefully. The application should therefore use suitable sampling intervals, avoid unnecessary network requests, handle temporary service failures, and provide meaningful feedback when a feature is unavailable. Emergency functions should also distinguish between an alert being generated, transmitted, and confirmed as delivered whenever the messaging service provides that information.

The integrated application can be evaluated using authentication success rate, database synchronization delay, location retrieval time, application response time, notification delivery status, battery consumption, and recovery from network interruptions. Testing across different smartphone models and network conditions can help identify compatibility issues and improve reliability. Overall, mobile application and cloud integration serves as the coordination layer of SheTorque, connecting vehicle monitoring, potential crash detection, location-based assistance, and emergency communication within a unified platform. The proposed services and capabilities require implementation-level validation before their reliability can be established in real-world riding conditions.

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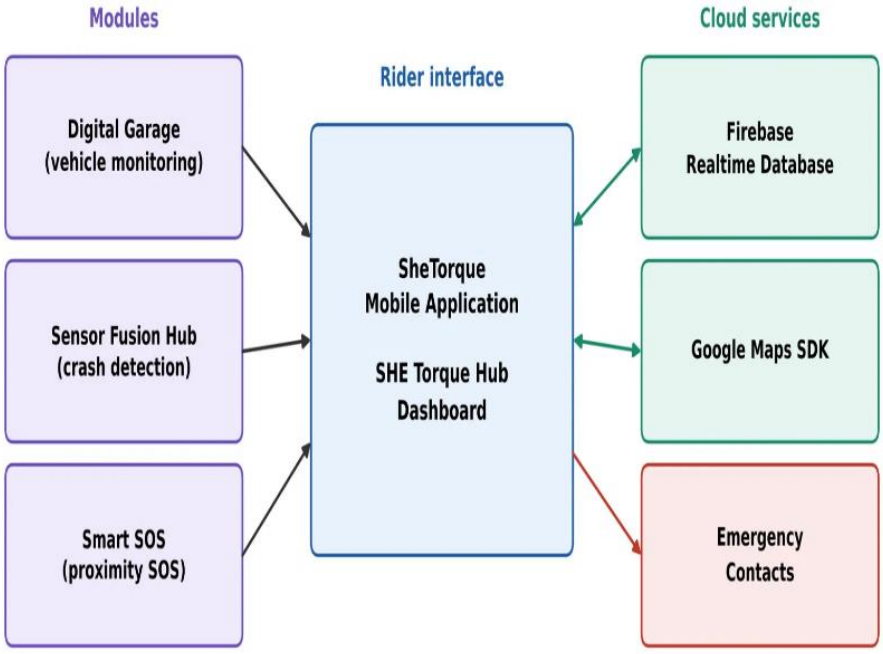


Fig 6. Mobile application and cloud integration of SheTorque Modules

G. Experimental Evaluation

The SheTorque system is evaluated through controlled tests to examine the functionality, reliability, and response performance of its implemented modules. Each module is tested independently before integration testing is performed. The evaluation focuses on identifying implementation issues, measuring relevant performance indicators, and verifying system behaviour under different operating conditions.

Crash detection is evaluated using smartphone inertial measurement unit (IMU) readings, including accelerometer and gyroscope data, under safe, simulated conditions. The system's response to sudden movements, orientation changes, and impact-like events is examined. Detection response time, false-positive events, and missed detections can be recorded to assess the effectiveness of the threshold-based approach.

Silent SOS is tested to evaluate the reliability of the three-second proximity trigger and its ability to avoid accidental activation. The tests examine sensor obstruction, activation timing, haptic feedback, and cancellation behaviour. Emergency-response performance is assessed by measuring alert initiation time, location retrieval, and message-delivery status under different network conditions.

Vehicle monitoring is evaluated by checking the availability and consistency of vehicle parameters received through the connected motorcycle interface. Guardian Eye is tested under different road-scene conditions to assess vehicle-detection accuracy, tracking continuity, and false alerts. Integration tests also examine mobile application responsiveness, cloud synchronization, connectivity recovery, and battery consumption.

The collected observations and measurements help identify system limitations and areas requiring improvement. Performance metrics such as detection accuracy, false-positive rate, activation success rate, and response time should be reported based on actual experimental results. Further testing across different smartphones, network conditions, and representative riding scenarios is required to establish the reliability of the SheTorque system in real-world conditions.

