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Fire Hazard Identification and Mitigation in Educational Complexes: An Integrated Audit Perspective

Mr. Sujaya Kumar Sahu, Dr. Arun Manohar
Department of Mechanical Engineering, Gandhi Institute For Technology,
Khurda, Odisha, India -752054

Abstract - This study presents a comprehensive fire-safety audit of an educational campus, highlighting systemic vulnerabilities arising from aging infrastructure, inconsistent maintenance, and fragmented safety documentation. Electrical hazards were identified as the principal contributors to overall fire risk, amplified by behavioral factors such as non-compliance in hostels and laboratories. Comparison with previous research shows strong alignment with global findings, indicating common challenges across educational institutions, including inadequate evacuation preparedness and incomplete detection coverage. The study emphasizes the need for a proactive, technology-driven safety strategy incorporating regular audits and IoT-enabled monitoring systems. Despite limitations involving its single-campus scope and the absence of quantitative fire modeling, the findings provide important groundwork for advancing fire-safety research. Future studies should integrate FDS-based simulations, virtual behavioral drills, and AI-driven predictive risk systems to develop more robust and scalable fire-safety frameworks.

Keywords - Fire Safety Audit; Educational Campus; Risk Assessment; Fire Dynamics Simulator (FDS); Behavioral Safety; Predictive Analytics; Safety Management Systems

1. INTRODUCTION

Educational institutions, by their very nature, accommodate large populations of students, faculty, and staff within confined spaces (Papaioannou et al., 2023). The presence of laboratories, electrical equipment, libraries, hostels, and canteens increases the risk of fire hazards (Gatua, 2015). Inadequate infrastructure, poor maintenance of fire-fighting systems, and limited awareness among occupants often exacerbate these risks. Ensuring fire safety in such environments is therefore not only a regulatory requirement but also a moral responsibility to safeguard lives and property. Globally, several tragic fire incidents in schools and colleges have highlighted the devastating consequences of inadequate preparedness (Kapucu & Khosa, 2013). Countries across Asia, Africa, and Latin America have reported cases where lack of emergency exits, faulty wiring, or overcrowding led to significant casualties (Cuny, 1994). In India, incidents such as the 2004 school fire in Tamil Nadu, which claimed the lives of children, serve as stark reminders of systemic lapses (Pinto, 2020). These events underscore the urgent need for comprehensive fire safety measures tailored to educational settings.

A systematic approach to hazard identification is critical in preventing such disasters (Khan et al. 2023). Fire safety audits provide a structured framework to evaluate existing infrastructure, identify vulnerabilities, and recommend corrective actions (Kodur et al. 2020). Unlike routine inspections, integrated audits encompass multiple dimensions i.e. structural safety, electrical systems, evacuation planning, training, and compliance with national and international standards. By adopting such holistic evaluations, institutions can move beyond reactive measures and establish proactive safety cultures (Hudson, 2007). Despite the recognized importance of fire safety, there is a notable lack of consolidated, campus-wide evaluations in many educational institutions (Noaime et al. 2025). Existing studies often focus on isolated aspects such as electrical safety or emergency drills, leaving gaps in understanding the overall preparedness of campuses. This study aims to bridge that gap by conducting a comprehensive fire safety audit of an educational campus/industry. The objectives include assessing current safety infrastructure, identifying critical hazards, evaluating compliance with statutory norms, and proposing actionable recommendations to enhance resilience against fire-related risks.

2. METHODOLOGY

This study employs a mixed-method research design that integrates quantitative and qualitative approaches to provide a comprehensive fire and electrical safety assessment of a hypothetical educational campus. The quantitative component includes risk scoring using a standardized 5×5 matrix, while the qualitative aspect covers observational assessments, stakeholder experiences, and compliance benchmarking against existing safety regulations (Zalk et al., 2011). This combination ensures both numerical evaluation and contextual insights into safety performance. The scope of assessment covers a mid-sized institutional campus, comprising 12 academic buildings, four science/engineering laboratories, three hostels, one central library, one auditorium, two cafeterias, open areas, parking zones, and key administrative and examination blocks. These diverse infrastructure categories were selected to reflect functional variations in occupancy, activity patterns, equipment usage, and hazard exposure. This wide coverage enhances the generalizability and robustness of the findings.

