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# Safety Helmet for Construction Workers: A Multi-Sensor IoT System for Real-Time Hazard Detection and Alerts

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**Abstract: The Safety Helmet enhances construction worker safety through multiple sensors and microcontroller-based monitoring. A Hall-effect sensor ensures helmet strap fastening, an infrared (IR) obstacle avoidance sensor detects nearby hazards, force-sensitive resistor (FSR)sensors measure impacts and helmet wear, and a GPS module enables worker location tracking. Raspberry Pi Pico W processes data in real time, triggering buzzer alerts under unsafe conditions. A Wi-Fi access point provides a web interface with live GPS coordinates and Google Maps links. The hardware is implemented using low-cost, readily available components, making the system suitable for cost-sensitive construction sites.**

***Keywords:*** *Smart Helmet, Construction Safety, IoT, Raspberry Pi Pico W, Multi-Sensor System, Hazard Detection.*

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## I. INTRODUCTION

Construction sites remain among the most hazardous working environments due to risks such as falling objects, collisions with moving machinery, and unsafe operating practices, leading to severe injuries and fatalities each year [2], [3]. Conventional industrial safety helmets provide only passive protection and do not monitor how the helmet is worn or detect hazardous situations in real time. As a result, supervisors have limited visibility into worker safety conditions, and incident response is often delayed. Recent research on smart helmets has introduced sensor equipped head gear that can monitor vital signs, environmental parameters, or impact events, often coupled with wireless communication for centralized monitoring [2], [3]. However, many existing solutions focus on specific sectors, rely on complex cloud backbends, or use costly hardware, making large-scale deployment challenging on typical construction sites. There is still a need for a compact, low-cost system that directly enforces proper helmet usage and provides on helmet alerts along with location visibility for supervisors.

This work presents a Safety Helmet for Construction workers that integrates a Hall-effect sensor for strap fastening detection, an infrared obstacle avoidance sensor for nearby hazard detection, a force-sensitive resistor (FSR RP-C10-LT) for impact and wear sensing, and a NEO-6MGPS module for location tracking, all controlled by a Raspberry Pi Pico W microcontroller. The Pico W establishes a Wi-Fi access point and hosts a web interface displaying real-time sensor status, live GPS coordinates, and a Google Maps link, while a buzzer provides immediate local alerts for unsafe conditions or SOS events. The prototype is implemented using readily available modules and demonstrates a practical safety enhancement suitable for deployment in construction and similar industrial environments. The prototype smart helmet is shown in Fig. 1. The main contributions of this work are: (i) the design and implementation of a low-cost, multi-sensor smart helmet based on Raspberry Pi Pico W, (ii) integration of a non-helmet Wi-Fi access point and web interface providing real-time status and location information, and (iii) a practical prototype evaluation including cost analysis aimed at deployment in construction and similar industrial environments.

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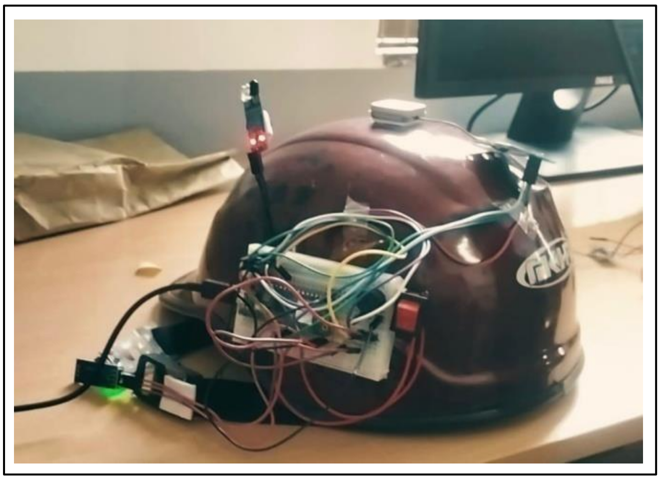

Fig 1 Safety Helmet Prototype with Integrated Sensors.

The remainder of this paper is organized as follows: Section II summarizes previous smart-helmet and IoT safety systems, Section III presents the overall hardware and system design, Section IV details the implementation and experimental results, Section V discusses cost considerations and application scenarios, Section VI outlines future development possibilities, and Section VII concludes the paper.

## II. LITERATURE SURVEY

Mohanapriya *et al.* proposed an IoT-enabled smart helmet for site workers that integrates temperature, heartbeat, vibration, MEMS, IR, GPS and GSM sensors and transmits data to the Thing Speak cloud for real time monitoring and emergency alerts [2]. The system demonstrates how multisensor fusion and cloud connectivity can enhance safety supervision on construction sites.

