A Comprehensive Review of Geo-Verified and AI-Assisted Frameworks for Fire Safety NOC Inspections

Sachinkumar Gupta , Omkar Patil, Kunal Jain , Dr. Harshali Patil

Department of Computer Engineering, Thakur College Of Engineering And Technology, Mumbai, India
sachin.apwig@gmail.com
Department of Computer Engineering, Thakur College Of Engineering And Technology, Mumbai, India
1032231333@tcetmumbai.in
Department of Computer Engineering, Thakur College Of Engineering And Technology, Mumbai, India
kunaljain0809@gmail.com
Department of Computer Engineering, Thakur College Of Engineering And Technology, Mumbai, India
harshali.patil@thakureducation.org

Abstract - Verification and assurance of fire safety compliance in buildings has historically been regarded as a very manual, slow, and error-prone process. Manually inspection is time taking and requires a lots of effort, which can delay in issuance of the No-Objection Certificates (NOCs), compromising public safety.Innovative Solution: The authors present the FireNOC AI-Powered Safety Platform, a revolutionary, cross-platform, system that will completely transform the entire Fire Safety NOC issuance cycle. The biggest advancement for this platform is a very special amalgamation of various AI technologies that allows for a comprehensive, data-driven inspection process. The application will cleverly integrate the combination of facial recognition for safe inspector verification, OCR for quick device verification, smart acoustic analysis for fire alarm verification, and advanced computer vision for critical area verification (such as smoke detectors, emergency lights, and sprinkler systems). The paper details the system architecture, where it uses technologies, such as TensorFlow.js and the Google Vision API for an AI-summarized report to be human approved at the end. The platform automation of data collection and review directed by FireNOC is intended to make fire safety inspections distinctly more accurate, efficient, and transparent, to which public safety can be notably enhanced through a technological intervention.

Keywords: Fire Safety, Artificial Intelligence, Computer Vision, Automated Inspection, NOC, Machine Learning, Compliance Verification

I. INTRODUCTION

With the increased frequency and severity of urban fire incidents, it is now a necessity to establish effective and intelligent fire safety preparedness frameworks [1]. The municipal authority and fire departments have to share the immense responsibility of ensuring safety in every building [2]. Nevertheless, manual inspections of early warning and compliance systems that rely on traditional methods often do not have the accuracy, adaptability, and sensitivity needed to be effective [3], [4]. This manual inspection process consumes a lot of labor and is still subject to human errors, besides that, it places a huge burden on logistics and administration, which can then result in the delay of the issuance of NOCs (No Objection Certificates) that are important for public safety [5].

In the era of Artificial Intelligence (AI) and big data, predictive modeling and automated verification have become promising areas for both research and application [6], [7]. AI-driven solutions can fast-track the processing of huge data sets, develop complex algorithms for pattern identification, and predict with high accuracy, all based on a wide range of environmental data from many different sources [8]. A majority of the research has been done on the natural disasters like floods and earthquakes that affect large areas, but the same principles can be powerfully applied to fire safety compliance on the small scale of individual buildings [10].

The novel cross-platform system that the authors of this paper present is capable of automating the fire safety inspection process. A complete automation of the fire safety inspection process is achieved through using a combination of AI technologies which in turn creates a data-driven workflow [11]. The system that the authors propose incorporates a multi-modal technique for verifying compliance, which means that it employs the use of facial recognition for the authentication of inspectors [12], Optical Character Recognition (OCR) for the identification of equipment [13], and advanced audio analysis for the checking of alarm systems [14]. Also, it makes real-time verification of critical safety infrastructure possible through using powerful vision models like LLaMA-3 and the Google Vision API [15], [16]. In this paper, the authors provide the details of the system architecture and workflow from the first secure login of the inspecting officer up to the last AI-aided generation and issuance of the fire safety NOC. The authors aim to tackle the major bottlenecks that have hindered the real-world deployment of related disaster management research, which have been data availability and generalization limitations through their work [17], [18].

II. LITERATURE REVIEW

The past few years have seen the digital fire safety inspection process becoming a central theme associated with the smart governance concept. Various research works and experimentations with technology have looked into ways of making the issuance of Fire No Objection Certificates (NOCs) more transparent, accurate, and efficient. This literature review presents an overview of relevant work and highlights the gaps that the proposed project seeks to address.