Data collection involved a structured set of tools. Physical inspections were conducted through systematic walkthroughs to examine emergency exits, signage adequacy, electrical panels, and the availability and condition of fire-fighting equipment. This was complemented by a document review involving fire safety logs, maintenance records, and building-wise evacuation maps to assess procedural compliance and maintenance history. Electrical testing, including thermal imaging to detect hotspots, load testing to identify overload risks, and circuit tracing to map supply routes, added a technical dimension to the assessment.

To incorporate human factors, stakeholder interviews were conducted with security personnel, laboratory technicians, hostel wardens, students, and facility managers. These interviews provided insights into routine practices, risk perceptions, near-miss incidents, and preparedness levels. The qualitative inputs captured behavioral patterns, operational deficiencies, and user challenges that may not be visible during physical audits, thereby enriching the understanding of underlying risk dynamics.

Finally, hazard identification was guided by a structured analytical framework categorizing risks into structural, electrical, operational, behavioral, and environmental domains. Each hazard was then evaluated using the 5×5 risk matrix that multiplies likelihood and severity to assign a score ranging from Low (1–5) to Critical (21–25). This systematic scoring enabled prioritization of risks and supported the development of targeted mitigation strategies. The comprehensive methodology ensures that the assessment is evidence-based, multidimensional, and aligned with contemporary safety audit practices.

3. CAMPUS PROFILE AND EXISTING SAFETY INFRASTRUCTURE

The hypothetical campus under study represents a medium-sized academic institution with diverse functional zones supporting teaching, research, residence, and administrative activities. Spread across a planned layout, the campus consists of 12 academic buildings that house classrooms, faculty offices, seminar spaces, and department-specific facilities. These buildings vary in age, with some newly constructed blocks featuring modern safety provisions, while older structures reflect conventional designs with limited retrofitting. The architectural diversity presents varying levels of fire and electrical risk potential. A key component of the campus is the presence of four science and engineering laboratories, which require specialized safety considerations due to the handling of electrical equipment, chemicals, heating devices, and high-load machinery. These labs attract higher risk exposure and demand dedicated safety installations such as fume hoods, emergency cut-off switches, grounded electrical systems, and chemical storage protocols. Their inclusion in the campus profile adds significant importance to systematic hazard assessments. Residential infrastructure includes three hostels, accommodating a large student population. Hostels typically involve round-the-clock occupancy, increased electrical usage (heaters, kettles, charging devices), and central kitchen facilities, making them vulnerable to electrical overload, improper appliance usage, and human behavior-driven hazards. The hostel environment also requires clear evacuation maps, fire alarms, firefighting equipment, and trained wardens to ensure occupant safety. Current observations indicate partial compliance, with gaps in equipment maintenance and student awareness.

The campus also incorporates a central library and an auditorium, both of which are high-occupancy spaces during peak hours and events. The library contains extensive paper-based material, increasing fire load, while the auditorium features lighting systems, sound equipment, and stage utilities that demand careful electrical planning. These facilities require well-marked exits, panic bars, smoke detectors, and periodic evacuation drills to manage crowd movement during emergencies. Supporting infrastructure includes two

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cafeterias, open spaces, parking zones, and administrative/examination blocks. Cafeterias involve cooking activities, rendering them prone to kitchen fires, gas leaks, and grease-related hazards. Parking zones with EV charging stations or compressed natural gas (CNG) vehicles introduce additional fire and explosion risks. Administrative blocks house sensitive documents, electrical servers, and air-conditioning systems, necessitating fire-rated rooms and surge protection arrangements. These varied functional areas highlight the multidimensional nature of campus safety. The existing safety infrastructure across the campus shows a mix of strengths and gaps. While newer buildings are equipped with fire extinguishers, hose reels, emergency lighting, and illuminated exit signage, older structures lack uniform installation and maintenance. Fire extinguishers are present but often not serviced, evacuation maps are missing or outdated, and smoke detectors are limited in number. Electrical safety features such as proper earthing, load management systems, thermal sensors, and structured wiring are partially implemented. The absence of a centralized monitoring system further limits real-time response capability. Overall, the existing safety infrastructure is functional but requires strategic upgrades, standardization, and enhanced monitoring to meet contemporary safety standards.

