

Operational Control of Keying Systems in Large High-Rise Building Projects

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Abstract:

Large high-rise projects routinely treat keying as a late closeout task, yet turnover failures often originate from earlier breakdowns in traceability, interface compatibility, and emergency-access alignment. This paper presents an anonymized coastal Florida high-rise case study demonstrating how mechanical keying can be managed as an operational control system spanning life-safety intent, security intent, and daily building operations. The project involved approximately 65–70 residential units, roughly 512 hollow metal openings, 14 elevators organized into seven elevator banks, and an AHJ-approved rapid-entry lockbox program totaling 32 boxes. A two-track architecture was adopted: a building-controlled hierarchy (Grand Master and Security/Master with seven operational subcategories) and unit keys maintained as Single-Keyed-Different (SKD). Execution was governed through a single tagged tracker linking opening identity, room logic, keying intent, and subcontractor coding, enabling “install-to-tracker” verification in the field. Observed installation-phase breakdowns were categorized into (i) cylinder–lock interface incompatibility at electrified unit access, (ii) finish-driven cylinder length misfit, and (iii) unit-level traceability slips causing SKD mismatches, with corrective actions standardized to prevent uncontrolled swaps. Turnover controls included auditable key packaging, custody transfer, construction-key retirement, phased credential activation, and lockbox contents rules that preserved emergency access without expanding key footprint. The case demonstrates that disciplined governance and verifiable identity control, not a more complex hierarchy, is the decisive factor in turnover readiness and emergency entry reliability.

Keywords: high-rise construction; master keying systems; keying hierarchy; construction keying (breakout); rapid-entry lockbox (Knox-type); life-safety egress; access control integration; turnover management; traceability control; cylinder–lock interface compatibility; Single-Keyed-Different (SKD) keys; Florida Building Code.

Note— This case study is anonymized. Project and company names, locations, permit numbers, and other identifiers have been removed to honor confidentiality and contractual obligations. Figures and field artifacts (e.g., photos, key schedules, tracker excerpts) are de-identified, with logos, serial numbers, stamps, and signatures cropped or blurred as needed. These edits do not affect the technical substance, control logic, calculations, or conclusions.

I. INTRODUCTION

On turnover morning, the unit is “done.” Punch is cleared. Paint is dry. The property management team is on-site to receive the keys and start the handover flow. Someone tries the entry key, and it does not turn. A second key does not turn either. The door is not stuck. The lock is not broken. The key simply does not match the cylinder. In the next ten minutes, the problem multiplies: security asks for a working key to secure the lobbies, the owner’s rep asks why a finished unit cannot be accessed, and the superintendent asks whether the whole building has the same problem. What looked like a single lockout becomes an operational threat. Turnover cannot proceed without reliable access, and “reliable access” is not a feeling. It is a controlled system.

That is the real identity of keying on large high-rise projects. Keying is not locksmith work. It is an operational control system that sits at the intersection of life safety, security, and building operations. In a high-rise, a key is not only a piece of metal. It is permission, liability, and continuity. The wrong key can stop turnover. The

wrong hierarchy can create a security hole. The wrong locking approach can conflict with the intent of the egress system. This paper treats keying as a disciplined project deliverable, not as a late-stage accessory.

A. Why keying fails at scale:

Keying failures on large projects are not mysterious. They are predictable outcomes of fragmentation. The door schedule evolves. Hardware sets get revised. Procurement happens in batches. Field substitutions occur when material is delayed or damaged. Electrified hardware decisions arrive late when access control scope is finalized. Meanwhile, keying information often lives in disconnected places: an Excel tracker, a door schedule PDF, a hardware submittal, a locksmith email, and field “workarounds” that never make it back into the record. The failure mechanism is usually a traceability break. A door ID no longer matches the hardware set. A hardware set no longer matches the cylinder format or length. A cylinder no longer matches the key code stamped on the tag. A key code no longer matches the current keying matrix version. Each break is small by itself. Together, they create key chaos: mismatched cylinders, wrong key levels, and doors that work only because someone swapped cylinders “to make it work” [1]. Those swaps are not fixes. They are undocumented design changes made in the field, and they are the fastest path to losing control of the system.

Three patterns show up repeatedly on high-rise work:

- 1) *Schedule drift:* Door functions and locations change, but the keying matrix does not.
- 2) *Substitution pressure:* A delayed lockset or cylinder triggers a substitute that is “close enough,” and then the keying hierarchy quietly changes.
- 3) *Weak governance:* Committee-driven decision making tends to degrade hierarchical key control unless a single accountable authority owns final approvals.

B. Why it matters: life safety, security, and operations:

Keying carries a unique risk profile because it touches both safety intent and security intent at the same time. Life safety requires doors in the means of egress to be openable from the egress side without needing a key or special knowledge, except in specific permitted cases [10]. Florida Building Code captures this intent clearly in the door operation requirements for egress doors.

Security pulls in the opposite direction. Owners and property managers want controlled access to critical spaces: stairs, service lobbies, equipment rooms, trash rooms, amenity back-of-house, and staff-only corridors. Convenience pulls in yet another direction. Property management needs a system that can be operated daily without turning operations into a scavenger hunt. Every additional key increase friction. Every reduction in key diversity can increase exposure. This is why keying is directly proportional to security and indirectly proportional to convenience. The more security you demand, the more structure and restriction you introduce. The more convenience you demand, the more you consolidate. Without a disciplined hierarchy, consolidation becomes carelessness.

Operations makes the consequences visible. Turnover requires keys in hand, not later. “We will fix it after TCO (Temporary Certificate of Occupancy)” is not a plan when residents, vendors, inspectors, and emergency responders must navigate the building immediately [13]. In practice, the keying system becomes the building’s access language. If that language is inconsistent, every department speaks a different dialect, and the building runs on translation errors.

C. Timing - keying starts at submittals, but it becomes real at turnover:

Keying is often treated as a closeout deliverable because keys are physically handed over at the end. That timing is deceptive. The keying system must be designed when hardware is being procured, because cylinders and cores are ordered, pinned, labeled, and shipped based on the approved hierarchy and the door schedule [1]. On large projects, hardware is not ordered one door at a time. It is ordered in controlled waves. That batching is efficient for procurement, but dangerous for keying unless the hierarchy is frozen, versioned, and traceable. This paper takes a direct position: the point of no return for keying is the door hardware submittal cycle, especially for hollow metal exterior doors and main unit entry doors. Those openings carry the highest operational risk because they shape perimeter security and unit access simultaneously. They also carry the highest coordination complexity because they are often tied to access control decisions, fire door requirements, and special use rooms. When keying is decided late, it is not “decided.” It is improvised.

Turnover is where the system is judged. Turnover includes not only unit keys, but also the operational keyset needed to run a high-rise like a living machine: garage remotes, mail room keys, mechanical and exterior cylinder keys, elevator-related keys (including fire-service keys), construction breakout keys, and access control credentials [7], [9]. If the project cannot produce a clean, auditable turnover package, the building opens with uncertainty embedded into daily operations.

