Development of a Fire and Life Safety Maturity Index (FLSMI): An Audit-Based Framework for Assessing Operational Readiness in Manufacturing Including High-Rise Facilities

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Abstract

Fire and life safety audits are widely used to examine whether facilities conform to statutory, code-based, and organizational requirements. However, audit outputs are typically reported as a list of discrete, unweighted observations, which limits management's ability to judge the overall maturity and operational readiness of a facility's fire and life safety systems, to benchmark performance across sites, or to prioritize corrective action. This study develops a Fire and Life Safety Maturity Index (FLSMI) that converts structured audit evidence into a single, measurable, and comparable performance indicator. The framework was applied retrospectively to third-party audit records from three facility types in India, comprising 22 individual sites in total: a 12-site industrial and warehousing park (Facility A), a 3-tower residential high-rise complex (Facility B), and a 7-site textile manufacturing plant (Facility C).

The proposed model uses a binary, evidence-based scoring method in which every applicable checkpoint is classified as Fully Established or Not Established; checkpoints that are not applicable to a given facility are excluded from the denominator. The assessment criteria were developed with reference to NBC 2016 Part 4 and relevant Indian Standards, including IS 2189, IS 2190, IS 13039, IS 15105, and IS 15301, and were cross-referenced against NFPA 101, NFPA 72, NFPA 25, and NFPA 1. The framework evaluates maturity across ten fire and life safety domains, including emergency response planning, means of egress, detection and alarm systems, hydrant and sprinkler systems, portable fire protection, electrical fire safety, emergency lighting and signage, housekeeping, special hazards, and training/ERT readiness.

Application of the FLSMI to the combined dataset of 234 applicable checkpoints (56 Fully Established, 178 Not Established) produced a combined maturity score of 23.9%, which falls within the Unsatisfactory band. The dominant contributors to unresolved deficiencies were hydrant/sprinkler system gaps, housekeeping and combustible-storage deficiencies, and weaknesses in training and emergency-response readiness. The FLSMI therefore offers a practical method for converting audit findings into a management-level indicator that supports benchmarking, gap identification, corrective-action prioritization, and continual improvement.

Keywords: *Fire and Life Safety Maturity Index (FLSMI); Fire Safety Audits; Operational Readiness; Leading Indicators; Safety Management Systems; Industrial Safety; Fire Protection Systems.*

1. Introduction

Fire and life safety remains a significant operational concern in industrial and built-environment facilities, particularly where systems are installed but not consistently inspected, tested, maintained, or managed [1].

Many safety management systems still depend heavily on lagging indicators, such as injury or incident rates. While useful for historical review, these indicators offer limited support for identifying weaknesses before an event occurs. In fire safety, underlying system failures may appear as poor equipment maintenance, blocked escape routes, inadequate inspection practices, or weak emergency preparedness [2].

Safety science literature also shows that serious accidents are rarely the result of a single unsafe act. They are often shaped by latent organizational weaknesses that remain unnoticed within day-to-day processes. In fire and life safety systems, these weaknesses may be reflected in recurring gaps related to inspection, testing, maintenance, training, documentation, and management oversight [3].

This study responds to that practical gap by developing a Fire and Life Safety Maturity Index that converts audit observations into measurable maturity indicators. The index is intended to help organizations recognize weak system areas before they contribute to serious fire or life safety events [4].

Audit findings can serve as useful leading indicators because they capture deficiencies before incidents occur. Nevertheless, many organizations do not have a consistent method for converting such observations into a single, understandable measure of operational readiness [5].

The primary objective of this study is therefore to develop and demonstrate a Fire and Life Safety Maturity Index (FLSMI) that converts audit observations into a measurable indicator of operational readiness. The study proposes a practical, audit-based framework for evaluating fire and life safety performance across industrial, warehousing, and residential facilities using structured, evidence-based scoring.

