JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

THE COMPLIANCE–EFFECTIVENESS GAP IN RESIDENTIAL (R2) FIRE-SAFETY SYSTEMS AND REAL-ESTATE DEVELOPER ACCEPTANCE: A SIX-MONTH POST-HANDOVER CASE STUDY OF 26 RESIDENTIAL BUILDINGS WITH A SHARED BASEMENT — AL-NARJES, NORTH RIYADH

Mohammed Hussien Ali ElHaggar
Researcher, Department of Natural Resources
National University of Sadat City, Sadat City, Monufia 32897, Egypt
Corresponding author: MOHAMMEDELLHAGGAR@GMAIL.COM

Abstract : Fire-safety compliance at handover does not necessarily demonstrate continuing protection after occupancy. This longitudinal single-case study examined an R2 residential development in Al-Narjes, north Riyadh, comprising 26 buildings, 312 units, and a shared basement. Five project documents and two semi-structured key-informant interviews were triangulated to compare handover conformity with operational availability six months later and interpret developer acceptance. For a like-for-like comparison, the same seven fire-protection subsystems and weights used at six months were retrospectively applied to handover evidence, yielding a documentary benchmark of 94.5%. Six-month weighted operational availability was 24.0%, a descriptive gap of 70.5 percentage points. A broader ten-domain documentary review produced 95.5%. Documented impairments included network pressure of 2 bar versus an expected 7–9 bar, 42.5 m³ of water in a 170 m³ tank, only 6 of 32 alarm zones operating, closed sprinkler valves, degraded emergency lighting, and an inoperative diesel pump. Interviews indicated that regulatory approval dominated developer acceptance, alongside cost and maintenance concerns. The findings support closed-loop post-occupancy assurance linking commissioning evidence, maintenance accountability, impairment reporting, and verification.

Index Terms - fire-safety systems; R2 residential buildings; handover conformity; operational availability; post-occupancy evaluation; facility management.

1. INTRODUCTION

Given the rapid growth in housing stock of Riyadh, the need for reliable fire protection in multi-residential units becomes evident. The protection systems of R2 buildings operate as life-safety features rather than approvals due to the presence of constantly changing people with different reaction abilities to an emergency situation.

The fire protection of multi-unit residential buildings according to the Saudi Building Code includes structural fire resistance, means of egress, detection and alarm, suppression, portable extinguishers, as well as ongoing inspection and maintenance [1-6]. Handover approval certifies the presence of necessary systems at a certain point of time. However, it does not guarantee their availability after the process of occupancy.

Both technical and organizational aspects of the issue will be explored in this research through one approved project in terms of the Civil Defense. It will allow comparing handover and a six-month inspection of a building, as well as collecting developer's opinion about the approval. Studies, which deal with a similar problem, use post-occupancy evaluation of a building to compare its performance to stated criteria and apply observation, documentation, and key-informants evidence to explore fire-safety problems [7-10].

Residential fire audit provides the most relevant empirical precedent. For instance, in their study of three occupied high-rise residential buildings, Akashah et al. found insufficient or damaged firefighting equipment, blocked evacuation routes, and limited occupant training [11]. Another integrated assessment of three residential buildings showed the role of regular maintenance and property fire management in ensuring the reliability of a system [12].

Recent research supports the idea of a lifecycle approach to fire safety issues. According to dynamic risk modeling, there are interactions between technical, human, and organizational factors which develop in time [13]. Inspections, enforcement, and building management are proved to be crucial factors affecting safety of high-rise residential buildings in the Gulf region [14]. Multi-building risk models emphasize transparency and repeatability of criteria [15,16,17]. Recent failure-analysis studies further show that cracking and corrosion in fire-water pipelines, together with damage in pressurized extinguisher cylinders, can compromise the reliability of installed fire-protection equipment and support condition-based inspection [25–27].

2. Problem Statement and Significance

There is a scarcity of Saudi-based applied evidence concerning the continuing performance of fire safety systems for residential buildings. However, international research has analyzed the deficiencies in active and passive fire safety measures for occupied buildings and highlighted the importance of testing, document triangulation, and post-occupancy evaluations [7–9,11,12]. In addition, dynamic and life-cycle assessments have shown that technical condition, maintenance, organizational control, and recurrent verification should be taken into account [13–17]. Qualitative assessments of fire safety have also been based on a limited number of professional informants in interpreting the stakeholder choices; however, the results were viewed as indicative, not statistical [10]. The specific research gap under discussion is concerned with the within-project transition from conformity documented at the handover stage to availability after six months along with the acceptance by the developers.

The present study offers a documented and time-related case study, not prevalence estimation. Practically, the study reveals the controls that allow maintaining the operational effectiveness after the compliance approval. Analytically, the study preserves three different constructs: documentary conformity at handover, technical availability after occupancy, and themes of qualitative acceptance reported by the project stakeholders.

Two closely related studies are particularly useful for positioning the present contribution. Meacham [18] frames post-occupancy fire safety in existing residential buildings as a whole-of-life regulatory and sociotechnical problem, whereas Moinuddin and Thomas [19] quantify sprinkler reliability using physical survey data from 26 Australian high-rise office buildings and fault-tree analysis. Table 1 distinguishes those contributions from the matched within-project comparison used here.