Jayasree *et al.* developed an IoT-based smart helmet specifically for construction workers with emergency security measures and alerts, highlighting the need for affordable multi-sensor safety systems in hazardous environments [4]. Ahmed *et al.* presented a construction site safety system with helmet based emergency location services to enable rapid worker rescue operations [5].

Karna *et al.* designed an IoT helmet for coal mine workers featuring multi parametric health monitoring through real time sensor fusion, demonstrating robust performance in harsh industrial conditions[6]. Rajkumar *et al.* introduced an intelligent helmet for workplace safety with comprehensive real-time health and environmental monitoring capabilities [7].

Campero-Jurado *et al.* introduced Smart Helmet 5.0, an industrial IoT helmet that uses artificial intelligence with convolution neural networks (CNNs) and multiple sensors to classify workplace risks with 92.05% accuracy using the Things Board IoT platform [3]. Ahmed *et al.* created a Raspberry Pi-based smart helmet with accident detection and rearview capabilities, proving the viability of low-cost microcontroller platforms for helmet safety systems [8].

These works validate the multi-sensor IoT helmet approach but often rely on complex cloud infrastructure or costly hardware, unlike the low-cost, standalone Raspberry Pi Pico W design proposed here that emphasizes direct supervisor access via Wi-Fi web interface.

## III. SYSTEM DESIGN

- *Block Diagram*

Fig.2 shows Raspberry Pi Pico Winterfacinga3.7 V Li-ion battery through a TP4056 charging module, an LM393 Halleffect sensor for strap detection, an infrared obstacle avoidance sensor for obstacle detection, an FSRRP-C10-LT force sensor for impact and wear sensing, a NEO-6M GPS module for position tracking, and an active buzzer for alerts.

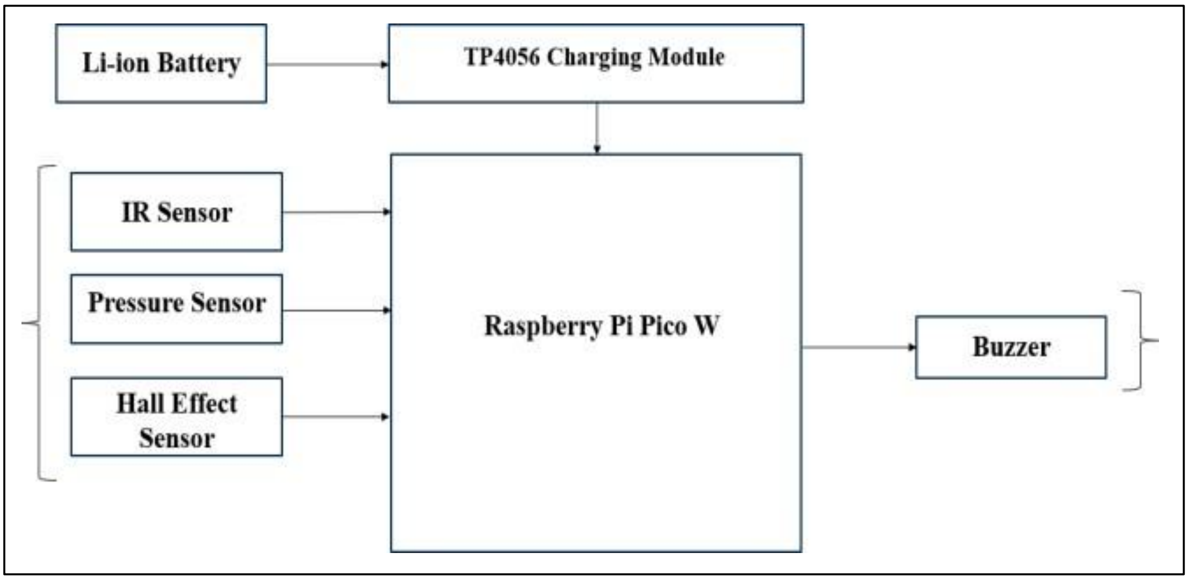


Fig 2 System Block Diagram.

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➢ *Hardware Components*

Table 1 Hardware Specifications.

| Component | Model/Specification |
|---|---|
| Microcontroller | Raspberry Pi Pico W |
| Force sensor | FSR RP-C10-LT |
| IR sensor | IR obstacle avoidance module (active-low) |
| Hall-effect sensor | LM393 digital Hall sensor module |
| GPS module | NEO-6M with EEPROM (9600 baud) |
| Main battery | 3.7 V Li-ion cell |
| AA holder | Single AA battery holder (prototype) |
| Charger | TP4056 Li-ion charging module |
| Buzzer | Active piezo buzzer |

## IV. IMPLEMENTATION

➢ *Working Principle*

The Hall-effect LM393 sensor is mounted near the helmet strap buckle so that the presence of a magnet indicates a fastened strap, while removal or improper fastening clears the magnetic field and triggers an alert condition. The IR obstacle avoidance sensor, configured as active-low, detects nearby machinery or obstacles in front of the helmet within a short range and asserts a digital signal when an object is too close.