2. Literature Review

The literature emphasizes the importance of systemic thinking in accident and disaster prevention. Heinrich's accident pyramid established early links between unsafe behavior, unsafe conditions, and incident occurrence, while Reason's model of organizational accidents highlighted the role of latent system failures embedded within organizational processes [3,4].

Modern EHS management frameworks have shifted focus from reactive measurement toward proactive risk identification through leading indicators. These indicators include audit findings, maintenance records, training effectiveness, and system reliability [2].

Contemporary occupational health and safety frameworks advocate increased use of leading indicators to complement traditional lagging indicators and support proactive risk management [6,7].

Fire safety assessment methodologies range from qualitative inspections to advanced risk-modelling approaches. In practical industrial applications, audit-based assessment methods continue to represent the most widely used and operationally feasible approach [8].

Previous studies have demonstrated the potential of risk-index methods to simplify complex safety information into actionable insight. However, limited research has focused on applying such models using real-world audit datasets across diverse facility types [9].

Related approaches include AHP-based fire safety assessment models [10] and proactive safety-control frameworks originally developed for construction and virtual organizations [11,12], which similarly show that leading-indicator methods can be operationalized through structured, criteria-based assessment.

Despite the availability of regulatory standards and audit protocols, organizations often lack a structured mechanism for translating audit findings into a measurable indicator of fire and life safety performance. As a result, management teams may struggle to compare facilities, identify systemic weaknesses, and track improvement over time [13].

3. Methodology

The study used a multi-site, audit-based design covering manufacturing facilities, warehousing operations, and residential high-rise environments. Including different facility types helped identify recurring fire and life safety deficiencies across varied operational contexts. The methodology combined field observations, document review, interviews, and structured scoring to convert qualitative audit evidence into a measurable maturity index.

3.1 Study Design

The research is based on a multi-site audit approach covering three facilities (referred to hereafter as Facility A, Facility B, and Facility C for confidentiality), which together comprise 22 individual sites or occupancies:

Facility A: an industrial and warehousing park comprising 12 co-located manufacturing/logistics occupancies.

Facility B: a residential high-rise complex comprising 3 residential towers.

Facility C: a textile manufacturing plant comprising 7 production/utility sites.

3.2 Data Collection

Data were collected through structured fire and life safety audits as follows.

3.3 Deficiency Classification

Audit findings were grouped into five key system categories to enable structured, comparable analysis across facilities, rather than being treated as an unordered list of isolated observations. This classification allowed recurring weaknesses to be traced to a specific system domain (e.g., engineered fire protection assets versus human and organizational readiness), which in turn supported the identification of concentration patterns — whether deficiencies clustered in physical infrastructure, operational controls, or management systems — and provided the categorical structure later used to compute section-level and facility-level FLSMI scores.

Fire Protection Systems — the engineered and mechanical assets responsible for detecting, suppressing, and containing fire, including fire detection and alarm systems, hydrant and sprinkler networks, portable fire extinguishers, and fire pumps.

Emergency Preparedness — the planning and physical readiness elements that govern occupant evacuation and incident response, including emergency response plans, means of egress, evacuation signage, and emergency lighting.

Electrical Safety — ignition-source controls associated with electrical installations, including panel condition, wiring practices, earthing/grounding, thermographic inspection, and protection of DG, battery, and server/UPS rooms.

Combustible Storage & Housekeeping — operational controls over combustible material accumulation and storage practices, including aisle clearance, segregation of combustibles, and clearance around sprinklers and fire equipment.

Training & Competency — the human and organizational readiness factors underpinning emergency response, including Emergency Response Team (ERT) training, fire drills, staff induction, and management oversight of fire safety performance.

3.4 Assessment Framework and Instrument

The assessment framework was developed using requirements derived from NBC 2016 Part 4 and supporting Indian fire protection standards, including IS 2189, IS 2190, IS 13039, IS 15105, and IS 15301 [1,14,15,16].

