

An AI-Enabled Strategic Project Management Framework for Resilient Fiber and Substation Infrastructure Delivery to Improve U.S. Grid Reliability

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Publication Date: 2026/10/03

Abstract: The United States is investing heavily in grid modernization, yet the literature guiding these investments is dominated by technical and policy perspectives, with limited attention to how utility infrastructure programs are actually delivered. This narrative review synthesizes project management maturity and organizational competence research, construction change-order and scope management research, and industry and regulatory evidence on right-of-way and permitting friction. From that synthesis I develop a strategic project management framework organized across four program lifecycle phases: scope discovery, sequencing, adaptation, and delivery. The framework is grounded in my experience managing more than thirty concurrent utility infrastructure programs across four states and two wholesale markets. I then propose, as a conceptual and forward-looking extension for future adoption, an AI-enabled decision support layer mapped onto the four phases, drawing on published research in construction natural language processing, delay-risk prediction, automated compliance checking, and cost forecasting. This layer is presented as a direction for future work rather than as a system that has been built, deployed, or validated. The framework is illustrated with an anonymized case and a hypothetical applied example, and implications are drawn for utilities, engineering firms, policymakers, and future research.

Keywords: Grid Modernization; Project Management; Substation Automation; Fiber Optic Infrastructure; Artificial Intelligence; Decision Support; Right-of-Way; Grid Resilience.

How to Cite: Adeola Aliu (2026) An AI-Enabled Strategic Project Management Framework for Resilient Fiber and Substation Infrastructure Delivery to Improve U.S. Grid Reliability. *International Journal of Innovative Science and Research Technology*, 11(8), 4198-4209. <https://doi.org/10.38124/ijisrt/26aug1364>

I. INTRODUCTION

➤ Background

The United States is in a major grid investment cycle. The Infrastructure Investment and Jobs Act of 2021 committed federal funds to grid resilience through the Department of Energy's Grid Resilience and Innovation Partnerships program, and the Federal Communications Commission has advanced a rulemaking aimed at removing state and local barriers to wireline infrastructure deployment [1], [2], [3]. The premise behind this investment is that an aging grid facing more frequent extreme weather and rising demand needs better observability, faster restoration, and stronger communication backbones [4]. Substation automation and outage response sit at the center of that premise: modern protection, control, and supervisory control and data acquisition (SCADA) systems depend on high-bandwidth, low-latency, interference-immune communications, for which fiber optics is the preferred

medium [5], and the governing standards, most prominently IEC 61850, are mature and well documented [6].

➤ Rationale for the Review

What is far less documented is how the programs that deliver this infrastructure are managed. Industry research shows that permitting complexity and right-of-way delays extend fiber deployment timelines and inflate costs [7], [8]. Construction research shows that a large share of change orders is avoidable through better front-end planning and scoping [9]. Maturity research shows that organizational capability drives repeatable delivery, but has largely developed outside the U.S. power sector [10], [11]. No existing work connects these findings to U.S. utility fiber and substation delivery across multiple jurisdictions, and none considers how emerging artificial intelligence methods might support that delivery. I write from inside that context, as a Project Management Professional (PMP) certified project manager responsible for more than thirty concurrent utility

infrastructure programs across Illinois, Ohio, Texas, and New Jersey, in both the PJM and ERCOT wholesale markets.

➤ *Aim and Objectives*

The aim of this paper is to develop a delivery-side strategic project management framework for U.S. utility fiber and substation automation programs, grounded in the literature and in documented field practice, and to propose a conceptual AI-enabled decision support extension for future adoption. The objectives are to: (i) synthesize project management maturity and organizational competence research relevant to power sector delivery; (ii) synthesize construction change-order research and industry and regulatory evidence on right-of-way and permitting friction; (iii) identify the gaps at the intersection of these literatures; and (iv) propose and illustrate a strategic framework, together with a forward-looking AI decision support layer, that addresses those gaps.

➤ *Scope of the Review*

The review addresses the management of delivery, not the design of technical systems. It takes the engineering standards for substation automation as settled and asks what determines whether programs built to those standards are completed on schedule and within budget. Geographic scope is the United States, with international maturity studies retained where their findings transfer. The review is narrative rather than systematic, for reasons stated in Chapter 3, and its claims about practice are bounded by the disclosed portfolio from which they are drawn. The proposed AI decision support layer is treated throughout as a conceptual extension for future work and is not claimed to have been implemented or validated.

II. LITERATURE REVIEW

➤ *Project Management Maturity and Organizational Competence in the Power Sector*

Maturity models describe how far an organization has progressed from ad hoc project delivery toward repeatable, measured, and continuously improving practice [12]. Jugdev and Thomas argued two decades ago that maturity models capture explicit processes but not the tacit, firm-specific capabilities that actually confer advantage, a critique that still disciplines the field [13]. The most current synthesis is a PRISMA-aligned systematic review of project management maturity in project-based organizations covering 2010 to 2023, which catalogued twenty-nine maturity models and identified sustainability, stakeholder engagement, continuous improvement, and technological advancement as recurring maturity drivers [10]. A companion empirical study by the same authors found that legal requirements had a statistically significant effect on the maturity of project-based organizations [14], a finding directly relevant to infrastructure sectors where regulatory obligations shape delivery.

Power-sector-specific maturity work exists but remains largely conceptual and concentrated outside the United States. Gareeb and Rwelamila reviewed existing models and concluded that none fit the South African power sector [11],

then developed PESTLE analysis and power sector factors as building blocks for a sector-specific maturity model concept [15]. In adjacent public infrastructure research, a survey of 129 practitioners in South African government infrastructure departments found that a project management office's strategic maturity had the strongest association with organizational project management capability across all nine knowledge areas examined [16], and a quantitative study of Australian project organizations linked maturity to competitive advantage in tendering [17]. This literature establishes that maturity matters for infrastructure delivery, but almost none of it examines U.S. investor-owned utilities operating across multiple regulatory jurisdictions.