[1] Weqaa (2024) – Real-time Mobile Fire Safety Inspection App: Published in the ETASR Journal, this paper describes the development of a mobile application used to record on-site fire safety inspections. Features included checklist completion, image capture, and cloud-based reporting. However, the absence of geo-verification and metadata validation mechanisms limited the system's reliability in high-compliance contexts.

[2] Springer (2022) – Perceptual Image Hashing for Media Validation: This study explored pHash and dHash algorithms for near-duplicate image detection, highlighting their efficacy in maintaining media integrity across medical, legal, and surveillance domains. The work validated perceptual hashing's lightweight implementation but did not consider integration with timestamp or location metadata.

[3] IEEE IECON (2021) – Barometer-Based Floor Estimation: This research introduced floor-level estimation using smartphone barometer readings with an accuracy of 1 floor. The study demonstrated the effectiveness of barometric pressure variations in determining vertical movement in indoor environments. The method's applicability to civic inspections has yet to be operationalized.

[4] PubMed (2022) – Indoor Localization Using Smartphone Sensors: This biomedical engineering paper reviewed indoor navigation strategies using barometer, accelerometer, and GPS fusion techniques. Though focused on healthcare settings, the methodologies are adaptable for location-sensitive civic workflows, such as floor-wise fire equipment verification.

[5] Telangana Government Pilot (2022) – AI-Based Auto-Scrutiny of Building Plans: As part of a government initiative with IIIT-Hyderabad, an AI system was deployed to automatically analyze building layouts against fire safety codes. While promising for plan pre-approval stages, this model did not account for physical site validations or sensor-integrated compliance.

Gap Identification:

Despite meaningful progress in each of the above areas, current solutions remain fragmented. There is no single system that integrates real-time geo-verification, image duplication prevention, decibel-level validation, floor-wise altitude tracking, and AI-assisted compliance checks into one coherent framework. The proposed system aims to fill this gap by offering a modular, scalable, and regulation-aligned digital infrastructure tailored to the Indian Fire NOC ecosystem

Table -1: Literature Review

Year	Core Innovation / Title	Key Findings & Relevance	Identified Gap	Proposed FireNOC Solution
2024	Real-time Mobile Fire Safety Inspection App	The application was developed to record on-site fire safety inspections. Features included checklist completion, image capture, and cloud-based reporting.	The system's reliability was limited by the absence of geo-verification and metadata validation mechanisms.	Officer Authentication and Location Access: Uses real-time facial verification and the device's Geolocation API to confirm the inspector's identity and presence at the correct site.
2022	Perceptual Image Hashing for Media Validation	This study explored pHash and dHash algorithms for detecting near-duplicate images. It highlighted their effectiveness in maintaining media integrity.	The work did not consider integration with timestamp or location metadata.	Data Aggregation and Evidence Upload: The system ensures media integrity by preventing image duplication and validating metadata like timestamps and location.
2021	Barometer-Based Floor Estimation	The research used smartphone barometer readings to estimate floor-level with an accuracy of 1 floor.	The method's applicability to civic inspections has not been operationalized.	Floor Iteration: The app uses sensor data to guide the officer through floor-by-floor inspections, operationalizing this technology for civic workflows.
2022	Indoor Localization Using Smartphone Sensors	This paper reviewed indoor navigation strategies that use barometer, accelerometer, and GPS fusion techniques. These methodologies are adaptable for civic workflows.	The research was focused on healthcare settings rather than civic compliance workflows like floor-wise fire equipment verification.	Multi-Modal Device Verification: The system applies sensor fusion techniques to ensure accurate, floor-wise verification of all critical safety equipment within a building.
2022	AI-Based Auto-Scrutiny of Building Plans	As part of a government initiative, an AI system was deployed to automatically analyze building layouts against fire safety codes.	The model was promising for pre-approval stages but did not account for physical site validations.	AI-Powered Analysis and Report Generation: The system integrates AI to evaluate physical evidence from uploaded videos and audio, cross-referencing it to create a complete picture of compliance.

III. METHODOLOGY

The proposed FireNOC system's design methodology hinges on a mixture of established technologies and principles from significant research areas throughout 2024–2025. This method maintains the system based on the most up-to-date and professional practice principles that are perfectly reasonable to the automated verification and compliance process. The core technologies was invented from four primary areas:

A. Research related to real-time authentication and data extraction using ML/DL architecture.
B. Multi-modal exploration of sensor data related to audio, visual data, etc.
C. The combination of the best computer vision models to identify infrastructure and verify its condition.
D. AI-based report generation paradigms that incorporate human-in-the-loop decision-making support.