Table 1. Positioning of the present study against two closely related fire-safety studies

Study	Design / scope	Relevant finding	Difference from the present study
Meacham (2023) [18]	Targeted literature review and systems framing of fire safety in existing residential buildings.	Post-occupancy use, modification, maintenance and reduced oversight can increase fire risk over the building life cycle.	Conceptual/regulatory analysis; it does not quantify a matched handover-to-follow-up change within the same project.
Moinuddin & Thomas (2014) [19]	Physical survey of wet-pipe sprinkler systems in 26 Australian high-rise office buildings plus fault-tree analysis.	Sprinkler reliability can be reduced by system isolation during tenancy changes and by out-of-specification sprinkler heads.	Strong empirical reliability study, but it addresses one subsystem across separate buildings rather than several subsystems over time in one complex.
Present study	Longitudinal documented case of 26 R2 buildings (312 units) in one interconnected residential complex; matched seven-subsystem comparison at handover and six months.	Matched documentary conformity was 94.5%, versus 24.0% six-month operational availability, a 70.5-percentage-point descriptive gap.	Within-project, multi-subsystem temporal comparison supported by auditable handover and follow-up records; it is a case study, not a prevalence estimate.

Accordingly, the contribution of the present study lies in its documented within-project, multi-subsystem temporal comparison, in which the same subsystem definitions and weights are applied to distinguish handover documentary conformity from operational availability six months later.

3. Objectives and Research Questions

3.1 Objectives

1. Assess documented conformity and in-use effectiveness of the fire-safety systems in the selected R2 residential project.
2. Compare the handover record with the measured system condition six months after occupation.
3. Examine developer acceptance qualitatively and identify the factors reported to influence it.
4. Propose a safety-assurance framework that links handover, operation, maintenance, and post-occupancy verification.

3.2 Research Questions

1. What level of documentary conformity was recorded at handover?
2. What level of operational availability was measured six months after handover?
3. What acceptance themes were reported by the developer and consultant, and how may they help interpret the technical findings?
4. What framework could reduce the gap between handover conformity and continuing effectiveness?

4. Reference Framework

This evaluation is based on the Saudi Building Code and the relevant NFPA codes as listed in Table 2 below. The technical codes specify the expected protective functions whereas the project documents provide the available evidence at handover and six months after that.

Table 2. Reference codes and standards

Reference	Scope and role in the study
SBC 801	Fire-protection requirements for residential buildings
SBC 201	R2 occupancy, construction type, and fire resistance
NFPA 72	Fire alarm and signaling
NFPA 13	Automatic sprinkler installation
NFPA 10	Portable extinguisher distribution and spacing
NFPA 101	Means of egress and life safety
Project records S1–S5	Handover and six-month case evidence

5. Case Description (the Project)

The project is located in Al-Narjes, northern Riyadh, in plan 3236/3 covering an area of 26,793 m2. The project consists of 26 residential buildings including 13 paired plots with a shared parking basement of approximately 24,372 m2 [20,23]. Upon visually inspecting the approved plans of the project, two patterns of building design can be observed; one pattern consists of 10 apartments (4 ground floor, 4 first floor, and 2 second floor), and another pattern consists of 14 apartments (4 ground floor, 4 first floor, 4 second floor, and 2 annex/roof floor apartments). Thus, the recorded total of apartments becomes 312 residential units, not the number of occupied families [20, Sheets 2–5]. The systems of the project were designed and supervised by Abdul Wali Al-Yahya Engineering Consulting (license 212) company, installed by Aljawhara Aldaema Contracting company, and approved in 2024. The project type is classified as R2 (light hazard), Type I-A [21-23].

Shared basement and shared fire-water system, pumps, alarm systems, and ventilation systems make the entire building complex interconnected. Therefore, a failure in such a system may lead to loss of protection for several buildings. Hence, the post-handover assessment considers maintenance management at the complex level instead of apartment level issues.

Table 3. Basic project data (per the approved acceptance documents)

Item	Details
Owner / developer	Dour Al-Shamal Real Estate
Location	Al-Narjes, north Riyadh; plan 3236/3
Land area	26,793 m²
Project configuration	13 paired plots; 26 residential buildings; shared basement
Residential units	312 units derived from S1 sheets 2–5: 13 × (10 + 14)
Floors	Drawings: ground, first, second, and roof/annex; shared basement
Occupancy / hazard	R2 permanent residential / light hazard
Construction type	Type I-A reinforced-concrete/block construction
Consultant / contractor	Abdul Wali Al-Yahya Consulting (Lic. 212) / Aljawhara Aldaema
Handover / follow-up	1 June 2024 / 1 December 2024
Approval	Civil Defense approved — 2024



Fig. 1. Conventional multi-zone fire-alarm control panel (from the project documents).



Fig. 2. Illuminated EXIT sign in a residential corridor (from the project documents).

