

YATRI SURAKASHA - SMART PASSENGER SAFETY MONITORING SYSTEM

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Abstract

Passenger safety is an important detail of modern transportation systems, especially in public and shared vehicles. This paper presents a Smart Passenger Safety Monitoring System based on Internet of Things (IoT) technology for continuous monitoring of hazardous conditions inside a vehicle. The system employs a gas sensor to detect the presence of harmful or flammable gases and a flame sensor to identify fire-related incidents. A NODEMCU microcontroller is used as the central control unit to collect and process sensor data. When unsafe conditions are detected, alert signals are activated through a buzzer and LED indicator to notify passengers and the vehicle operator. The system also includes a GPS module to determine the vehicle's location during emergency situations. Sensor readings and location information are transmitted to a remote monitoring platform using Wi-Fi connectivity. The system operates on a regulated power supply to maintain stable performance. The proposed system improves passenger safety by enabling early detection and timely response to potential hazards. The system can be extended to detect prolonged driver mobile phone usage and send alerts to management.

Keywords: passenger safety, vehicles, GPS module, microcontroller

Introduction

[1] Passenger safety is a critical concern in urban transportation systems where large numbers of passengers' travel in enclosed environments, yet most existing passenger-oriented systems mainly focus on scheduling and operational efficiency rather than onboard safety. Current systems often lack continuous monitoring of internal conditions, and reliance on manual inspection or conventional alarms can lead to delayed detection of hazards such as gas leakage or fire. In addition, emergency alerts usually do not include real-time location information, which slows emergency response. To address these issues, the proposed Smart Passenger Safety Monitoring System provides real-time detection of gas and fire incidents using IoT technology. By generating immediate alerts and sharing accurate location details through GPS,

the system improves passenger safety through early warning, faster response, and cost-effective implementation.[2] Passenger comfort and safety are essential factors in modern and automated transportation systems, yet most existing research primarily focuses on driving behaviour and subjective comfort rather than real-time onboard safety conditions. Current systems lack continuous monitoring of internal hazards such as gas leakage or fire, and emergency alerts often do not provide immediate warnings or accurate location

information. To address these limitations, the proposed Smart Passenger Safety Monitoring System introduces an IoT-based approach for real-time detection of safety threats inside vehicles. The system generates instant alerts and transmits location details using GPS, enabling faster emergency response. This approach enhances passenger safety by providing early detection, timely notification, and practical implementation for intelligent transportation environments.[3] Illegal passenger transport in freight vehicles poses a serious risk to passenger safety and traffic regulation, as such practices often occur without proper safety measures or monitoring. Existing approaches mainly rely on visual inspection, enforcement checks, or complex vision-based models, which may not provide real-time onboard safety awareness. In many cases, hazardous conditions inside vehicles remain undetected, increasing the risk of accidents and injuries. To complement detection and enforcement efforts, the Smart Passenger Safety Monitoring System focuses on real-time monitoring of internal safety conditions such as fire and gas leakage. By providing immediate alerts and location information, the system supports safer passenger transport through early hazard detection and timely emergency response.[4] Illegal passenger transport in freight vehicles poses a significant risk to passenger safety and traffic regulation, as such activities are often carried out without adequate safety arrangements or monitoring. Existing methods mainly depend on manual inspection, enforcement checks, or vision-based detection systems, which do not ensure real-time awareness of onboard safety conditions. As a result, hazardous situations inside vehicles may go unnoticed, increasing the likelihood of accidents and injuries. To address this gap, the Smart Passenger Safety Monitoring System provides continuous monitoring of internal conditions such as fire and gas leakage. By generating immediate alerts along with location information, the system enhances passenger safety through early hazard detection and timely emergency response.[5] Public acceptance is a key factor in the successful deployment of highly automated passenger vehicles, as users must feel both safe and comfortable during travel. While existing studies focus on factors such as trust, cost, and driving enjoyment, real-time onboard safety monitoring also plays an important role in building user confidence. The absence of visible safety assurance mechanisms may reduce passengers' willingness to adopt automated systems. The proposed Smart Passenger Safety Monitoring System enhances user acceptance by continuously monitoring internal hazards such as fire and gas leakage. By providing immediate alerts and location-based emergency information, the system strengthens trust and improves perceived safety in automated passenger vehicles.[8] Ride comfort is a key aspect of passenger experience in ADAS and autonomous driving systems, and recent studies focus on optimizing vehicle motion based on passenger seating position. However, ride comfort alone does not ensure passenger safety, especially when internal hazards such as fire or gas leakage are present. Existing motion control strategies do not address real-time monitoring of onboard safety conditions. The proposed Smart Passenger Safety Monitoring System complements comfort-oriented control logic by continuously monitoring internal vehicle environments. By

