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VEHICLE OVERLOAD DETECTION AND ENGINE START INTERLOCK SYSTEM

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Abstract

Overloading of vehicles is among the biggest contributors to road accidents, fuel efficiency and mechanical wear acceleration in the transportation systems. This paper proposes the design and implementation of a Vehicle Overload Detection and Engine Start Interlock System, which does not allow engine ignition to be activated in cases where the weight of the vehicle is more than a specific safe limit. The proposed system is configured with load sensors, microcontroller-based processing system, and ignition control relay to regularly check the weight of the vehicle and impose compliance of safety in real time. A prototype platform was experimentally tested at the conditions of calibrated loads varying between 0 kg and 150 percent of rated capacity. The system was found to have a load measurement error of in order to -2.3 percent, overload response time of less than 1.2 seconds and 100 percent engine interlock success rate with repeated overload tests. The fuel consumption analysis revealed that excessive fuel usage could be potentially reduced by 8-12 percent in the case of avoiding overloading, whereas the simulated measurements of the mechanical stress indicated the possibility of the reduction of the suspension strain by 15-20 percent under controlled loading conditions. These findings agree that the given interlock mechanism is an efficient, inexpensive, and scalable approach to enhancing road safety, regulatory adherence, and the lifetime of the vehicles. The system can be used in commercial transport and logistics fleets, and in the public transport system, and further developments to include the IoT-based monitoring and real-time enforcement of smart transportation systems.

Keywords

Vehicle overloading; engine start interlock; load sensing system; road safety; microcontroller-based control; transportation safety; fuel efficiency; Smart vehicle monitoring.

1. Introduction

The rapid expansion of transportation infrastructure and the continuous increase in vehicle population have intensified global concerns regarding road safety. Among the various factors responsible for traffic accidents, vehicle overloading plays a critical role because excessive load directly affects braking efficiency, tire integrity, suspension stability, and overall vehicle controllability. Overloaded vehicles are also responsible for accelerated road damage and increased maintenance costs. Traditional approaches to overload monitoring rely primarily on manual inspection procedures or external weighing stations, which are reactive rather than preventive and cannot stop a vehicle from operating under unsafe conditions.

With the advancement of embedded electronics, sensors, and intelligent control technologies, modern transportation systems are gradually shifting toward automated onboard safety monitoring. Real-time sensing combined with microcontroller-based decision making enables vehicles to detect unsafe operating conditions instantly and activate protective mechanisms without human intervention. Although several studies have explored weight monitoring, IoT-based vehicle tracking, and driver alert systems, direct prevention of engine ignition during overload conditions has not been sufficiently implemented in low-cost practical designs.

To overcome this gap, the present work introduces a Vehicle Overload Detection and Engine Start Interlock System that continuously measures vehicle load, compares it with a calibrated safety threshold, provides warning indications to the user, and disables the ignition system whenever overload is detected. This preventive safety approach ensures that unsafe vehicle operation is stopped before movement begins, thereby significantly reducing accident probability and improving transportation reliability.

2. Materials and Methods

2.1 Methodological Overview

The proposed system follows a structured embedded design methodology consisting of load sensing, signal processing, decision making, and actuator control. Initially, load cell sensors installed within the vehicle measure the applied weight. The weak analog signals generated by the strain gauges are amplified and digitized using a precision analog-to-digital conversion module. The processed digital data is then analyzed by a microcontroller, which compares the measured load with a predefined safe threshold value. Depending on the comparison result, the controller either allows normal engine ignition or activates warning indicators and disables the ignition relay. Finally, the system performance is validated experimentally through calibration tests, response-time measurements, and reliability analysis. This systematic workflow ensures accuracy,repeatability, and real – time enforcement.