➤ *Substation Automation and Grid Communications*

Mackiewicz summarized the architecture and interoperability benefits of IEC 61850, the dominant substation automation standard [6]. Gungor et al. mapped the communication technologies underpinning smart grid applications and identified the properties that favor fiber optics for substation and backbone communications, including high bandwidth, low latency, and immunity to electromagnetic interference [5]. Panteli and Mancarella provided the conceptual resilience framework most often cited in grid modernization work, distinguishing the ability to withstand disturbances from the ability to observe, respond, and restore [4]. This literature defines what should be built; route acquisition, permitting lead times, contract structures, and the capability to manage them are effectively absent, though they routinely determine whether these architectures are energized on schedule.

➤ *Scope Change and Change-Order Management in Infrastructure Construction*

Construction research offers the most direct peer-reviewed evidence on what happens when scope is unstable. Taylor et al. analyzed 610 Kentucky roadway projects and found that the leading causes of change orders consistently included contract omissions, owner-induced enhancements, and item overruns, and that many high-risk change orders are avoidable through improved front-end planning and scoping [9]. Gunduz and Mohammad used the analytic hierarchy process to rank change-order impact factors on project performance [18]. Naji et al. developed a change-order management performance measurement framework through a Delphi study, identifying forty-nine performance factors across seven management groups [19], and demonstrated through structural equation modeling that change-order management factors have a measurable effect on overall construction project success [20]. Although this literature is rooted in roadway and building construction rather than utility fiber programs, its central findings, that scope instability is a managed variable and that front-end scoping discipline pays, transfer directly.

➤ *Right-of-Way and Permitting: Industry and Policy Evidence*

The evidence on right-of-way and permitting friction comes primarily from industry and regulatory sources rather than peer-reviewed academic literature, and is cited here on that basis. The Fiber Broadband Association's Deployment

Specialists Committee found that complex and inconsistent permitting processes across states slow fiber deployment and place federal investment at risk [7], and the association's deployment cost research found that providers facing higher permitting burdens reported longer approval delays that pushed back timelines and produced compounding cost effects across other project components [8]. Local permitting practices have also been shown to shape broadband deployment outcomes at the municipal level [21]. Federal guidance treats permitting as a distinct program workstream, with the National Telecommunications and Information Administration publishing right-of-way and permitting resources for broadband grant recipients [22]. The FCC opened WC Docket No. 25-253, Build America: Eliminating Barriers to Wireline Deployments, with a Notice of Inquiry in September 2025, and on June 25, 2026 adopted a Notice of Proposed Rulemaking proposing a rebuttable presumption that a jurisdiction violates Section 253 of the Communications Act if it fails to act on a wireline right-of-way authorization within 120 days, together with cost-based limits on permitting fees [3]. As of this writing, the NPRM has not yet been published in the Federal Register, so comment deadlines are not set.

➤ *Artificial Intelligence in Construction and Contract Analytics*

A growing body of peer-reviewed research applies artificial intelligence to construction delivery problems that parallel the four phases of the framework developed in this paper. In contract and scope analysis, natural language processing has been used to identify contractual requirements automatically [23], to detect substantial contractual changes

[24], and to detect missing contract clauses through deep learning [25]. In scheduling and risk, machine learning has been applied to construction delay-risk prediction [26] and to infrastructure project risk management through machine learning and optimization [27]. In compliance, semantic natural language processing has been used for automated building code compliance checking [28]. In cost and portfolio control, artificial intelligence has been proposed for optimized project management and risk mitigation, including predictive cost analytics [29]. These studies are drawn largely from building and roadway construction rather than utility fiber and substation programs, and none is specific to the U.S. multi-market grid delivery context. They establish the plausibility of the decision support layer proposed in Chapter 4, not its validation in this setting.

➤ *Gaps in the Existing Literature*

These literatures do not currently meet, as Figure 1 shows. Maturity research addresses organizational capability but rarely the U.S. power sector; change-order research demonstrates that scope discipline is measurable but is rooted in roadway and building construction; technical research defines the target architecture but not the path to deliver it; permitting evidence frames fiber as a broadband access question, overlooking utility-owned fiber built for grid automation; and artificial intelligence research demonstrates capability on isolated construction tasks without organizing around grid delivery. The unaddressed intersection is project management capability, and its potential AI augmentation, applied to U.S. utility fiber and substation automation programs across multiple regulatory jurisdictions.