To align the checkpoint criteria with internationally recognized life-safety benchmarks, the instrument also drew on NFPA 101: Life Safety Code [17], NFPA 72: National Fire Alarm and Signaling Code [18], NFPA 25: Standard for Water-Based Fire Protection Systems [19], and NFPA 1: Fire Code [20], alongside the applicable Indian Standards.

The assessment elements included:

1. Fire Documentation and Emergency Response Planning
2. Means of Egress and Life Safety
3. Fire Detection and Alarm Systems
4. Fire Hydrant and Sprinkler Systems
5. Portable Fire Protection Systems
6. Electrical Fire Safety
7. Emergency Lighting and Exit Signage
8. Housekeeping and Combustible Storage Management
9. Special Hazards and Utility Protection Systems
10. Training, Emergency Response Team Readiness, and Management Oversight

Each assessment element was supported by predefined checkpoints based on applicable regulatory requirements, recognized fire safety practices, and commonly observed operational controls in industrial and logistics facilities.

The FLSMI instrument was designed as a structured, audit-based tool covering multiple fire and life safety domains and detailed assessment checkpoints. Its purpose is to support consistent evaluation of fire and life safety maturity across manufacturing, warehousing, and residential facilities. Building on this framework, the authors have subsequently developed a complete, detailed FLSMI self-assessment checklist comprising 206 checkpoints across the same ten domains, structured for direct facility-level deployment and intended for use in future validation studies. Owing to the length limitations of a journal manuscript, this complete checklist is not reproduced here; representative assessment items are presented instead, and the full instrument may be obtained from the corresponding author upon reasonable request.

3.5 Scoring Methodology

Each checkpoint was verified and classified as Fully Established, Not Established, or Not Applicable. This three-state classification follows the conformity / non-conformity logic used in formal management-system auditing, in which each audit criterion is judged against objective evidence rather than subjective impression [21].

A checkpoint was marked Fully Established when objective evidence confirmed that the requirement had been implemented, maintained, and was functioning as intended.

A checkpoint was marked Not Established when the requirement was absent, partially implemented, ineffective, or not supported by adequate evidence.

Not Applicable checkpoints were excluded from all calculations to ensure that only relevant requirements influenced the final maturity score.

This binary, criteria-based evaluation approach is consistent with established risk-management principles of transparent, evidence-based assessment [22], and the underlying scoring logic mirrors the long-standing convention of expressing the proportion of criteria meeting a defined standard as a percentage of the total applicable criteria — a convention with a documented history in behavior-based safety measurement and compliance auditing more broadly [23].

3.6 Section Score Calculation

The maturity score for each fire and life safety element was calculated using the following equation, which follows the same ratio-based scoring logic used in fire-safety risk-index methods, where an index is computed as the number of satisfied criteria divided by the total number of applicable criteria [9]:

$$\text{Section Score (\%)} = [\text{Fully Established} / (\text{Fully Established} + \text{Not Established})] \times 100 \quad (1)$$

Not Applicable checkpoints were excluded from the denominator.

Example: assume Fire Detection and Alarm Systems contained 16 Fully Established, 4 Not Established, and 2 Not Applicable checkpoints. The two Not Applicable checkpoints are excluded, and the section score is:

$$16 / (16 + 4) \times 100 = 80\%$$

3.7 Facility-Level FLSMI Calculation

The overall FLSMI score for each facility was calculated by applying the same ratio-based logic as Equation (1) to the total number of Fully Established and Not Established checkpoints across all applicable assessment elements [9,22]:

$$FLSMI\ (\%) = [Total\ Fully\ Established\ /\ (Total\ Fully\ Established + Total\ Not\ Established)] \times 100 \quad (2)$$

This method ensures that each applicable assessment requirement contributes equally to the final score while avoiding subjective weighting factors.

