

Construction Execution Methodologies for Modular Data Center Deployment: A Field-Based Framework for Mission-Critical Infrastructure Delivery

Rushi Jariwala

RUS Industrial, LLC, USA

ARTICLE INFO

ABSTRACT

Modular construction has shifted from a niche delivery choice to a central strategy for mission-critical infrastructure, yet the field execution methods that decide whether a modular data center is delivered on schedule and defect-free remain thinly documented in the practitioner literature. This article presents a field-based execution framework built around four connected components: a module-based readiness matrix, a three-gate quality verification structure spanning factory, receiving, and field readiness, a heavy-lift and logistics risk-control routine, and a critical-path control loop for schedule recovery. The primary case application is a live 120 million dollar mission-critical modular data center program of 78 OptiStax modules, roughly 600,000 manhours, and peak manpower near 440 personnel, on which the author has led quality assurance, quality control, and turnover execution since December 15, 2025 (data cutoff July 2026). Supporting context is drawn from three prior industrial programs in petrochemical and methanol construction, which informed the package-based quality and turnover principles underlying the framework but did not constitute a controlled comparison of the module-specific gates or heavy-lift framework. Outcomes are reported as the author's practitioner observations, not as independently audited or measured results: the set sequence completed with no set failure observed by the author, a quality-gate structure intended to concentrate defect discovery upstream, schedule slippage addressed through short-interval control without the commissioning window moving during the author's tenure, and turnover packages assembled continuously to support commissioning and energization readiness. The framework aligns field practice with established standards for project management, advanced work packaging, quality management, and data center topology. Its contribution is a transferable, practitioner-grade sequence of gates, checks, and control loops that execution leaders can adapt for modular mission-critical delivery, offered with explicit limitations tied to its single-practitioner evidence base and the absence of a controlled comparison group.

Keywords: modular data centers; mission-critical infrastructure; construction execution methodology; heavy-lift logistics; turnover management; commissioning readiness; energization readiness; quality integration; schedule recovery; operational readiness tracking

1. Introduction

Demand for computing capacity has compressed data center delivery timelines to a point where conventional stick-built construction struggles to keep pace. Modular and prefabricated methods answer that pressure by moving a large share of the build into a controlled factory setting, then completing assembly on site. The wider construction sector has been slow to change: construction represents about 13 percent of global gross domestic product yet has posted roughly 1 percent annual productivity growth for two decades, and modular methods sit among the disruptions expected to reshape that picture, with permanent modular construction's share of new North American real estate construction growing 50 percent from 2015 to 2018 and an estimated 265 billion dollar annual profit

pool available to firms that adapt [10]. Practitioner surveys reinforce the operational case, with about 90 percent of respondents reporting improved productivity, improved quality, and increased schedule certainty when using prefabrication and modular methods against traditional construction [11].

Mission-critical facilities raise the stakes. A data center must satisfy topology and availability expectations [5], structured infrastructure requirements [6], and thermal management criteria [7] before it can carry live load. The gap the author has repeatedly encountered lies neither in design intent nor in factory capability, but in the field execution layer that connects factory output to a commissioned, energized facility. Modules arrive engineered and pre-tested, and a program can still lose weeks at the point of set, tie-in, and turnover when the receiving and field-readiness controls are weak.

This article addresses that gap from the vantage point of a construction and turnover execution leader rather than a researcher. The author has led quality and turnover execution on a live 120 million dollar mission-critical modular data center program of 78 OptiStax modules, roughly 600,000 manhours, and peak manpower near 440 personnel since December 15, 2025, and previously managed site quality control across three major industrial capital projects. Drawing on that record, the article proposes a field-based framework that integrates a module readiness matrix, three verification gates, heavy-lift and logistics risk control, and a critical-path recovery loop.

The objective is practical. Execution leaders on modular mission-critical programs need a repeatable sequence of gates and control routines they can apply without waiting for tool development or digital instrumentation. The sections that follow describe the standards and literature base behind the framework, the projects that form its practice base, the framework itself, the execution outcomes observed, and the lessons that transfer to other modular deployments.

2. Materials and Methods

2.1 Literature and standards base

The framework rests on two bodies of reference material: formal standards that define what a mission-critical facility and a controlled quality program must satisfy, and applied construction research that documents how modular and industrial execution behaves in practice.

On the standards side, project delivery structure follows the performance domains and principles codified in the PMBOK Guide, Seventh Edition [1], and the workforce execution logic follows advanced work packaging as defined by the Construction Industry Institute, which breaks design and construction into aligned work packages carried through to installation [2]. Quality management structure follows ISO 9001:2015 together with Amendment 1:2024, which frames the process approach, documented information, and nonconformance control the author applies at each gate [9]. Retrospective schedule-forensics reasoning, used here only to characterize how slippage is diagnosed after the fact, draws on the AACE recommended practice for forensic schedule analysis [3]; the framework's active weekly schedule recovery instead follows live project-controls and short-interval-planning practice consistent with the Last Planner System [4]. Mission-critical facility criteria come from the Uptime Institute tier topology standard [5], the ANSI/TIA-942 telecommunications infrastructure standard for data centers [6], and the ASHRAE thermal guidelines for data processing environments [7], cited here as reference criteria and applied on a given program only to the extent they are contractually required. Electrical safety at the point of energization follows NFPA 70E [8].