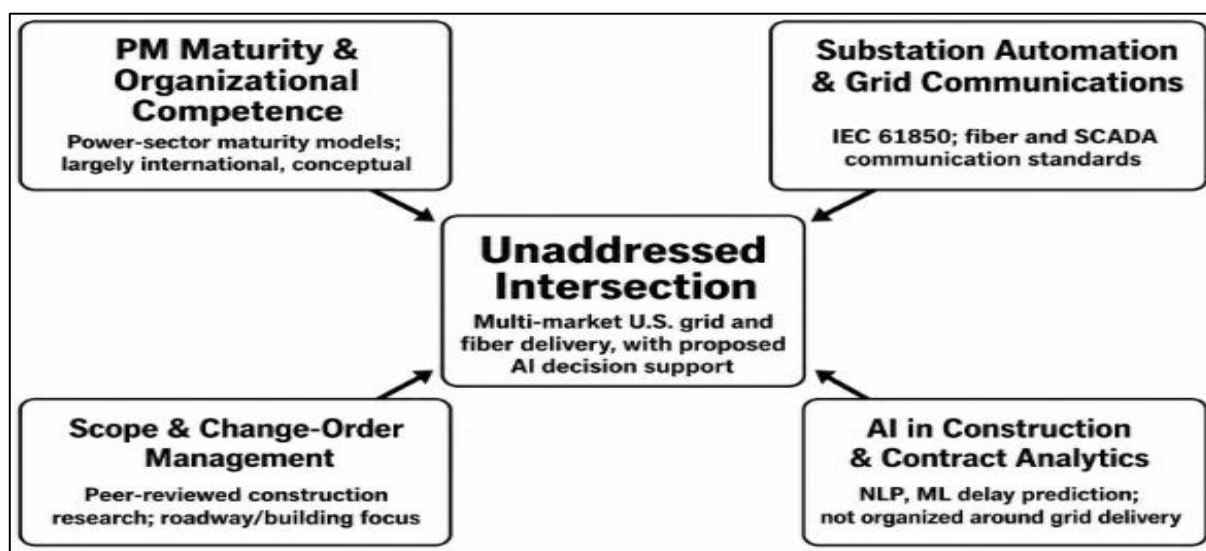


Fig 1 Literature Landscape Showing the Four Parent Bodies of Work and the Unaddressed Intersection this Paper Occupies: Multi-Market U.S. Grid and Fiber Delivery, with a Proposed AI Decision Support Layer.

III. METHODOLOGY

➤ *Review Design*

This paper uses a narrative review design supplemented by disclosed practitioner experience. A narrative rather than systematic design is appropriate because the relevant evidence spans heterogeneous bodies of work, peer-reviewed

project management and construction research, technical engineering literature, artificial intelligence research, and regulatory and industry grey literature, that cannot be meaningfully pooled or scored on a common quality instrument. The review nonetheless borrows transparency practices from systematic methods, reporting the search strategy, sources, and selection criteria in full [10].

➤ Search Strategy

Searches were conducted using Google Scholar and open-access aggregators, with full texts retrieved from publisher platforms where openly available, using the following Boolean string: ("project management" OR "program management" OR "organizational competence" OR "maturity model") AND ("grid modernization" OR "substation automation" OR "smart grid" OR "fiber deployment") AND ("resilience" OR "reliability" OR "outage") AND (United States OR U.S.). A parallel search paired the artificial intelligence terms ("natural language processing" OR "machine learning" OR "predictive analytics") with the construction and contract terms ("construction contract" OR "change order" OR "delay prediction" OR "compliance checking"). The search covered January 2010 through June 2026. Consistent with the narrative design stated in Section 3.1, no formal screening counts are reported; sources were assessed against the criteria in Section 3.3, and reference lists and regulatory dockets were hand-searched for additional material.

➤ Inclusion and Exclusion Criteria

Sources were included if they met all of the following:

- Peer-reviewed journal articles, reviews, or conference papers published in English, or authoritative regulatory and industry documents identified as grey literature;
- A substantive project management, organizational competence, maturity, change management, or applied artificial intelligence focus;
- Application to grid modernization, substation automation, smart grid, fiber deployment, or infrastructure construction with transferable findings; and
- Engagement with reliability, resilience, outage, or delivery performance outcomes.
- Sources were excluded if any of the following applied:
- Purely algorithmic or technical optimization content with no delivery or organizational dimension;
- Non-infrastructure sector settings without transferable findings; or
- Editorials or commentary without a stated method.

A general recency preference limited sources to the last five years, with two deliberate exceptions retained because they are the foundational technical references for smart grid communications and IEC 61850 respectively and are conventionally cited in this literature regardless of age: Gungor et al. [5] and Mackiewicz [6].

➤ Data Extraction and Synthesis

Retained sources were charted in a matrix recording study focus, method, sector, geography, and principal findings, then coded into themes. Three themes structure the synthesis in Chapter 4: organizational capability and maturity as delivery determinants; scope volatility and change-order management; and external friction arising from rights-of-way, permitting, and regulatory variation. This three-theme structure is a deliberate organizing choice as much as an inductive result: the themes were shaped by the review questions and by my practice-informed reading of the

sources, and a different reviewer could defensibly organize the same material along other lines. My practitioner experience served as an interpretive lens for judging transferability, disclosed as such rather than treated as evidence. The artificial intelligence sources were mapped separately onto the four framework phases to structure the proposed decision support layer, summarized in Table 1.