Example: for a hypothetical facility with 112 Fully Established, 38 Not Established, and 12 Not Applicable checkpoints:

$$FLSMI = 112\ /\ (112 + 38) \times 100 = 74.67\%$$

3.8 FLSMI Interpretation Criteria

FLSMI Score (%)	Maturity Level	Interpretation
90–100	Excellent	Robust fire and life safety systems consistently implemented
80–89	Good	Systems largely effective with limited improvement opportunities
70–79	Satisfactory	Key controls established; improvement opportunities remain
60–69	Needs Improvement	Multiple deficiencies affecting operational readiness
Below 60	Unsatisfactory	Significant weaknesses affecting fire and life safety performance

Table 1: FLSMI interpretation criteria.

4. Results

The FLSMI framework was applied to structured audit findings from three facilities, comprising 22 individual sites in total: a 12-site industrial and warehousing park (Facility A), a 3-tower residential high-rise complex (Facility B), and a 7-site textile manufacturing plant (Facility C). Across the three facilities, 234 applicable checkpoints were evaluated (56 Fully Established, 178 Not Established); Not Applicable items were excluded from all calculations. Reporting completeness varied across facilities and assessment elements — Facility B's audit report, for example, documented fewer checkpoints for Electrical Fire Safety and Housekeeping than Facilities A and C — which limits direct element-by-element comparison in places, but the available records still reveal clear and recurring patterns in fire and life safety deficiencies.

4.1 Facility-Level FLSMI Scores

Table 2 summarizes the overall FLSMI score for each facility, calculated using Equation (2). All audited facilities fall within the Unsatisfactory band, confirming systemic rather than site-specific deficiencies.

Facility	Applicable Checkpoints	Fully Established	Not Established	FLSMI (%)
Facility A – Industrial & Warehousing Park (12 sites)	155	32	123	20.6
Facility B – Residential High-Rise (3 towers)	9	4	5	44.4
Facility C – Textile Manufacturing Plant (7 sites)	70	20	50	28.6
Combined (All Facilities)	234	56	178	23.9

Table 2: Facility-level FLSMI scores.

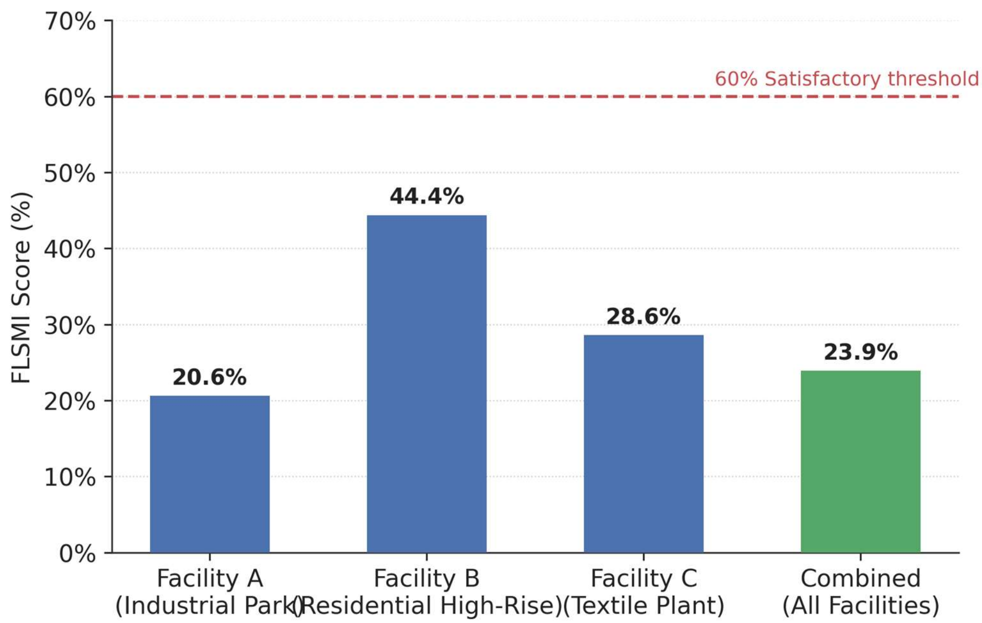

Figure 1: FLSMI scores by facility against the 60% Satisfactory threshold.