Several research streams inform specific parts of the framework. Advanced work packaging cost and benefit assessment supports the packaging economics that justify front-loaded planning [12], and recent work identifies the benefits and success conditions for advanced work packaging in front-end planning and design [22]. Heavy-lift planning research demonstrates route and crane optimization methods that parallel the author's manual lift-planning discipline [13]. Offsite quality control review literature maps the defect and verification landscape the three-gate structure targets [14], and modular

factory quality information management research documents how factory-side records should be structured [19]. Schedule delay research provides the analytic backing for the critical-path control loop, including delay-analysis methods using modified and updated schedules [15] and a broader review of schedule delays on major projects [16]. Labor productivity research on offsite construction identifies the dominant risk factors the framework tries to contain, reporting that across 100 responses covering 20 labor-productivity risk factors, 80 percent of those factors fell into the high-overall-risk category, with the top five being unskilled or improperly trained labor, poor logistics, errors and omissions and rework, work-area congestion, and insufficient coordination [20]. Transportation-induced impact research on prefinished volumetric modules informs receiving inspection for transit damage [18]. Handover research identifies the recurring turnover failures the framework's turnover package is designed to prevent [21]. Digital delivery perceptions in the modular integrated construction frame where the field is heading, though the framework here stays deliberately at the level of field methodology rather than digital tooling [17].

Table 1 maps each literature and standards stream to the framework component it informs and the practical decision it supports.

Table 1. Literature and Standards Streams Informing the Framework

Stream	Practical Decision Supported
Project management & advanced work packaging standards	Structures project delivery and the module-based readiness matrix; justifies front-loaded packaging economics
Data center / mission-critical facility standards	Defines topology, infrastructure, thermal, and electrical-safety acceptance criteria for field-readiness and energization gates
Quality management & offsite QC research	Frames the three-gate verification structure and factory-record discipline
Heavy-lift, logistics & transportation research	Informs lift-planning discipline, receiving-gate transit-damage checks, and dominant productivity risk factors
Schedule delay & recovery research	Grounds the critical-path control loop and its weekly-reliability baseline
Modular adoption & handover research	Frames market context, digital-delivery trajectory, and turnover/handover failure modes

2.2 Practice base of supporting projects

The framework was not designed in the abstract. It consolidates methods the author developed and refined across four capital programs between 2014 and the present.

The current and most direct program is a live mission-critical modular data center delivered for RUS Industrial, LLC, valued at 120 million dollars and comprising 78 OptiStax modules with roughly 600,000 manhours and peak manpower near 440 personnel. Since December 15, 2025, the author has led quality assurance, quality control, and turnover execution on this program, which is the primary source of the module-based readiness and turnover practices described here. Because modules on this program arrive as engineered, factory-assembled units and are set, tied in, tested, and turned over on a compressed schedule, the program exercises every element of the framework under live conditions.

Three prior programs at Bilfinger Westcon, where the author served as site quality control manager from 2014 to 2022, provide the industrial practice base. The INEOS Styrolution 100KT ASA expansion involved 765 hydrotest packages, 824 equipment packages, 5,264 instrumentation packages, and 121

commissioning systems, and it established the author's practice for large-scale package-based quality and turnover control. The Braskem polypropylene recovery program was a brownfield effort with live-plant interfaces, which sharpened the author's methods for sequencing work around operating assets and controlling tie-ins to energized systems. The NatGasoline methanol facility involved roughly 25,000 welds, 830 hydrotest packages, and 170 static plus 73 rotating equipment units, and it tested the author's weld quality, hydrotest, and equipment turnover disciplines at scale.

These four programs share a common execution challenge: many discrete deliverables, each requiring inspection, testing, documentation, and formal handover, all converging on a commissioning and energization window that cannot move easily. The petrochemical and methanol programs handled that challenge through package-based turnover on relatively conventional field construction. The data center program handles it through module-based turnover on prefabricated units. The framework is the author's attempt to carry the package-based discipline proven on the industrial programs into the module-based reality of mission-critical data center deployment.

2.3 Framework construction method

The framework was built by abstracting the repeatable control points from the author's direct execution practice and organizing them into four connected components: a module-based readiness matrix, a three-gate quality verification structure, a heavy-lift and logistics risk-control routine, and a critical-path control loop.