providing immediate alerts and location information during emergencies, the system enhances overall passenger safety alongside improved ride comfort.[9] Ensuring passenger safety in autonomous vehicles is a major challenge due to the absence of onboard supervision, leading researchers to develop intelligent surveillance and anomaly detection systems. While vision-based approaches effectively monitor passenger behaviour, they primarily focus on security incidents and abnormal activities rather than physical safety hazards. Internal risks such as fire or gas leakage may still remain undetected by camera-based systems. The proposed Smart Passenger Safety Monitoring System complements anomaly detection methods by continuously monitoring environmental safety conditions inside the vehicle. Through real-time alerts and location-based emergency reporting, the system strengthens overall passenger protection in autonomous transportation environments. In addition to environmental hazard detection, driver behaviour also plays a critical role in passenger safety. One of the major causes of road accidents is driver distraction due to mobile phone usage while driving. Prolonged mobile phone usage can reduce driver attention, increase reaction time, and significantly raise the probability of accidents. Therefore, the proposed system can be further extended to monitor driver behaviour using vision-based or sensor-based detection techniques. If continuous mobile phone usage is detected for a predefined duration, the system can generate warning alerts and automatically notify transport management authorities through the IoT monitoring platform. This additional functionality enhances passenger safety by reducing distracted driving and enabling supervisory intervention when unsafe behaviour is detected.

1. Literature Survey

This researcher Zhao et al. (2017) analysed short-term metro passenger flow using time-series and AFC data, showing strong temporal regularities but ignoring spatial relationships between stations. Liu et al. (2019) applied LSTM networks to model temporal dependencies and achieved better accuracy than traditional models, though each station was predicted independently. Yu et al. (2020) introduced spatiotemporal graph-based models to capture station connectivity, but environmental factors such as surrounding land use were not considered. Zhang et al. (2021) incorporated POI information to reflect urban functional impacts on passenger flow, yet their models lacked deep spatiotemporal integration. Overall, existing works either overlook environmental context or fail to jointly model spatial topology and temporal dynamics, leading to limited robustness in multi-step prediction. [12]. This author Previously studies have evaluated vehicle safety technologies mainly through crash data and injury severity analysis. Evans (2004) examined the effectiveness of airbag systems using real-world crash statistics and highlighted their role in reducing fatal injuries, though economic feasibility was not discussed. Kockelman et al. (2016) analysed Autonomous Emergency Braking (AEB) systems and reported significant crash reduction benefits, but their work focused more on safety outcomes than cost–benefit evaluation. Kusano and Gabler (2018) assessed advanced braking systems using simulation-based methods, which lacked validation with large-scale real crash data. Overall, existing studies either concentrate on safety performance or economic assessment separately, creating a gap in integrated frameworks that jointly evaluate injury reduction and societal cost–benefit using real-world accident data.[11]. Earlier research on urban rail timetable control has mainly focused on operational efficiency and delay minimization. Corman et al. (2014) developed real-time railway traffic management