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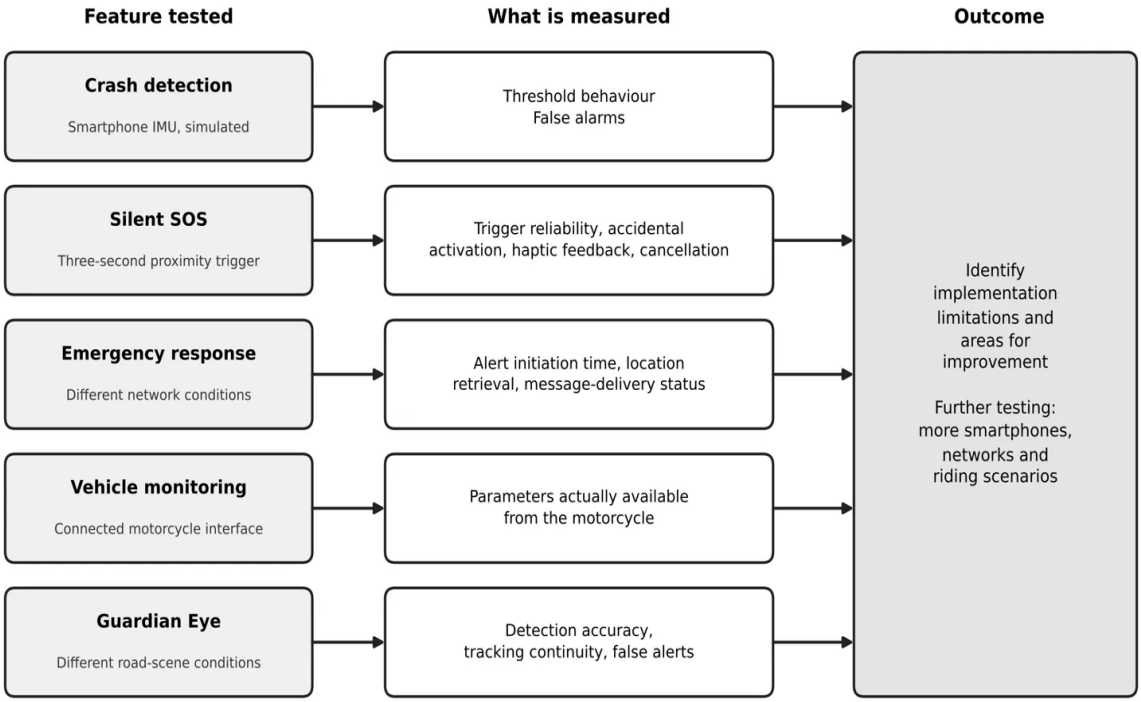


Fig 7. Experimental evaluation plan: features tested and metrics measured.