The module-based readiness matrix is the organizing spine. Each module is treated as a discrete unit of turnover, and the matrix tracks that module through an ordered set of readiness states: civil and foundation release, module receipt, set and alignment, mechanical and electrical tie-ins, controls and instrumentation, quality control inspection, testing, punch list, turnover package assembly, and commissioning acceptance, ending at energization release. The matrix borrows its logic from the package-based turnover systems the author ran on the industrial programs, where each package advanced through a defined state sequence, and it aligns with the workforce execution philosophy of advanced work packaging [2] and the documented-information discipline of ISO 9001 [9].

Overlaid on the readiness states are three quality verification gates. The factory gate is a framework requirement rather than a process the author personally executes: it requires that a module leave the fabrication facility complete and conforming, with factory records structured to travel with the unit, consistent with modular factory quality information practice [19]. On the programs informing this framework, factory-release inspection was owned by the module manufacturer or fabricator rather than by the author; the author's role was to require, receive, and verify those factory records at the subsequent receiving gate. The receiving gate verifies the module on arrival, checking for transit-induced damage of the kind documented in volumetric module transportation research [18] and confirming completeness against the factory records. The field-readiness gate verifies that a module is fully set, tied in, inspected, tested, punched, and documented before it is released into the turnover package and offered for commissioning acceptance. Together the three gates concentrate defect discovery as far upstream as possible, which is the central lesson of offsite quality control review literature [14].

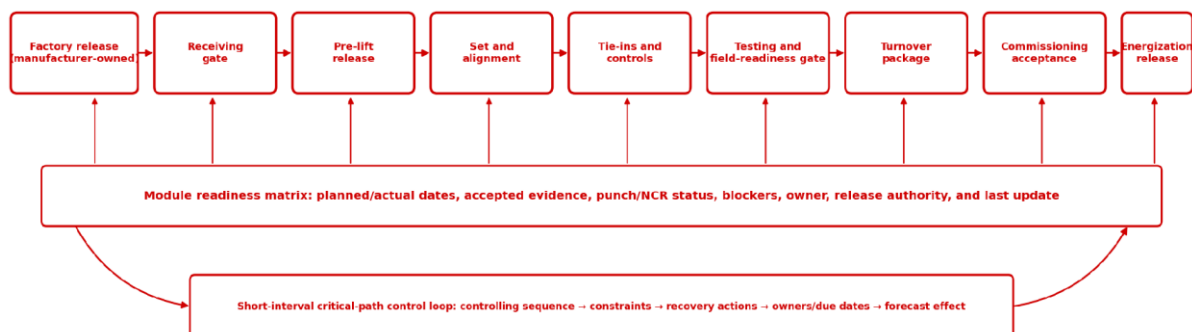
Tables 2 and 3 define the readiness sequence and the minimum per-module tracking fields. Figure 1 shows how the matrix, gates, lift release, turnover evidence, and schedule-control loop interact.

Table 2. Module Readiness States, Evidence, and Release Criteria

Readiness state	Governing gate or control	Minimum evidence	Release criterion
Factory release	Factory gate (manufacturer/fabricator owned)	Factory release record; inspection/test records; approved deviation list; shipping configuration.	Required factory evidence received and accepted for shipment.
Civil/foundation release	Pre-set control	Survey and foundation acceptance; anchor/embedded-item verification; access and crane-area readiness.	Foundation and access released for receipt and set.
Module receipt	Receiving gate	Bill of lading; module identity; shipping-condition and transit-damage inspection; factory-record completeness check.	Identity, condition, quantity, and required records accepted or formally dispositioned.
Pre-lift readiness	Heavy-lift/logistics control	Approved lift plan; route; ground condition; crane configuration and load chart; rigging inspection; weather; exclusion zone; briefing.	Authorized lift release issued by designated project and lift personnel.
Set and alignment	Field-readiness gate	Set survey; elevation, plumb, alignment, interface, support, and connection checks.	Module set accepted for tie-in work.
Mechanical/electrical tie-ins	Field-readiness gate	Inspection reports; torque/tension records; continuity/insulation tests; pressure or leak tests, where applicable.	Applicable mandatory tie-ins and tests accepted.
Controls and instrumentation	Field-readiness gate	Termination, calibration, continuity, power, loop, interface, and documentation records required by approved procedures.	Project-specific controls prerequisites accepted.
Quality/NCR review	Field-readiness gate	Inspection records; punch log; NCR/CAR dispositions; approved deviations.	No unresolved mandatory or startup-blocking quality item.
Functional testing	Field/commissioning interface	Approved test procedure; signed functional and sequence-of-operations records; prerequisite verification.	Mandatory functional tests accepted.
Turnover package	Turnover gate	Indexed and accepted quality, test, vendor, redline, punch, NCR, and commissioning-prerequisite records.	Module-specific turnover package accepted by the designated authority.
Commissioning/energization release	Client/commissioning release	Accepted turnover package; required permits; approved procedures; safety controls; client/AHJ acceptance criteria.	Formal release issued under project-specific commissioning and energization procedures.