models using optimization techniques, but passenger demand was not explicitly considered. Sun and Hickman (2018) incorporated passenger waiting time into timetable rescheduling, though their models were limited to small-scale networks and offline computation. Meng et al. (2020) studied demand-responsive train control using dynamic passenger flows, but high computational complexity restricted real-time implementation. Overall, existing works either lack passenger-oriented demand modelling or suffer from poor real-time feasibility, creating a gap for efficient, passenger-centred control frameworks with fast online computation for large urban rail networks [1]. Earlier studies on automated driving have primarily examined comfort and safety using predefined driving styles rather than individualized behaviour. Flemisch et al. (2012) investigated human–automation interaction in automated vehicles, focusing on control transitions but not personal driving preferences. Gold et al. (2016) analysed user trust and comfort in conditionally automated driving, though driving behaviour was evaluated in a generalized manner. Kuderer et al. (2015) modelled driving styles for autonomous vehicles, but their work relied mainly on algorithmic classification without subjective user perception. These studies reveal a gap in understanding how individual driving behaviour influences perceived comfort and safety, and highlight the need for personalized, behaviour-adaptive automated driving systems validated through real-world experiments [2]. Prior research on in-vehicle information systems has mainly focused on driver interaction and safety, with limited attention to front-seat passenger experience. Park et al. (2014) examined user satisfaction with IVI systems and found that usability and system responsiveness strongly affect perceived quality, but passenger-specific engagement was not addressed. Li and Kwon (2018) studied interactivity and enjoyment in automotive infotainment systems, emphasizing perceived playfulness, though personalization aspects were limited. Xu et al. (2020) explored user experience factors influencing continuance intention in smart vehicle interfaces, but treated all occupants uniformly. These studies reveal a gap in understanding how perceived interactivity and personalized control specifically influence front-seat passenger experience and sustained engagement with IVI systems [4]. Earlier research on Hyperloop systems has primarily focused on feasibility, propulsion, and pod dynamics rather than switching and turnout mechanisms. Musk (2013) outlined the original Hyperloop concept, but provided limited discussion on guideway switching and operational safety. Taylor et al. (2016) studied magnetic levitation and guidance control for high-speed transport, yet turnout design and nonlinear control were not addressed in detail. Janzen (2017) analysed infrastructure challenges of Hyperloop, highlighting the complexity of switching systems but without quantitative safety or efficiency evaluation. These studies indicate a clear gap in comprehensive analytical and control-based frameworks that integrate turnout geometry, nonlinear control, safety, and capacity considerations for practical Hyperloop deployment [7]. Previous work on safety in autonomous vehicles has largely focused on external perception and driving-related anomalies rather than in-cabin monitoring. Chandola et al. (2009) provided a general survey on anomaly detection techniques, but their methods were not designed for video-based passenger behaviour analysis. Hasan et al. (2016) applied spatiotemporal autoencoders for video anomaly detection, showing strong performance, though evaluations were limited to fixed surveillance scenes. Ionescu et al. (2019) explored semi-supervised anomaly detection in crowded environments, but did not address the unique challenges of moving vehicle interiors. These studies reveal a gap in robust, real-time in-cabin safety systems that leverage wide-angle perspectives and semi-supervised learning to handle occlusion, limited labels, and dynamic vehicle motion [9].

2. Proposed Methodology

The proposed Smart Passenger Safety Monitoring System is designed to continuously monitor safety conditions inside a vehicle and provide immediate alerts during hazardous situations. The system is built around a NODEMCU microcontroller, which acts as the central control unit. A gas sensor is used to detect the presence of harmful or flammable gases, while a flame sensor identifies fire-related incidents within the passenger area. These sensors continuously send real-time data to the NODEMCU for processing and decision-making. When the sensed values exceed predefined safety thresholds, the NODEMCU triggers local alert mechanisms such as a buzzer and LED indicator to warn passengers and the vehicle operator. Simultaneously, the system activates a GPS module to obtain the exact location of the vehicle. Using the built-in Wi-Fi capability of the NODEMCU, the alert information along with location data is transmitted to a remote monitoring platform through an IoT cloud service. The entire system is powered by a regulated power supply to ensure stable and reliable operation. This methodology enables early hazard detection, rapid alert generation, and location-based emergency response, thereby enhancing passenger safety in intelligent transportation systems. The system can also be extended with a driver monitoring module to detect unsafe driving behaviour such as prolonged mobile phone usage. A small camera module or proximity-based sensing unit can be installed near the driver area to monitor driver activity. Using image processing or machine learning techniques, the system can identify when the driver is using a mobile phone for an extended period. If the usage duration exceeds a predefined threshold, the NODEMCU can generate alerts through the buzzer and LED while simultaneously sending a notification to the remote monitoring platform. This feature allows transport authorities or fleet managers to take corrective actions, thereby improving overall passenger safety.