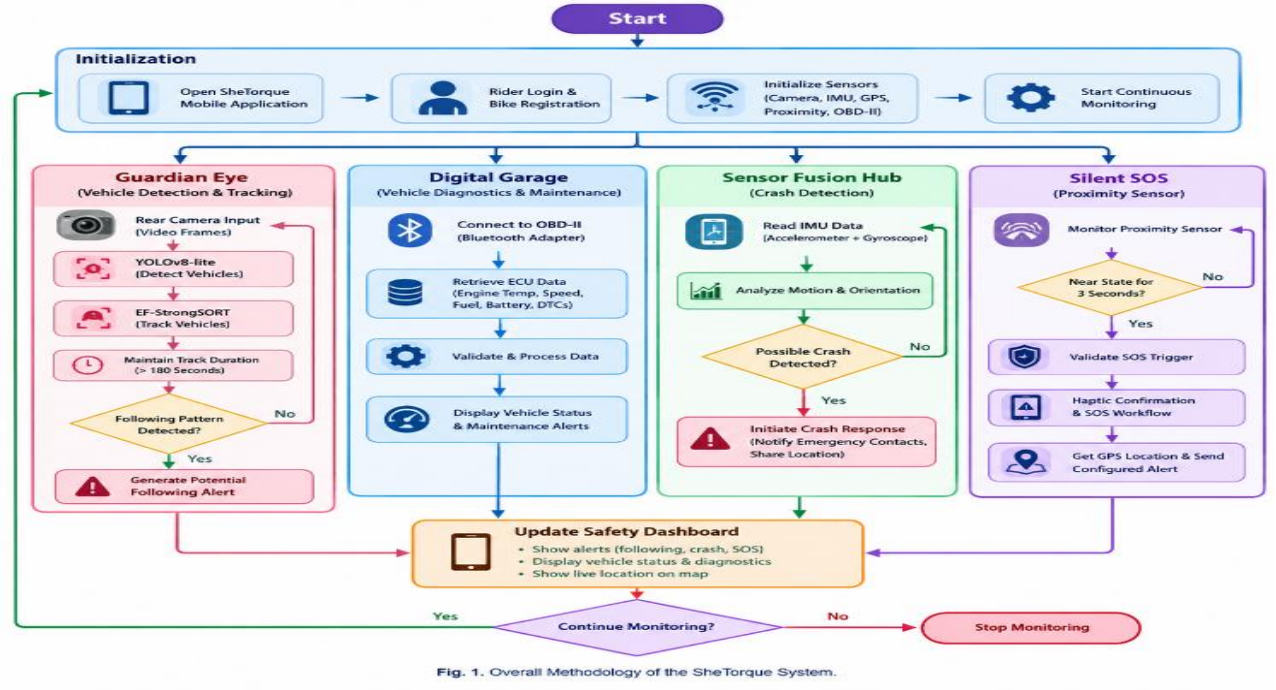


Fig. 1. Overall Methodology of the SheTorque System.

IV.EXISTING SYSTEM AND FUTURE IMPLEMENTATION

A. Existing System

Existing motorcycle safety systems primarily focus on individual functions such as GPS tracking, emergency alert services, vehicle diagnostics, or crash detection. These systems may operate independently and may not provide an integrated solution for women motorcyclists. Some applications require manual SOS activation, which can be difficult during emergencies. Similarly, conventional vehicle monitoring systems may depend on compatible hardware to access real-time engine information.

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The current Phase-1 implementation of SheTorque focuses on smartphone-based safety features, including IMU-based crash detection and proximity-based Silent SOS. The crash detection module monitors acceleration changes and initiates an emergency warning countdown when the configured threshold is exceeded. The Silent SOS module detects a sustained proximity-sensor activation and supports emergency SMS dispatch, location updates, and safe-status confirmation. These features provide the foundation for the proposed integrated safety ecosystem.

B. Future Implementation

Future development will extend SheTorque by integrating additional AI, computer vision, and IoT-based capabilities. The planned enhancements include:

1. Guardian Eye: Integrate a rear-view camera and YOLOv8-based vehicle detection and tracking to identify potentially

ECU Data-Bridge: Connect a compatible motorcycle through an OBD-II Bluetooth adapter to retrieve supported vehicle diagnostic information.

2. Smart Bike Vitals: Develop fuel-range estimation, maintenance reminders, and vehicle health monitoring using rider inputs and available sensor data.
3. Enhanced Emergency Response: Improve crash-event validation and emergency notifications through further testing under different riding conditions.
4. HerRide Tribe and Safe-Zone Mapping: Develop a rider community platform and map verified safe locations, such as police stations and suitable emergency assistance points.
5. External Camera Support: Explore an external camera connected to the smartphone to reduce the need for continuous smartphone-camera operation.

The future implementation will focus on integrating these modules into a unified mobile application and evaluating their performance through systematic testing. Further work will assess detection reliability, response time, battery consumption, hardware compatibility, and usability under real-world riding conditions.

V. RESULTS AND DISCUSSION

The SheTorque system is designed as an integrated safety platform for women motorcyclists, combining AI-based vehicle tracking, motorcycle diagnostics, and sensor-based emergency assistance. The system comprises three primary objectives: Guardian Eye for security monitoring, ECU Data-Bridge for motorcycle diagnostics, and Sensor Fusion Hub for crash detection and emergency response. The Phase-1 implementation focuses on crash detection, proximity-based Silent SOS, and emergency communication. The following results distinguish the functions demonstrated during Phase 1 from the proposed modules that require further implementation and evaluation.