6. METHODOLOGY

In a longitudinal and documented single-case study approach, an investigative post-occupancy evaluation that compares the actual building performance with the technical criteria was used [8,9]. Five technical documents were triangulated as follows: fire-fighting and alarm drawings (S1), installation-completion certificate (S2), safety systems acceptance certificate No. 2024/71 (S3), handover report dated 1 June 2024 (S4) and technical inspection report dated 1 December 2024 (S5) [20–24]. Values, test statements, and configurations were validated not only textually but also visually in comparison with the rendered documentation. The qualitative part of the study has remained unchanged in that there have been held two semi-structured key-informant interviews with individuals from the developer side and the project consultant. The purpose of these interviews was purely explanatory and included approval motives, system value perception, cost issues, sprinklers and maintenance responsibility rather than any numeric values for system acceptance. Resident interviews have not been performed.

The inspection was performed on 1 December 2024 by a multidisciplinary technical team led by a lead assessor, with qualifications in fire-safety and fire-protection, mechanical fire-suppression and electrical fire-alarm. The lead assessor had an active certificate of the CFPS on the inspection date. In order to maintain the blinded assessment, the name and the credential number of the lead assessor have not been presented. Redacted credential evidence can be provided confidentially to the editor. The professional credential supports assessor competence but was not used as a substitute for documentary or measured evidence. The field protocol included visual comparison with approved drawings, pump operation and pressure measurement, tank-level and water-quality checks, alarm-zone and manual-call-point testing, inspection of valves, hose cabinets, and extinguishers, and emergency-light and EXIT-sign testing under loss of mains power [24, pp. 1–2].

The two interviewees are reported by professional role only, and the analysis uses no identifying quotation or personal data. Interview evidence was retained only when it clarified the interpretation of the documented technical sequence; it did not replace a missing measurement, inspection record, or project document.

For the retrospective handover re-audit, ten safety domains were scored using one uniform documentary rule: 100% when installation or required provision, conformity, and functional evidence were explicit and internally consistent; 95% when

conformity and functioning were explicit but retained raw test measurements were incomplete; and 90% when acceptance was categorical while important configuration or performance detail remained incomplete or unreconciled. The domains were equally weighted because the handover records contained no validated differential weighting model. The resulting values—four domains at 100%, three at 95%, and three at 90%—sum to 955 points; 955/10 = 95.5%, rounded to approximately 96%. This is therefore a reconstructed documentary conformity score, not a direct measurement of occupied-building effectiveness. At six months, operational effectiveness was taken from S5's seven-subsystem weighted calculation and independently reproduced as 24.0% [24, p. 5]. Interview notes were analyzed thematically and were not converted to percentages.

To permit a like-for-like comparison with the six-month calculation, the handover evidence was also reconstructed for the same seven subsystems and with the identical weighting scheme used in S5: fire pumps/pump room (20%), fire-water tank (10%), sprinkler network/valves (20%), alarm and detection (20%), hose cabinets/reels (10%), portable extinguishers (10%), and emergency lighting/EXIT (10%). The retained handover evidence supports documentary scores of 90%, 90%, 95%, 95%, 95%, 100%, and 100%, respectively; because Table 4 treats fire pumps and water storage as one combined handover domain, its 90% score was applied to both corresponding S5 subsystems solely for this matched reconstruction. The resulting weighted contributions are 18.0, 9.0, 19.0, 19.0, 9.5, 10.0, and 10.0 percentage points, giving a matched seven-subsystem handover score of 94.5%. This matched reconstruction is a documentary benchmark rather than a contemporaneous measurement of operational availability at handover.

7. RESULTS

7.1 Compliance at Handover (as designed)

Table 4 presents the reconstructed handover score. The mean is 95.5%, reported as approximately 96%. The number is reproducible from the stated rule and the ten displayed domain scores, but it should be interpreted as the strength of the documented conformity evidence at handover. It is not equivalent to a field measurement of system availability after occupation.

Table 4. Retrospective documentary conformity score at handover

System domain	Documented handover evidence	Score	Interpretation
Structural fire resistance	Type I-A; stated fire-resistance provisions	100%	Explicit and consistent
Portable extinguishers	Powder units; ≤22.9 m spacing; signage	100%	Explicit and consistent
Emergency and exit lighting	Emergency units and illuminated EXIT signs	100%	Explicit and consistent
Means of egress	Two exits per floor and protected routes	100%	Explicit and consistent
Automatic sprinklers	Installed, tested, and reported efficient	95%	Conforming; raw test data incomplete
Hose cabinets / standpipes	Indoor/outdoor cabinets and 30 m hose	95%	Conforming; raw test data incomplete
Detection and alarm	Conventional zoned system tested and accepted	95%	Conforming; raw test data incomplete
Fire pumps / water storage	Accepted; configuration/capacity records differ	90%	Categorical acceptance; detail unreconciled
Basement ventilation	Accepted; drawing/report airflow values differ	90%	Categorical acceptance; detail unreconciled
Evacuation / operation plan	Plan included in approved drawing set	90%	Accepted; implementation evidence limited
Mean	Equal weighting: 955 ÷ 10	95.5% ≈ 96%	Retrospective documentary score