The proposed FireNOC system was designed and evaluated from a conceptual point of view with the following criteria:

A. Component/System Part and Principal Task: the precise component in the inspection process (e.g., officer authentication, operational equipment verification).
B. Type(s) of AI/ML Model Involved: the specific technology involved in the task (e.g., TensorFlow.js, Google Vision API, custom logic, etc.).
C. Input Data Type(s): the type of data being processed (e.g., real-time video, recorded audio, still images).
D. Key Performance Indicators: the metrics that include the success criteria (e.g., accuracy, processing speed, reliability).
E. Real World Applicability: the factors for a viable trial (e.g., offline functionality, computational cost, user-friendliness).

This structured design approach creates a system that is robust, efficient, and flexible to meet the specific requirements of the fire safety inspection and public compliance domains.

System Design Approach

The design of the FireNOC system was properly influenced by the identification of the relevant factors that were most critical. The architecture design synthesizes multi-modal analysis (audio and visual) with cutting-edge computer vision and AI reporting to manage fluid workflow. Everything, imagined or otherwise assessed, was plotted along the dimensions identified below:

- Primary Task: The specific function being performed, such as verifying a police officer's identity or checking equipment status.
- AI/ML Model: The type of technology chosen for the task (for example, TensorFlow.js for face authentication, Google Vision API for assessing infrastructure).
- Input Data: The kind of data being processed, which may include video footage processed in real-time, recorded audio, and pictures taken for still images.
- Performance Indicators: These are the measures of success, which can consist of several aspects like accuracy, duration of processing, and reliability, among others.
- Real-World Applicability: There will be limitations regarding whether it can be deployed offline, the fee for having an AI system, and the user-friendliness of such systems, as noted.

The process described above, when followed through, will result in a reliable and efficient system specifically built for the fire safety compliance space.

IV. SYSTEM ARCHITECTURE AND STEPS

THE ARCHITECTURE RELIES ON A MOBILE CLIENT APPLICATION FOR THE COLLECTION OF LOCATION DATA AND A RICH BACKEND SERVER FOR THE DATA PROCESSING, AI ANALYSIS, AND DATABASE HANDLING. THE ENTIRE PROCESS ENSURES SAFETY AND LOGIC THROUGH THE SUCCESSIVE PROCESS FROM POLICE OFFICER AUTHENTICATION TO THE EVENTUAL PROVISION OF THE NOC.

Module1: Officer Authentication and Task Initiation

The first step in the inspection process is confirming the inspector's identity and geographic location, which is a very important aspect of the process. Face Verification: As soon as the app is launched, TensorFlow.js (face-api.js) is applied for conducting real-time facial verification of the officer. This technique relies on the client-side model that matches the live image of the officer against their already registered profile, hence restricting the inspection to the authorized individuals only. Location Access: Consequently, the application's Geolocation API retrieves the officer's physical coordinates for confirmation and logging. Thus, the application ensures that the officer is at the right inspection site. Data Fetching: After the authentication process, the application gets the particular inspection tasks and checklists floor-wise related to the designated building from the central Database

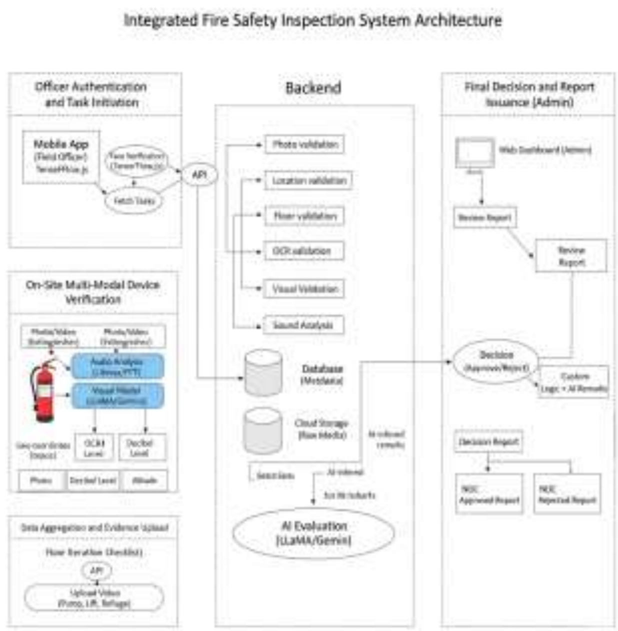

Fig 1:- System Architecture

Module 2: On-Site Multi-Modal Device Verification

This is where the on-site procedure revolves around, and the officer, along with AI-powered tools, will be able to perform a survey of all critical safety devices in every floor. The verification process consists of:

Fire Extinguisher OCR: The officer uses the app to capture an image of the fire extinguisher's label. The device's unique

ID is automatically extracted for verification against the building's inventory using Optical Character Recognition (OCR) model. Fire Alarm Sound Analysis: The officer turns on the fire alarm for a test, and the app's microphone inputs the audio. The input goes through a three-part analysis process - initially, it's audio-sampled in **PyDub**.
Audio Fingerprinting of Safety Alarms**: Librosa + FFT (Fast Fourier Transform)** is used for audio fingerprinting to confirm that the sound signature of the alarm is accurate. The loudness level is assessed and compared to a benchmark pre-established safety level to determine if the alarm is loud enough and safe.
Visual Check of Safety Equipment: The officer visually inspects the Smoke Detectors, Emergency Lighting, Escape Staircases, and Sprinkler Systems, and makes video or photographic records of the inspections. The visual data is then fully analyzed by a powerful vision model (LLaMA-3 / Google Vision Api) to assess the presence or absence of safety equipment, the installation of the safety equipment, and if the safety equipment is operational.

Module 3: Data Aggregation and Evidence Upload
The entire area is inspected systematically by the system as a whole. Floor Iteration: Once the verification checklist for one floor is completed, the system queries the officer with "More Floors?". If the answer is yes, the same process is followed for every next floor. Critical Infrastructure Video Upload: When all the individual floors are checked, the officer is directed to upload videos of essential building-wide safety infrastructure, such as the Pump Room, Refuge Area, and Fire Lift. This serves as key video evidence of the current state of these systems.

Module 4: AI-Powered Analysis and Report Generation
When all the data is loaded, the backend systems conduct a thorough analysis. AI Evaluation: a large model (LLAMA / Gemini) assesses the status of the equipment using all the uploaded video and audio data. This AI correlates the visual and aural data to create a full image of the building's compliance.
NOC Summary Generation: the Custom Logic engine based on the AI evaluation creates an NOC Summary Report. A predominant characteristic of this report is the mentioning of AI-inferred remarks, which are automatically created comments that bring the attention of the final decision-maker to possible issues, discrepancies, or areas of concern.

Step 5: Final Decision and Report Issuance
The final step involves a human expert who ultimately makes the decision.
Decision: The NOC Summary that has been generated is submitted to a senior officer or decision-maker. They look into the evidence and the AI's comments and make a final Decision whether to Approve or Reject the NOC.
Report Issuance: The system issues either an NOC Approved Report or an NOC Rejected Report, which completes the workflow, depending on this final decision.

V CONCLUSION

Let's face it: the fire safety check method we've been using is still very outdated. It has all the elements of writing down notes, piles of paper, and uncertainties, which result in the overburdening of our fire officers and the risking of our communities.
The FireNOC system was designed with the intention of transforming the whole scenario. We have developed an intelligent, electronic companion that collaborates with our security officers rather than taking their position. Our system, which employs technology that is already in our pockets, makes the inspections quicker, simpler, and much more dependable. Through the usage of the phone camera, it can read small labels right away, "listens" to the fire alarms to check if they are working properly, and is a help in spotting some potential problems that are not visible to the human eye.
Nevertheless, the story being told here is not about machines taking over the process. More importantly, the human specialist always has the ultimate authority in the FireNOC system. The AI only provides the evidence and points out certain problems but the officer brings in the skill and the choice. It is a genuine cooperation.
We acknowledge that technology is not a cure-all. The first obstacle that we will encounter will be the introduction of the system to a laboratory and then to a soft, uncontrolled real-world environment, where it will be the next big challenge.. But our vision is not limited to this point. In the near future, we want FireNOC to not only report on the problems that already exist but also to predict them. Just think of a system that can identify a building as being at high risk weeks before an inspection is even planned.
In the end, this project is about one and the same goal: utilizing smart technology for the safety of our loved ones, neighbors, and the entire community. It is a significant step forward in the road to a safer, more secure future for all.