Table 3. Minimum Per-Module Readiness-Matrix Fields

Field	Purpose	Example or controlled value
module_id	Unique identifier linking all readiness, quality, lift, schedule, and turnover records.	MOD-042
readiness_state	Current approved stage in the sequence defined in Table 2.	set and alignment
governing_gate	Identifies the release gate or control responsible for acceptance.	receiving / field readiness
planned_date actual_date	/ Supports variance, sequence, and recovery analysis.	2026-04-15 / 2026-04-17
responsible_party release_authority	/ Names the owner of the work and the role authorized to release the stage.	Field E&I lead / Commissioning manager
evidence_required evidence_location	/ Defines and links the records needed to substantiate completion.	Torque log; inspection report; CDE link
punch_class	Separates startup-blocking, non-blocking, and cosmetic punch items.	A-blocking / B-non-blocking / C-cosmetic
NCR_status disposition	/ Shows open nonconformance and approved disposition state.	Open; repair pending
blocker_status blocker_reason	/ Identifies whether the module may advance and why it is held.	Blocked; incomplete functional test
forecast_date recovery_action	/ Records the current forecast and agreed recovery action.	2026-04-19; add second test crew
last_updated source_record	/ Provides freshness, auditability, and traceability to the system of record.	2026-04-17T18:00Z; turnover tracker

Figure 1. Integrated Field Execution Sequence for Modular Data Center Deployment

The heavy-lift and logistics risk-control routine governs the physical movement and setting of modules. Its discipline is manual and procedural in the author's practice, built on lift planning, route confirmation, ground-bearing and crane-capacity checks, rigging verification, and a pre-lift readiness

confirmation, and it parallels the structured lift-planning logic that route and crane optimization research formalizes [13]. The routine is governed by OSHA's cranes-and-derricks-in-construction standard, 29 CFR 1926 Subpart CC [23], and by the applicable ASME B30 volumes, principally B30.5 for mobile cranes and B30.26 for rigging hardware [24]. Consistent with these requirements, the routine assigns ground-condition adequacy to the controlling entity, which under 29 CFR 1926.1402 must ensure that ground preparations are provided so the equipment can be assembled and used safely; assigns load-chart interpretation and crane setup to a qualified person as defined under Subpart CC; requires rigging to be selected, inspected, and installed by a qualified rigger, meaning a rigger who meets the Subpart CC criteria for a qualified person, before each lift; and requires a signal person meeting Subpart CC qualification requirements whenever the operator's view of the load or landing point is obstructed. The pre-lift readiness confirmation holds a module from lifting until ground-bearing capacity is verified for actual site conditions, the load chart is confirmed against the module's rigged weight and radius, rigging is inspected, weather conditions (wind speed and other applicable limits) are checked against the crane manufacturer's and site's operating limits, the exclusion zone around the lift path and landing point is established and enforced, and, for lifts meeting the program's critical-lift criteria, a documented critical-lift plan and dedicated pre-lift briefing are completed. Poor logistics ranks among the dominant labor-productivity risk factors in offsite construction [20], so the routine deliberately front-loads coordination among transport, receiving, and set crews.

The critical-path control loop drives schedule recovery. It runs on short-interval planning against the baseline critical path, compares planned against completed work each cycle, and reallocates crews and equipment to protect the controlling sequence. The loop draws its analytic footing from forensic and delay-analysis practice [3][15] and from the recognition that traditional weekly planning completes on average only 54 percent of the work planned for a given week [4], which is the reliability gap the loop is designed to close. Evidence that schedule delay is endemic on major projects reinforces the case for an active recovery loop rather than passive reporting [16].

2.4 Evidence boundaries, records reviewed, and analytical method

The primary-case evidence reviewed by the author included factory-release records received at site, module receiving and transit-condition inspections, lift plans and pre-lift checklists, set/alignment and tie-in inspection records, punch and nonconformance logs, schedule updates and short-interval plans, turnover-package indices, and commissioning/energization acceptance status available within the author's role. The article reports only aggregate scale and qualitative observations. Gate-by-gate NCR counts, cost effects, detailed schedule deltas, and client-confidential module-level data are not disclosed.

Analysis is descriptive and retrospective. There is no control group, randomization, before-and-after baseline designed for research, or independent audit. A lack of observed lift-related set failure does not establish that the routine caused the outcome, and an unchanged commissioning window does not isolate the schedule loop's contribution from design, procurement, client, contractor, or other project factors. The cases illustrate how the controls were structured and used; they do not provide causal effect estimates.

3. Results

The results below are the author's own direct project execution records, drawn primarily from the live 78-module data center program and, where noted, from the three prior industrial programs. No controlled comparison group exists; the outcomes describe what the framework produced in live delivery.

3.1 Heavy-lift and logistics risk control outcomes

Every module on the author's 78-module program required transport to site, receiving inspection, and a crane set onto prepared foundations. Using the heavy-lift and logistics risk-control routine, the set sequence for all 78 OptiStax modules was executed without a set failure, in the author's direct experience, meaning no module was damaged in the lift or rejected at the point of set for a lift-related cause. The pre-lift confirmation step, which holds a module from lifting until route, ground bearing, crane capacity, and rigging are jointly confirmed, was the control point the author credits most, because it forced the transport, receiving, and rigging interfaces to resolve before the crane was committed.