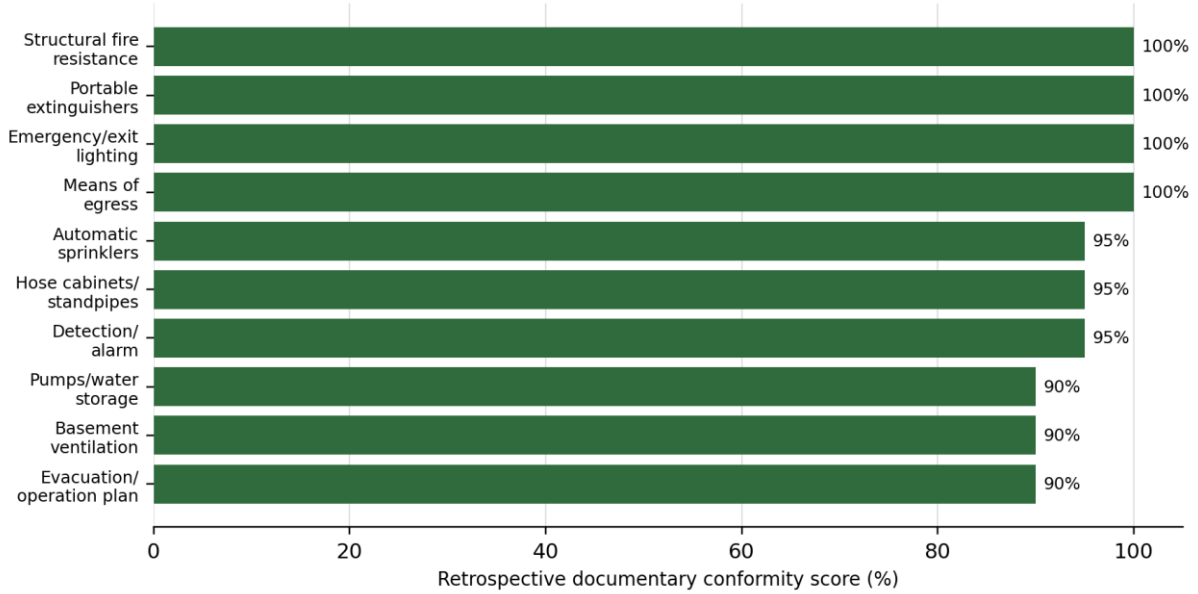


Fig. 3. Retrospective handover documentary score by system (mean = 95.5%, reported as approximately 96%).

7.2 System Readiness and Operational Responsiveness

The installation-completion and acceptance records state that the suppression and alarm systems were installed, tested, and conforming at handover [21–23]. Table 5 places that categorical baseline beside the six-month operational values reported in S5. For the matched quantitative comparison, the same seven subsystems and identical weights yield the reconstructed handover benchmark of 94.5% described above. The six-month weighted calculation is 3.00 + 2.50 + 4.00 + 3.60 + 3.00 + 4.50 + 3.40 = 24.00% [24, p. 5].

Table 5. Handover evidence and six-month operational availability

System	Handover evidence	Six-month availability	Weighted contribution
Fire pumps / pump room	Accepted as operating	15% (weight 20%)	3.00
Fire-water tank	≥170 m³ reference; accepted	25% (weight 10%)	2.50
Sprinkler network / valves	Tested and reported efficient	20% (weight 20%)	4.00
Alarm and detection	Tested and reported in good condition	18% (weight 20%)	3.60
Hose cabinets / reels	Installed and ready	30% (weight 10%)	3.00
Portable extinguishers	Spacing and signage accepted	45% (weight 10%)	4.50
Emergency lighting / EXIT	Installed at handover	34% (weight 10%)	3.40
Overall	Categorically conforming	— (weight 100%)	24.00%

7.3 Operational Effectiveness After Occupancy and the Gap

Six months after handover, S5 documented an overall weighted operational availability of 24.0%. For the like-for-like comparison, the same seven subsystems and the same weighting scheme produced a reconstructed handover documentary benchmark of 94.5%, giving a matched descriptive gap of 70.5 percentage points. The broader ten-domain documentary conformity score remains 95.5% and is reported separately in Table 4. The matched handover benchmark is still documentary rather than a field measurement of operational availability; nevertheless, comparison of the same subsystem set and weights shows how little continuing protection can be inferred from handover approval alone. The principal documented mechanisms were:

1. Alarm impairment. Only 6 of 32 alarm zones were functional (18.75%, reported as 18.8%); cut wiring, disconnected zones, and missing detector heads were recorded [24, p. 4]. The report links part of this impairment to post-handover finishing work but does not identify every responsible person.
2. Late preventive maintenance: S5 had late preventive maintenance, poor batteries, leaking, and absence of periodic documentation for certain systems (see [24], pp. 2–6).
3. Lack of governance on shared systems: Despite the presence of a contract for operation and maintenance, problems such as closed valves, pump defects, lack of documentation, and delayed remediation still occurred. It appears that there is a problem of implementation and accountability, rather than total lack of responsible entity.
4. Tampering after hand-over: Examples of this include closed sprinkler valves, tampered sprinklers through painting and obstruction, modification of alarm wiring, and usage of hose cabinets as cleaning stations [24, pp. 4–6].

5. Decreased water storage and pumping capability: The network pressure was 2 bar, while it should have been 7–9 bar; the water tank had 42.5 m³ water out of the designed 170 m³; the diesel pump was not working; and the electric and jockey pumps were faulty [24, pp. 2–3].