D. Florida context - egress intent and emergency access intent:

Florida adds a clear boundary condition that large projects cannot ignore: egress must function as intended, and emergency access must be supported as intended. On the egress side, the Florida Building Code's door operation requirements reinforce that egress doors must be readily openable from the egress side without keys, tools, or special knowledge, except where specifically permitted [10], [15]. This means keying decisions cannot be made in a vacuum. A "secure" door that compromises egress intent is not secure. It is noncompliant risk disguised as security.

On the emergency access side, Florida Fire Prevention Code (FFPC) adopts NFPA 1 and NFPA 101 with Florida-specific amendments, and local authorities having jurisdiction (AHJs) commonly require rapid-entry lockboxes (often Knox) where access is restricted and fire department access is necessary [2], [4], [6], [12], [14].

Regardless of the specific model or local detail, the operational requirement is consistent: the emergency access system must stay aligned with the keying system [8]. If rekeying happens and the rapid-entry lockbox is not updated, the fire department has a box full of confidence and a handful of useless metal [8].

This is why keying must be coordinated with the life safety plan and path of egress, and why rapid-entry lockbox planning cannot be an afterthought. In high-rise work, emergency intent is part of the access architecture.

E. Gap - standards exist, but workflow discipline is missing:

Industry standards do not ignore keying. ANSI/BHMA A156.28 outlines recommended practices for mechanical keying systems, including the importance of a keying conference and disciplined key management [1]. The problem is not a lack of standards. The problem is that projects often do not operationalize them into a construction workflow that survives schedule changes, procurement waves, substitutions, and closeout pressures.

A standard can tell you what good key management looks like. It does not automatically give the project a control structure that prevents field swaps, preserves hierarchy integrity, and keeps records aligned with the installed condition. High-rise projects need more than definitions of GM (Grand Master key), MK (Master/Security key), and change keys. They need a traceable system that ties door identity to hardware identity to cylinder identity to key identity, and a governance model that controls how changes occur.

F. Contribution and scope

This paper contributes an operational workflow for controlling keying systems on large high-rise building projects, demonstrated through an anonymized field case study. The workflow is built around four practical principles:

- Keying is designed early, at the hardware submittal and procurement stage.
- Keying is governed, with a clear approval authority and version control.
- Keying is traceable, from door to hardware to cylinder to key to record.
- Keying is turnover-ready, including property management deliverables and emergency access alignment.

The case study follows the lifecycle of a high-rise keying system from planning through execution, including the creation of a grand master structure with security subcategories, the use of single-keyed-different (SKD) unit keys, the management of construction breakout keys, and the integration of electrified egress conditions and lockbox planning [1], [9], [10], [14]. It also documents common failure modes encountered in the field, such as cylinder mismatches, hierarchy errors, pinning or biting issues, and schedule drift between door schedules and keying matrices. The objective is not to describe ideal behavior. The objective is to show how

operational control is built under real project constraints, and how that control prevents key chaos at the moment it matters most: turnover.

II. CASE STUDY SETUP: PROJECT AND DOOR ECOSYSTEM

This case study comes from an anonymized coastal high-rise project in Florida where “keying” was not a late closeout item, but a system that had to survive procurement waves, design finish changes, and turnover pressure. The building is best understood as two overlapping worlds: the resident-facing world (units, lobbies, amenities) and the back-of-house world (service circulation, critical rooms, emergency functions). The keying problem lives in the overlap.

A. Project profile and access scale:

The project contained approximately 65–70 residential units, including 12–14 penthouse units, and a door scope where cylinders were required across two main populations:

- Approximately 512 hollow metal (HM) openings (dominant share of the building’s perimeter and BOH (Back of House) network, including service-foyer unit doors and other service-critical rooms, all requiring tight cylinder coordination).
- Approximately 65–70 wood unit-entry openings (primary resident entry doors from the public side, requiring cylinder coordination at turnover and alignment with the overall keying hierarchy).

Vertical circulation and daily operations created repeated access touchpoints:

- Fourteen elevators (7 passenger, 7 service) are grouped into seven elevator banks; each bank has a passenger lobby and an adjacent service lobby at grade.
- 7 trash rooms and 1 trash holding room at ground level, plus recurring BOH closets tied to unit operations (FA closets, electrical closets, trash rooms etc.) in service lobby zones on every floor.
- Building services and control spaces: 3 main electrical rooms, 1 emergency electrical room, fire command center, fire booster pump room, MDF room (Main Distribution Frame), plus public support areas (public bathrooms, janitor closet).
- Resident and support zones: 2 pool equipment rooms, valet parcel/valet storage, concierge, concierge storage, and one mail room serving all units.
- Resident amenities included spa/massage and a small restaurant (restaurant openings were part of the HM count).
- Administrative spaces: an admin suite/admin office with controlled-access doors supporting day-to-day property operations (included in the HM count)

This inventory matters because the project is not “512 doors.” It is 512 access decisions spread across different risk categories, users, and life-safety intent.

B. The door ecosystem (where keying complexity actually comes from)

On paper, keying looks like a hierarchy exercise. In the field, it is a door ecosystem problem: different doors exist for different reasons, and those reasons control what the keying system is allowed to do.

Hollow Metal (HM) doors concentrated the high-risk locations: stairs, service lobbies, trash rooms, equipment rooms, storage rooms, operational rooms, and BOH paths. These doors are security-sensitive because they protect infrastructure and circulation that staff and vendors use daily.

Unit entries concentrated turnover risk: if unit access fails, turnover stops. Units also carry repeat patterns that multiply errors fast: each unit has a service foyer and a foyer condition, with doors tied to controlled access. That means keying had to remain consistent not only across mechanical cylinders but also across the electrified access-control layer.

The system becomes fragile when the same “key” is expected to serve too many intents: resident comfort, staff operations, emergency access, and life-safety egress. That is why keying cannot be treated as a single trade task. It is coordination.

C. Circulation logic that forced early decisions (stairs, egress-only intent, penthouse layer)

In high-rise projects, keying decisions cannot be made solely by room names or stakeholder preferences [4], [10]. The building's life-safety circulation plan determines how occupants are expected to move during normal use and during emergencies, which directly affects door intent (routine access vs-controlled access vs egress-only behavior). Because stair, corridor, and BOH circulation often serve different user groups and emergency scenarios, the keying hierarchy must be planned early enough to align with door functions and any electrified egress logic. In this case, the density of service lobbies, stair connections, and upper-level support areas increased the number of "special intent" openings, making early categorization essential before cylinders were ordered.