Receiving inspection caught transit-related findings before modules reached the set point, consistent with the transportation-induced impact that volumetric module research documents [18]. Because the receiving gate confirmed completeness against factory records at arrival, discrepancies surfaced while the responsible party and the shipping records were still fresh, rather than emerging during tie-in where they would have interrupted the controlling sequence. The author's experience across the industrial programs, where heavy static and rotating equipment moves on the NatGasoline facility involved 170 static and 73 rotating units, informed the discipline applied here; the same lift-planning rigor that protected those equipment sets protected the module sets.

3.2 Quality gate outcomes across the three verification gates

The three-gate structure changed where defects were found. At the factory gate, modules were verified complete and conforming before shipment, with records structured to travel with the unit in the manner modular factory quality information research recommends [19]. At the receiving gate, arrival condition and completeness were confirmed. At the field-readiness gate, each module had to pass inspection, testing, and punch-list closure before entering its turnover package.

The three-gate structure is designed, in principle, to concentrate nonconformance discovery upstream of field readiness, where defects are most expensive to resolve; this is the objective a layered verification approach is intended to achieve, consistent with offsite quality control review literature [14]. On the 78-module program, this remains a design objective rather than a measured result: the author does not have gate-by-gate nonconformance-report data to confirm the actual distribution of where nonconformances were found, and notable factory-originated issues were in fact identified during field installation on this program, indicating the gate structure did not fully prevent factory-side defects from reaching the field. The design intent mirrors the package-based inspection discipline the author applied on the INEOS program, where 765 hydrotest packages and 5,264 instrumentation packages were carried through inspection and turnover under an ISO 9001-aligned quality system [9]. The gate structure is intended to contain several of the top labor-productivity risk factors identified in offsite construction research, particularly errors and omissions and rework, by catching conformance issues before they propagate into installed work [20], though the author cannot confirm this containment effect with gate-by-gate data on the 78-module program.

3.3 Schedule recovery outcomes using the critical-path control loop

Modular mission-critical programs run on compressed schedules, and slippage is normal rather than exceptional [16]. In the author's program, the critical-path control loop was the mechanism used to recover slippage without moving the commissioning window. Each planning cycle compared completed work against the plan for the controlling sequence, and crews and equipment were reallocated to protect that sequence.

The value of the loop is best understood against the baseline reliability that traditional weekly planning achieves, where on average only 54 percent of the work planned for a given week is completed within the allotted schedule [4]. The author's short-interval loop was aimed squarely at closing that gap by making the controlling sequence, rather than the full work front, the unit of commitment each cycle. In

the author's direct experience, periods of schedule erosion on the 78-module program were recovered by concentrating resources on the modules sitting on the critical path for set, tie-in, and turnover, and by deferring non-controlling work rather than spreading crews thin. The delay-analysis logic behind the loop, comparing modified and updated schedules to isolate the true driver of slippage, follows established practice [15] and the forensic reasoning of the AACE recommended practice [3].

3.4 Turnover and energization readiness outcomes

Turnover is where modular programs most often lose the schedule they saved in the factory, because the documentation, punch-list closure, and system acceptance work converges at the end. Handover research consistently identifies post-construction defects, poor information fidelity, poor interoperability between building and facility-management information, and insufficient consideration of end users as the most-cited handover challenges [21]. The framework's turnover package, assembled per module through the readiness matrix, was the author's countermeasure.

Table 3 reports the author's direct project execution data across the primary case-application program and the three earlier programs that informed it, spanning the INEOS Styrolution expansion, the Braskem polypropylene recovery program, the NatGasoline methanol facility, and the RUS Industrial modular data center delivered for the Core Scientific end client, showing scale metrics and the readiness practices applied on each.

Table 4. Cross-Project Scale and Readiness Practices (Author's Direct Project Execution Data)

Project	Sector	Approx. Value	Key Records	Readiness Structure
INEOS Styrolution 100KT ASA Expansion	Petrochemical	Not separately disclosed	765 hydrotest packages; 824 equipment packages; 5,264 instrumentation packages	121 commissioning systems
Braskem Polypropylene recovery program	Petrochemical (recovery)	Not separately disclosed	Not separately itemized	Brownfield recovery, live-plant interfaces
NatGasoline Methanol Facility	Methanol production	Not separately disclosed	Approx. 25,000 welds; 830 hydrotest packages; 170 static + 73 rotating equipment units	Not separately itemized
Anonymized U.S. modular mission-critical program	Mission-critical data center	~\$120 million	78 modules; ~440 peak manpower; 600,000+ manhours	78-module readiness matrix, factory + site

Note: figures are the author's direct project execution records; entries marked "not separately disclosed/itemized" reflect the scope the author tracked and can verify for that project.