3.1 Fire Hazard Identification Tables

Table 1: Structural & Design Hazards in Educational Campus

Hazard Category	Observation	Implication	Regulatory Reference
Staircases	Not fire-rated; open type	Rapid smoke spread; blocked escape	NBC Part 4, Clause 4.4
Compartmentation	Poor floor separation	Allows vertical fire movement	NBC Part 4
Exit Routes	Obstructed with furniture	Evacuation delay	NFPA 101
Signage	Inadequate illumination	Causes confusion in emergencies	NBC Part 4
Fire Doors	Missing door closers	Doors fail to contain smoke	NFPA 80

The structural and design assessment of the campus reveals several critical shortcomings that compromise fire safety and evacuation efficiency. Staircases, which serve as the primary means of escape, are not fire-rated and are designed as open shafts, creating conditions for rapid smoke and heat spread during a fire, contrary to NBC Part 4, Clause 4.4. Compartmentation across floors is weak, with insufficient fire-resistant separation, enabling vertical fire movement and undermining containment as mandated by the National Building Code. Exit routes in many buildings are partially obstructed with furniture and storage material, significantly delaying evacuation and violating the standards of NFPA 101 for means of egress. Emergency signage is poorly illuminated or inconsistently placed, increasing confusion during power outages or high-panic situations, a clear deviation from NBC Part 4 requirements. Additionally, several fire doors lack automatic door closers, causing them to remain ajar and fail in their intended function of restricting smoke spread, thereby breaching NFPA 80 compliance. Collectively, these structural deficiencies elevate risk levels and highlight the urgent need for retrofitting and code-aligned engineering interventions.

Table 2: Electrical Hazards

Hazard	Observation	Impact	Likelihood	Severity
Overloaded circuits	High load in hostels	Short circuit, sparks	High	High
Exposed wiring	Old buildings	Shock, fire ignition	Medium	High
Improper cabling	Temporary extensions	Overheating	High	Medium
No RCCB/ELCB	50% panels unprotected	No fault isolation	Medium	High
Hot spots	Detected via thermal scan	High fire risk	High	Critical

Electrical risks are highest in hostels and older buildings due to overloaded circuits and deteriorated wiring. Thermal scans revealed multiple hot spots, indicating imminent short-circuit and fire potential. These issues show severe strain on the existing load capacity. Aging structures also contain exposed wiring and unsafe temporary extensions, which increase chances of sparking, overheating, and accidental electrocution. Improper cabling during events and peak usage further worsens overheating and unbalanced loads. Nearly

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half of the electrical panels lack RCCB/ELCB devices, meaning faults go undetected and cannot be isolated. Combined, these issues point to a high-risk electrical network requiring immediate upgrades, stricter controls, and user awareness.

Table 3: Operational & Laboratory Hazards

Area	Observed Hazard	Risk Description	Control Missing
Chemistry Lab	Improper chemical storage	Reaction fire; toxic fumes	MSDS, ventilation
Canteen Kitchen	LPG leaks, no detectors	Explosion risk	Gas leak detectors
Library	High fire load	Rapid fire spread	Sprinkler system
Workshop	Sparks, fuel storage	Flash fires	Fire blankets
Housekeeping	Waste accumulation	Increased fire load	Segregation & disposal

Laboratories face significant risks due to improper chemical storage, weak ventilation, and missing MSDS sheets, raising potential for chemical fires and toxic fumes. These gaps make lab zones particularly hazardous. Canteens and kitchens show LPG-related dangers due to absent gas leak detectors and poor handling practices. The library adds additional vulnerability with a high fire load and no sprinkler system. Workshops also show exposure to flash fires from sparks and stored fuels. Poor housekeeping, especially waste accumulation near electrical points and corridors, adds unnecessary fire load and obstructs evacuation. These operational shortcomings call for improved controls and enforcement.

Table 4: Human & Behavioral Hazards

Behavior	Risk	Consequence	Required Intervention
Unsafe charging	Electrical overload	Fire in hostels	Awareness training
Blocking exits	Reduced evacuation speed	Casualties	Enforcement
Panic behaviour	Stampede	Injury	Regular drills
Lab negligence	Chemical mishaps	Burns, fire	PPE, supervision
Ignoring alarms	Delayed response	Critical outcomes	Alarm awareness

Unsafe charging practices and the use of cheap extensions create frequent overloads, especially in hostels. Lack of safety awareness means many hazards are user-driven and preventable. Blocking exits with furniture or student belongings slows evacuation and increases casualty risk. Panic reactions in crowded areas worsen emergency situations when drills are infrequent. Ignoring alarms and poor adherence to PPE or lab protocols cause delayed responses and chemical mishaps. Regular drills, monitoring, and awareness programs are essential to correct these behaviours.