Facility A recorded the largest number of applicable checkpoints (155) owing to its 12 co-located occupancies, and the lowest FLSMI score (20.6%), reflecting widespread deficiencies in training, housekeeping, and fire detection coverage. Facility B, a residential high-rise with a smaller representative checkpoint set (9 items), scored highest (44.4%), largely due to fully established fire documentation, portable fire protection, and emergency lighting provisions, though its means-of-egress and special-hazard checkpoints were all rated Not Established. Facility C, a textile manufacturing plant, scored 28.6%, with comparatively stronger hydrant/sprinkler provisions but Not Established ratings across all housekeeping checkpoints. All facilities — and the combined dataset — fall in the "Unsatisfactory" band (below 60%) defined in Section 3.8, indicating that operational readiness across all three facility types requires significant improvement.

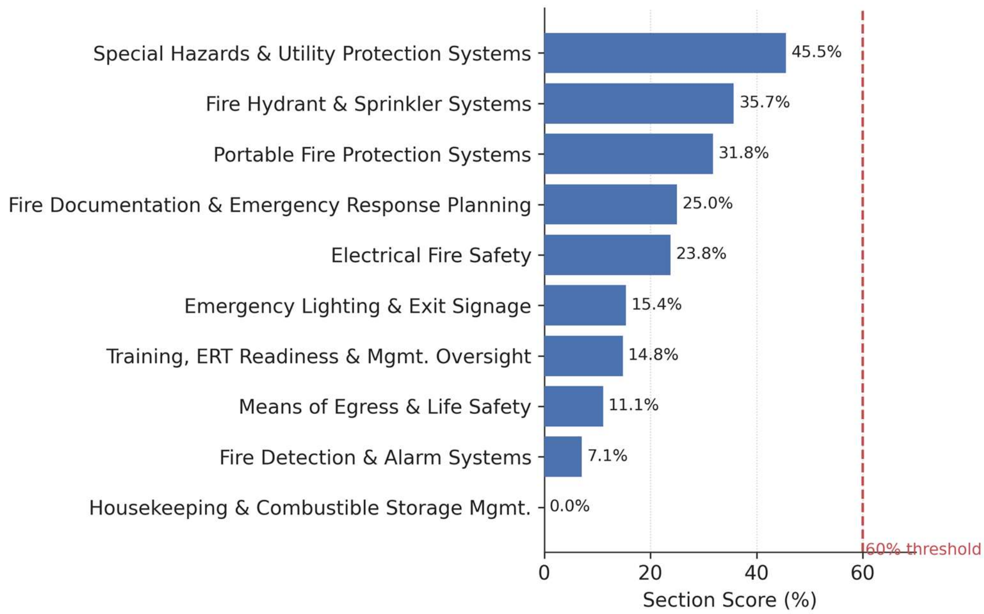

Figure 2: Section scores ranked by performance, with the 60% Satisfactory threshold shown for reference.

Housekeeping and fire detection systems recorded near-zero compliance, while even the best-performing sections remained well below the Satisfactory threshold. The lowest-scoring section was Housekeeping & Combustible Storage Management, at 0.0% (0 of 24 checkpoints), and the highest-scoring section was Special Hazards & Utility Protection, at 45.5% (15 of 33 checkpoints). Operational controls and engineered systems alike showed unresolved deficiencies across all ten sections.