On the 78-module program, each module's turnover package was built up as the module advanced through inspection, testing, and punch-list closure, so that commissioning acceptance was offered against a complete, module-specific record rather than a facility-wide document assembled late. Energization readiness followed the same module logic. NFPA 70E governs the electrical-safety work

practices observed at and around the point of energization [8], but the energization acceptance gate itself is defined by the program's approved energization, testing, and commissioning procedures, client acceptance criteria, and the requirements of the authority having jurisdiction; NFPA 70E alone does not constitute that gate. The facility's topology and infrastructure criteria [5][6] and thermal criteria [7] inform the acceptance context and are applied to the extent they are contractually required on a given program, rather than as universal energization prerequisites. In the author's direct experience, building the turnover package continuously through the readiness matrix, rather than compiling it after physical completion, was the single practice that most protected the commissioning and energization window. The industrial programs offered supporting experience for the same principle: on the INEOS expansion, 121 commissioning systems were turned over against package-based records, and the discipline of assembling those records as work progressed, rather than retrospectively, carried directly into the module-based approach.

4. Discussion

The framework's contribution is not a new tool but a disciplined sequence that any modular mission-critical execution leader can apply. Its core claim, supported by the author's direct execution primarily on the 78-module data center program and informed by three earlier industrial programs, is that the field-execution layer between factory output and energization is where modular programs win or lose their schedule, and that a small set of gates and control loops governs that layer effectively.

Three observations stand out. First, defect economics favors upstream verification. The three-gate structure is designed to concentrate nonconformance discovery at the factory and receiving gates, which aligns with the objective offsite quality control review findings identify for layered verification [14] and is intended to reduce the rework that offsite productivity research ranks among the top risk factors [20]; as noted in Section 3.2, the author cannot confirm the actual gate-by-gate distribution of nonconformances on the 78-module program, so this observation describes the structure's design intent rather than a measured outcome. Second, schedule reliability is a function of what is committed, not what is reported. Making the controlling sequence the unit of commitment each cycle attacks the reliability gap that leaves traditional weekly planning at 54 percent completion [4] and reflects the delay-analysis discipline of isolating the true schedule driver [3][15]. Third, turnover is a continuous activity, not a terminal one. Building module-specific turnover packages through the readiness matrix directly counters the information-fidelity and post-construction-defect problems that dominate handover research [21].

The framework stays deliberately at the level of field methodology. Digital delivery is advancing in modular integrated construction, and practitioner perceptions of it are mixed but broadly forward-looking [17]; the framework here is compatible with digital tooling but does not depend on it, which matters for programs that must execute now rather than wait for instrumentation. The economics that justify front-loaded packaging and planning are consistent with advanced work packaging cost-benefit assessment [12] and with the benefits and success conditions recent research identifies for advanced work packaging in front-end planning and design [22], while the underlying project-delivery structure follows established project management practice [1].

Table 5 distills the lessons learned for modular deployment execution leaders, pairing each lesson with the framework component and the supporting evidence.

Table 5. Field Lessons for Modular Deployment Execution Leaders

Lesson	Practical implication
Layered verification should move discovery upstream without eliminating field checks.	Require factory evidence, receiving inspection, and field-readiness acceptance; retain downstream verification for escape defects.

Lesson	Practical implication
Readiness states require accepted evidence and release authority, not physical completion alone.	Define the evidence, blocker rules, responsible party, and acceptance authority for every module stage.
Heavy-lift control depends on coordinated interfaces.	Hold the lift until route, ground, crane configuration, load chart, rigging, weather, exclusion zone, and landing point are confirmed under the approved lift plan.
Schedule recovery should focus on the controlling sequence and documented variance.	Use current logic, constraints, owners, due dates, percent plan complete, reasons for variance, and forecast effect.
Turnover is a continuous evidence process.	Build and audit the module-specific turnover package throughout installation and testing rather than after physical completion.
Digital tools should support, not redefine, field governance.	Implement the same gates, evidence requirements, blockers, and release authority in any selected digital platform.

The wider significance is that modular mission-critical delivery is expanding faster than its execution playbook is being documented. Modular market share and productivity gains are well evidenced [10][11], but the field methods that realize those gains under mission-critical constraints are largely held as tacit practitioner knowledge. This article converts part of that tacit knowledge into a transferable structure that other execution leaders can test and adapt.

5. Conclusions

Modular data center deployment succeeds or fails in the field-execution layer that connects factory-built modules to a commissioned, energized facility. The framework presented here organizes that layer around a module-based readiness matrix, a three-gate quality verification structure, a heavy-lift and logistics risk-control routine, and a critical-path control loop. Developed most directly on a live 78-module mission-critical data center program and informed by three earlier industrial programs, these components were, in the author's practitioner observation, designed to move defect discovery upstream (though gate-by-gate data to confirm this distribution are not available), associated with heavy-lift and logistics risk held under control through the set sequence, schedule slippage addressed without the commissioning window moving during the author's tenure, and turnover and energization readiness protected through continuously assembled module packages. These are practitioner observations from live, uncontrolled delivery rather than independently audited or measured outcomes. The framework aligns field practice with established standards for project management [1], advanced work packaging [2], quality management [9], and mission-critical data center topology and infrastructure [5][6].