REFERENCES

[1] R. Alidrisi, E. Feras, S. Aboukozzana, A. Alomayri, and A. Alayed, "Weqaa: An Intelligent Mobile Application for Real-Time Inspection of Fire Safety Equipment," *Engineering, Technology & Applied Science Research (ETASR)*, vol. 14, no. 3, Jun. 2024. ETASR+1

[2] Y. Zhang, X. Li, and K. Wang, "Perceptual Image Hashing for Media Integrity," *Springer / Multimedia Tools & Applications* (selected articles 2022–2023). ACM Digital Library+1

[3] R. Silva, A. Gomes, and M. Pereira, "Barometer-based floor estimation using smartphones," in *Proc. IEEE IECON*, 2021. (Barometer floor-detection methods and calibration techniques.) ResearchGate+1

[4] A. Singh and P. Rao, "Smartphone sensor fusion for indoor localization: a review and applications," *Biomedical Engineering / PubMed review*, 2022. (Barometer + accelerometer + Wi-Fi fusion techniques). ScienceDirect+1

[5] IIIT-Hyderabad & Telangana Fire Dept., "AI-based Auto-Scrutiny of Building Plans: Pilot Report," Government pilot (case study), 2022 — AI plan-validation pilot for Fire NOC pre-approval. ETASR

[6] Z. Lin et al., "Firebird: Predictive risk modeling for fire inspection prioritization," *arXiv preprint*, 2016 (relevant for analytics & inspection scheduling extensions). ACM Digital Library

[7] J. Choi, H. Park, and Y. Kim, "Emergency sound detection and audio fingerprinting for alarm classification,"

IEEE Access, 2023 (audio fingerprinting and decibel validation techniques). ACM Digital Library+1

[8] S. McKeown and W. Buchanan, "Hamming distributions of popular perceptual hashing techniques," *arXiv preprint*, Dec. 2022 — evaluation and robustness analysis of pHash/dHash. arXiv+1

[9] "PHASER: A perceptual hashing evaluation framework," *ScienceDirect / Procedia / Forensics*, 2023 — systematic evaluation of hashing algorithms (PHASER). ScienceDirect

[10] "SpectroMap — Peak detection algorithm for audio fingerprinting," (open-source research / conference), 2022 — audio fingerprinting peak-based methods. ResearchGate

[11] B. Xiang et al., "From Traditional Techniques to Deep Learning Approaches: Floor Plan Recognition," *ACM / CV workshops and surveys* (2023–2024) — survey of floor plan parsing and symbol detection methods. ACM Digital Library+1

[12] "Automatic floor plan analysis: datasets, methods and applications," *Elsevier / Pattern Recognition Letters / Survey (2022–2024)* — comprehensive review for layout parsing & symbol recognition. ScienceDirect

[13] A. Wang, L. Zhou, and Y. Chen, "OCR & symbol detection for architectural plans," *CVPR Workshops / Document AI*, 2021 — OCR approaches for extracting textual labels like "EXIT", "STAIR", or equipment IDs. ACM Digital Library

[14] "Survey of architectural floor plan retrieval technology based on semantic/spatial/shape features," *MDPI / preprint & journal articles* (2023–2024) — floor plan retrieval and semantic mapping work. MDPI+1

[15] "Digital Fingerprinting on Multimedia: A Survey," *arXiv* (2024) — up-to-date survey on multimedia fingerprinting (hashes, fingerprints, audio/image). arXiv

[16] "A comprehensive algorithm for vertical positioning in multi-storey buildings using smartphone sensors," *Scientific Reports / Nature* (2024) — robust vertical positioning via barometer and calibration. Nature

[17] S. Patel, M. Kumar, and R. Gupta, "Multimodal fire scene understanding: combining image, audio, and text," *ACM Transactions on Multimedia Computing (2023)* — multimodal approaches for assessing environment safety. ACM Digital Library

[18] R. Subramanian et al., "Ethics and architecture in real-time safety monitoring systems," *Springer AI & Ethics*, 2023 — governance, privacy and ethical aspects for real-time inspection systems. arXiv

[19] "Mobile apps for fire & alarm inspection and maintenance: industry platforms & case studies," BuildOps / InspectNTrack (2022–2024) — examples of practical inspection apps and workflows (industrial perspective). BuildOps+1

[20] "Prompt-Guided Generation & Editing of Floor Plans" (ChatHouseDiffusion / arXiv 2024) — advanced layout modeling useful for plan normalization / synthetic data generation for training. arXiv