4.2 Section-Level (Assessment Element) Scores

Table 3 aggregates checkpoint outcomes across all facilities for each of the ten FLSMI assessment elements, ranked by section score. No section achieved the 60% threshold. Housekeeping & Combustible Storage Management recorded the lowest maturity score (0.0%), followed by Fire Detection & Alarm Systems (7.1%) and Means of Egress & Life Safety (11.1%). The highest-scoring section was Special Hazards & Utility Protection Systems (45.5%), followed by Fire Hydrant & Sprinkler Systems (35.7%). Even the highest-scoring sections remained within the Unsatisfactory range.

Assessment Element	Fully Established	Not Established	Section Score (%)
Special Hazards & Utility Protection Systems	15	18	45.5
Fire Hydrant & Sprinkler Systems	15	27	35.7
Portable Fire Protection Systems	7	15	31.8
Fire Documentation & Emergency Response Planning	5	15	25.0
Electrical Fire Safety	5	16	23.8

Assessment Element	Fully Established	Not Established	Section Score (%)
Training, ERT Readiness & Management Oversight	4	23	14.8
Emergency Lighting & Exit Signage	2	11	15.4
Means of Egress & Life Safety	2	16	11.1
Fire Detection & Alarm Systems	1	13	7.1
Housekeeping & Combustible Storage Management	0	24	0.0

Table 3: Section-level (assessment element) scores.

4.3 Deficiency Distribution Analysis

Across the combined dataset, Not Established checkpoints were concentrated in three areas: Fire Hydrant & Sprinkler Systems (27 of 178 Not Established checkpoints, 15.2%), Housekeeping & Combustible Storage Management (24 checkpoints, 13.5%), and Training, ERT Readiness & Management Oversight (23 checkpoints, 12.9%). Recurring patterns included:

- Fire hydrant/sprinkler maintenance, calibration, and record-keeping deficiencies (Facilities A and C)
- Housekeeping and combustible storage conditions on shop floors and in stores (all facilities)
- Absence of drills, Emergency Response Team readiness, and refresher training records (Facilities A and C)

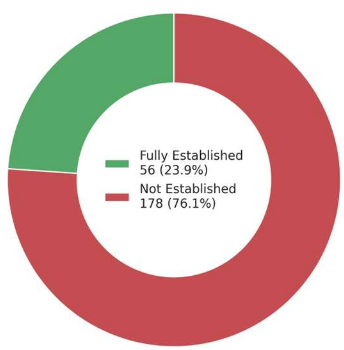

Figure 3: Overall distribution of Fully Established and Not Established checkpoints across the combined dataset.

This pattern indicates that day-to-day operational controls — housekeeping, routine maintenance, and training — account for a substantial share of overall fire and life safety deficiencies, more so than the initial design or installation of fire protection systems.

4.4 Pareto-Based Risk Prioritization

The four leading assessment elements by Not Established count — Fire Hydrant & Sprinkler Systems (27), Housekeeping & Combustible Storage Management (24), Training/ERT/Management Oversight (23), and Special Hazards & Utility Protection Systems (18) — together account for 92 of the 178 Not Established checkpoints (51.7%), consistent with a Pareto-type concentration of risk in a small number of recurring categories.