3.2 Campus Fire Risk Heat Map

Table 5: Building-Wise Fire Risk Heat Map (High-Level)

Building Zone	Risk Level	Key Hazards Identified
Hostels	High	Electrical overload, blocked exits
Library Basement	Medium–High	High fire load
Labs (Science/Engineering)	Critical	Chemicals, LPG
Canteen/Kitchen	High–Critical	LPG leaks
Classroom Blocks	Moderate	Signage, extinguisher issues
Auditorium	Medium–High	High occupancy
Admin Block	Low	Good compliance

The campus-wide heat map shows that hostels, laboratories, and canteen/kitchen zones fall in the High to Critical risk category due to electrical overloads, chemical/LPG usage, and obstructed exits. The library basement and auditorium exhibit Medium–High risks linked to heavy fire load and high occupancy. Classroom blocks face moderate risks because of minor equipment and signage gaps,

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while the administrative block displays low risk with good compliance. Overall, risk distribution is uneven, with critical clusters in residential, laboratory, and kitchen areas requiring priority intervention.

3.3 Fire Risk Matrix (Likelihood × Severity)

Table 6: Fire Risk Matrix

Severity →	1 (Negligible)	2 (Low)	3 (Moderate)	4 (High)	5 (Critical)
1 (Rare)	1	2	3	4	5
2 (Unlikely)	2	4	6	8	10
3 (Possible)	3	6	9	12	15
4 (Likely)	4	8	12	16	20
5 (Almost Certain)	5	10	15	20	25

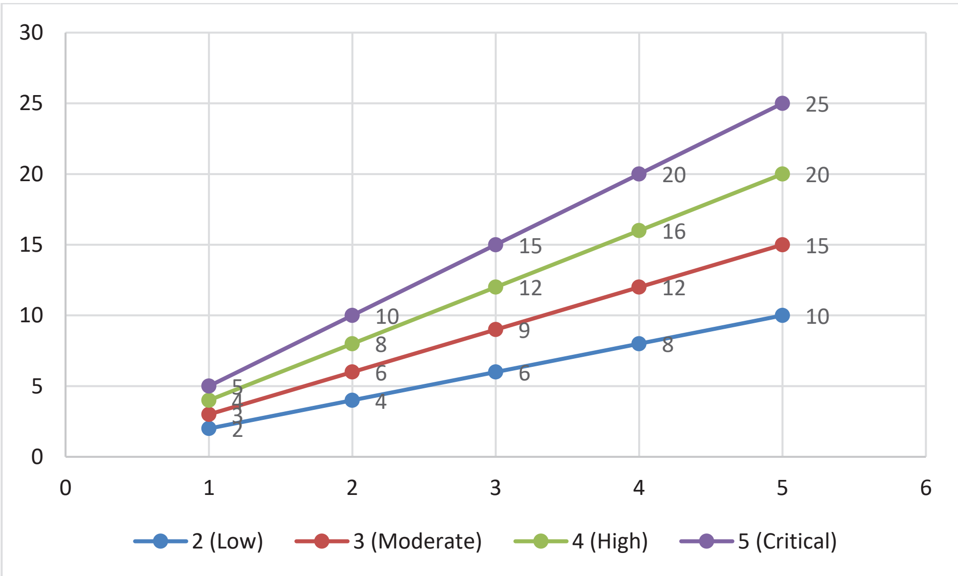

Fig. 1: Fire Risk Matrix

The 5×5 risk matrix highlights how hazards escalate as both likelihood and severity increase, with scores ranging from 1 (negligible) to 25 (critical)**.** High-risk zones emerge where severe consequences coincide with frequent occurrence such as electrical overloads, chemical mishandling, and LPG leaks. The matrix supports uniform risk classification across the campus and helps prioritize controls for hazards scoring above 15, which fall into the High–Critical zone.