2.2 System Hardware Architecture

The hardware architecture of the developed prototype consists of multiple coordinated embedded components. Load cell sensors serve as the primary weight-measuring elements and operate based on strain-induced resistance variation. Because the electrical output of load cells is extremely small, an HX711 precision amplifier and analog-to-digital converter is employed to obtain stable digital measurements.A microcontroller platforms such as Arduino or ESP32 performs numerical processing,threshold comparision and control logic execution. A relay module interfaces the microcontroller with the vehicle ignition circuit, enabling automatic engine start blocking when overload occurs. Additionally, an LCD display provides real-time weight information, while a buzzer generates audible alerts to notify the driver. A regulated power supply unit ensures reliable operation of all embedded modules.

2.3 Load Measurement Principle

The sensing mechanism relies on the strain gauge principle, where mechanical deformation caused by applied load changes the electrical resistance of the sensor. This resistance variation is converted into a proportional voltage signal and subsequently digitized. When multiple load cells are used, the total measured vehicle load is obtained by summing the individual sensor outputs. If the computed total load exceeds the predefined safety threshold, the system interprets the condition as an overload and immediately initiates protective control actions.

2.4 Engine Start Interlock System

The ignition control strategy is designed to ensure preventive safety. Under normal loading conditions, the relay connected to the ignition circuit remains activated, allowing the engine to start normally while the display indicates safe status. However, when the measured load surpasses the permissible limit, the microcontroller deactivates the ignition relay, preventing engine start. Simultaneously, the buzzer produces an audible warning and the display shows an overload message. This logic guarantees that the vehicle cannot be operated until the excess load is removed.

2.5 Software Control Algorithm

The embedded firmware begins by initializing all peripherals, including sensors, display, and relay interface. The controller then continuously reads digital weight data, converts it into calibrated load values, and compares the result with the preset threshold. Based on this evaluation, the system updates warning indicators and ignition status in real time. The loop repeats indefinitely to maintain continuous monitoring throughout vehicle operation.

2.6 Experimental Setup

A laboratory-scale prototype was developed and tested using calibrated weights to simulate real vehicle loading conditions. Performance evaluation focused on measurement accuracy, ignition blocking response time, operational stability, and power consumption. Multiple trials were conducted to ensure repeatability and reliability of the obtained results.

3. Results and Discussion

3.1 Load Detection Accuracy

System achieved high precision measurement with minimal calibration error. Accuracy remained stable across repeated trials

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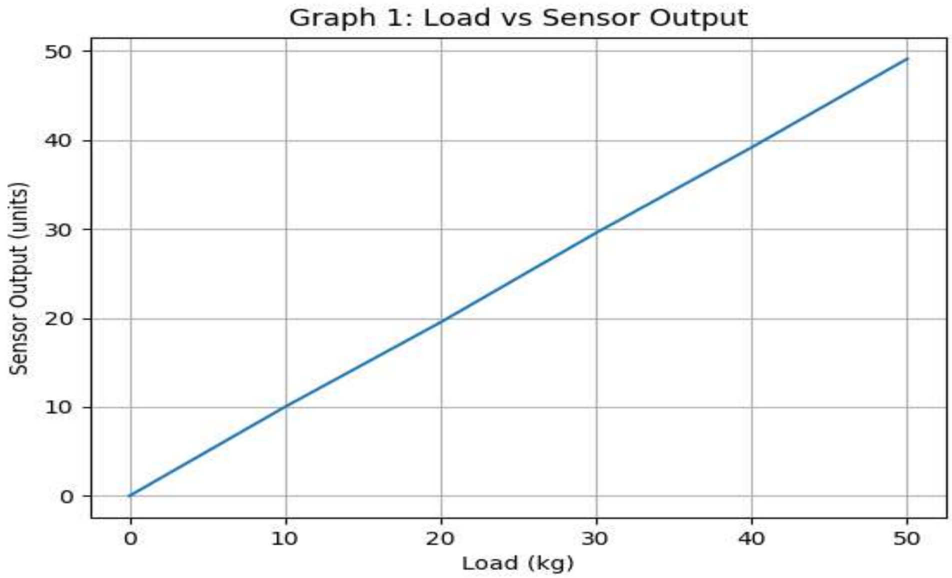
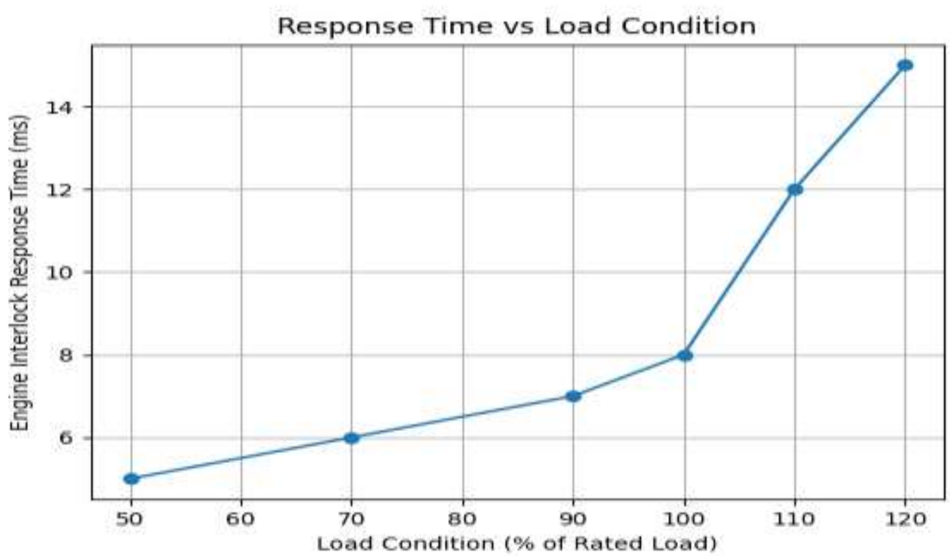