Limitations are real and should temper any generalization. The evidence base is a single practitioner's direct execution record across four programs, with no controlled comparison group and no counterfactual measurement of what a program without the framework would have achieved. The reported outcomes are the author's own project records, not independently audited metrics, and they describe live delivery rather than a designed experiment. The context is exclusively U.S. industrial and data-center construction, so transfer to other regulatory regimes, module types, or facility classes should be tested rather than assumed. The framework also stays at the level of field methodology and does not address the digital-delivery layer developing around modular construction.

Future work should test the framework against programs led by other execution leaders and, where possible, against comparison cases, and should examine how the gate and readiness structure interfaces with the emerging digital-delivery methods in modular integrated construction. Even within its limits,

the framework offers execution leaders a concrete, transferable starting point for modular mission-critical delivery.

Acknowledgments

None.

Funding

This work received no external funding.

Author Contribution

Rushi Jariwala is the sole author and is responsible for conceptualization, methodology, investigation, and writing of the substantive content of the manuscript in its entirety. Formatting, reference-list preparation, and submission-package assembly were supported by a professional editorial services provider acting under the author's direction; the provider did not originate or alter the manuscript's substantive technical content, claims, or conclusions.

Ai-Use Disclosure

The author wrote the substantive technical content, claims, and conclusions of this manuscript. A professional editorial services provider assisted with formatting the manuscript to the target journal template, reference-list and citation formatting, and preparation of the submission package; this support did not extend to originating or altering the manuscript's substantive content. AI-assisted tools were used during preparation in a supporting capacity for formatting assistance, language and copy-editing, and reference-formatting checks under the author's review and direction; no AI tool independently generated the manuscript's technical claims, methodology, or results, and the author takes full responsibility for the accuracy and integrity of the content.

Conflict Of Interest

The author declares no conflict of interest.

Data Availability Statement

The detailed project records underlying this practitioner case analysis are proprietary to the relevant employers, clients, and project participants and are not publicly available. The manuscript reports only aggregated or anonymized information that the author can verify within the scope of his project responsibilities. Any additional disclosure should be made only with documented authorization.

References

- [1] Project Management Institute. "A Guide to the Project Management Body of Knowledge (PMBOK Guide) and The Standard for Project Management," 7th Edition. Project Management Institute (PMI), Newtown Square, PA, 2021. <https://www.pmi.org/standards/pmbok>
- [2] Construction Industry Institute (CII), Research Team 272. "Advanced Work Packaging: Design through Workface Execution, Version 3.1" (Implementation Resource IR272-2, Volume I). Construction Industry Institute, Austin, TX, 2013. <https://www.construction-institute.org/advanced-work-packaging-design-through-workface-execution-version-3-1>
- [3] AACE International. "Recommended Practice No. 29R-03: Forensic Schedule Analysis" (TCM Framework 6.4). AACE International, rev. 2011. https://web.aacei.org/docs/default-source/toc/toc_29r-03.pdf
- [4] Lean Construction Institute (LCI). "Last Planner System: From Pull Planning to Weekly Work Planning." Lean Construction Institute, Arlington, VA. <https://leanconstruction.org/lean-topics/last-planner-system/>