A. Rider Authentication and Application Interface

The first result of the SheTorque project is the development of the rider sign-in interface, which serves as the entry point to the proposed safety and vehicle intelligence platform. The interface allows riders to enter their registered mobile number or email address and password/passcode to access the Digital Garage. It also provides a password recovery option to support account access.

The interface incorporates the SheTorque logo, clearly arranged input fields, and a prominent access button. A dark background with cyan highlights provides a consistent visual appearance and distinguishes important interactive elements. The sign-in screen establishes the front-end structure through which riders can access the application's vehicle monitoring, diagnostic

This result demonstrates the initial user interface developed for SheTorque and provides the foundation for integrating the different project modules into a unified mobile application. However, the screenshot demonstrates the interface design only; successful authentication, account recovery, and backend connectivity require separate functional verification.

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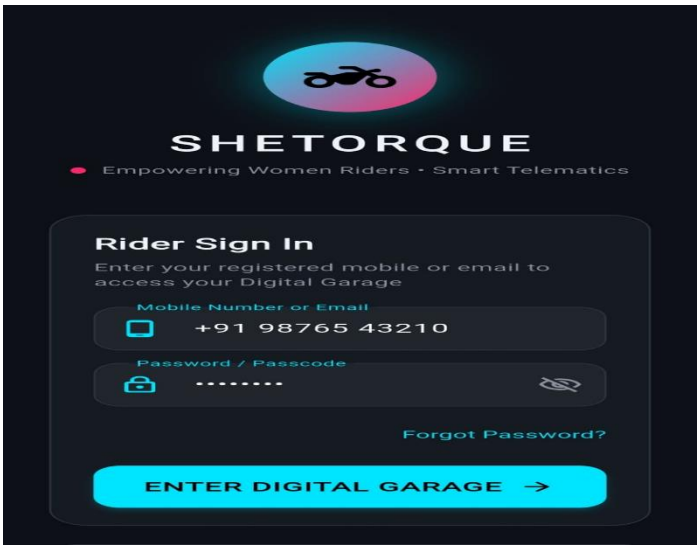


Fig 8. SheTorque rider sign-in interface.

B. Guardian Eye-AI-Based Vehicle Tracking

Guardian Eye is designed as an AI-based vehicle-monitoring module to improve situational awareness and security for women motorcyclists. The objective is to identify vehicles approaching or travelling behind the rider and monitor their movement over time. The proposed system integrates the YOLOv8 object-detection model with a Multi-Object Tracking (MOT) algorithm to detect vehicles in rear-facing camera footage and maintain their identities across consecutive video frames.

The proposed processing pipeline consists of five stages: rear-view video acquisition, vehicle detection, multi-object tracking, tracking-duration analysis, and safety-alert generation. First, the rear-facing camera captures video of the surrounding traffic. The YOLOv8 model processes individual frames and identifies

vehicles within the camera's field of view. The detected vehicles are represented by bounding boxes, which indicate their approximate positions in each frame. Subsequently, the tracking algorithm associates detections across successive frames and assigns a consistent tracking identifier to each vehicle while it remains trackable.

The tracking information is analysed to estimate how long a vehicle continues to appear behind the rider. In the proposed design, a persistent-tracking duration exceeding 180 s (3 min) is considered a potential alert condition. When this threshold is reached, the system is intended to generate a warning through the SheTorque mobile application, allowing the rider to become more aware of the surrounding traffic situation. The threshold represents a configurable design parameter and requires evaluation under different traffic conditions.

The Guardian Eye module is intended to provide an additional layer of security by identifying persistent vehicle-following patterns. However, continuous tracking alone cannot establish stalking or malicious intent, since vehicles may follow the same route because of normal traffic flow. Therefore, the alert should be interpreted as a potential safety warning rather than a definitive classification of threatening behaviour.

Guardian Eye is the first security objective of the SheTorque system. The proposed architecture defines the processing stages required for vehicle detection, tracking, duration monitoring, and alert generation. However, based on the available Phase-1 implementation information, the complete YOLOv8-based vehicle-tracking pipeline has not yet been experimentally validated. Consequently, numerical detection accuracy, tracking performance, processing time, and false-alert rate cannot be reported as measured results. Further implementation and testing are required to evaluate vehicle detection and tracking under varying lighting conditions, traffic densities, camera positions, and vehicle movements.

