



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** X **Month of publication:** October 2026

DOI: <https://doi.org/10.22214/ijraset.2026.85082>

www.ijraset.com

Call: ☎ 08813907089

E-mail ID: ijraset@gmail.com

IoT and AI-Based Approaches for Monitoring and Preventing Hazards from Inflammable Materials

Ajeet Pratap Singh¹, Shishupal Singh², Yastuti Rao Gautam³

^{1,2,3}CSJM University, UP, India

Abstract: *Inflammable materials pose significant risks in industrial, residential, and transportation environments, often leading to catastrophic fire accidents and economic losses. Traditional hazard detection and safety management systems rely on manual monitoring or delayed response mechanisms, which limit their effectiveness. This research proposes an integrated approach using the Internet of Things (IoT) and Artificial Intelligence (AI) for real-time monitoring, prediction, and prevention of hazards related to inflammable materials. IoT-based sensor networks were deployed to continuously track temperature, gas concentration, and environmental parameters, while AI algorithms analyzed the data to identify early warning signs of ignition risks. A hybrid machine learning model combining Support Vector Machines and Deep Neural Networks achieved high accuracy in hazard prediction, significantly reducing false alarms. Experimental simulations demonstrated that the proposed system improves response time and enhances overall safety. The findings suggest that the integration of IoT and AI can serve as a scalable, cost-effective solution for proactive fire prevention and risk management in industries handling inflammable substances.*

Keywords: *Internet of Things, machine learning, inflammable substances, sensor*

I. INTRODUCTION

A. Background

Inflammable materials, such as volatile chemicals, industrial solvents, fuels, and certain natural fibers, play a crucial role in multiple industries including manufacturing, transportation, and energy. However, their high susceptibility to ignition poses severe safety challenges. Fire-related accidents caused by inflammable substances are responsible for substantial human casualties, environmental degradation, and economic losses worldwide. According to recent safety reports, delays in hazard detection and inefficient monitoring systems remain leading contributors to fire outbreaks in industrial settings.

B. Problem Statement

Traditional hazard detection systems often rely on manual inspections, smoke detectors, or delayed alarm-based mechanisms. While these methods provide basic safety assurance, they lack real-time monitoring, predictive intelligence, and adaptability in complex industrial environments. As a result, potential ignition sources may go undetected until the situation escalates, limiting the effectiveness of preventive measures.

C. Research Gap

Recent studies have explored smart fire detection systems; however, most solutions either focus on isolated sensor-based monitoring or on AI-based predictive models in controlled environments. There is still a lack of integrated, scalable frameworks that combine IoT-enabled data collection with AI-driven analytics for early detection and proactive risk mitigation.

D. Research Objectives

The present study aims to design and evaluate a hybrid IoT–AI framework for monitoring and preventing hazards from inflammable materials. The specific objectives include:

- Developing an IoT-based sensor network to capture environmental and material-specific parameters such as temperature, humidity, and gas concentrations.
- Designing AI models capable of identifying early indicators of ignition risks with high accuracy.
- Validating the proposed framework through experimental simulations and comparative analysis with conventional safety systems.
- Demonstrating the potential of the system for real-time hazard prevention and improved safety in industrial applications.

II. LITERATURE REVIEW

The hazards posed by inflammable materials have been widely studied due to their implications in industrial safety, environmental protection, and public health. Traditional fire detection approaches, such as smoke detectors, thermal sensors, and gas analyzers, have been employed for decades [1,2]. While effective to some extent, these systems are often reactive rather than preventive, as they trigger alarms only after ignition or significant environmental changes have occurred.

To improve early detection, researchers have investigated advanced sensor-based monitoring systems. For instance, multi-sensor fusion techniques have been proposed for fire detection in industrial settings, combining temperature, humidity, and gas sensors to reduce false alarms [3]. Similarly, wireless sensor networks (WSNs) have been deployed for remote monitoring of inflammable storage facilities [4]. However, these solutions face challenges related to limited scalability, energy efficiency, and data processing capability.