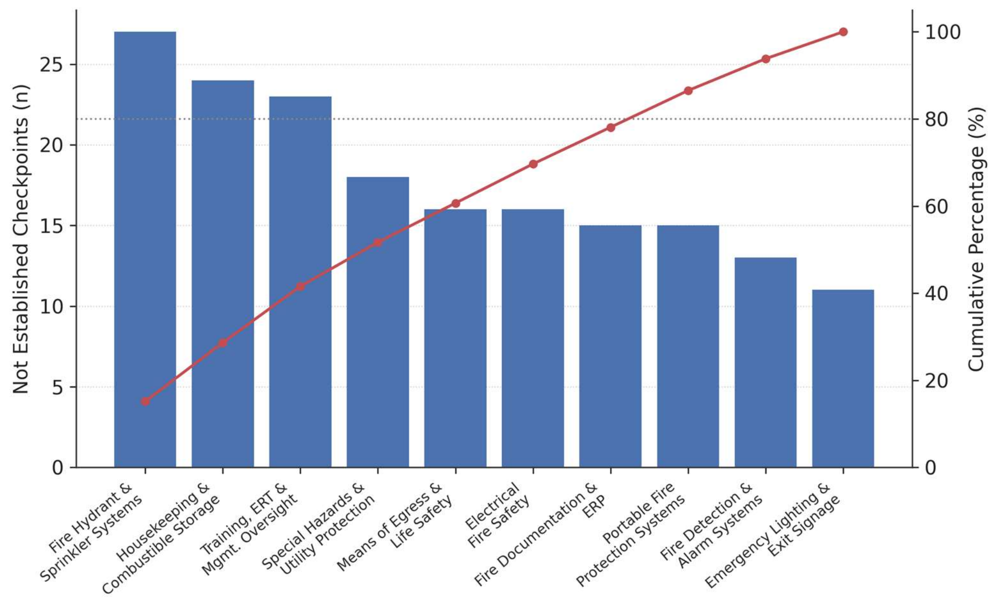

Figure 4: Pareto analysis showing the concentration of Not Established checkpoints by assessment element.

4.5 System Reliability versus Compliance Gap

The findings show that the presence of installed systems should not be interpreted as evidence of operational reliability. Several deficiencies were associated with incomplete maintenance records, poor functional verification, non-operational devices, or inadequate inspection discipline. This supports the central interpretation that system availability does not necessarily indicate system reliability.

4.6 Cross-Category Risk Interaction

The results also suggest interaction among technical, behavioral, and management controls. Poor housekeeping can increase combustible load and fire probability, while weak training and ERT readiness can reduce emergency-response effectiveness. Fire and life safety maturity should therefore be viewed as an integrated system condition rather than as a narrow compliance measure.

5. Discussion

The study indicates that fire and life safety performance depends not only on whether fire protection systems are available, but also on whether they are inspected, maintained, tested, documented, and managed effectively. In several facilities, basic infrastructure was available; however, deficiencies were observed in inspection schedules, preventive maintenance, record control, emergency preparedness, and management follow-up.

The FLSMI provides a practical way to convert numerous audit observations into a single maturity score. This is useful because traditional compliance audits often focus on individual findings, whereas management teams require an integrated view of system performance to compare facilities and prioritize resources.

This integrated view is consistent with the Fire & Life Safety Ecosystem approach [24], which frames life-safety outcomes as the product of interacting design, maintenance, and human factors rather than any single element, and with safety climate and safety culture research showing that organizational and behavioral factors strongly shape safety performance [25,26,27]. Hale [28] similarly argued that safety performance indicators are most useful when embedded within a broader management system, a view echoed in the UK Health and Safety Executive's guidance on managing for health and safety [29] and reflected in the FLSMI's intended use for benchmarking and continual improvement rather than as a standalone metric. This is broadly consistent with the systematic self-assessment approach recommended by ILO-OSH 2001 [30] and OSHA's Recommended Practices for Safety and Health Programs [31], and with a recent systematic review of safety leading indicators, which found that indicator frameworks are most effective when built on a manageable set of clearly defined, auditable checkpoints [32].

The findings also suggest that organizations should give greater attention to sustaining operational readiness through routine testing, planned inspections, emergency drills, training-effectiveness reviews, and periodic management evaluation. Compliance with prescriptive requirements remains important, but it is not sufficient unless systems continue to perform reliably during normal operations and emergency conditions.

5.1 Limitations & Scope

The findings above should be interpreted within the boundaries of the underlying dataset and audit methodology. Four specific limitations are identified below. None is judged to compromise the study's central finding — a combined FLSMI of 23.9%, with every facility and every one of the ten assessment elements falling below the 60% Satisfactory threshold — because that finding is corroborated independently across three separately audited facility types, using three independently prepared third-party audit reports, rather than resting on a single site or a single data source.