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Proposed Guardian Eye output showing rear-mounted camera monitoring, YOLOv8 vehicle detection, multi-object tracking, and persistent-following alerts.

Fig 9. Guardian Eye interface showing rear-camera vehicle detection, multi-object tracking, and persistent-following alerts

.

C. ECU Data-Bridge-Motorcycle Diagnostics

The second objective of SheTorque is to develop the ECU Data-Bridge to integrate motorcycle diagnostic information into the mobile application. The proposed module uses an ELM327-based OBD-II Bluetooth adapter to establish communication between a compatible motorcycle's electronic control unit (ECU) and the SheTorque application. Its purpose is to help riders monitor available vehicle parameters and identify potential maintenance requirements.

The proposed system retrieves supported diagnostic parameters through the vehicle's diagnostic interface and transfers the available data to the mobile application using Bluetooth communication. The application processes the received values and presents them through the Digital Garage and Diagnostics interfaces. The parameters specified in the project objective include fuel level, engine temperature, and battery voltage. Additional parameters, such as vehicle speed and diagnostic trouble codes (DTCs), may be displayed when supported by the motorcycle and diagnostic adapter.

The diagnostic workflow consists of connecting the OBD-II adapter, establishing Bluetooth communication, requesting supported parameters, processing the returned data, and displaying the results on the dashboard. The availability and accuracy of individual parameters depend on the motorcycle's ECU, supported communication protocol, and adapter compatibility. Therefore, unsupported or unavailable values should be identified clearly rather than displayed as verified measurements.

The SheTorque application screenshots demonstrate the motorcycle dashboard and diagnostic interface intended to present vehicle information. These interfaces provide the foundation for integrating diagnostic readings with the rider's safety and vehicle-management functions. However, the available Phase-1 results do not confirm that live OBD-II data has been successfully retrieved from a motorcycle. Consequently, diagnostic accuracy, Bluetooth communication reliability, and data-refresh performance cannot yet be reported as experimentally validated results.



Fig 10. SheTorque Hub dashboard

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Further testing should be conducted using a compatible motorcycle and OBD-II adapter. Retrieved values should be compared with suitable reference readings, and the system should be evaluated for parameter availability, communication interruptions, response time, and incorrect or missing data. Once validated, the ECU Data-Bridge can support vehicle-condition monitoring and provide a foundation for maintenance reminders within SheTorque.

C. Sensor Fusion Hub: Automated Crash Detection

The Sensor Fusion Hub is a core safety component of SheTorque implemented during Phase 1. It is designed to detect sudden motion patterns that may indicate a motorcycle accident and initiate an emergency-response procedure. The module combines smartphone sensor data, alert generation, a cancellation mechanism, and location-based emergency communication within a single application workflow. Although the overall project architecture proposes IMU-based sensing, the documented crash-detection implementation uses smartphone accelerometer readings.

1) Acceleration-Based Crash Detection

The application monitors acceleration values along the three coordinate axes of the smartphone. The resultant acceleration magnitude is calculated using

[
a_r=\sqrt{a_x^2+a_y^2+a_z^2}
]

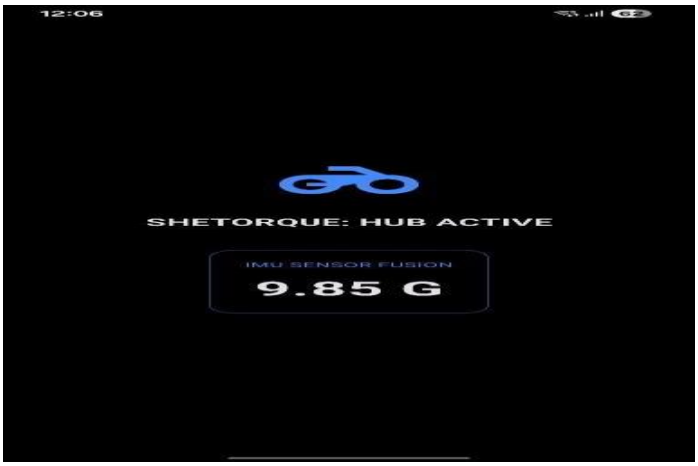


Fig 11. Hub active screen showing live acceleration reading.

where (a_x), (a_y), and (a_z) represent acceleration along the X, Y, and Z axes, respectively, and (a_r) represents the resultant acceleration magnitude.