- [5] Uptime Institute. "Tier Standard: Topology." Uptime Institute, LLC. <https://uptimeinstitute.com/resources/asset/tier-standard-topology>
- [6] Telecommunications Industry Association (TIA). "ANSI/TIA-942 Standard: Telecommunications Infrastructure Standard for Data Centers" (ANSI/TIA-942-C, 2024). <https://tiaonline.org/products-and-services/tia942certification/ansi-tia-942-standard/>
- [7] ASHRAE. "ASHRAE Datacom Series Book 1: Thermal Guidelines for Data Processing Environments, 5th Edition" (2021). <https://webstore.ansi.org/standards/ashrae/ashraedatacombook5thedition>
- [8] National Fire Protection Association (NFPA). "NFPA 70E, Standard for Electrical Safety in the Workplace" (2024 edition). <https://www.nfpa.org/product/nfpa-70e-standard-for-electrical-safety-in-the-workplace/p0070ecode>
- [9] International Organization for Standardization (ISO). "ISO 9001:2015 Quality management systems Requirements" (ISO, 2015), <https://www.iso.org/standard/62085.html>; and "ISO 9001:2015/Amd 1:2024 Quality management systems Requirements Amendment 1: Climate Action Changes" (ISO, 2024). <https://www.iso.org/standard/88431.html>
- [10] Ribeirinho, M.J., Mischke, J., Strube, G., Sjödin, E., Blanco, J.L., Palter, R., Biörck, J., Rockhill, D., & Andersson, T. "The Next Normal in Construction: How Disruption Is Reshaping the World's Largest Ecosystem." McKinsey & Company, 2020. <https://www.mckinsey.com/capabilities/operations/our-insights/the-next-normal-in-construction-how-disruption-is-reshaping-the-worlds-largest-ecosystem>
- [11] Dodge Construction Network. "Prefabrication and Modular Construction 2020" (SmartMarket Report). Dodge Data & Analytics, 2020. <https://www.construction.com/resource/prefabrication-modular-construction-2020/>
- [12] Halala, Y.S., & Fayek, A.R. "A Framework to Assess the Costs and Benefits of Advanced Work Packaging in Industrial Construction." Canadian Journal of Civil Engineering, 46(3), 216-229, 2019. <https://doi.org/10.1139/cjce-2018-0072>
- [13] Mousaei, A., Taghaddos, H., Bagheri, S.M., & Hermann, U. "Optimizing Heavy Lift Plans for Industrial Construction Sites Using Dijkstra's Algorithm." Journal of Construction Engineering and Management, 147(11), 04021160, 2021. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002157](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002157)
- [14] Liu, Y., Yao, F., Ji, Y., Tong, W., Liu, G., Li, H.X., & Hu, X. "Quality Control for Offsite Construction: Review and Future Directions." Journal of Construction Engineering and Management, 148(8), 03122003, 2022. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002317](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002317)
- [15] Çevikbaş, M., Okudan, O., & Işık, Z. "New Delay-Analysis Method Using Modified Schedule and Modified Updated Schedule for Construction Projects." Journal of Construction Engineering and Management, 148(11), 04022119, 2022. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002394](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002394)
- [16] Park, J.E. "Schedule Delays of Major Projects: What Should We Do About It?" Transport Reviews, 41(6), 814-832, 2021. <https://doi.org/10.1080/01441647.2021.1915897>
- [17] Wang, S., Lu, Y., Lu, J., Mao, Y., Wang, N., & Guo, Z. "Exploring Practitioners' Perceptions of Digital Delivery in Modular Integrated Construction Projects." Journal of Management in Engineering, 41(2), 04024070, 2025. <https://doi.org/10.1061/JMENE.MEENG-6304>
- [18] Song, S.H., Choi, J.O., & Cho, H. "Transportation-Induced Impact on a Prefinished Volumetric Modular House Using Trailer Bogie: Case Study." Journal of Construction Engineering and Management, 150(7), 05024007, 2024. <https://doi.org/10.1061/JCEMD4.COENG-14567>
- [19] Shin, J., & Choi, B. "Design and Implementation of Quality Information Management System for Modular Construction Factory." Buildings, 12(5), 654, 2022. <https://doi.org/10.3390/buildings12050654>

- [20] Assaad, R.H., El-adaway, I.H., Hastak, M., & Needy, K.L. "Key Factors Affecting Labor Productivity in Offsite Construction Projects." *Journal of Construction Engineering and Management*, 149(1), 04022158, 2023. <https://doi.org/10.1061/JCEMD4.COENG-12654>
- [21] Zhu, L., Shan, M., & Xu, Z. "Critical Review of Building Handover-Related Research in Construction and Facility Management Journals." *Engineering, Construction and Architectural Management*, 28(1), 154-173, 2021. <https://doi.org/10.1108/ECAM-10-2018-0442>
- [22] Demetracopoulou, V., Faust, K.M., & O'Brien, W.J. "Benefits and Conditions for Successful Implementation of Advanced Work Packaging in Front-End Planning and Design." *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 17(4), 04525055, 2025. <https://doi.org/10.1061/JLADAH.LADR-1357>
- [23] Occupational Safety and Health Administration (OSHA). "29 CFR 1926 Subpart CC Cranes and Derricks in Construction." U.S. Department of Labor, 2010 (as amended). <https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926SubpartCC>
- [24] American Society of Mechanical Engineers (ASME). "ASME B30 Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings" (B30.5 Mobile and Locomotive Cranes; B30.26 Rigging Hardware). ASME, New York, NY. <https://www.asme.org/codes-standards/find-codes-standards/b30-5-mobile-locomotive-cranes>

Biographical Sketch

Rushi Jariwala is a project manager and construction and turnover execution leader specializing in mission-critical infrastructure delivery. Since December 15, 2025, he has led quality assurance, quality control, and turnover execution on a live 120 million dollar modular data center program of 78 OptiStax modules for RUS Industrial, LLC, running roughly 600,000 manhours with peak manpower near 440 personnel. From 2014 to 2022 he served as a site quality control manager at Bilfinger Westcon across major industrial capital projects, including the INEOS Styrolution 100KT ASA expansion, a Braskem polypropylene recovery program with live-plant interfaces, and the NatGasoline methanol facility. His practice centers on quality integration, heavy-lift and logistics control, schedule recovery, and turnover and commissioning readiness for large industrial and data-center programs. He is based in the United States.