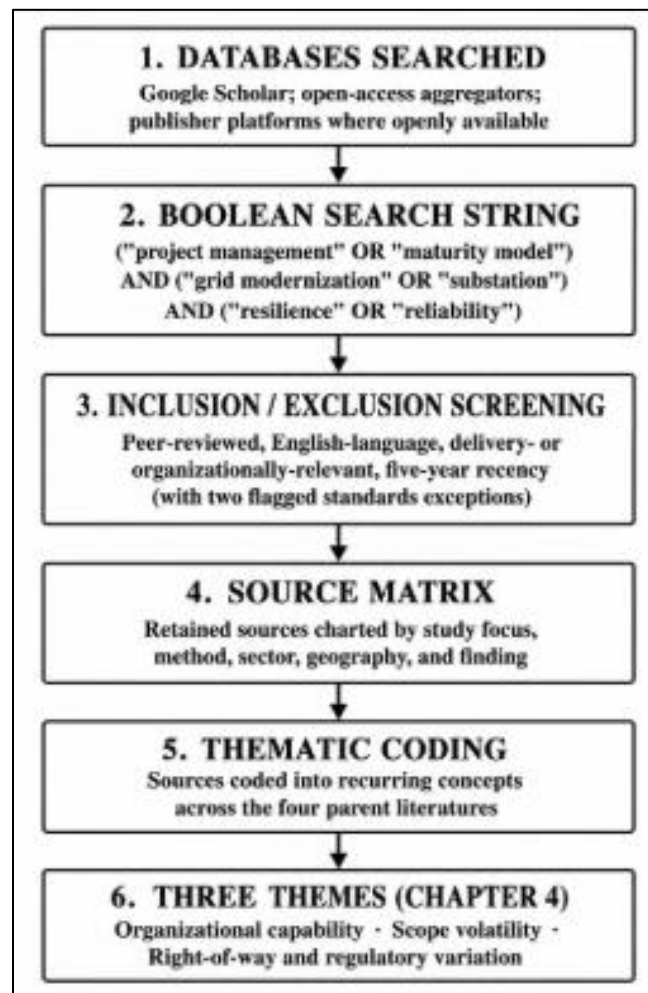


Fig 2 Methodology and Search Strategy Flow, from Database Search Through Boolean String, Screening, Source Matrix, and Thematic Coding, to the Three Themes Structuring Chapter 4.

➤ Conceptual Framework and Figures

The core framework is a four-phase program lifecycle model, shown in Figure 3, in which scope discovery, sequencing, adaptation, and delivery feed a set of grid reliability outcomes, with a continuous reconciliation loop returning from delivery to scope discovery. Figure 2 shows the proposed AI-enabled decision support layer positioned above the four phases, feeding predictive analytics, machine learning, natural language processing, and risk intelligence into each phase. The AI layer in Figure 2 is a conceptual proposal for future adoption; the arrows denote intended information flows that could support program-manager judgement, not a system that has been built or tested. Table 1 maps each phase to candidate AI capabilities and the published research that motivates them.

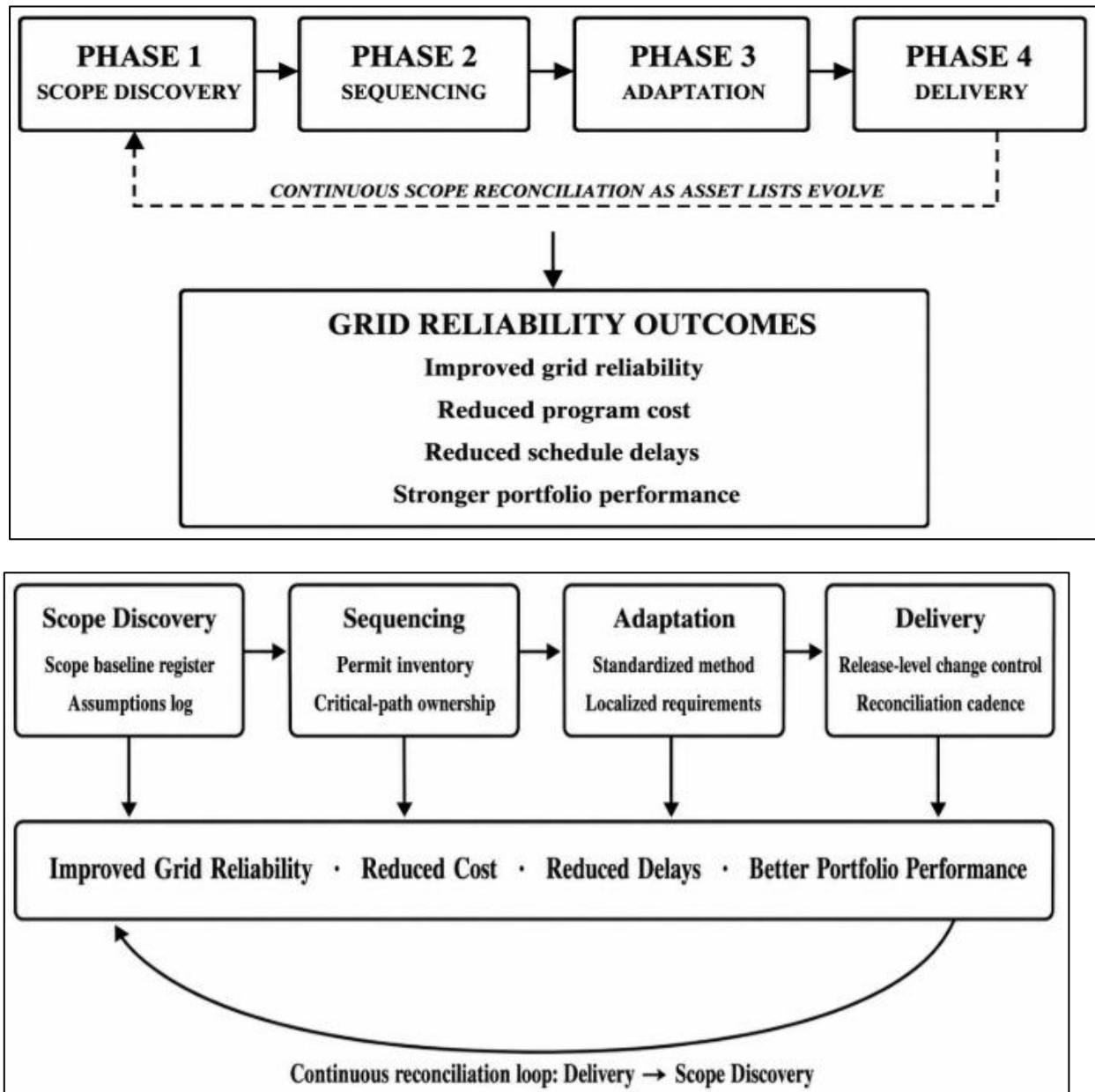
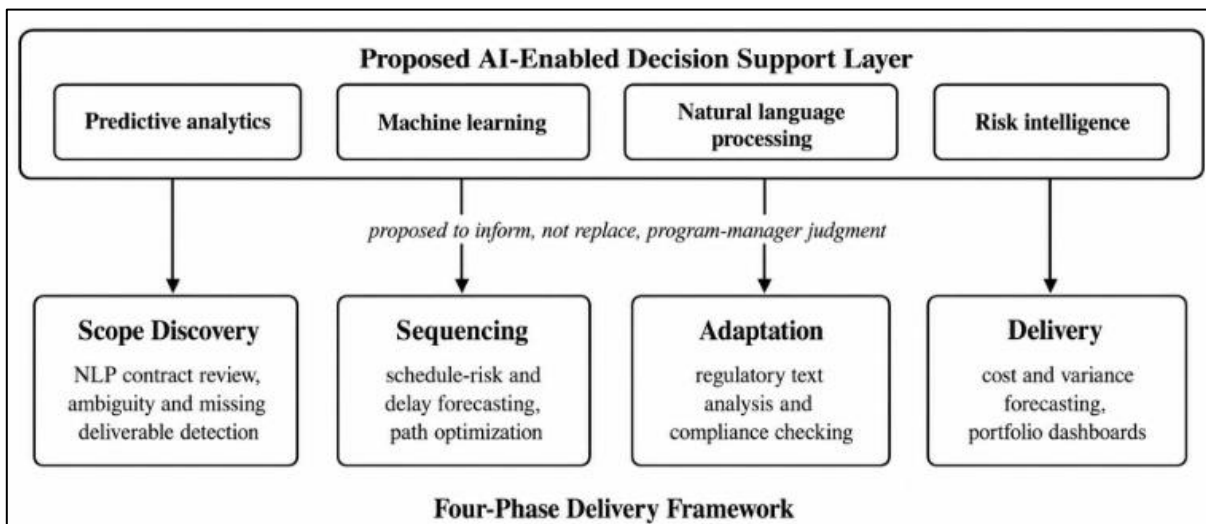