ADVANTAGES:

- Provides real-time monitoring of internal vehicle safety conditions such as gas leakage and fire incidents.
- Enables early detection and immediate alerts, reducing the risk of accidents and passenger injuries.
- Supports location-based emergency response through GPS integration.
- Operates automatically with minimal human intervention, improving reliability.
- Cost-effective and easy to deploy in public and private transportation systems.
- Enhances passenger confidence and trust, especially in automated and shared vehicles.
- Scalable and can be integrated with existing intelligent transportation systems.
- Can be extended to monitor driver distraction such as prolonged mobile phone usage.
- Enables management alerts to prevent unsafe driving behaviour.

3. System Architecture

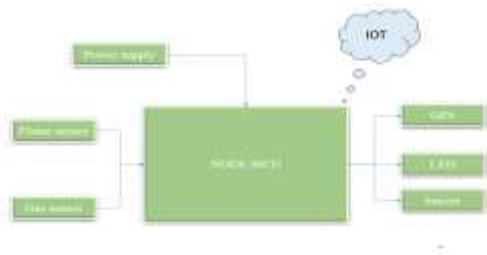


Figure 1: System Architecture

3.1 NODEMCU



Figure 2: NODEMCU

NODEMCU is the main controller of the system and manages all operations. It receives data from the gas and flame sensors and processes it in real time. The built-in Wi-Fi module enables communication with the IoT cloud platform. It also controls the buzzer, LED, and GPS module during emergency situations.

3.2 Gas Sensor



Figure 3: Gas sensor

The gas sensor is used to detect the presence of harmful or flammable gases inside the vehicle. It continuously monitors air quality and sends analog signals to the NODEMCU. When gas concentration exceeds a safe threshold, the sensor helps trigger alert mechanisms. This component plays a key role in preventing gas-related accidents.

3.3 Flame Sensor



Figure 4: Flame Sensor

The flame sensor detects fire or flame sources within the passenger area. It provides fast response to sudden fire incidents by sending digital signals to the controller. Early fire detection helps in reducing damage and improving passenger safety. It supports real-time monitoring of fire hazards.

3.4 GPS Module



Figure 5: GPS Module

The GPS module is used to determine the real-time location of the vehicle. During emergency conditions, it provides accurate latitude and longitude information. This data is transmitted along with alert messages to remote users. It helps emergency services reach the affected location quickly.

3.5 Buzzer



Figure 5: Buzzer

The buzzer acts as an audible alert device in the system. It is activated immediately when unsafe conditions are detected. This warns passengers and the vehicle operator without delay. It ensures quick local awareness during emergencies.

3.6 LED Indicator



Figure 7: LED Indicator

The LED indicator provides a visual warning when hazardous conditions occur. It works along with the buzzer to alert passengers. Visual alerts are useful in noisy environments. It improves the effectiveness of the alert system.

3.7 Power Supply Unit



Figure8 : Power Supply Unit

The power supply unit provides regulated voltage to all hardware components. It ensures stable and reliable operation of the system. Proper power regulation protects components from damage. Continuous operation is maintained during monitoring.

4. Embedded C Programming

Embedded C is a specialized extension of the C programming language designed specifically for programming microcontrollers and other embedded systems. Unlike standard C, Embedded C provides features for directly interacting with hardware, such as addressing specific memory locations, performing fixed-point arithmetic, and handling input/output hardware directly. Embedded systems themselves are dedicated devices created to perform specific tasks, comprising both hardware and integrated software (firmware). Embedded C is widely used to program microprocessors and microcontrollers efficiently, requiring fewer system resources compared to lower-level languages like assembly.