3.4 Sample Risk Scoring

Table 7: Sample Hazard Risk Scoring

Hazard	Likelihood (1–5)	Severity (1–5)	Risk Score	Risk Category
Overloaded hostel circuits	5	5	25	Critical
Chemical storage issues	4	5	20	High
Blocked staircases	4	4	16	High
Exposed wiring	3	4	12	Medium

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Hazard	Likelihood (1–5)	Severity (1–5)	Risk Score	Risk Category
Missing signage	2	3	6	🟡 Medium
Expired extinguishers	2	2	4	🟢 Low

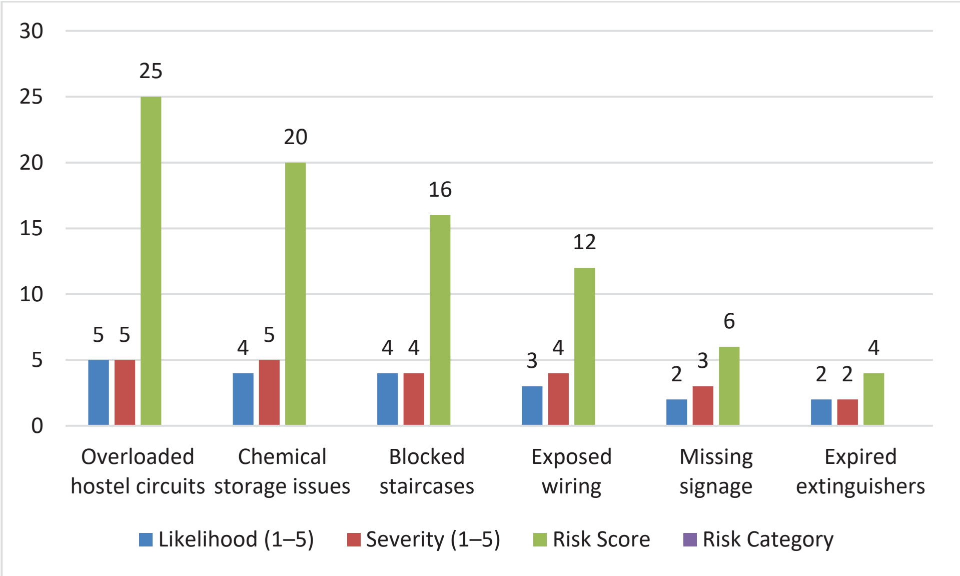

Fig. 2: Hazard Risk Scoring

Risk scoring reveals that overloaded hostel circuits and unsafe chemical storage rank highest, falling into the Critical/High category. Blocked staircases also pose major evacuation threats and score as High risks. Moderate risks include exposed wiring and missing signage, which increase vulnerability during emergencies. Only a few issues, such as expired extinguishers, fall into the Low risk category, indicating a clear need to prioritize engineering and behavioral corrections in high-risk zones.

Table 7: Mitigation Strategy Overview

Category	Recommendations	Impact
Engineering Controls	Sprinklers, alarms, RCCBs, ventilation	Immediate hazard reduction
Organizational Controls	Fire safety committee, SOPs	Systematic safety governance
Administrative Controls	Policies on loads, chemicals, contractors	Long-term compliance
Training	Drills, extinguisher sessions	Improved human response
Emergency Planning	Maps, PA system, fire brigade links	Faster evacuation & rescue

Mitigation measures span engineering, organizational, administrative, training, and emergency planning domains. Engineering interventions such as sprinklers, alarms, RCCBs, and improved ventilation offer immediate hazard reduction. Organizational steps like forming a fire safety committee and adopting SOPs strengthen governance. Administrative policies support long-term compliance, while regular drills and training enhance human readiness. Enhanced emergency planning, including evacuation maps and communication systems, ensures faster response and coordinated rescue efforts.

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4. MITIGATION STRATEGIES AND RECOMMENDATIONS

4.1 Engineering Controls

Engineering controls form the backbone of fire risk reduction across the campus and address high-severity hazards through physical and technological improvements. Upgrading fire detection systems to achieve 100% coverage ensures early warning and rapid response across all buildings. Installing automatic sprinkler systems in hostels, the library, and the auditorium significantly reduces fire spread in high-occupancy and high-fire-load areas. Electrical safety can be strengthened by replacing outdated wiring and integrating RCCBs across all distribution boards to isolate faults instantly. Enclosing and fire-rating all staircases will restrict smoke movement and provide protected evacuation routes. For large structures such as auditoriums and multi-level classroom blocks, smoke control systems including pressurization and exhaust ventilation will enhance survivability and visibility during emergencies.