The FSR RP-C10-LT is placed inside the helmet shell to sense helmet wear, through light pressure from the wearer's head, and high-impact events caused by falling objects. The NEO-6M GPS module communicates with the Pico W over UART at 9600 baud and outputs NMEA sentences,from which latitude and longitude are parsed for display and recording. The Pico W also controls an active buzzer that generates audible warnings under unsafe conditions or when the SOS button is activated.

➢ *Wi-Fi and Web Interface*

The Raspberry Pi Pico W runs firmware that configures it as a Wi-Fi access point so that nearby supervisors can connect directly to the helmet network. An embedded HTTP server presents a web page with live sensor status, GPS coordinates, and a hyperlink to open the helmet position in Google Maps, enabling quick incident localization.

Alert logic combines sensor inputs: missing strap, obstacle too close, abnormal FSR reading, or SOS activation all cause the buzzer to sound in a 0.5s on / 0.5s off pattern while the web page highlights the fault state. This combination of local and remote feedback improves both worker awareness and supervisor response.

## V. RESULTS AND APPLICATIONS

➢ *Experimental Results*

The prototype testing demonstrated reliable detection of helmet strap fastening using the Hall-effect sensor and accurate identification of helmet removal events. The IR sensor provided obstacle detection in the approximate range of 2–10 cm in front of the helmet, and the FSR RP-C10-LT produced distinguishable readings for normal wear pressure versus impact events.

The system was evaluated in approximately 10–15 manual test runs for each scenario (strap open/closed, obstacle present/absent, impact/no impact), and all scenarios were detected correctly. The NEO-6MGPS module achieved a time-to-first-fix between 5 and 30 s depending on sky visibility, with a typical position accuracy of a few meters, which is sufficient for locating workers on a construction site. With Wi-Fi enabled, the system operated for several hours on a single charge of the lithium-ion battery, demonstrating the practicality of a work shift when combined with charging intervals. The current evaluation is limited to controlled indoor and outdoor tests with a small number of trials; largescale field validation on active construction sites is left for future work.

➢ *Estimated Cost of Components Used in the Prototype*

Table 2 Component Cost

| Component | Cost(INR) |
|---|---|
| Raspberry PiPicoW microcontroller board | 610 |
| FSRRP-C10-LT force sensor | 250 |
| NEO-6MGPS module with EEPROM | 240 |
| 3.7V Li-ion rechargeable battery | 70 |
| Single A A battery holder | 20 |
| IR obstacle avoidance sensor module | 30 |
| TP4056 Li-ion charging module | 30 |
| Solder less breadboard | 50 |
| Misc .wiring, connectors, mounting | 195 |

The component level cost breakdown shows that the proposed helmet can be implemented using low-cost, off-theshelf modules, which supports deployment in resourceconstrained construction and industrial environments.

➢ *Applications*

The proposed system is suitable for deployment on construction sites where continuous monitoring of helmet usage and proximity to hazards is required. It can also be applied in industrial plants, mining operations, and road maintenance works, where location tracking and real-time alerts improve operator safety.

With minor customization of the firmware and web interface, the platform can support additional sensors such as gas detectors or temperature probes, extending its applicability to confined-space work or high temperature environments.

## VI. FUTURE WORK

The current system is a basic prototype intended to demonstrate the feasibility of a low-cost, sensor-based safety helmet. It can be further improved by designing a custom PCB to reduce wiring complexity and the overall space required inside the helmet, making the solution more robust and comfortable for daily use.

Future development can focus on making full use of the capabilities of the Raspberry Pi Pico W by adding richer

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functionality and integrating newer technologies. Possible enhancements include camera-based monitoring, AI-driven incident and fall detection using convolution neural networks, improved communication through Smartphone connectivity and a more refined supervisor interface and features such as helmet owner identification and better ergonomics. These extensions can make the system more usable and scalable in real-world deployments.

## VII. CONCLUSION

This paper presented a multi-sensor IoT safety helmet based on Raspberry Pi Pico W that integrates Hall-effect, IR, FSR, and GPS modules to monitor strap fastening, obstacle proximity, impact events, and worker location. The system provides both local buzzer alerts and a Wi-Fi web interface with live GPS data and Google Maps links, enabling supervisors to respond quickly to unsafe conditions.

Using low-cost, readily available components, the prototype delivers functionality comparable to more complex smarthelmet solutions while remaining practical for cost-sensitive environments. Future enhancements such as cloud or mobile network connectivity, machine-learning-based event classification, and optimized power management can further improve the practicality and impact of the system.

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