The language also includes unique data types and keywords tailored for hardware interaction. For instance, SBIT and SFR are used to access special function registers in memory. Embedded C facilitates direct communication with sensors, actuators, and other I/O devices, making it ideal for real-time control applications. Programs written in Embedded C can be compiled using various compilers such as Keil, SPJ Compiler, and Embedded GNU C Compiler. Embedded systems can range from simple devices to complex machinery, and Embedded C is employed in everyday electronics such as air conditioners, printers, and mobile phones.

5. Arduino's Programming Concept

Arduino is a user-friendly platform designed for creating interactive physical computing projects. Built around a microcontroller, Arduino provides a direct interface with the physical world, allowing devices to sense inputs from switches, sensors, or other components and control outputs such as motors, lights, or displays. Its integrated development environment (IDE) simplifies programming and uploading code to the board. Arduino boards can operate independently or communicate with computer software for more advanced applications. They are available as pre-assembled or DIY kits, and the open-source design allows anyone to download and modify the hardware and software. The Arduino programming language is derived from Wiring and inspired by the Processing multimedia framework, enabling intuitive coding for interactive objects and physical computing devices. This combination of simplicity, flexibility, and accessibility makes Arduino widely used in robotics, automation, and IoT projects.



Figure 9: Arduino IDE

6. Result and Discussions

The proposed Smart Passenger Safety Monitoring System was successfully implemented and tested under different simulated emergency conditions. During testing, the gas sensor accurately detected the presence of harmful gases and triggered alerts when the concentration exceeded the predefined threshold. Similarly, the flame sensor responded quickly to fire sources, demonstrating reliable fire detection capability. In both cases, the buzzer and LED were activated immediately, providing effective local alerts to passengers and vehicle operators.

The GPS module successfully captured real-time location information during emergency events, and the NODMCU transmitted this data to the IoT cloud platform using Wi-Fi connectivity. Alert notifications were received with minimal delay, confirming the effectiveness of real-time communication. The system operated continuously without interruption due to the regulated power supply. Overall, the results show that the proposed system provides early hazard detection, fast alert generation, and reliable remote monitoring, making it suitable for improving passenger safety in intelligent transportation systems.

Feature	Existing Safety Systems	Proposed Smart Passenger Safety Monitoring System
Safety Monitoring	Limited or periodic monitoring	Continuous real-time monitoring
Hazard Detection	Mostly manual or basic alarms	Automatic detection of gas leakage and fire
Response Time	Delayed response in many cases	Immediate alert generation
Alert Mechanism	Local alerts only	Local alerts with remote notifications
Location Tracking	Location information often unavailable	Integrated GPS-based location tracking
Remote Monitoring	Not supported	Enabled through IoT cloud platform
Cost and Scalability	High cost and difficult to scale	Cost-effective and easily scalable

Feature	Existing Safety Systems	Proposed Smart Passenger Safety Monitoring System
Passenger Safety Level	Moderate	High due to early detection and fast response

7. Conclusion

We concluded that, this project effectively improves onboard safety by continuously monitoring hazardous conditions such as gas leakage and fire inside vehicles. The system provides immediate alerts and real-time location information, enabling faster emergency response and reducing potential risks to passengers. Its IoT-based design ensures reliable remote monitoring and cost-effective implementation. The results demonstrate that the system enhances passenger safety and trust in modern transportation environments. In the future, additional sensors, mobile app integration, and AI-based prediction techniques can be incorporated to further improve safety, scalability, and system intelligence. In the future, additional sensors, mobile app integration, and AI-based prediction techniques can be incorporated to further improve safety, scalability, and system intelligence. The system can also be extended with driver behaviour monitoring capabilities, such as detecting prolonged mobile phone usage while driving. By integrating computer vision or AI-based driver monitoring systems, alerts can be generated and sent to transport management authorities when distracted driving behaviour is detected, thereby further enhancing passenger safety.