Fig 3 Core Four-Phase Strategic Project Management Framework, Showing the Delivery Lifecycle and its Intended Grid Reliability Outcomes.



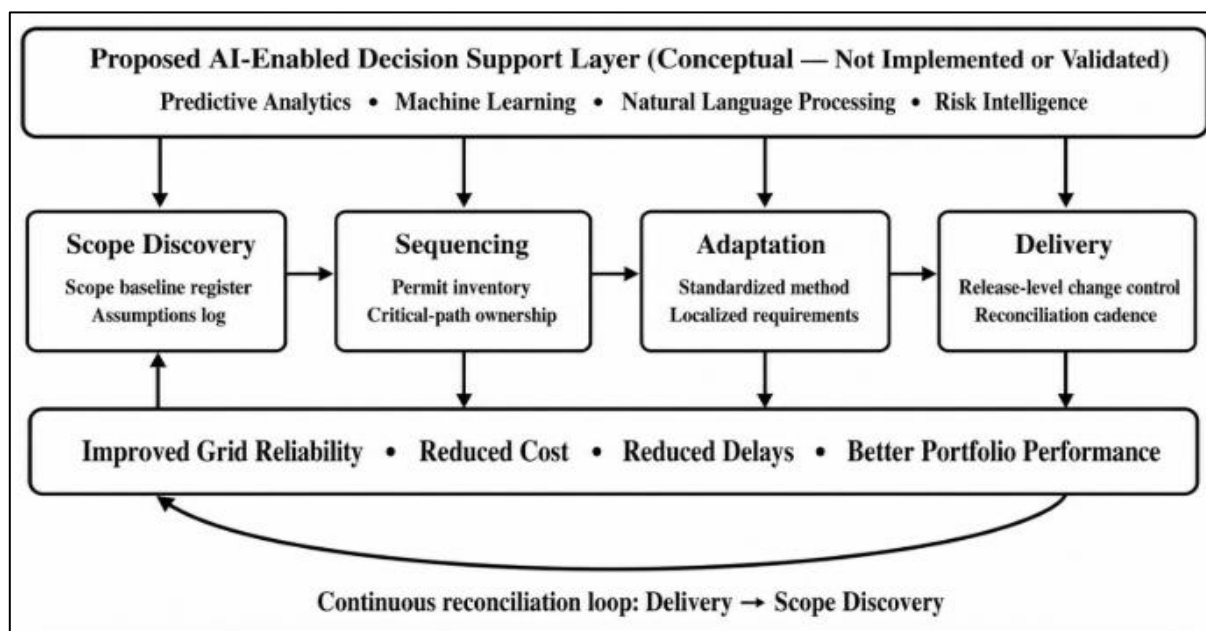


Fig 4 Proposed AI-Enabled Decision Support Layer Mapped onto the Four-Phase Framework. The Layer is a Conceptual Extension for Future Adoption and is not a Validated or Deployed System.

Table 1 Proposed AI Decision Support Capabilities Mapped to Framework Phases, with Motivating Research. All Capabilities are Proposed for Future Adoption; Reported Metrics are Attributed to the Cited Studies, Not to this Framework.