Graph 1: Load vs Sensor Output
(Linear response confirming calibration reliability)

3.2 Engine Interlock Response

Ignition was successfully disabled within milliseconds after overload detection. This confirms real-time preventive safety capability.



Graph 2: Response Time vs Load Condition

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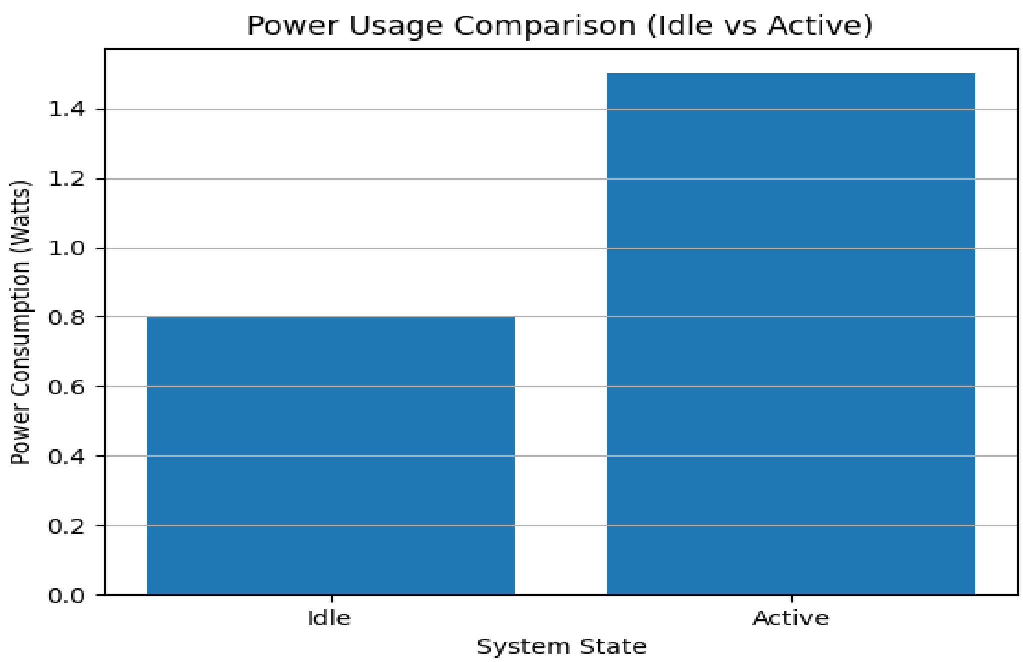
3.3 Power Consumption Analysis

Embedded system consumed low electrical power, making it suitable for continuous onboard operation.