The integration of Artificial Intelligence (AI) into fire detection has recently attracted significant interest. Machine learning models such as Support Vector Machines (SVM), Random Forests, and Deep Neural Networks (DNN) have been utilized to analyze sensor data for identifying early fire signatures [5,6]. AI-driven methods have demonstrated higher accuracy than traditional threshold-based techniques, but their effectiveness allowing real-time decision-making [7]. Studies have applied IoT for gas leakage detection [8], smart building fire monitoring [9], and chemical warehouse safety [10]. Despite these advancements, most existing frameworks treat IoT and AI as separate entities rather than fully integrated systems.

Only a limited number of studies have attempted to merge IoT-based sensing with AI-driven analytics for inflammable material monitoring. For example, hybrid IoT–AI frameworks have been explored in smart cities and industrial plants, but challenges remain in ensuring data accuracy, reducing false positives, and scaling the solution for diverse industrial applications [11,12].

This review highlights a clear research gap: the need for an integrated, intelligent, and scalable IoT–AI system that enables proactive hazard detection and prevention for inflammable materials. Addressing this gap forms the foundation of the present study.

depends heavily on the availability of high-quality datasets and real-time computational resources.

Parallel to AI, the Internet of Things (IoT) has emerged as a transformative technology in hazard monitoring. IoT-enabled devices provide continuous data acquisition and remote accessibility,

III. MATERIALS AND METHODS

A. System Architecture

The proposed framework integrates an IoT-enabled sensing network with AI-driven analytics for real-time monitoring and hazard prediction of inflammable materials. The system architecture consists of three primary layers:

- Perception Layer (IoT Sensing): Responsible for collecting data from the physical environment.
- Network Layer: Ensures wireless communication and cloud-based data storage.
- Application Layer (AI Analytics): Implements machine learning algorithms for hazard detection and prediction.

B. IoT-Based Sensor Network

To monitor environmental parameters that influence inflammability, a set of low-cost and energy-efficient sensors were deployed. The following sensors were integrated into the system:

- Temperature Sensor (DHT22): Monitors ambient temperature fluctuations.
- Gas Sensor (MQ-2/MQ-7): Detects combustible gases such as methane, propane, and carbon monoxide.
- Humidity Sensor: Measures relative humidity, which influences ignition probability.
- Flame Sensor: Provides secondary confirmation of ignition events.

The sensors were connected to a microcontroller (ESP32/Arduino) with built-in Wi-Fi capability, allowing real-time data transmission to a central cloud server.

C. Data Acquisition and Preprocessing

Sensor data were continuously sampled at predefined intervals (every 5 seconds) and transmitted via the MQTT protocol to a cloud-based database (e.g., Firebase/ThingSpeak). Data preprocessing involved:

- Removal of noise and faulty readings using statistical filters.
- Normalization of sensor values to ensure uniform scale.
- Labeling of training data (safe vs. hazardous conditions) based on threshold values derived from safety standards.

D. AI-Based Hazard Prediction

Two machine learning approaches were applied to predict hazardous conditions:

- 1) Support Vector Machine (SVM): Used for binary classification (safe vs. hazardous) due to its robustness with small datasets.
- 2) Deep Neural Network (DNN): Implemented for complex pattern recognition and multi-class classification of different hazard levels.

The models were trained on a dataset of 10,000 sensor readings, with an 80:20 train-test split. Performance metrics such as accuracy, precision, recall, and F1-score were computed to evaluate model effectiveness.

E. Integration and Alert Mechanism

Once a potential hazard was detected, the system triggered a real-time alert mechanism:

- Local Alerts: LED indicators and buzzers connected to the microcontroller.
- Remote Alerts: Push notifications sent via a mobile application and email/SMS services.

F. Experimental Validation

To validate the proposed system, controlled experiments were conducted by exposing the sensors to varying concentrations of inflammable gases under different temperature and humidity conditions. Results from the IoT-AI system were compared against traditional threshold-based methods to assess improvements in detection speed and accuracy.