Secondary-data classification. This study analyzed pre-existing third-party audit reports rather than administering the FLSMI checklist directly during data collection, which introduces two related constraints. First, because the FLSMI instrument specifies a native Fully Established / Not Established / Not Applicable checklist, each reported finding had to be mapped onto these three categories retrospectively (compliant or low-risk findings as Fully Established; non-compliant, partially compliant, and medium/high/critical-risk findings as Not Established); this mapping step involves classification judgment, and inter-rater reliability was not formally tested. Second, because the source audit reports are corrective-action-oriented documents, prepared explicitly to identify deficiencies for remediation, they may under-represent fully compliant conditions relative to a purpose-built FLSMI audit administered with the specific intent of producing a balanced maturity score. Facility-level FLSMI scores reported here should accordingly be read as a conservative, lower-bound estimate of operational readiness.

Uneven checkpoint coverage across facilities. The ten assessment elements were not documented with equal depth across facilities — Electrical Fire Safety and Housekeeping, for example, were sparsely represented in Facility B's report — which limits the precision of element-level, facility-to-facility comparison, even though the facility-level and combined FLSMI scores themselves remain robust to this variation.

Sample size and regulatory context. The study draws on three facilities (22 sites) audited against Indian fire and life safety codes (NBC 2016 Part 4 and associated Bureau of Indian Standards requirements), cross-referenced against NFPA benchmarks. While the sample spans three distinct occupancy types — industrial, warehousing, and high-rise residential — it is too small to support statistical generalization, and jurisdictions governed by materially different code regimes may require local recalibration of the checkpoint set before the FLSMI is applied elsewhere.

No independent outcome validation. The FLSMI has not yet been tested against an independent safety-outcome measure, such as fire-incident history, near-miss frequency, or insurance loss data. Its face validity as a structured, code-aligned audit-scoring method is well supported (Section 3.4–3.7), but its predictive validity remains to be established.

Taken together, these limitations define a clear agenda for follow-on research: administering the FLSMI checklist directly during future audits rather than retrospectively coding existing reports, formally testing inter-auditor reliability, expanding the sample across a larger and more geographically diverse set of facilities, and validating FLSMI scores against longitudinal incident data. None of them alters the study's central, cross-validated conclusion — that the audited facilities' fire and life safety systems, spanning industrial, warehousing, and residential occupancies, are being managed well below the level required for consistent operational readiness.

6. Conclusion

This study developed a Fire and Life Safety Maturity Index (FLSMI) to convert structured audit observations into a measurable indicator of operational readiness. The model uses a transparent, binary scoring approach in which applicable checkpoints are classified as Fully Established or Not Established, while Not Applicable items are excluded from calculations.

Application of the FLSMI to three facilities (22 individual sites) showed a combined score of 23.9%, which falls within the Unsatisfactory band. The leading contributors to Not Established findings were Fire Hydrant & Sprinkler Systems, Housekeeping & Combustible Storage Management, and Training/ERT Readiness. These findings indicate that operational readiness depends strongly on routine maintenance, housekeeping control, emergency preparedness, and management oversight.

The FLSMI offers a practical alternative to conventional observation-based audit reporting by presenting fire and life safety performance as an integrated maturity measure. It can support facility benchmarking, gap identification, corrective-action prioritization, and continual improvement. A complete, 206-checkpoint FLSMI self-assessment checklist has already been developed on this basis for future validation work and direct field deployment (Section 3.4); future studies should apply this instrument across larger datasets, test inter-auditor reliability, and examine the relationship between FLSMI scores and fire/life safety outcomes over time.

07. Funding

This research received no external funding.

08. Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available because they contain organizationally sensitive safety audit and behavioral observation information but are available from the corresponding author on reasonable request, subject to organizational approval and confidentiality requirements.

09. Competing Interest Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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