The implementation uses a configured threshold of (25.0,\mathrm{m/s^2}) as part of its crash-trigger logic. When the measured acceleration satisfies the programmed trigger condition, the application interprets the event as a possible accident and activates the warning procedure. This threshold-based approach provides a simple mechanism for identifying sudden motion events. However, a high acceleration value alone cannot confirm that a real accident has occurred.

2) Warning and Cancellation Mechanism

After the crash-trigger condition is satisfied, the application displays a full-screen warning and activates an audible siren to notify the rider. A 90-second countdown is provided to allow the rider to cancel the alert if the detected event is not an actual emergency. This cancellation mechanism helps reduce unnecessary emergency messages caused by accidental triggering or non-emergency motion events.

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Fig 12. Crash alert screen with countdown and cancel option.

If the rider cancels the warning within the permitted period, the emergency-dispatch procedure can be stopped. If the countdown expires without cancellation, the application proceeds to the emergency communication stage. The warning and countdown therefore act as an intermediate verification step between sensor-based detection and emergency notification.

3) Emergency Communication and Location Sharing

Following the expiry of the countdown, the application initiates SMS dispatch to the configured emergency contact. The message includes the available GPS location information so that the recipient can identify the rider's reported location and respond accordingly. The process integrates motion monitoring, user confirmation time, location retrieval, and cellular communication into one emergency-response workflow.



Fig 13. Emergency SMS with crash alert and rider location.

The effectiveness of this stage depends on the availability of location data, mobile network connectivity, SMS permissions, and correctly configured emergency contact information. If GPS or cellular service is unavailable, the emergency communication process may be delayed or incomplete. These dependencies must be considered when evaluating the reliability of the system.

D. Sensor Fusion Hub: Proximity-Based Silent SOS

The proximity-based Silent SOS module is another safety feature implemented during Phase 1 of SheTorque. Its purpose is to provide a discreet method for initiating an emergency alert when a rider may be unable to operate the application normally. Unlike a conventional SOS button that requires direct screen interaction, this module uses the smartphone's native proximity sensor to detect a sustained near-state and initiate the alert sequence

.

1) Proximity-Based Trigger Mechanism

The application monitors the proximity sensor to identify whether an object is held close to the sensor. When the near-state remains active for three continuous seconds, the application begins the Silent SOS activation procedure. This approach avoids the need for a dedicated external sensor or camera-based gesture-recognition model in the documented implementation.

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The sustained-duration condition acts as an initial filter against brief or accidental sensor activation. Once the condition is satisfied, the application provides haptic feedback and enters a timed validation and cancellation stage. If the activation is not cancelled, the system proceeds to emergency notification

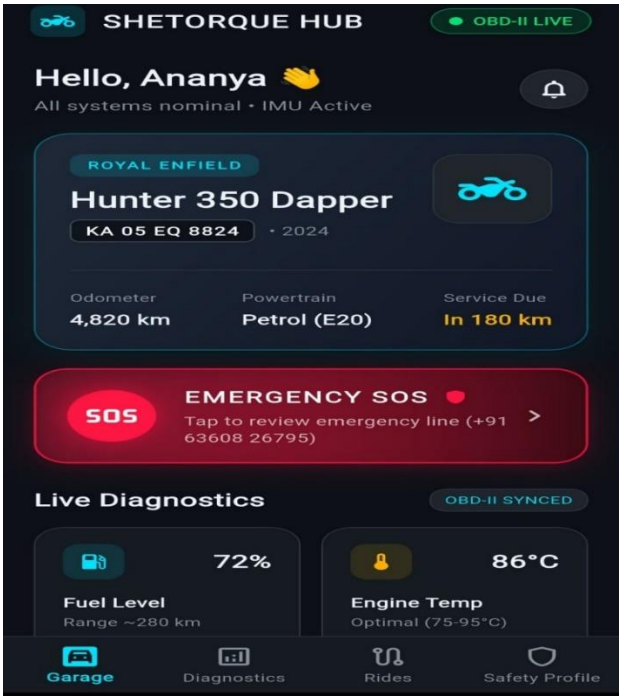


Fig 14. SheTorque Hub home screen with vehicle details, SOS control, and live diagnostics.