D. Why HM exterior and unit entry doors drove the keying risk

This project's keying risk was not evenly spread. It concentrated in HM doors and unit entry doors because:

- 1) *Security consequence is highest at HM perimeter/BOH doors:* If too many people can open too many critical rooms, security is weak. If every room has a different key, operations collapses into key chaos.
- 2) *Mechanical interface tolerance is unforgiving:* HM openings commonly use mortise cylinder hardware, where correct operation depends on cylinder format, cylinder length, and cam/tailpiece compatibility [16], [17]. That's why field issues like wrong cylinder length (due to laminated/thicker door conditions) and cam-piece incompatibility with security hardware can look like "keying failures" even when the key code is correct.
- 3) *Turnover amplifies small mistakes:* A single mismatch can delay unit closure, create security exposure, and consume labor that should be used on true closeout work. Issues observed included this directly through cylinder mismatch/swap issues and the time spent re-verifying and reinstalling cylinders correctly.

E. Stakeholders and scope boundaries:

Keying only worked here when responsibilities were made explicit:

1) Primary decision chain:

- GC (General Contractor)/Owner representative (combined in this project) driving coordination and closeout priorities.
- Hollow Metal door/hardware subcontractor supplying and coordinating the majority of cylinders and HM hardware.
- Property management team shaping the hierarchy around real operations (because they inherit the system at turnover).
- Security/access control contractor primarily responsible for credentials (fobs/programming) and electrified lock integration.

2) Secondary contributors (turnover keys ecosystem):

- Garage door vendor (remotes/controllers),
- elevator vendor (elevator keys and fire-service keys),
- glazing/door vendor for specific lobby keys,
- plumbing/irrigation-related service keys.

One scope decision is central to this case study and should be stated clearly because it explains later coordination outcomes: although the security contractor provided electrified lock hardware for unit foyer/service-foyer conditions, the project pulled cylinder supply back under the HM door /hardware scope to keep the mechanical keying hierarchy consistent across the building. In other words: one party controlled the cylinder system so the building would not end up with multiple incompatible cylinder sources and broken hierarchy control.

With the project access ecosystem defined, the case study next explains how life-safety circulation and procurement timing drove the keying architecture decisions.

III. CASE STUDY DECISION: KEYING ARCHITECTURE CHOSEN

The case study life-safety review produced four representative egress patterns that governed door intent and emergency access locations [4], [10].

A. Life-Safety Plan Study as the Starting Constraint (Path of Egress):

1) *Ground-floor stair discharge as an egress-controlled condition:* At grade, stair discharge doors were shown as part of the final segment of the means of egress, completing occupant movement from stair enclosure to exit discharge (Fig. 1) [4], [10]. Because these doors represent a high-consequence interface between the protected stair and the exterior, emergency access provisioning was planned at this boundary condition. Rapid-entry key boxes were therefore designated outside the ground-floor stair discharge doors, aligning fire department access with the building's principal discharge point rather than treating it as a scattered, door-by-door decision [8], [12], [14].

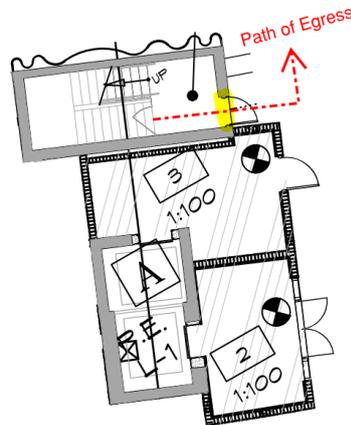


Fig. 1. Ground-floor stair discharge egress path

2) *Service-foyer → service-lobby → stair: the unit-to-BOH-to-stair route:* A second critical route ran through the building's BOH network: from the service foyer door, into the service lobby, and then directly to the adjacent stair enclosure (Fig. 2). This condition mattered because it established that some openings typically viewed as “operational”, or “service” doors are also part of the functional egress chain [4], [10]. When these doors are egress-linked, cylinder selection, hardware coordination, and reliability expectations become stricter because failure does not only affect convenience. It affects the continuity of the exit route.

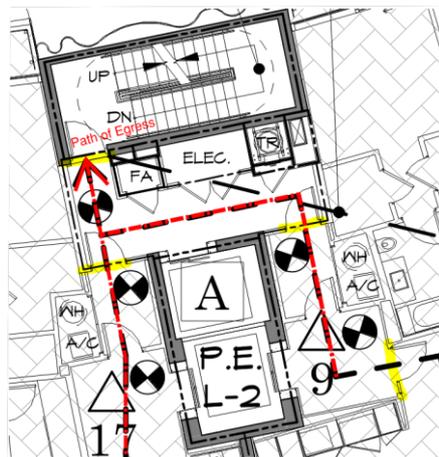


Fig. 2. Service-foyer → service lobby → stair route

3) *Corridor-to-stair doors: direct corridor discharge with FCC-enabled (Fire Command Center) emergency entry:* A third pattern involved doors connecting unit corridors directly to stair enclosures (Fig. 3). The life-safety drawings show these as direct emergency discharge points from corridor to stair. Importantly, this stair-door family included an emergency access feature: the locking configuration supported FCC-controlled release, allowing authorized entry from the stair side when emergency response required corridor access [18]. Operationally, the life-safety intent was twofold: (i) preserve protected stair behavior during normal use, and (ii) enable emergency entry through a controlled release function when commanded from the

fire command system. At this stage, the conclusion remains strictly about intent: these doors are egress-critical interfaces where emergency access is enabled through system-controlled release, not routine daily circulation.

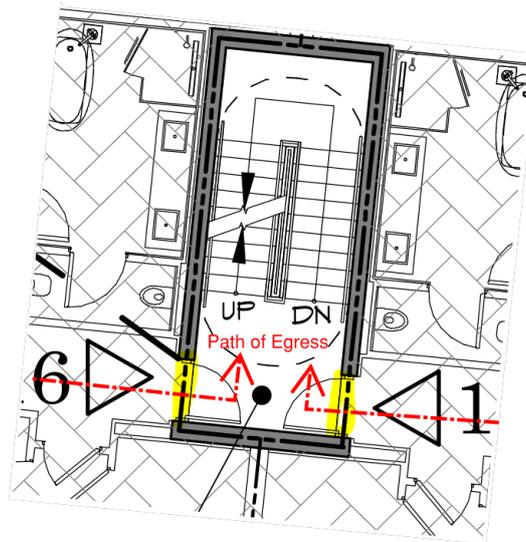


Fig. 3. Corridor-to-stair egress doors

4) *Penthouse pool-deck egress: exterior-rated electrified locks and roof/mechanical-yard access strategy:* At the penthouse level, egress routing expanded across outdoor and support zones associated with pool deck and cabana areas (Fig. 4). Evacuation paths connected either through stair discharge routes or through a mechanical-yard path that returned occupants to service circulation and ultimately to discharge. Because these locations are exterior-exposed, the door hardware strategy differed from interior corridor conditions: doors were configured with exterior-rated electrified locking rather than the same interior release-enabled lock type [19]. This difference drove emergency access planning toward location-based lockbox placement at the roof/mechanical-yard interface, with one rapid-entry lockbox inside the stairwell (interior side) and one at the mechanical-yard side exterior (outside at the egress door), rather than placing key boxes at every corridor-to-stair opening. In short, the life-safety study showed that roof-level egress paths required a distinct emergency-access strategy because exposure and lock type constraints were different.