Phase	Proposed AI capabilities	Motivating research (attributed findings)	Source
Scope Discovery	NLP-based contract review, scope ambiguity detection, and missing deliverable identification	NLP identified contractual requirements (reported SVM recall of 95% in that study); ML/NLP detected substantial contractual changes; deep learning detected missing clauses (reported multi-label accuracy of 93% in that study)	[23], [24], [25]
Sequencing	Schedule-risk and delay forecasting; critical path and route-sequencing optimization	ML models predicted construction delay risk from objective data; ML and optimization addressed interacting and systemic infrastructure project risks	[26], [27]
Adaptation	AI-based regulatory text analysis and automated compliance checking (proposed extension toward cross-jurisdiction comparison)	Semantic NLP performed automated building code compliance checking; cross-jurisdiction comparison is proposed here as an extension not yet demonstrated in the cited work [VERIFY: no source directly demonstrates automated multi-jurisdiction regulatory comparison]	[28]
Delivery	Cost prediction, schedule variance forecasting, and portfolio health dashboards	AI proposed for optimized project management, predictive cost analytics, and risk mitigation in construction	[29]

IV. FRAMEWORK, RESULTS, AND DISCUSSION

➤ Thematic Synthesis

The synthesis produced three themes: organizational capability and maturity as measurable determinants of delivery outcomes; scope volatility as a managed variable with a substantial avoidable component; and rights-of-way, permitting, and regulatory variation as external friction that programs must plan around rather than react to. Each theme is grounded in the cited literature and connected to field experience from the disclosed portfolio. Table 2 summarizes the themes, key findings, and representative sources.

➤ Theme 1: Organizational Capability and Maturity as Delivery Determinants

The maturity literature converges on a consistent claim: more mature organizations deliver more reliably. The

strategic dimension of project management office maturity was the strongest correlate of organizational project management capability [16]; maturity was associated with competitive advantage in tendering [17]; and legal requirements were a significant determinant of maturity in project-based organizations [14]. Table 3 compares principal maturity frameworks with the framework proposed here. In my portfolio, this theme is visible in the difference between programs run on institutionalized artifacts and programs run on the memory of experienced individuals; the former survive staff turnover and scope growth, the latter do not.

➤ Theme 2: Scope Volatility and Change-Order Management

The change-order literature treats scope instability as a management outcome with identifiable, partly preventable drivers: the leading causes are contractual and owner-driven, a large share is avoidable through front-end planning [9],

impact pathways can be ranked [18], and structured change-order management measurably affects success [19], [20]. The transfer to utility programs is direct. Utility capital programs are routinely contracted before scope is fully determined: agreements are signed while substation candidate lists are still being finalized, route studies are incomplete, and the boundary between engineering deliverables and construction-phase support is undefined. The failure mode is treating the contract as though it defined scope, then discovering mid-program that the parties hold different understandings of what was purchased. Section 4.6 develops the response on which the literature and my field practice converge.

➤ *Theme 3: Right-of-Way, Permitting, and Regulatory Variation*

The industry and regulatory evidence establishes permitting as a first-order schedule and cost driver: complexity and inconsistency slow deployment [7], higher permitting burden correlates with delay and compounding

cost effects [8], and the federal government now treats the problem as significant enough to warrant both grant-program guidance [22] and a preemption rulemaking [3]. A fair objection is that this evidence base is broadband-centric, and utilities differ: they often hold franchise rights, existing easements, and their own pole plant, which reduces some friction. The claim here is correspondingly narrow. Utility fiber routes serving substation automation still cross public rights-of-way, railroad corridors, and multiple municipal jurisdictions on segments outside utility-controlled property, where the documented friction applies with full force. In my programs, permits on such segments are typically among the longest-lead and highest-variance schedule items. The corollary that legal requirements significantly shape organizational maturity [14] connects this theme back to Theme 1: the capacity to manage regulatory variation is itself an organizational capability, one that mature program organizations institutionalize.

Table 2 Summary of Themes, Key Findings, and Representative Sources.

Theme	Key findings	Representative sources
1. Organizational capability and maturity	Maturity is linked to delivery outcomes and competitive advantage; strategic PMO maturity shows the strongest association with organizational PM capability; legal requirements are a significant maturity determinant	[14], [10], [17], [16], [11], [15]
2. Scope volatility and change-order management	Many change orders are avoidable through front-end planning; leading causes include contract omissions and owner-induced enhancements; structured change-order management measurably affects project success	[9], [18], [19], [20]
3. Right-of-way, permitting, and regulatory variation	Permitting complexity and inconsistency slow deployment and compound costs; federal proceedings target authorization timelines and fees; federal guidance treats permitting as a distinct program workstream	[7], [8], [3], [22], [21]

➤ *Discussion*

Read together, the themes say something the parent literatures do not say individually: capability, scope discipline, and friction management behave as a single problem in practice. Maturity without sequencing produces well-documented programs that stall at the first denied crossing. Scope discipline without regulatory adaptation produces clean baselines that transplant badly across state lines. The most consequential and least priced decision the synthesis surfaces is deferral: deferring right-of-way work feels efficient because it avoids spending on routes that may change, but a denied crossing discovered late forces redesign at the most expensive point in the program, and the deferral's budget implications, redesign exposure, re-mobilization, and carrying cost, are rarely priced when the decision is made. Deferral pricing is singled out among the framework's practices because it requires no organizational maturity to adopt: a single program manager can apply it to the next deferral decision, whereas baseline registers and dedicated permitting ownership require structural change.

➤ *Proposed Strategic Framework*

The framework organizes three delivery principles, scope reconciliation under contractual ambiguity, right-of-way and permitting sequencing, and cross-market regulatory adaptation, across four program lifecycle phases: scope discovery, sequencing, adaptation, and delivery, as shown in Figure 1.