2) Emergency Alert and Location Tracking

After trigger confirmation, the application sends an SMS message to the configured emergency contact containing the available location information. During an active SOS session, the system can continue sending location updates at intervals of five minutes or when the rider's reported location changes by at least 100 m, according to the documented implementation.



Fig 15. Silent SOS alert SMS with location and periodic updates.

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4) Emergency Session Resolution

An "I Am Safe" control allows the rider to resolve the active emergency session. This feature provides a mechanism to indicate that assistance is no longer required and helps prevent unnecessary continuation of the alert workflow.



Fig 16. "I Am Safe" resolution screen.

he figure illustrates the emergency response system's handling of the rider's safety status. When the rider selects the "I Am Safe" button and confirms their identity using the secure PIN, the system sends a safety confirmation SMS to the designated emergency contacts. It then terminates continuous location tracking and resets the SOS session to the idle state. This mechanism informs emergency contacts that the rider is safe and prevents unnecessary continuation of emergency alerts.

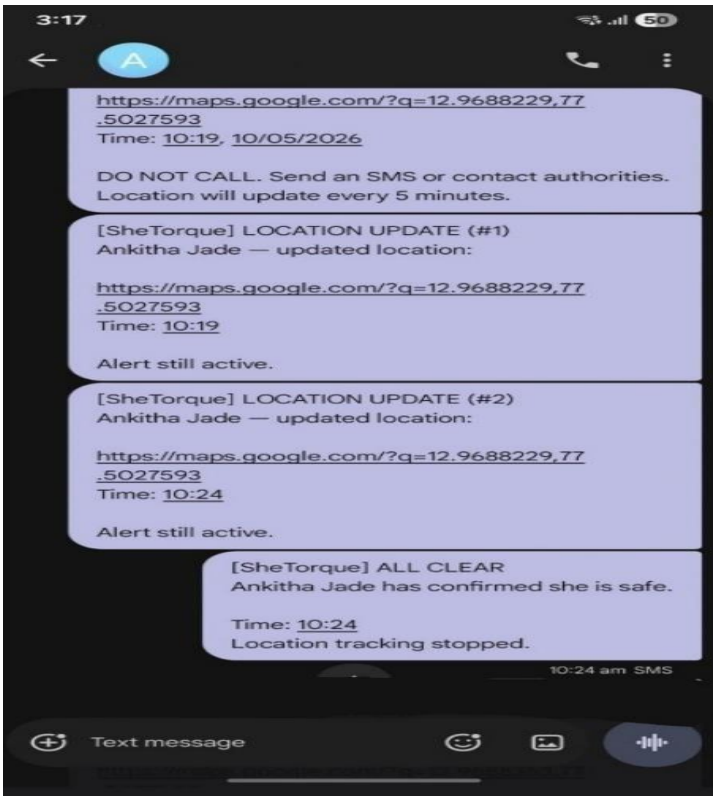


Fig 17. Location updates and all-clear SMS after the rider confirms safety.

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VI.CONCLUSION

SheTorque is an AI-integrated safety and vehicle intelligence platform proposed to improve the safety and riding experience of women motorcyclists. The Phase-1 implementation focused on smartphone-based crash detection using inertial measurement unit (IMU) data and proximity-based Silent SOS activation. The system supports emergency warning countdowns, SMS alerts, location sharing, and rider safety confirmation. The tested Silent SOS module successfully triggered in all 15 controlled test attempts, demonstrating the feasibility of the implemented activation mechanism under the tested conditions. However, further testing is required to evaluate its reliability in real-world riding environments. Future work will focus on integrating Guardian Eye for computer vision-based vehicle tracking, OBD-II-based motorcycle diagnostics, predictive maintenance, and safe-zone mapping. Overall, SheTorque aims to provide an integrated, accessible, and extensible safety ecosystem that combines mobile computing, AI, and IoT technologies to support safer

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