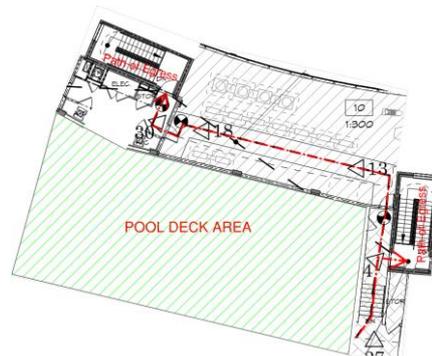


Fig. 4. PH pool-deck egress route

B. Procurement Trigger and Decision Timing:

The keying decision was finalized during the hardware submittal and procurement window because cylinders and keyed sets were released in coordinated batches [1]. Once ordered and distributed, correcting keying errors required repinning, replacement cylinders, and field labor, creating avoidable schedule and security exposure [1]. This procurement reality forced the hierarchy to be confirmed before cylinder orders were released. With that deadline established, the next step was to align the hierarchy with property management operations before the system was “locked in” through procurement.

C. Keying Conference with Property Management

With the access inventory defined and the egress constraints reviewed, the project held a focused keying conference with property management to lock the operating hierarchy before cylinder ordering progressed [1]. The purpose was not to debate hardware theory. The purpose was to agree on an access structure that could be operated daily after turnover without creating either (i) a security exposure through over-broad keys or (ii) operational chaos through excessive key fragmentation.

The meeting produced a two-track architecture (Fig. 5) [1]. First, the project adopted a building-controlled master structure: a Grand Master (GM) above a Security/Master key, with the Security/Master key subdivided into seven operational subcategories: Pool, Housekeeping, Trash, Restaurant, Valet, Concierge, Wellness. Second, the project-maintained unit keys as Single-Keyed-Different (SKD), meaning each unit key was independent and restricted to that unit's assigned openings [1]. This separation was intentional: unit keys were not to be controlled by the GM/Security structure, preserving resident privacy, and limiting master-key exposure.

The operating rule set was defined clearly to prevent overlap confusion later in the field [1]. A subcategory key opens only its own assigned room set, but higher-level keys retain controlled override:

- Example: A trash-room door is operable by Trash Key, Security/Master Key and Grand Master Key.
- Non-overlap rule: A Pool Key cannot operate Trash doors, and a Trash Key cannot operate Pool doors. Subcategories do not cross-open each other.
- Hierarchy integrity rule: The Security/Master and GM provide controlled, higher-level access across all subcategories, but subcategory keys remain strictly scoped.

Immediately after the meeting, the GC translated this hierarchy into a room-by-room category assignment (which rooms belong to which subcategory) and transmitted that categorized scope to the hollow metal door/hardware subcontractor for cylinder planning and procurement alignment. Keyset code formats were assigned later by the hardware vendor as part of their standard keying schedule, but the controlling decision from the project side was the hierarchy and category mapping, not the vendor's label style.

Any change to door category, keying intent, or cylinder substitution was controlled by the GC and required conformance to the approved hierarchy and the latest issued keying assignment.

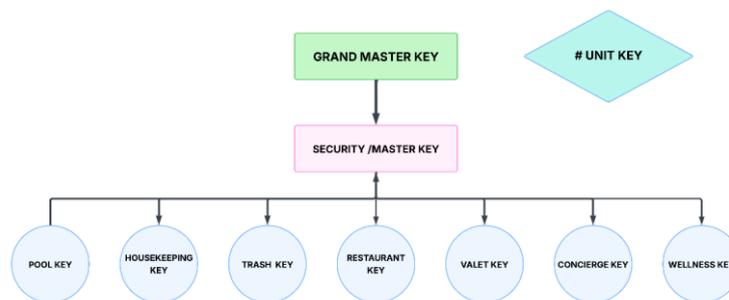


Fig. 5. Keying hierarchy adopted

IV. TRANSLATING THE KEYING HIERARCHY INTO INSTALLED REALITY

Once the keying hierarchy was approved, the project moved from “architecture” to execution. The risk at this stage was not selecting the wrong philosophy. The risk was losing control while hundreds of openings moved through procurement, installation, and turnover pressure. The control method used here was intentionally simple: a single Excel tracker that tied each opening tag to its room logic, and later to the subcontractor's coding and cylinder labeling.

A. GC categorization of openings

The first execution step was a GC-led categorization pass. This was not a vendor exercise and not a locksmith exercise. It was a project decision: each door was assigned to a keying intent based on what the door protects, who uses it, and how it behaves within daily operations and emergency circulation.

1) **Grand Master-only (administrative control):** Administrative suite and administrative office openings were designated as Grand Master-only. These were intentionally excluded from Security/Master and from subcategory keys to keep administrative access narrowly controlled.

2) **Security/Master-controlled:** The Security/Master category carried the building-wide controlled access population. In this case study, security intent covered the following openings and room sets:

- Ground-floor stair doors and ground-floor service-lobby doors supporting the primary discharge and building interface conditions.
- Main electrical rooms and the emergency electrical room.
- Fire command center, fire booster pump room, and MDF room.
- Typical-floor BOH operational closets, including electrical closets, fire alarm closets, and IDF closets in service-lobby zones.
- The stair-door family connected directly to unit corridors (the egress-only corridor-to-stair condition) [4], [10]. These doors were treated as critical circulation interfaces that still required authorized access under controlled circumstances.
- Upper-level and roof interfaces tied to penthouse egress circulation, including:
- Pool deck area doors that connect toward the mechanical yard, and
- Roof service-lobby doors that connect toward the mechanical yard.

In this project, all such penthouse/roof mechanical-yard interface doors were categorized under Security/Master.

This Security/Master key population was defined deliberately. These doors sit at the intersection of security and life-safety intent. Treating them as miscellaneous “service doors” would have created inconsistent access outcomes and turnover risk.

3) **Subcategory-controlled:** Where operational delegation was needed without creating key chaos, openings were grouped into functional subcategories. Each group was defined so staff could operate daily without carrying a unique key for every room, while still preventing cross-opening between unrelated functions.

- Pool: pool equipment rooms across the project, including cabana/penthouse pool-equipment rooms.
- Trash: all trash rooms and the trash holding room.
- Housekeeping: janitor closet and pool bathrooms.
- Restaurant: restaurant exterior/openings.
- Valet: valet storage and parcel storage.
- Concierge: concierge storage area.
- Wellness: spa and massage amenity rooms.

4) **Unit SKD-controlled:** Unit access was treated as independent from the building-controlled hierarchy. Each unit key was Single-Keyed-Different in intent and applied to the unit’s assigned openings, including [1]:

- Service foyer HM door opening toward the service lobby (electrified access hardware condition).
- Main unit entry wood door from the public-side foyer into the unit.
- AC/WH closet doors located in the service foyer.

For penthouse units, the unit SKD also controlled designated penthouse support openings (pool storage, pool-deck bathrooms, AC/WH closets for pool cabana where applicable), aligning unit access with the penthouse’s split-level living pattern.