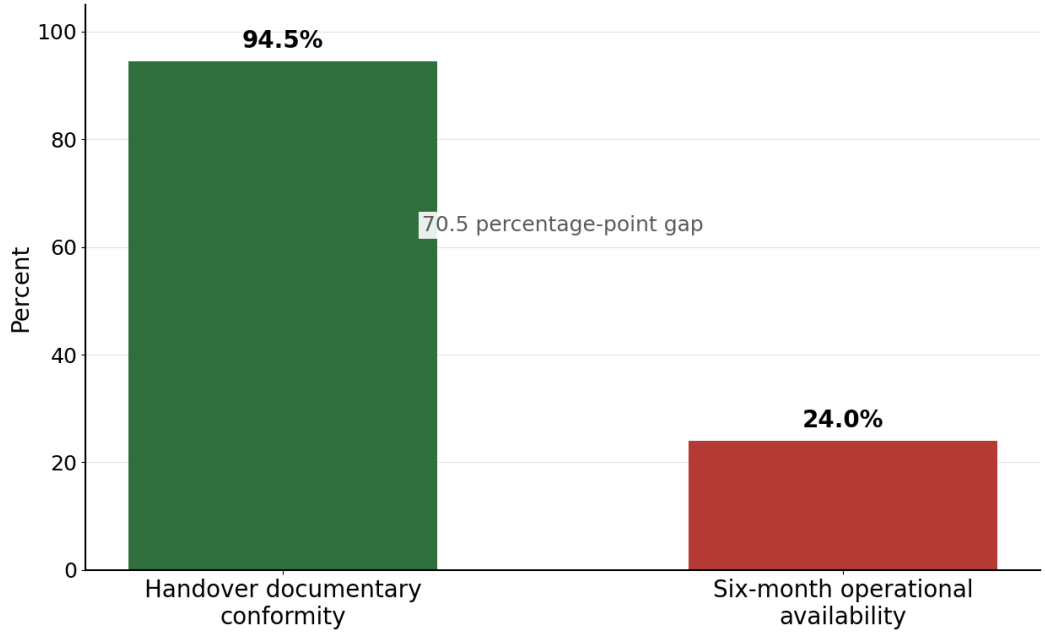


Fig. 4. Matched descriptive gap between the reconstructed seven-subsystem handover benchmark (94.5%) and six-month weighted operational availability (24.0%).

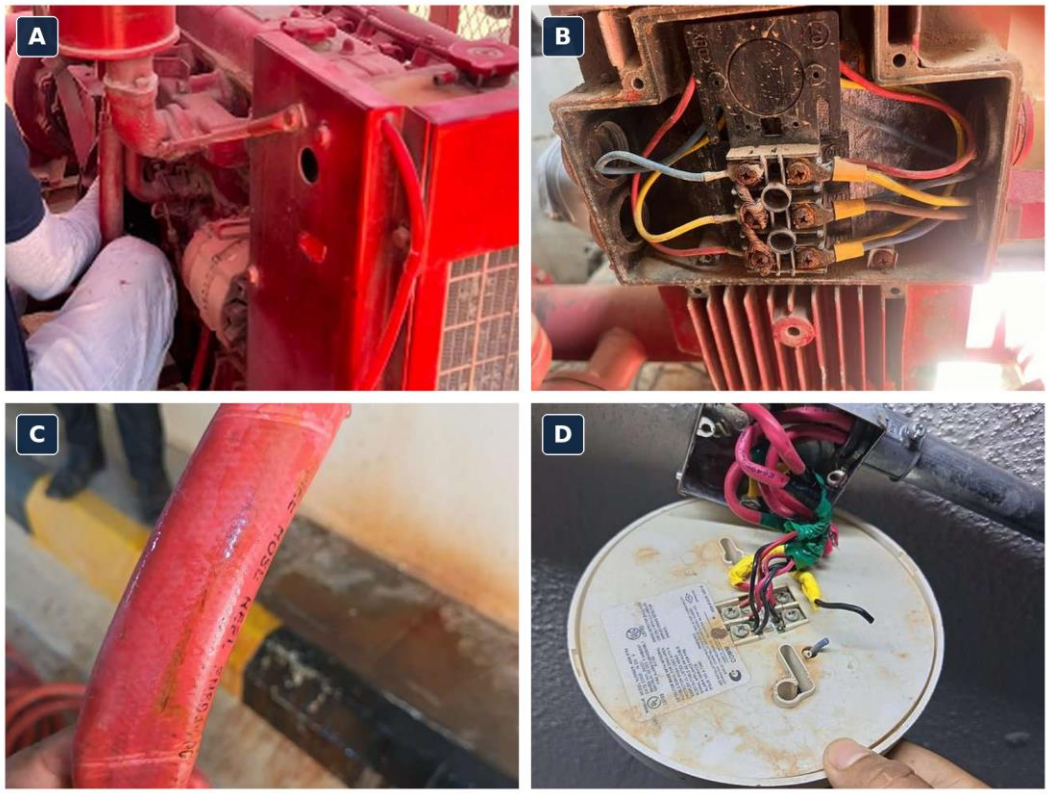


Fig. 5. Examples of documented six-month impairments: (A) diesel-pump motor recorded as inoperative; (B) corroded and exposed electrical junction box; (C) deteriorated hose with evidence of non-firefighting use; and (D) detector base with disconnected wiring (S5, pp. 2, 3, and 5).