- Phase 1: Scope discovery. The program accepts at initiation that scope is partly undetermined and manages that fact explicitly. A scope baseline register maps every contractual deliverable to the current asset list and is re-baselined whenever the list changes, so the question of contracted scope always has a current, documented answer. An assumptions log distinguishes contracted deliverables from client-furnished inputs and client-side dependencies, because most scope disputes are really disputes about whose dependency failed. Manhole and duct inspection illustrates the point: it is field engineering work rather than a right-of-way activity, yet it routinely surfaces scope no contract anticipated, a duct found full or damaged, or a third-party-owned manhole whose access requires an unanticipated permission agreement. The register and assumptions log exist to absorb these discoveries as documented scope events before they can harden into disputes. Contingency is sized to the share of scope that remains undetermined rather than to a flat percentage. This phase operationalizes the front-end planning findings of the change-order literature [9] in a professional services context.
- Phase 2: Sequencing. Right-of-way feasibility runs concurrently with preliminary engineering rather than after it. The program maintains a permit inventory ranked by lead time and denial risk, assigns the permitting workstream a dedicated owner separate from design management, and makes high-risk authorizations

predecessors to detailed design wherever the route is contingent on them. Where deferral is chosen, it is priced: its budget implications are documented as owned risks. Programs should track WC Docket No. 25-253, where the proposed 120-day presumption and cost-based fee limits would, if adopted, change the assumptions that currently force conservative permitting floats [3].

- **Phase 3: Adaptation.** For organizations delivering across jurisdictions, the operating rule is to standardize the process and localize the requirements. The management method, reporting structure, change control mechanics, and quality gates stay constant across markets. What is localized is the requirements layer: a market-specific compliance checklist, a state-level stakeholder map, a communication cadence matched to each client's regulatory calendar, and prevailing critical infrastructure protection obligations where SCADA and communication assets are in scope. Treating adaptation as a program-level competence reflects the strategic maturity finding of Khalema et al. [16].
- **Phase 4: Delivery.** Change control operates at the release or task-order level rather than the whole-program level, keeping commercial adjustments small, frequent, and uncontentious, consistent with the performance measurement logic of Naji et al. [19]. A recurring scope reconciliation cadence with the client closes the loop back to Phase 1 as asset lists continue to evolve.

- **Proposed AI-Enabled Decision Support Layer**

As a conceptual extension for future adoption, an AI-enabled decision support layer could sit above the four phases and feed each one, as shown in Figure 4 and mapped in Table 1. The layer is proposed, not built: nothing in this section describes a system that exists, has been deployed, or has produced results in my programs, and any performance figures cited belong to the underlying studies rather than to this framework. In scope discovery, natural language processing methods that have identified contractual requirements [23], detected substantial contractual changes [24], and detected missing clauses [25] could support

ambiguity detection and missing-deliverable identification against a scope baseline. In sequencing, delay-risk prediction [26] and machine-learning-based infrastructure risk management [27] would enable earlier, evidence-informed schedule-risk forecasting. In adaptation, automated regulatory text analysis and compliance checking [28] is proposed to support jurisdiction-specific compliance monitoring, with cross-jurisdiction comparison identified as a direction not yet demonstrated in the cited literature. In delivery, AI-based cost and risk analytics [29] could inform cost prediction, schedule variance forecasting, and portfolio dashboards. Throughout, the layer is proposed to inform program-manager judgement, not to replace it, and its adoption would require validation that this paper does not provide.

- **Alignment with Recognized Project Management Methodology**

The four-phase framework is not offered as a replacement for recognized project management methodology but as a domain-specific operationalization of it. Mapped against the Project Management Institute's process groups, Initiating, Planning, Executing, Monitoring and Controlling, and Closing [30], the framework's four phases correspond most directly to Initiating and Planning (Scope Discovery), Planning (Sequencing), Executing (Adaptation), and Executing together with Monitoring and Controlling (Delivery), as summarized in Table 3. The Closing process group is deliberately not treated as terminal in this framework; the reconciliation loop shown in Figure 3 returns Delivery-phase findings to Scope Discovery for the next release or asset within an ongoing, multi-year program portfolio, a structure more consistent with rolling-wave and hybrid delivery models than with single-project closeout [10]. What the framework adds beyond generic process-group guidance is not new process architecture but a specific, disclosed answer to how each process group should be executed under U.S. multi-market utility conditions: which artifacts to maintain, who owns them, and how they connect to earned value reporting.

Table 3 Alignment of the Four-Phase Framework with PMI Process Groups, Showing Standard Guidance and this Framework's Domain-Specific Extension.

PMI Process Group	Standard Guidance	Framework Extension (This Paper)
Initiating	Define stakeholders and high-level scope	Scope Discovery: formal reconciliation register for field-discovered vs. contracted scope
Planning	Develop schedules, budgets, risk register	Sequencing: right-of-way and permitting treated as a dedicated critical-path workstream with named ownership
Executing	Direct and manage project work	Adaptation: stable core methodology with a thin, jurisdiction-specific requirements layer
Monitoring & Controlling	Track performance; manage change	Delivery: release-level change control tied to earned value indices (Figure 5)
Closing	Formal project closeout	Not terminal here; Delivery findings loop back to Scope Discovery for the next release (Figure 3)

➤ **Case Illustration**

The following case is drawn from a program I managed and is anonymized as a matter of professional discretion: no client, company, or program names are used, geography is

stated at the state level, and scale and duration are given as approximations. The program is a regional fiber optic engineering program supporting substation automation and outage response for a large Midwestern investor-owned

utility, covering multiple substations in Illinois over a multi-year horizon, delivered under a professional services arrangement in which scope is released progressively as the utility confirms sites and priorities.