At this point, the tracker reflected decisions in plain language: opening tag, from/to location logic, and the category intent. No subcontractor codes were inserted yet.

B. Tracker format used to communicate intent:

The categorization was issued in tracker form so door identity could not drift away from the access decision. Each line item anchored the decision to the opening tag and its real context (for example, a room-to-room relationship such as “Service Lobby FROM Electric Room”). This matters because keying problems rarely start as “bad keys.” They start as doors being treated as interchangeable when they are not.

Fig. 6 and Fig. 7 show excerpts of the tracker approach, including the opening tag, location-to-location logic, and the assigned keying intent that would later be translated into formal keyset codes.

C. Subcontractor coding and internal SKD numbering:

After receiving the categorized tracker, the hollow metal door/hardware subcontractor translated the project’s intent into a formal coded keying schedule and returned it for review. This is the correct sequence: the project defines hierarchy and room mapping; the subcontractor assigns the coding structure used for pinning, labeling, and production [1].

CASE STUDY PROJECT - COMMON AREA				
OPENING TAG #	LOCATION		LOCATION	KEY SET
Y1-04	CONCIERGE	TO	CONCIERGE STORAGE	CONCIERGE
Y1-05	VALET	TO	VALET STORAGE	VALET
Y1-06	VALET	TO	PARCEL STORAGE	VALET
X2-01	SERVICE LOBBY	FROM	SERVICE FOYER	UNIT SKD FOR 201
X2-01.1	FOYER	FROM	LIVING AREA	UNIT SKD FOR 201
X2-02	SERVICE LOBBY	FROM	FA CLOSET	Security
X2-02.1	SERVICE LOBBY	FROM	FA CLOSET	Security
X2-03	SERVICE LOBBY	FROM	ELECTRIC ROOM	Security
X2-03.1	SERVICE LOBBY	FROM	ELECTRIC ROOM	Security
X2-04	SERVICE LOBBY	FROM	TRASH ROOM	PASSAGE LATCHSET
X2-04.1	SERVICE LOBBY	FROM	TRASH ROOM	PASSAGE LATCHSET
X2-05	SERVICE LOBBY	FROM	SERVICE FOYER	UNIT SKD FOR 202
X2-05.1	FOYER	FROM	LIVING AREA	UNIT SKD FOR 202

Fig. 6. Tracker excerpt, common-area openings: opening tag, room-to-room context, and assigned keying intent used for coordination and later coding.

CASE STUDY PROJECT - EXTERIOR AREA				
OPENING TAG#	LOCATION		LOCATION	KEY SET
ST-01A	DRIVE WAY	FROM	STAIR	Security
X1-03	DRIVE WAY	FROM	TRASH ROOM	Trash
ST-01B	DRIVE WAY	FROM	STAIR	Security
X1-01	DRIVE WAY	FROM	SERVICE LOBBY	Security
ST-01A.1	DRIVE WAY	FROM	STAIR	Security
X1-03.1	EXTERIOR LOBBY	FROM	TRASH ROOM	Trash
ST-01B.1	EXTERIOR LOBBY	FROM	STAIR	Security
X1-01.1	EXTERIOR LOBBY	FROM	SERVICE LOBBY	Security
ST-01A.2	DRIVE WAY	FROM	STAIR	Security
Y1-03	EXTERIOR LOBBY	FROM	TRASH ROOM	Trash

Fig. 7. Tracker excerpt, exterior-area openings: exterior interfaces categorized under Security/Master intent & other room groups for controlled delegation.

The returned schedule used the following code structure [1]:

- Grand Master: A
- Security/Master: AA
- Subcategories: AA1–AA7 (Pool, Housekeeping, Trash, Restaurant, Valet, Concierge, Wellness)
- Unit keys: SKD # assigned as an internal sequence not tied to unit numbering (example pattern: Unit 201 mapped to SKD 14 based on the subcontractor’s internal sequence, not unit ID).

The GC reviewed the returned tracker and hierarchy schedule line-by-line to confirm that:

- Each opening category matched the intended room logic, and
- Coded assignments aligned with the approved hierarchy rules (subcategory scoped; AA as controlled override; A as top-level control; unit SKDs independent).

Only after that review was the tracker released for production and field execution. For clarity, the Figure 8 presents the coded hierarchy graphic returned by the subcontractor.

D. Cylinder and key identification in the field:

The field-control advantage of the approach was traceability at the point of installation [1]. Cylinders and keys arrived with identification that matched the coded tracker:

- Cylinder packaging tags carried the keyset designation (AA, AA3, SKD #, etc.).

- Keys were also marked/stamped with the same designation.

This created a practical verification loop: the opening tag and keyset on the tracker could be checked against the cylinder tag and key stamp before installation [1]. It reduced the conditions that produce the most expensive kind of failure later: a “working” door created by a swap that solves the moment but breaks the system.

E. Release to production and field control:

After the subcontractor returned the updated tracker with keying codes, the GC reviewed it, approved it, and released it as the single field reference. Cylinders were delivered early so installation could stay on schedule, while the final keys were delivered later during the finishing stage. During installation, basic functionality was checked using the construction keys, but this was treated as a preliminary confirmation only [9]. The main control at this stage was “install-to-tracker”: each opening tag was matched to the tracker, the cylinder tag/code was verified against the assigned keyset, and the cylinder’s physical fit (length and cam/tailpiece compatibility) was confirmed [1], [16], [17]. Full final verification with the permanent keys was intentionally deferred until the finishing stage, when the final keyset was issued [1].

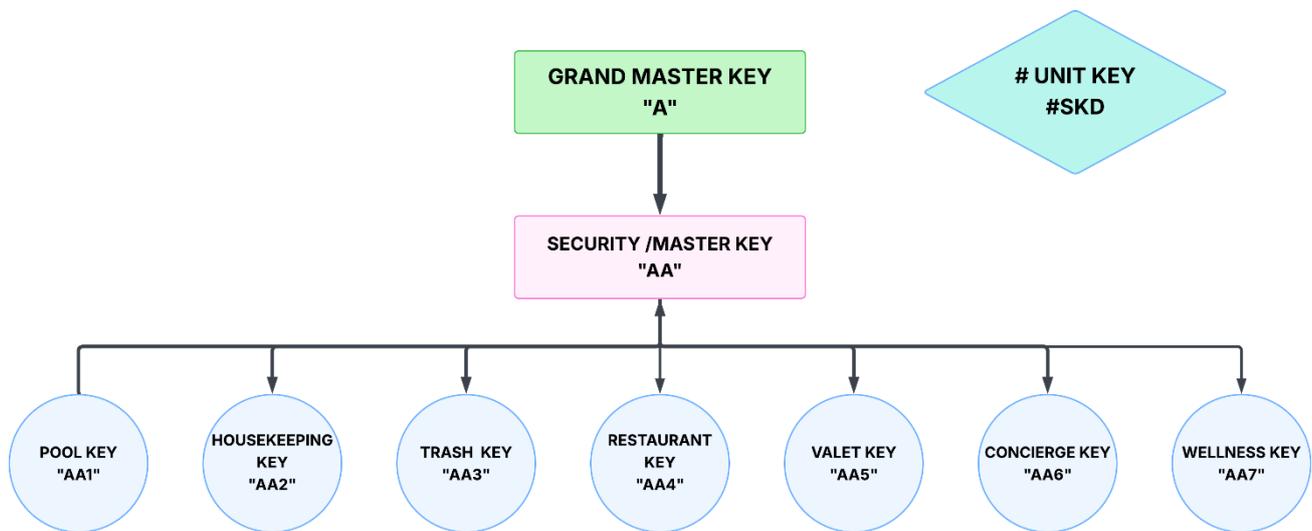


Fig. 8. Final coded hierarchy used for production labeling and field verification