7.4 Real-Estate Developer Acceptance

Regulatory approval turned out to be the factor that played the dominant role in determining the acceptability of the fire safety systems by the developer. The other issues that were discussed during key-informant interviews included cost considerations and the rejection of automatic sprinklers in the dwellings on the grounds that their presence was unnecessary and doubts about the maintenance of the shared system. These factors are used to analyze the technical trajectory and not to attribute a certain acceptance rate or claim that the developers' decision-making process was based only on licensing concerns. Technical documents confirm the presence of the operation-and-maintenance contract and reveal that the maintenance work was not satisfactory [24].

8. DISCUSSION

The main finding highlights the significant difference between the handover document and the current occupied building status. The matched seven-subsystem handover benchmark using the same subsystem set and weights as S5 was 94.5%, while S5

documented weighted operational availability of 24.0% at the six-month interval, giving a matched difference of 70.5 percentage points. The broader retrospective ten-domain documentary audit was 95.5% and is reported separately as contextual handover evidence. It corresponds to the findings in post-occupancy evaluation literature where return visits are viewed as crucial elements along with the comparison against specific criteria in order to ascertain the fitness-for-purpose of the completed building [8,9]. Similarly, fire-protection audit literature points out the necessity of regular testing and maintenance of the installed equipment since its deficiencies could be hidden until the inspection [7].

The present results also connect directly with these two fire-safety precedents. Meacham [18] identifies loss of oversight, maintenance control and management of modifications after occupancy as a systems-level weakness in the fire safety of existing residential buildings; the present case provides a documented six-month example of how that lifecycle concern can coincide with a marked reduction in operational availability. Moinuddin and Thomas [19] found that sprinkler-system reliability in high-rise offices can be affected by zone isolation during tenancy changes and by sprinkler-head deficiencies. In the present complex, the related readiness problem is broader: closed sprinkler valves occurred alongside pump, water-storage, alarm, hose-cabinet and emergency-lighting impairments. The comparison therefore supports a multi-system post-handover verification approach rather than reliance on a single-system or approval-stage indicator.

There is the evidence for the combination of the technical and organizational explanations. S5 directly describes the post-handover modifications, misuse, delayed maintenance, missing logs, shut-off valves, and impaired equipment. The interview data provide more specific context of regulatory approval having been of higher importance compared to the current operational significance. However, it would be an exaggeration to conclude on the only motive or to blame the residents or the developer for all the defects. In the same way, the assumption that the owners give priority to visible daily services, such as plumbing and air conditioning, over the rarely used safety systems, is the interpretation of a researcher of the observed result and has not been empirically verified in this case.

Therefore, the case shows an assurance issue rather than an installation issue. Initial conformity, contractual existence, and later equipment availability are separate phenomena. Bridging the gap needs test evidence, maintenance accountability chain, impairment notification, and post-occupancy re-inspection. No economic efficiency conclusion can be provided since there is no information in the supplied project records that would confirm the previously mentioned approximate cost. This system-level interpretation complements component-focused investigations of fire-water pipelines and high-pressure extinguishers, which demonstrate how material and service-condition failures can undermine readiness even when the equipment remains nominally installed [25–27].

The most similar field publication is the study by Akashah et al. in Kuala Lumpur [11] where structured on-site checklist was used in three occupied residential buildings and revealed numerous deficiencies in equipment and management. The present case is more geographically focused and cannot estimate the prevalence; however, it provides a time-based comparison in the same complex: accepted handover documentation goes with the reinspection done in six months. Such design allows observing post-handover changes without claiming that two percentage values are the same concepts. In related failure-analysis literature, Knyziak et al. examined a disproportionately extensive fire in a reinforced-concrete building during construction [28]; the present study instead evaluates the degradation of active fire-safety provisions after handover and before a fire event.

The observed pattern corresponds to the models that take into account the property management, human and organizational factors, and condition of the system over time [12,13]. The literature on the Gulf region and multi-building studies confirms the necessity of recurring inspections and clear indicators [14,15]; lifecycle and monitoring models support the proposed closed-loop assurance [16,17]. Thus, the case provides the empirical and procedural contribution: it demonstrates how the approval record, later field inspection, and limited stakeholder evidence can be triangulated without substitution of certification, professional judgment, and interviews for facts.

9. Proposed Framework to Close the Gap

Building on the results from above, the following framework is developed to track the development of the project through occupied operation. The aim is to preserve the focus of the original research on both technical efficacy and stakeholder acceptability, but to anchor each recommendation in observations made in the case study.

1. Beginning safety considerations from the outset of design. Consider SBC and NFPA standards, make provision for accessible maintenance, implement system isolation measures, and determine post-handover responsibilities before construction begins.
2. Retaining evidence of functionality. Save calibrated pump test results, pressure levels, alarm zone results, valve status, and approved final configuration data as part of the handover documentation package.
3. Ensuring ongoing effectiveness in occupied operation. Tie in the maintenance contract to scheduled testing, impairment reports, repair schedules, and verification by independent third party.
4. Managing shared facilities at the complex level. Transfer control over shared basement facilities, pumps, tank, alarm interface, and maintenance data to the property owners' association or similar governing body.
5. Applying appropriate tamper-proofing measures. Install tamper switches and device status notification were warranted by economics and technology, as well as resident awareness and evacuation drills.