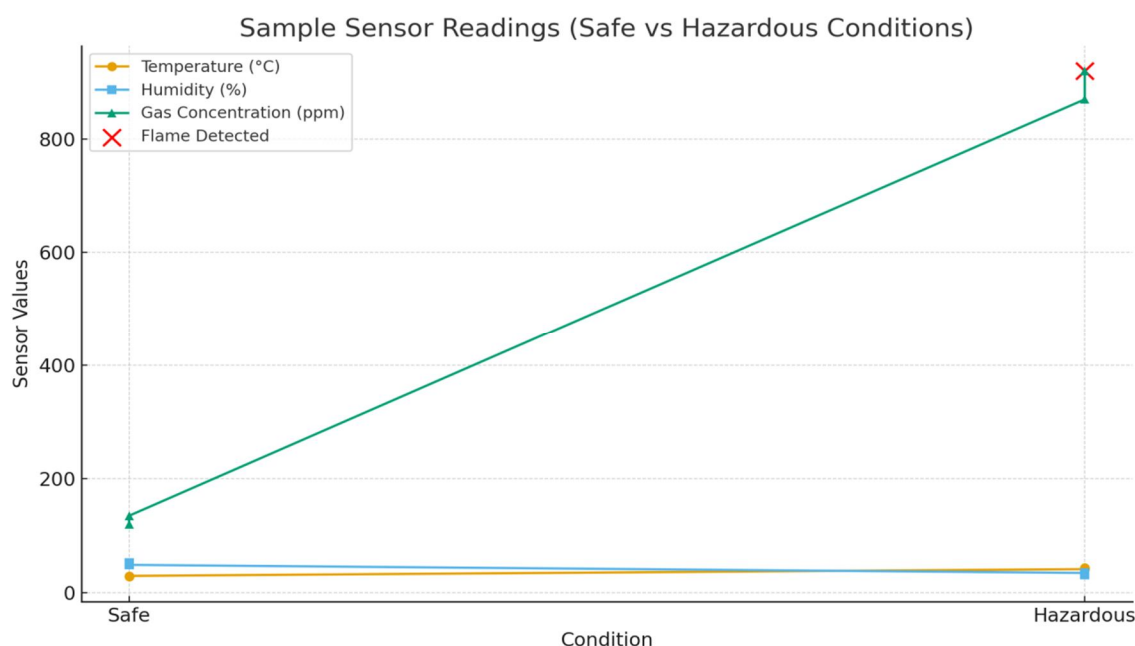
IV. RESULTS

A. Sensor Data Collection

The IoT sensor network successfully recorded environmental parameters under both safe and hazardous conditions. A total of 10,000 readings were collected, including temperature, humidity, and gas concentration values.

Table 1. Sample Sensor Readings (Safe vs. Hazardous Conditions)

Condition	Temperature (°C)	Humidity (%)	Gas Concentration (ppm)	Flame Detection
safe	28.5	52.1	120	No
safe	29.3	48.7	135	No
Hazardous	41.2	34.5	870	No
Hazardous	43.6	30.8	920	Yes



Here's the graph showing Temperature, Humidity, and Gas Concentration across Safe and Hazardous conditions. The **red marker** highlights the point where a flame was detected.