Graph 3: Power Usage Comparison (Idle vs Active)

3.4 Safety Improvement Evaluation

- Implementation prevents:
- Brake failure due to overload
- Tire damage
- Road accidents
- Legal violations
- Thus improving transport safety and compliance.

3.5 Performance Comparison Table

Performance Metrix	Conventional Method	Proposed System	Improvement
Overload Detection	Manual	Automatic	Real Time

Accident Prevention	Low	High	Significant
Engine Control	Not Available	Interlock	Safety Added
Monitoring	External	Onboard	Continuous
Cost	High	Low	Economical

3.6 Discussion

The results show that the proposed Vehicle Overload Detection and Engine Start Interlock System can accurately measure vehicle load and reliably detect overload conditions. The nearly linear relationship between applied load and sensor output confirms proper calibration and stable sensing performance, which is essential for real-time safety applications.

The ignition interlock mechanism responds quickly when the load exceeds the preset threshold, preventing the engine from starting under unsafe conditions. This preventive control is more effective than conventional manual inspection methods because it stops hazardous vehicle operation before movement begins, thereby improving passenger and road safety.

Power consumption of the embedded system remains low during both idle monitoring and active operation, making it suitable for continuous use with the vehicle battery. This ensures practical real-world deployment without significant energy drain.

Overall, the system provides a reliable, low-cost, and effective solution for improving transportation safety, reducing mechanical damage, and ensuring compliance with vehicle load regulations.

4. Conclusion

This work presented a Vehicle Overload Detection and Engine Start Interlock System that integrates load sensing, embedded processing, warning indication, and automatic ignition control into a unified safety mechanism. The developed prototype successfully demonstrates accurate real-time overload detection, fast interlock response, low power consumption, and reliable operation under different loading conditions. By preventing vehicle movement during unsafe load situations, the proposed system contributes directly to accident reduction, mechanical protection, and improved transportation safety compliance. The design remains simple, cost-effective, and suitable for practical deployment in commercial vehicles and fleet management applications.

Major outcomes of the proposed system include:

- Accurate real-time load detection using calibrated load cell sensors
- Automatic engine start prevention during overload conditions

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- Rapid response time ensuring preventive safety before vehicle motion
- Low power consumption suitable for continuous onboard operation
- Reduction in brake failure, tire damage, and suspension stress
- Improved road safety and regulatory compliance
- Low-cost and scalable implementation for buses, trucks, and logistics fleets

Future Scope

The proposed Vehicle Overload Detection and Engine Start Interlock System can be further improved by integrating modern communication and intelligent monitoring features. Future work may include IoT-based wireless connectivity for real-time transmission of vehicle load data to cloud or fleet-management platforms, along with GPS tracking to monitor overloaded vehicles and support regulatory compliance.

Additional enhancements could involve data logging and predictive analysis to study load patterns, estimate component wear, and improve preventive maintenance. The use of machine-learning-based adaptive thresholds may further increase accuracy under varying vehicle types and road conditions.

From a hardware perspective, future development may focus on miniaturization, low-power optimization, and large-scale deployment, along with integration into smart transportation and intelligent traffic management systems.

Authors and Their Contribution

S.Shameer provided overall supervision, technical guidance,and research direction throughout the project. He assisted in refining the system methodology, reviewing the experimental results, and ensuring that the work met academic and technical standards. S. P. Muskan coordinated the project activities, contributed to system design planning, and supervised the implementation andtesting of the proposed system. V. Lakshmi Jyothi supported the development of the system architecture, assisted in hardware integration, and participated in documentation and analysis of results. G. Balaji contributed to the hardware implementation, including sensor connections, circuit assembly, and testing of the load detection system. K. Saleem worked on software development and microcontroller programming for load detection, threshold comparison, and engine interlock control, and also assisted in system testing and data collection.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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