V. INSTALLATION-PHASE FAILURE MODES AND CORRECTIVE ACTIONS

After the coded tracker was released and cylinder installation began, the project used a controlled construction-key protocol to keep field operations moving without breaking hierarchy control. Cylinders were delivered early so doors could be cored and installed on schedule, while the permanent keysets were issued later during finishing. During this installation window, the field team verified basic cylinder operation using two construction key types provided by the hollow metal door/hardware subcontractor: CMK, a construction master key for openings under the Security/Master category, and CMKSK, a construction master key for openings under the Unit SKD category [9]. Approximately 15 copies of each were maintained to avoid key bottlenecks in day-to-day site work. Full final verification was intentionally deferred until the permanent keys were released.

Within this installation window, the project encountered three recurring issues that are often mislabeled as ‘keying problems.’ They are presented below as distinct failure modes: (1) mechanical interface incompatibility, (2) dimensional misfit, and (3) installation-stage traceability breakdown.

A. Interface incompatibility - third-party cylinders & cam/tailpiece mismatch at electrified unit access locks

A recurring coordination constraint in this project was that the electrified access-control locksets at unit entry conditions required third-party mortise cylinders [16], [17]. The access-control contractor provided the electrified lock hardware, but cylinder procurement was intentionally kept under the hollow metal

door/hardware subcontractor to preserve one consistent mechanical keying hierarchy across the building. That scope decision protected the hierarchy, but it also created a critical interface point: the cylinder's cam/tailpiece geometry had to match the lock's actuator requirements [16], [17].

During installation, the initial cylinder configuration used a common cam type (selected based on general industry practice and the lockset guidance that multiple cam options could be used) [16], [17]. Once installed, the failure presented in a very specific way: the deadbolt would not fully throw, and as a result the key could not be reliably turned through the full locking cycle and removed cleanly [16]. In practical terms, a bolt that only projects partially is not an acceptable "working" condition on a high-rise turnover path, because it creates inconsistent locking behavior and key bind risk. The team also observed that only a small subset of locks (approximately a few units) behaved acceptably with the original cam, while the majority did not, which pointed away from random workmanship and toward a systematic compatibility mismatch.

The corrective method was controlled and technical, not improvised. The project ordered a sample cam of an alternate compatible type, performed a field mock-up on a representative opening, and confirmed full deadbolt throw and clean key operation [16], [17]. Based on that confirmation, the decision was made to standardize the cam/tailpiece type across all affected unit access-control cylinders [16], [17]. Because some cylinders had already been installed with the original cam, the field correction required planned rework: remove the cylinder, replace the cam/tailpiece component, reinstall, and re-check operation. Importantly, the cost impact was contained because the corrective action required cam component replacement, not full cylinder replacement, and the change was executed as a disciplined field correction rather than an uncontrolled swap.

This incident is keying-relevant for a specific reason: the keying codes and hierarchy were not the failure. The failure was that mechanical compatibility at the cylinder-lock interface can invalidate an otherwise correct keying plan if it is not verified early with a mock-up standard [16], [17].

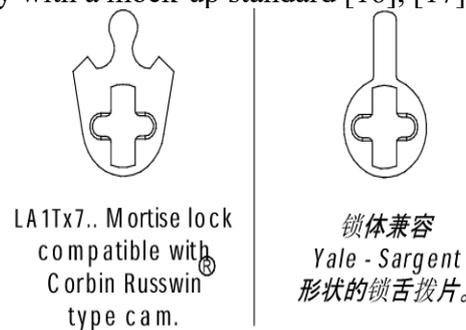


Fig. 9. Example cam compatibility reference illustrating how cam geometry must match the mortise lock actuator requirement [16], [17].

B. Dimensional misfit: laminated door thickness driving cylinder length error:

A second issue emerged from finish-driven conditions rather than hierarchy decisions. A subset of unit entry wood doors used a laminated finish configuration that resulted in a thicker-than-typical door/trim stack-up. However, cylinder length was initially ordered using the same length assumption as standard conditions, which proved incorrect once cylinders were installed. The symptom was straightforward: cylinders were physically short relative to the door and trim, creating an installation condition that could not be properly secured and operated as intended.

The correction required treating cylinder length as a measurable geometry problem, not a guess. The project recalculated the required cylinder length using the dimensional relationship [17]:

- $L \geq P + C$, where

P is the distance from the door face to the lock centerline (half the door thickness when the lock is centered), and

C is the trim/collar projection required by the selected cylinder/trim configuration.

In this case, the door thickness was approximately 2 inches, so the centerline distance P was treated as 1 inch. The trim projection C was approximately 5/8 inch, resulting in a required cylinder length of at least 1.625 inches, and the project selected a standard length of 1.75 inches to satisfy the requirement and avoid borderline fit. New cylinders were then ordered and installed to match the corrected length [17].

This incident matters because it illustrates a predictable installation risk on luxury projects: interior design finish decisions can change cylinder geometry requirements. If those finish-driven deviations are not captured before ordering, the project pays later in re-ordering, rework, and schedule friction, even when the keying hierarchy is perfectly designed [1], [17].

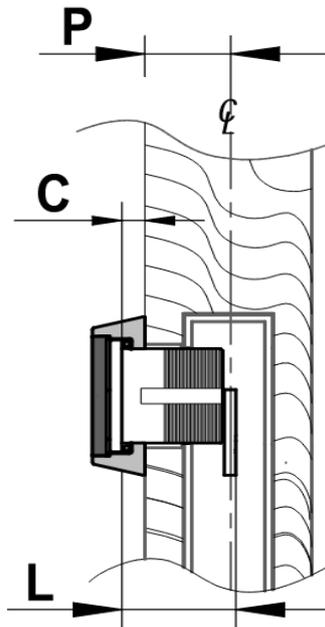


Fig. 10. Cylinder length geometry across door thickness and trim stack-up (P = face-to-centerline distance; C = trim projection).