10. Conclusion, Recommendations, and Limitations

10.1 Conclusion

This case study of 26 R2 buildings has shown that there is a significant gap between the handover conformity and operational efficiency. The matched seven-subsystem reconstruction using the same subsystem set and weights as the six-month assessment produced a handover documentary score of 94.5%, while the six-month technical report gave an easily reproducible weighted availability of 24.0%, corresponding to a matched gap of 70.5 percentage points. The broader retrospective ten-domain audit produced 95.5% (about 96%) and is reported separately as contextual handover evidence. There are approved drawings that show 312 residential units located in two building types that repeat each other. Technical deterioration is related to improper pressure and water storage, failure of the pump, loss of capability of alarm zones, closed valves, misuse of equipment, and degraded emergency lighting. According to interviews, developer compliance played the main role, but they do not confirm the assignment

of each further deficiency to a particular stakeholder and their motivation. It means that the safety will be ensured only through a closed loop of assurance.

10.2 Recommendations

1. Implementation of Monitored and Tamper-Resistant Controls should be undertaken selectively, specifically where valve-position monitoring, alarm-zone supervision, device status, and digitized maintenance records are warranted by the outcome of a technical and economic assessment of the project.
2. Maintenance of Systems should be continuous and should be evidenced by the existence of an updated contract which identifies the party responsible for maintenance; this will be through weekly log keeping and action plans for impairments.
3. Approval process for controls should relate to post occupancy verification in terms of carrying out a functional inspection after occupancy and retaining of measurements for pumps, water systems, alarm zones, emergency lighting, and valves.
4. Technical controls should be complemented by User Awareness in terms of highlighting the impact of valve closure, interference with sprinkler system, cutting off the alarm system, and use of hose cabinets.

10.3 Limitations

Six limitations of the study exist. Firstly, the research is conducted in one specific residential complex and calls for analytical but not statistical generalization. Secondly, both the 95.5% ten-domain handover score and the 94.5% matched seven-subsystem handover score are retrospective documentary reconstructions based on the author's three-level criterion; they are transparent and replicable but are not validated universal compliance or availability indices. Thirdly, the two key informant interviews provide the contextual interpretation and are not representative of all developers, consultants, owners or residents. Fourthly, the records supplied do not prove the previously mentioned project cost estimate and thus do not allow assessing the cost effectiveness. Fifthly, the source set contains some documentary contradictions: drawings show the 340 m^3 tank, diesel pump, 291,665 CFM basement ventilation calculation and layout of the second floor, and longitudinal reports mention the 170 m^3 tank, one instance of 10,000 CFM fan, and different summarization of the floor layouts. Six-month calculations use the explicit S5 denominators, which makes the inference between the design and installation impossible and needs to be addressed in the documentation. Lastly, the inspection is done by the author. Although the professional qualifications of the lead assessor, multidisciplinary team, photographs, measurements and replicable calculations increase the credibility of the technical part of the paper, they do not remove any possible bias.

11. SUPPLEMENTARY MATERIAL

This accompanies the attached paper which contains the following project records: Supplementary File S1: Fire-fighting, fire alarm, and life safety system plans (15 sheets); S2: Certificate of completion for installation; S3: Safety systems acceptance certificate #2024/71; S4: Safety systems transfer report (8 pages); and S5: Technical inspection report #JET-SR-2024-118 after 6 months (6 pages).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Mohammed Hussien Ali ElHaggar: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing, Project administration.

Data availability

The documentary evidence supporting this study is provided in Supplementary Files S1–S5. De-identified interview materials are not publicly available because they contain confidential professional information, but they may be made available to the editor on reasonable request, subject to applicable permissions.

Ethics approval and informed consent

Verbal informed consent was obtained from both participants before the interviews and was documented in the interview records.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used OpenAI ChatGPT to assist with language editing, condensation of the abstract, preparation of submission materials, and formatting. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

References

[1] Saudi Building Code National Committee, Saudi Fire Code (SBC 801-CR-18), 2018.
[2] Saudi Building Code National Committee, Saudi Building Code—General (SBC 201-CR-18), 2018.
[3] National Fire Protection Association, NFPA 72: National Fire Alarm and Signaling Code, 2013 ed., Quincy, MA, 2013.
[4] National Fire Protection Association, NFPA 13: Standard for the Installation of Sprinkler Systems, 2013 ed., Quincy, MA, 2013.