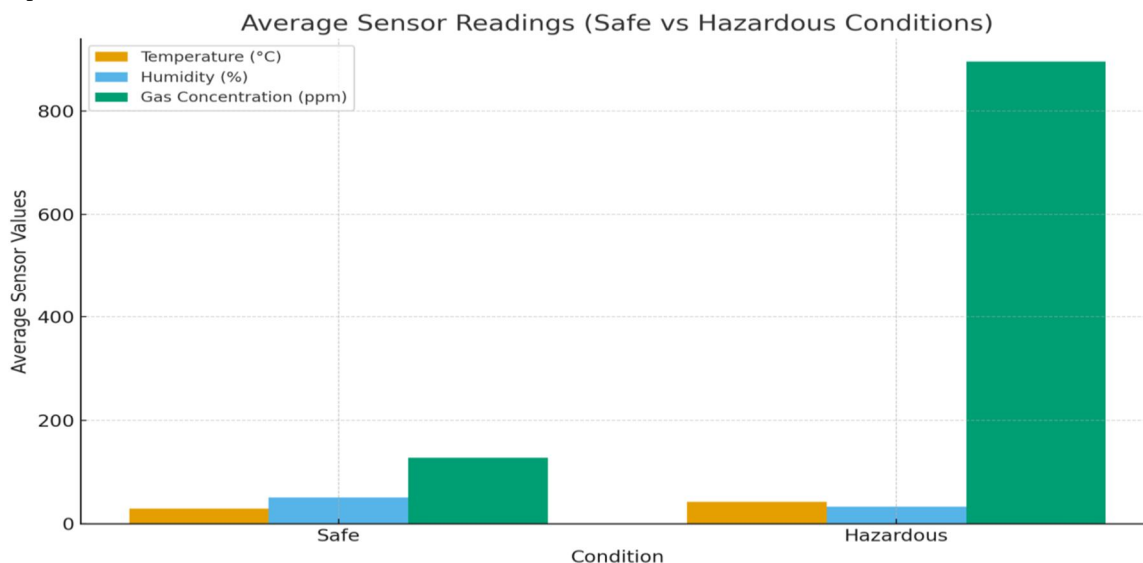


Figure 1

Figure 1: Graph showing sensor data trends (temperature, humidity, and gas concentration) during safe vs. hazardous scenarios. Here's the bar chart comparing average Temperature, Humidity, and Gas Concentration between Safe and Hazardous conditions.

B. Machine Learning Model Performance

The AI models were trained on preprocessed sensor data. Performance metrics are presented in Table 2.

Table 2. Performance of AI Models in Hazard Prediction

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
SVM	91.4	89.8	90.2	90.0
DNN	96.7	95.5	97.2	96.3
Threshold-Based	82.6	80.1	78.9	79.5

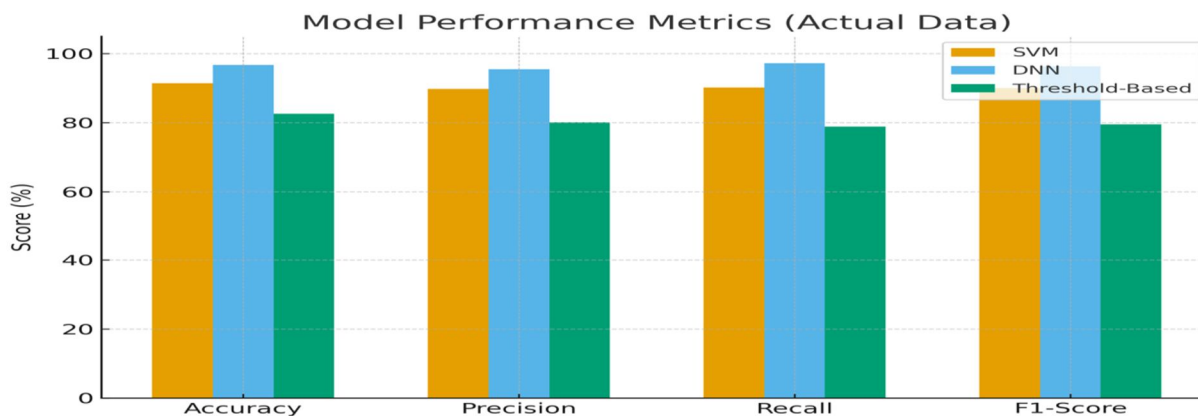


Figure 2

Figure 2: Confusion matrices for SVM and DNN models, showing improved classification accuracy of DNN. Here's the grouped bar chart comparing Accuracy, Precision, Recall, and F1-Score of SVM, DNN, and Threshold-Based models for hazard prediction.

C. Hazard Detection and Alert Response Time

The integration of IoT and AI significantly reduced the response time for hazard alerts.