C. Traceability break: SKD cylinder mismatch at the unit level:

The third issue was not a compatibility or dimensioning problem. It was a control problem: the right cylinders existed, but the wrong SKD cylinder was installed at the wrong opening [1]. During a GC walkthrough, a mismatch was identified where one unit had multiple unit-controlled openings, and at least one opening carried an SKD cylinder that belonged to a different unit sequence. A representative example was a unit assigned to one SKD number, while a different SKD number was installed on one of its doors, even though another door in the same unit had the correct cylinder. That pattern is a classic indicator of an installation-stage traceability slip: cylinders are present, labeled, and issued, but field placement drift occurs under volume and repetition.

The response was operationally clean: the issue was treated as a priority security and turnover risk, the team identified the affected units, built a targeted correction list, and reinstalled cylinders to match the tracker assignments [1]. No change order was needed, but the impact was still real. Each mismatch consumes labor that should be spent on closeout work and introduces avoidable security exposure while the mismatch exists. This incident is important in the paper because it shows the real boundary of keying control: hierarchy design alone is not enough. A high-rise needs installation discipline that prevents “small swaps” from becoming system-wide integrity loss [1].

VI. TURNOVER PACKAGE AND CONSTRUCTION-KEY DEACTIVATION

Once cylinder installation and finishing reached the turnover threshold, the project’s priority shifted from “install-to-tracker” to handover-ready access control. The hollow metal door/hardware subcontractor delivered the final keying package as a controlled turnover set, not as loose keys. Keys were organized into small, labeled envelopes, separated by key type and key group [1]. This packaging mattered because it preserved traceability: each envelope represented a defined access scope, aligned with the approved hierarchy [1].

A. Turnover keysets delivered and how they were organized:

The turnover package included:

- Grand Master (GM) keys: 5 copies (top-level access).
- Security/Master keys: 12 copies (building-wide critical access set).

- Subcategory keys (Pool, Housekeeping, Trash, Restaurant, Valet, Concierge, Wellness): quantities were issued based on the number of openings in each group, and each opening was supported by two keys in the issued set.

- Unit SKD keys (65–70 units): SKD volume was the largest. Each unit's SKD key operates that unit's assigned cylinders, but the turnover set still issued two keys per unit opening for practical operations and redundancy during handover.

All keys were labeled and grouped so property management received them as an operating system, not as a pile of metal [1]. The project also received a printed copy of the approved keying submittal as part of the final turnover record package [1].

Custody transfer control: the GC issued a transmittal to the property manager, and the property manager signed as received, establishing a clean handoff point for key custody and accountability [1].

B. Breakout keys and the logic of construction-key retirement

A critical turnover step was deactivating construction access so that temporary construction keys could not continue to operate the building after handover. This was handled through a construction breakout process built into the cylinder system.

In construction-keyed cylinder systems (commonly implemented using “construction keying” features), the cylinder is configured so a construction master can operate the lock during the job, but the system can later be permanently transitioned to final keys without replacing cylinders. One widely used method is a ball-bearing (“lost ball”) mechanism: small ball bearings are held in a specific chamber during construction use, and when the deactivation (breakout) key is used, those balls drop into drilled plug holes and force an internal pin condition that prevents the construction key from rotating afterward [9]. In short: the breakout action changes the cylinder's internal state so the construction key stops working, while the final key remains valid.

How it was executed in this case study:

- The cylinder is initially active for construction access.
- A construction breakout key is inserted and rotated through the prescribed deactivation rotation (in this project, roughly a 120-degree turn, direction dependent on the cylinder/handing and the manufacturer's breakout instructions).
- That rotation triggers the internal “lost ball” effect, after which the construction key becomes void and only the final keying remains effective.

Two breakout keys were issued to keep the deactivation process aligned with the system's separation:

- One breakout key used to void Unit SKD-related construction access, and
 - One breakout key used to void the GM-side construction access group (the building-controlled hierarchy).
- This separation prevents accidental cross-impact: the project can retire construction access in the correct “lane” without destabilizing other operating groups during staged turnover.

C. Electronic credentials: programming sequence and construction credential deactivation:

In parallel with mechanical key turnover, the access-control credentialing followed a staged activation path consistent with operational priorities:

- Exterior/common access first (lobbies, service lobbies, primary stair doors, pool gates) so the building perimeter and circulation points were controlled immediately.
- Unit-by-unit closeout activation: when a resident unit reached closeout, the unit's access control that had been running on a construction credential/card was deactivated, and the permanent resident credential (small circular key fob) was activated for that unit.

This sequencing prevented an access-control “big bang” event and allowed turnover to progress without leaving construction credentials live longer than necessary.

D. Other turnover items included in the access package

To make the turnover set operationally complete, property management also received:

- Private garage door remotes: two remotes per garage door (as issued per garage).
- Mail room keys.

- Irrigation / exterior water control keys (“wall hydrant” keys): issued for exterior irrigation or landscape water-control points serving penthouse landscaping and common landscaping irrigation zones (scope varies by project, but the operational intent is consistent: maintenance access without forcing master-key exposure everywhere).

E. Elevator keys and fire-service key control:

The project contained 14 elevators. For routine operation and maintenance, each elevator had three key types issued for its operating and service needs (maintenance/inspection operations require multiple keyed functions, and they are typically controlled separately).

In addition, the project required a fire-service emergency key process tied to the local AHJ’s emergency access expectations [3], [20], [22]. This fire-service key is commonly treated as controlled distribution, obtained through an approved process (often via an authorized program/vendor with application and fees), and then stored so emergency responders can access it rapidly when needed [22]. Elevator emergency access is frequently managed through a rapid-entry lockbox (e.g., Knox-type system) [8], [21]. For this project, fourteen (14) elevator fire-service keys were issued for placement in the rapid-entry key boxes (one dedicated to each elevator), and one (1) additional fire-service key was issued to property management for controlled custody.

In the end, turnover was successful because it followed one principle: the system was handed over in a form that could be operated, audited, and secured on day one. Keys were grouped with intent, custody was documented, construction access was permanently removed through the breakout process, and electronic credentials were activated in step with real closeout.

Now that the final keys and emergency keys exist and custody is transferred, the remaining control question is: where those emergency keys live and how they stay current. That is the Knox box system.

VII. RAPID-ENTRY LOCKBOX SYSTEM (KNOX-TYPE) AND EMERGENCY KEY PLACEMENT

After mechanical and electronic turnover controls were established, the remaining life-safety access question was how emergency responders could gain fast, authorized entry without forced damage or uncontrolled master-key circulation. The project addressed this requirement through an AHJ-approved rapid-entry lockbox program (Knox-type) [8], [21]. In Florida practice, the AHJ typically dictates the approved box type/vendor, placement rules, required contents, labeling expectations, and inspection/acceptance steps [21]. Within this framework, the lockbox served as a regulated handoff point between building security and emergency response, with contents limited to the minimum keys necessary for emergency operations [21].

A. System scale and placement strategy:

A total of thirty-two (32) lockboxes were installed, distributed by emergency-use logic rather than by convenience:



Fig. 11. Example Knox-type rapid-entry lockbox used on the project (AHJ-approved configuration) [8]

1) *Ground-floor responder access layer (14 boxes):* To establish immediate entry to primary circulation, fourteen (14) lockboxes were placed at the ground floor: seven (7) at stair locations and seven (7) at lobby locations. This arrangement creates redundancy: responders can reach a stair or lobby access point quickly depending on the incident location and the safest approach route.