[5] National Fire Protection Association, NFPA 10: Standard for Portable Fire Extinguishers, 2013 ed., Quincy, MA, 2013.
[6] National Fire Protection Association, NFPA 101: Life Safety Code, 2015 ed., Quincy, MA, 2015.
[7] Z. Djunaidi, N.A.A. Tuah, G. Rafifa, Analysis of the active and passive fire protection systems in the government building, Depok City, Indonesia, KnE Life Sci. 4 (5) (2018) 384-398. https://doi.org/10.18502/kls.v4i5.2569.
[8] I.O. Durosaiye, K. Hadjri, C.L. Liyanage, A critique of post-occupancy evaluation in the UK, J. Hous. Built Environ. 34 (2019) 345-352. https://doi.org/10.1007/s10901-019-09646-2.
[9] M. Al Mughairi, T. Beach, Y. Rezgui, Post-occupancy evaluation for enhancing building performance and automation deployment, J. Build. Eng. 77 (2023) 107388. https://doi.org/10.1016/j.jobe.2023.107388.
[10] B.G. Olsø, R. Stølen, R.F. Mikalsen, N.S. Bunkholt, K.L. Friquin, J. Hjertnes, Factors affecting the fire safety design of photovoltaic installations under performance-based regulations in Norway, Fire Technol. 59 (2023) 2055-2088. https://doi.org/10.1007/s10694-023-01420-9.
[11] F.W. Akashah, T.K. Baaki, S.P. Lee, Fire risk assessment of low-cost high rise residential buildings in Kuala Lumpur: A case study, J. Des. Built Environ. Special Issue 2017 (2017) 124-139. https://doi.org/10.22452/jdbe.sp2017no1.11.
[12] H. Mi, Y. Liu, W. Wang, G. Xiao, An integrated method for fire risk assessment in residential buildings, Math. Probl. Eng. 2020 (2020) 9392467. https://doi.org/10.1155/2020/9392467.
[13] S. Tan, D. Weinert, P. Joseph, K.A.M. Moinuddin, Incorporation of technical, human and organizational risks in a dynamic probabilistic fire risk model for high-rise residential buildings, Fire Mater. 45 (2021) 779-810. https://doi.org/10.1002/fam.2872.
[14] M. Omar, A. Mahmoud, S.B. Abdul Aziz, Critical factors affecting fire safety in high-rise buildings in the Emirate of Sharjah, UAE, Fire 6 (2) (2023) 68. https://doi.org/10.3390/fire6020068.
[15] L.-N. Zhang, X.-M. Wang, J. An, H.X. Li, J.-Q. Guo, G.-B. Han, P.-F. Gou, A fire risk pre-warning framework for high-rise buildings based on unascertained method, Environ. Sci. Pollut. Res. 31 (2024) 61912-61926. https://doi.org/10.1007/s11356-024-35396-y.
[16] H. Frantzich, M.S. McNamee, E. Kimblad, B.J. Meacham, Decision support framework for sustainable and fire resilient buildings (SAFR-B), Fire Technol. 61 (2025) 213-246. https://doi.org/10.1007/s10694-024-01678-7.
[17] U.I. Abdullahi, W. Zhang, Y. Cao, G. Irankunda, Integrating IoT technology for fire risk monitoring and assessment in residential building design, Buildings 15 (8) (2025) 1346. https://doi.org/10.3390/buildings15081346.
[18] B.J. Meacham, Fire safety of existing residential buildings: Building regulatory system gaps and needs, Fire Saf. J. 140 (2023) 103902. https://doi.org/10.1016/j.firesaf.2023.103902.
[19] K.A.M. Moinuddin, I.R. Thomas, Reliability of sprinkler system in Australian high rise office buildings, Fire Saf. J. 63 (2014) 52–68. https://doi.org/10.1016/j.firesaf.2013.11.009.
[20] Project consultant, Approved fire-fighting, fire-alarm, and life-safety drawings for the R2 residential complex, plan 3236/3, Al-Narjes, Riyadh (15 sheets), Supplementary File S1, 2024.
[21] Aljawhara Aldaema Contracting, Installation-completion certificate for fire-fighting and fire-alarm systems, Supplementary File S2, 1 June 2024.
[22] Project consultant, Safety-systems acceptance certificate No. 2024/71, Supplementary File S3, 1 June 2024.
[23] Project consultant, Safety-systems handover report, R2 residential complex, Al-Narjes, Riyadh (8 pages), Supplementary File S4, 1 June 2024.
[24] Innovative Tomorrow (JET), Technical report on the current condition of fire-prevention and protection systems, Report No. JET-SR-2024-118 (6 pages), Supplementary File S5, 1 December 2024.
[25] Z. Xia, Y. Huang, J. Zhong, K. Guan, Cracking failure analysis on a high-frequency electric resistance welding pipe in buried fire water pipeline, Eng. Fail. Anal. 146 (2023) 107072. https://doi.org/10.1016/j.engfailanal.2023.107072.
[26] X. Liu, N. Li, J. Zhang, W. Liu, Y. Wang, Y. Song, K. Dong, Y. Cai, E.-H. Han, Failure analysis of leaking firefighting pipeline used in nuclear power plant: Corrosion development process and key influence factors, Eng. Fail. Anal. 161 (2024) 108341. https://doi.org/10.1016/j.engfailanal.2024.108341.
[27] J.L. González-Velázquez, D.I. Rivas-López, M.A. Beltrán-Zúñiga, S.J. García-Núñez, Failure analysis of high-pressure fire extinguisher, Eng. Fail. Anal. 162 (2024) 108448. https://doi.org/10.1016/j.engfailanal.2024.108448.
[28] P. Knyziak, R. Kowalski, M. Głowacki, J.R. Krentowski, disproportionately wide range of fire in a RC building during construction stage, Eng. Fail. Anal. 137 (2022) 106260. https://doi.org/10.1016/j.engfailanal.2022.106260.