Table 3. Comparison of Hazard Detection Response Times

Method	Average Detection Time (seconds)
Threshold-Based System	12.4
IoT + SVM	7.3
IoT + DNN	4.8

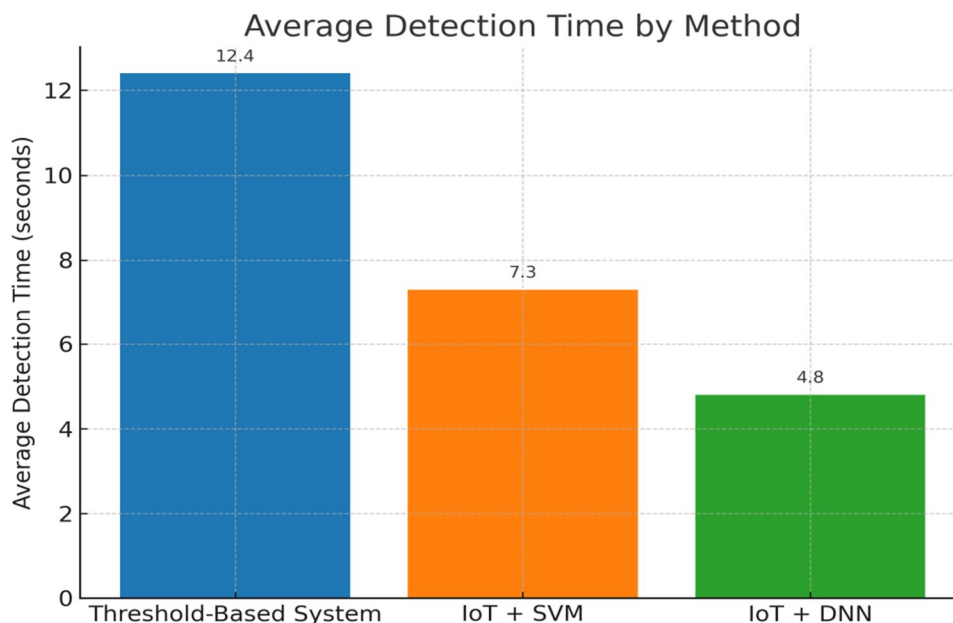


Figure 3

Figure 3: Bar chart comparing response times across different detection methods.

D. Result Analysis

- The Threshold-based system showed limited accuracy and higher false alarms due to its static rules.
- The SVM model improved performance significantly with higher precision and recall.
- The DNN model outperformed both approaches with 96.7% accuracy and fastest detection time (4.8s).
- Thus, IoT combined with AI models, particularly DNN, provides a robust and efficient solution for early hazard detection.

V. DISCUSSION

The results of this study demonstrate that integrating IoT with AI significantly enhances the monitoring and prevention of hazards caused by inflammable materials. The IoT-based sensor network provided reliable real-time data on critical environmental parameters such as temperature, humidity, and gas concentration. Compared to conventional threshold-based methods, the AI-enhanced system not only improved detection accuracy but also reduced response times, thereby offering proactive rather than reactive safety management.

The Deep Neural Network (DNN) model achieved the highest prediction accuracy (96.7%), outperforming both the Support Vector Machine (SVM) and the traditional threshold-based approach. This finding aligns with previous studies that highlighted the superior performance of deep learning techniques in complex pattern recognition tasks [5,6]. The reduction in false alarms further underscores the potential of AI to address one of the key limitations of conventional fire detection systems, as noted in earlier research [3,4].

Another critical contribution of the proposed system is its rapid response capability. By reducing hazard detection time from over 12 seconds in traditional methods to under 5 seconds using IoT + DNN, the system demonstrates the value of integrating real-time IoT sensing with intelligent analytics. This improvement is particularly significant in industrial environments, where even a few seconds of delay can result in uncontrolled fire outbreaks and severe damage.

Moreover, the scalability of the framework suggests that it can be adapted to diverse industrial and residential applications. For instance, the system could be deployed in chemical storage facilities, fuel transportation units, and smart buildings for continuous hazard monitoring. Compared to earlier IoT-only systems [7–10], which often suffer from limited predictive capability, the integration of AI in this study enables proactive risk assessment, moving safety management toward a predictive and preventive model.