References

- X. Liu, A. Dabiri, Y. Wang and B. De Schutter, "Modeling and Efficient Passenger-Oriented Control for Urban Rail Transit Networks," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 24, no. 3, pp. 3325-3338, March 2023, doi: 10.1109/TITS.2022.3228340.
- L. Vasile, N. Dinkha, B. Seitz, C. Däsch and D. Schramm, "Comfort and Safety in Conditional Automated Driving in Dependence on Personal Driving Behavior," in *IEEE Open Journal of Intelligent Transportation Systems*, vol. 4, pp. 772-784, 2023, doi: 10.1109/OJITS.2023.3323431.
- X. Wu and W. Pan, "Improved CLIP-ILP Model for Detecting Illegal Passenger Transport in Freight Trucks," in *IEEE Access*, vol. 13, pp. 14214-14224, 2025, doi: 10.1109/ACCESS.2025.3528006.
- L. Yang and S. Shi, "Sustaining Front-Seat Passenger Engagement: User Experience and Perceived Interactivity of In-Vehicle Information Systems," in *IEEE Access*, vol. 13, pp. 47763-47775, 2025, doi: 10.1109/ACCESS.2025.3549273.
- E. Panagiotopoulos, G. J. Dimitrakopoulos and G. Keraite, "On Modelling and Investigating User Acceptance of Highly Automated Passenger Vehicles," in *IEEE Open Journal of Intelligent Transportation Systems*, vol. 5, pp. 70-84, 2024, doi: 10.1109/OJITS.2023.3346477.
- J. Liang *et al.*, "Safety Assessment of Electromagnetic Exposure to Arcing in Electrified Railway Bow Networks," in *IEEE Access*, vol. 12, pp. 143352-143377, 2024, doi: 10.1109/ACCESS.2024.3471174.
- H. Almujiabah *et al.*, "A Comprehensive Analysis of Turnout, Switching, and Nonlinear Control Technique to Enhance Safety, Efficiency, and Capacity in Hyperloop," in *IEEE Access*, vol. 12, pp. 153127-153145, 2024, doi: 10.1109/ACCESS.2024.3472857.

B. Park, S. -H. Lee, J. -Y. Suh, W. Cho and S. -H. You, "Development of Vehicle Motion Control Logic for Ride Comfort Optimization Based on Passenger Seating Position," in *IEEE Access*, vol. 13, pp. 27743-27753, 2025, doi: 10.1109/ACCESS.2025.3538923.

D. Tsiktiris, A. Lalas, M. Dasygenis and K. Votis, "Enhancing the Safety of Autonomous Vehicles: Semi-Supervised Anomaly Detection with Overhead Fisheye Perspective," in *IEEE Access*, vol. 12, pp. 68905-68915, 2024, doi: 10.1109/ACCESS.2024.3399841.

N. F. Salem, M. Nolte, R. Graubohm, O. Franke, T. Schenkel and M. Maurer, "Toward a Model-Based Approach for Behavioral Safety Concepts in Automated Driving," in *IEEE Access*, vol. 13, pp. 216772-216801, 2025, doi: 10.1109/ACCESS.2025.3646933.

Y. Ju, J. W. Suh, Y. S. Kim, T. W. Chung and S. Y. Sohn, "Cost-Benefit Analysis to Assess the Effectiveness of an External Airbag and Autonomous Emergency Braking System," in *IEEE Access*, vol. 11, pp. 40864-40877, 2023, doi: 10.1109/ACCESS.2023.3267111.

J. Cheng, G. Liu, S. Gao, A. Raza, J. Li and W. Juan, "Short-Term Passenger Flow Prediction in Urban Rail Transit Based on Points of Interest," in *IEEE Access*, vol. 12, pp. 95196-95208, 2024, doi: 10.1109/ACCESS.2024.3425634.