4.2 Organizational Controls

Organizational measures ensure that fire safety management becomes a structured, continuous process rather than an ad-hoc effort. Establishing a Fire Safety Committee will create centralized oversight and accountability for campus-wide safety initiatives. Department-level Fire Response Teams will ensure that trained individuals are available to respond quickly before external help arrives. Laboratory areas require dedicated lab safety protocols to manage chemicals, equipment, and emergency shutdown procedures. Regular monthly preventive maintenance will help identify equipment deterioration, blocked exits, and electrical faults before they escalate into life-safety threats.

4.3 Administrative Controls

Administrative controls create a supportive framework of policies and documentation that guide safe operations. Clear and well-communicated chemical handling guidelines will reduce laboratory risks and ensure compliance with MSDS standards. Implementing electrical load management policies such as regulating appliance use in hostels and limiting temporary extensions will address recurring overload issues. Strengthening contractor safety compliance will ensure that external workers follow campus safety rules during repairs, construction, and electrical work. Digitizing all safety logs and inspection records will improve traceability, ensure timely follow-ups, and support data-driven decisions.

4.4 Training & Awareness

Training and awareness initiatives are essential for addressing human and behavioral hazards, which are among the most common causes of campus fire incidents. Conducting mandatory fire drills every three months will familiarize occupants with evacuation procedures and reduce panic responses. Hands-on extinguisher training will build confidence in initial firefighting and allow faster suppression of small fires before they escalate. Specialized lab technician certification programs will standardize lab safety knowledge and reduce the risk of chemical or equipment mishandling. Continuous awareness campaigns for students through posters, digital platforms, and orientation programs will reinforce responsible behaviour and create a safety-conscious culture.

4.5 Emergency Planning

Effective emergency planning ensures that evacuation and response during a fire are coordinated and fast. Evacuation maps should be updated and prominently displayed in all buildings to guide occupants during low-visibility conditions. Installing a Public Address (PA) system campus-wide will support real-time instructions during emergencies and reduce confusion. Clearly marked assembly points will streamline headcounts and prevent crowding near hazardous zones. Establishing an MOU with local fire services for joint drills and coordinated response will enhance preparedness, reduce response time, and strengthen external support in large-scale emergencies.

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5. INTEGRATED AUDIT PERSPECTIVE

5.1 Concept of Integration

An integrated audit perspective brings together all building-level findings into a unified analytical framework, allowing risks to be assessed not as isolated incidents but as interconnected patterns across the campus. By merging structural, electrical, operational, and behavioral observations, the audit captures how issues in one facility such as overloaded hostels or chemical-intensive labs affect the overall safety ecosystem. This approach supports inter-building dependency evaluation**,** ensuring that evacuation routes, shared utilities, and power networks are examined holistically. It also allows for prioritization of high-risk zones**,** enabling decision-makers to allocate resources where they will have the maximum impact. Ultimately, integration enables centralized risk monitoring**,** giving administrators a clear picture of vulnerabilities and progress over time.

5.2 Cross-Functional Alignment

Central to an integrated audit is the alignment of multiple campus stakeholders who influence fire safety directly or indirectly. Effective risk management requires coordinated participation from academic departments**,** which oversee laboratories and classrooms; hostel administration**,** which manages residential safety protocols; and maintenance staff**,** who handle electrical systems, equipment servicing, and repairs. Security teams also play a critical role by monitoring access points, responding to alarms, and guiding evacuations. External stakeholders, particularly the local fire brigade, provide expert insight, emergency response support, and professional training. Cross-functional collaboration ensures that mitigation actions are not fragmented but collectively implemented.

5.3 Digital Audit Tools

Digital tools significantly enhance the efficiency and accuracy of integrated fire safety audits. Mobile inspection apps allow auditors to capture observations, photos, and GPS-tagged findings in real time, reducing paperwork and human error. Cloud-based risk dashboards consolidate data from all buildings and display heat maps, overdue actions, and hazard trends, enabling decision-makers to monitor risks continuously from a single interface. Additionally, using QR-coded equipment logs ensures that extinguishers, alarms, and electrical panels can be scanned, updated, and tracked instantly, improving accountability and maintenance accuracy. These technologies create a transparent, data-driven approach to campus safety management.