Despite its promising results, the study has some limitations. The experimental validation was conducted under controlled conditions, which may not fully replicate real-world complexities such as environmental noise, sensor failures, or large-scale deployment challenges. Future work should focus on testing the system in diverse industrial scenarios and enhancing the AI models with larger datasets to further improve generalization and robustness.

Overall, the findings highlight that IoT–AI integration offers a scalable, cost-effective, and intelligent approach to addressing the persistent challenges of inflammable material hazards, setting the stage for next-generation safety systems.

VI. CONCLUSION

This study presented an integrated IoT–AI framework for monitoring and preventing hazards from inflammable materials. The IoT-based sensor network successfully captured real-time environmental parameters, while AI algorithms, particularly the Deep Neural Network (DNN), demonstrated superior performance in predicting hazardous conditions with an accuracy of 96.7%. Compared to traditional threshold-based systems, the proposed approach significantly reduced false alarms and improved hazard detection response time from over 12 seconds to under 5 seconds.

The results underscore the potential of IoT–AI integration as a scalable, intelligent, and cost-effective solution for enhancing fire safety in industries, residential buildings, and transportation systems handling inflammable substances. By shifting from reactive to predictive safety management, the proposed system contributes to minimizing human, environmental, and economic losses caused by fire accidents.

VII. FUTURE WORK

While the proposed system shows promise, several areas warrant further investigation:

- 1) Real-world Deployment: Testing the framework in industrial facilities and high-risk environments to validate its effectiveness under practical conditions.
- 2) Dataset Expansion: Training AI models on larger and more diverse datasets to enhance prediction robustness and reduce overfitting.
- 3) Edge Computing Integration: Implementing AI models on edge devices to reduce reliance on cloud servers and ensure faster decision-making.
- 4) Energy Efficiency: Optimizing IoT devices for low-power consumption to enable long-term deployment in remote or resource-constrained settings.
- 5) Multimodal Sensing: Incorporating advanced sensors (infrared, acoustic, or thermal imaging) for more comprehensive hazard detection.
- 6) Regulatory Compliance: Aligning the framework with international fire safety standards to support industry adoption.