2) *Critical room layer (3 boxes, grouped by adjacency)*: Where multiple life-safety/support rooms were physically co-located, the project used a single lockbox to serve the cluster, reducing confusion and preventing unnecessary duplication:

- (1) box for Main Electrical Room 1.
- (1) box serving Main Electrical Room 2 and the Emergency Electrical Room (co-located).
- (1) box serving the Fire Command Center, Fire Booster Pump Room, and the associated main electrical/MDF room cluster (co-located).

This brings the subtotal to 17.

3) *Roof and mechanical-yard access layer (15 boxes)*: The remaining boxes supported rooftop circulation and mechanical-yard interfaces that must remain accessible under emergency conditions: seven (7) at roof stair connections to the pool-deck circulation and eight (8) at exterior mechanical-yard access points. Subtotal 15, bringing the project total to 32.

B. Contents philosophy: “minimum keys, maximum function”

The contents were intentionally restrained. The objective was not to store a full building key ring. Instead, the intent was to store only what is required to (1) gain immediate controlled entry, and (2) reach critical life-safety/support rooms.

C. Ground-floor boxes: contents by door function:

Because ground-floor points are the first-contact interfaces for responders, the contents were tuned to likely entry scenarios:

1) *Ground-floor stair lockboxes (7 locations)*: Each stair lockbox contained:

- (1) access-control credential (key fob) to support normal electronic entry, and
- (1) Security/Master mechanical key as a fail-safe if the access-control system does not grant entry mechanically (power loss, reader failure, or programming issue).

This dual-path approach prevents a single-point failure at the first life-safety circulation interface.

2) *Ground-floor lobby lockboxes (7 locations)*: Each lobby lockbox contained [21]:

- (2) elevator fire-service emergency keys (one for the passenger elevator and one for the service elevator, where applicable to the lobby’s elevator interface) [7], [20],
- (1) access-control credential (key fob) for the lobby access-control doors, and
- (1) Security/Master mechanical key as the mechanical fail-safe.

This combination supports immediate building entry and rapid elevator fire-service control at the primary responder interface. Across the seven (7) lobby lockboxes, this staging total fourteen (14) elevator fire-service keys (two per lobby location), aligning emergency access with the elevator banks associated with each lobby.

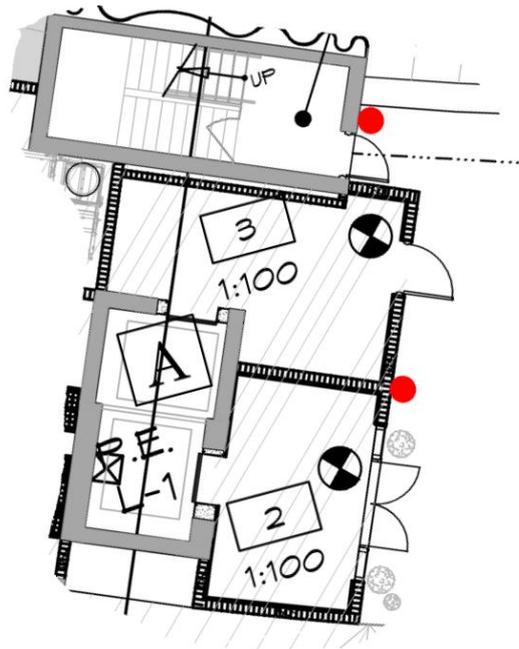


Fig. 12. Ground-floor Knox box locations at lobby and stair access points.

D. Critical-room, roof-stair, and mechanical-yard boxes: simplified content rule:

For the remaining lockbox populations, the content rule was deliberately consistent to avoid field confusion during emergencies [21]:

- Critical rooms (electrical/FCC/fire pump/MDF clusters), roof-stair boxes, and mechanical-yard boxes each received (1) Security/Master mechanical key only [21].

That single-key approach matched the project's hierarchy logic: these locations are high-consequence and must be accessible, but they do not require expanded keysets inside the lockbox to achieve emergency entry [8], [21].

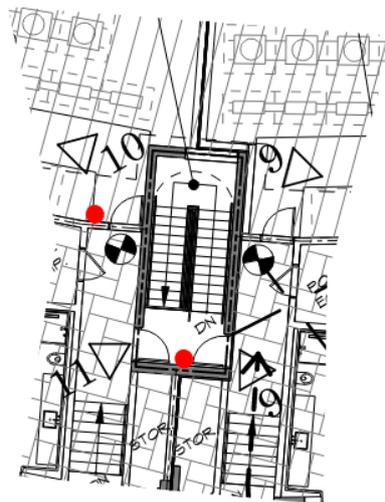


Fig. 13. Roof-level Knox box locations at stair and mechanical yard access points.

VIII. LESSONS LEARNED

A high-rise keying system succeeds or fails based on whether the hierarchy can survive contact with the field. The hierarchy on paper is only an access theory until it is forced through procurement waves, installation substitutions, and the time pressure of turnover. The most consistent failure pattern is not technical complexity, but traceability erosion: when door identity, hardware identity, and cylinder identity stop matching one another, the project silently trades governance for “workarounds,” and the building inherits those workarounds as permanent security debt. For this reason, keying control must be treated like a baseline deliverable, not a late-stage accessory, and it has to be frozen early enough that procurement batching does not create multiple competing versions of the “truth” [1].

Construction-key management is the second decisive risk layer because it represents temporary permission that can outlive the job if retirement is not designed and executed intentionally. A breakout strategy is not just a locksmith procedure; it is a project control action that must be scheduled, verified, and documented with the same seriousness as any other critical turnover handoff. The difference between a safe turnover and a vulnerable one is whether temporary access is provably removed, not merely assumed to be removed [9].

Finally, emergency access integrity is only real when it stays synchronized with the operating key system. A rapid-entry lockbox is a controlled interface between responders and the building, and its contents must remain minimal but current; outdated keys create a false sense of readiness that fails at the exact moment the building is most exposed [8], [21]. The lesson is simple: emergency access is not an add-on to security, and security is not an add-on to life safety. In high-rise work, keying is the operational language that connects both, and it must be managed as a single, auditable system from submittals through turnover.

IX. CONCLUSION

This case study demonstrates that large-project keying is best managed as an operational control system, not a late-stage hardware decision. The core contribution of the paper is a field-tested method for keeping the hierarchy stable by tying design intent to verifiable identities and auditable handoffs across procurement, installation, and turnover. By organizing observed breakdowns into clear failure categories and pairing them with practical controls, the paper converts “lock problems” into traceable, preventable control breaks. The result is a repeatable approach that improves turnover readiness and preserves emergency entry reliability without expanding the key footprint beyond what is necessary [1], [21]. In high-rise delivery, the winning strategy is not a more complex hierarchy, but a more disciplined system of custody, verification, and closeout.

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