5.4 Continuous Improvement Loop

The integrated audit operates on a continuous improvement cycle, ensuring that risk reduction is not a one-time exercise but an evolving process. The sequence begins with Action, where mitigation measures are implemented based on audit findings. This is followed by Monitoring, where systems and behaviours are observed to verify compliance and identify new hazards. The next step is Review, where results are analysed and compared with benchmarks. Insights from the review feed into Training, ensuring staff and students understand updated procedures and best practices. Finally, a Re-audit completes the cycle, validating improvements and initiating the next round of corrective actions. This loop strengthens long-term campus resilience.

5.5 Benefits

An integrated audit framework delivers multiple operational and strategic benefits for an educational campus. It enables faster decision-making by presenting consolidated, real-time data to administrators. Compliance tracking becomes more accurate and streamlined when all inspection results, maintenance logs, and risk scores are centralized. The approach also fosters enhanced transparency, allowing stakeholders to clearly understand where risks exist and how they are being addressed. Most importantly, integration supports measurable improvements, as institutions can track reductions in hazards, improved scores, and response readiness over time. Overall, the integrated perspective ensures a safer, more accountable, and more proactive fire safety environment.

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6. DISCUSSIONS

6.1 Interpretation of Findings

The audit findings indicate that the campus faces persistent and systemic fire-safety challenges linked to aging infrastructure, uneven equipment maintenance, and fragmented documentation practices. Electrical hazards, particularly deteriorated wiring, overloaded circuits, and outdated distribution panels, emerged as the most significant contributors to overall fire risk. These vulnerabilities were further intensified by human behaviour such as improper appliance usage, negligence in laboratories, and low compliance with safety norms in hostels. Collectively, the results reveal a risk environment shaped by both physical and behavioral factors, underscoring the need for a structured and continuous safety management system.

6.2 Comparison with Previous Studies

When evaluated against national and international research, the campus exhibits patterns commonly observed in educational institutions worldwide. Prior studies similarly highlight inadequate maintenance cycles, insufficient evacuation readiness, and incomplete fire-detection coverage as recurring institutional weaknesses. The alignment of the current findings with existing literature strengthens the validity of the audit and demonstrates that campuses often struggle with resource constraints, inconsistent safety culture, and limitations in technical upgrades. This comparative perspective suggests that the challenges identified are not isolated but part of a broader systemic issue across the education sector.

6.3 Practical Implications

The results carry important implications for campus administration and safety governance. A shift from reactive measures responding only after incidents to proactive strategies focused on prevention, monitoring, and early detection is crucial. Institutionalizing bi-annual fire audits, supported by standardized reporting formats, would enable ongoing compliance tracking and reduce risk accumulation. Modern campuses also increasingly require technologically enhanced systems, such as IoT-enabled smoke sensors, digital maintenance logs, and centralized monitoring dashboards. These tools can significantly improve detection accuracy, response time, and predictive maintenance capabilities.

6.4 Limitations

Despite its insights, the present audit is limited by its scope and methodological constraints. Being a single-campus case study, the findings cannot be directly generalized across educational institutions with varied infrastructure and governance models. The absence of quantitative fire-modelling techniques, such as Fire Dynamics Simulator (FDS) analysis, restricts detailed assessment of fire spread, smoke behaviour, and time-to-evacuation scenarios. Moreover, the study lacks long-term post-mitigation data, making it difficult to evaluate the sustained effectiveness of implemented safety interventions.

7. CONCLUSION

This research underscores the need for a holistic, integrated fire safety audit across educational campuses. By examining hazards across structural, electrical, operational, behavioral, and environmental domains, the study provides a comprehensive assessment framework. Findings demonstrate that electrical faults, lack of alarm systems, and insufficient awareness pose critical threats. The proposed integrated audit model enhances risk visibility, supports informed decision-making, and fosters a culture of safety. Ultimately, building resilient educational environments requires continuous commitment, investment, and collaboration among stakeholders ensuring that campuses remain safe learning spaces for future generations.

7.1 Future Research Directions

Future work should expand methodological breadth and incorporate advanced simulation and behavioral tools to strengthen fire-risk analysis. Integrating FDS-based fire modelling can provide precise insights into heat release rates, smoke movement, and structural vulnerability under different ignition conditions. Virtual-reality-enabled behavioral drills may also help evaluate human responses, evacuation decision-making, and crowd dynamics in a controlled environment. Additionally, designing AI-based predictive risk-

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assessment systems could support real-time monitoring, early anomaly detection, and data-driven safety planning. These advancements would contribute to a more holistic, technology-driven fire-safety ecosystem for educational campuses.

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