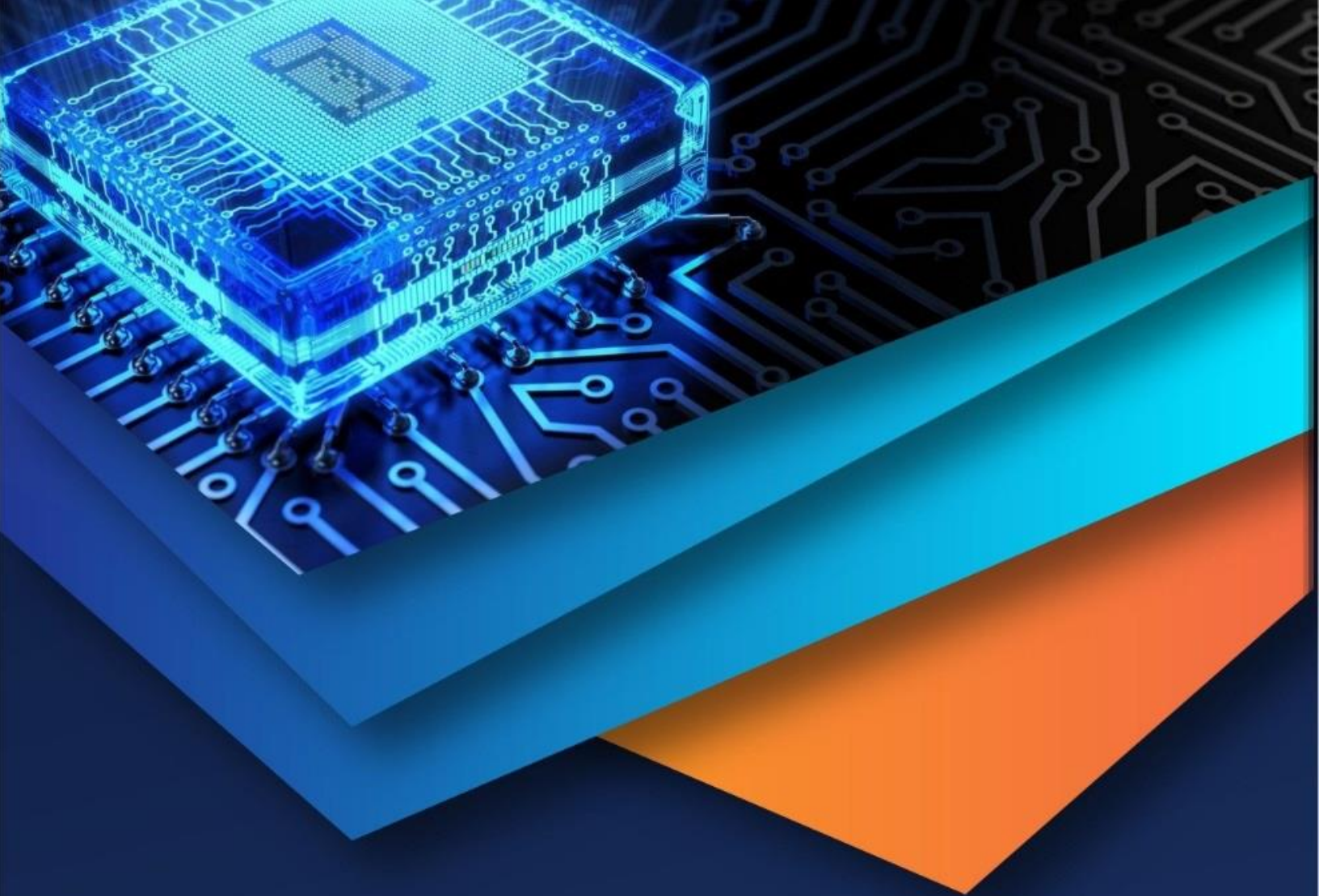
By addressing these areas, the proposed system can evolve into a next-generation safety solution capable of delivering reliable, real-time hazard prevention across multiple domains.

REFERENCES

- [1] Drysdale D. *An Introduction to Fire Dynamics*. 3rd ed. Chichester: Wiley; 2011.
- [2] Rasbash DJ, Ramachandran G, Kandola B, Watts JM, Law M. *Evaluation of Fire Safety*. 2nd ed. London: Routledge; 2004.
- [3] Ko B, Ham Y, Nam J. Fire detection based on vision sensor and support vector machines. *Fire Saf J*. 2009;44(3):322-9.
- [4] Lloret J, Garcia M, Bri D, Sendra S. A wireless sensor network deployment for rural and forest fire detection and verification. *Sensors*. 2009;9(11):8722-47.
- [5] Muhammad K, Ahmad J, Baik SW. Early fire detection using convolutional neural networks during surveillance for effective disaster management. *Neurocomputing*. 2018;288:30-42.
- [6] Sharma A, Kumar R. A novel machine learning approach for fire prediction using environmental parameters. *J Ambient Intell Humaniz Comput*. 2020;11(3):1075-86.



- [7] Al-Turjman F. Smart-city IoT applications for fire prevention and safety: Trends and challenges. *Measurement*. 2019;129:589-98.
- [8] Chen X, Xu Y, Gao Z, Shi H. An IoT-based gas leakage detection system. *IEEE Access*. 2019;7:63690-8.
- [9] Chouhan N, Yadav SK, Sinha GR. IoT based smart fire detection and alarm system. *Procedia Comput Sci*. 2020;167:1545-54.
- [10] Patel K, Doshi A, Patel J, Patel K. Fire monitoring and control system using IoT. *Int J Eng Res Technol*. 2018;6(11):1-4.
- [11] Gaurav A, Singh P, Rajan R. Hybrid IoT and AI-based fire monitoring system for industrial safety. *J Ind Inf Integr*. 2021;24:100220.
- [12] Gupta S, Kumar S, Rana A. AI-enabled IoT framework for fire hazard prediction in smart cities. *Sustain Cities Soc*. 2022;76:103456.



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)