All four phases were exercised. The contract was executed while the final substation list was still being determined, and the boundary between engineering deliverables and later construction-phase support was initially ambiguous; the scope baseline register and assumptions log kept the question of contracted scope answerable at every point, and release-level change control absorbed successive site additions without renegotiating the program. Field inspection of existing manholes and ducts likewise surfaced conditions outside the contracted scope, including third-party access arrangements, which entered the program through the same register. Several route segments crossed public rights-of-way outside utility property; early feasibility screening surfaced the crossings with the longest authorization lead times so the schedule could account for them from the start, and where right-of-way work was deferred, the deferral's budget implications were documented as owned risks rather than left implicit. The program's artifacts subsequently became the template layer for programs in other states and in ERCOT; the process transferred intact, while the requirements layer was rebuilt for each new jurisdiction. I make no quantitative performance claims for this program; verified figures suitable for publication are not included here. The proposed AI decision support layer was not used in this program and is not implied by it; the case illustrates the four phases as executed manually.

➤ *Applied Example (Hypothetical)*

The following example is hypothetical. It does not describe any actual program, client, or contract; it exists solely to show the phases operating in sequence. Suppose a utility initiates a fiber buildout connecting twelve substations across two adjacent states under an engineering services agreement signed while four sites remain unconfirmed. In

scope discovery, deliverables are baselined against the eight confirmed sites, the four unconfirmed sites are logged as pending scope with client confirmation as the recorded dependency, and contingency is sized to that undetermined third of the program. In sequencing, desktop feasibility identifies two railroad crossings and one state highway crossing as the longest-lead authorizations; those permits are initiated before detailed design begins on the affected segments, and a proposal to defer the highway crossing is evaluated only after its redesign and re-mobilization exposure is priced into the risk register. In adaptation, the management method carries between the two states unchanged while the permitting checklist, stakeholder map, and compliance obligations are rebuilt for the second state. In delivery, each confirmed site is released as its own change-controlled scope package, so a later site substitution is a routine release-level change rather than a program renegotiation. Were the proposed AI layer available and validated, it could, in principle, flag the ambiguous scope boundary during discovery and forecast the highway-crossing delay risk during sequencing; this remains a proposed capability, not a demonstrated one.

➤ *Performance Measurement*

The framework is intended to be assessed with standard, citable project performance metrics rather than bespoke measures. Earned value management provides the schedule performance index and cost performance index, along with schedule variance and cost variance, which together describe whether a program is ahead of or behind plan and over or under budget. Within this framework, scope discovery and delivery discipline would be expected to influence cost variance by reducing unplanned change, while sequencing discipline would be expected to influence schedule variance by reducing permit-driven delay. I attach no numeric values to these indices here, because this paper reports no measured program data; the metrics are described structurally, in terms of what they would measure and why, so that a future empirical study could apply them to real programs.

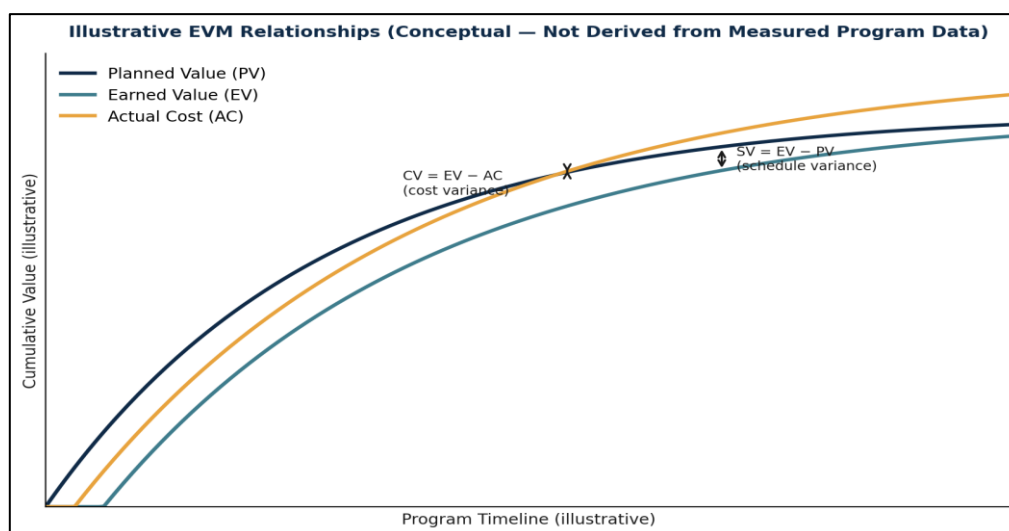


Fig 5 Illustrative Earned Value Management Relationships Showing Planned Value, Earned Value and Actual Cost, with Schedule Variance and Cost Variance Shown as the Gaps Between Curves. Values are Conceptual and are Not Derived from Measured Program Data.

➤ *Policy and Practice Implications*

- For industry leaders in utilities and engineering firms: the framework functions as an owner-side capability lens. The maturity evidence ties repeatable delivery to organizational practice; individual skill does not scale across a portfolio [10], [17], [16]. Leaders can ask whether their programs maintain current scope baselines against moving asset lists, whether permitting is a first-class workstream with a dedicated owner, and whether requirements are localized when programs cross jurisdictions.
- For policymakers: the connection runs through variance. The record in WC Docket No. 25-253 documents permitting timelines that are long and, more importantly for program management, unpredictable [8], [3]. Predictable authorization deadlines would convert stochastic permitting risk into deterministic scheduling inputs, reducing contingency, carrying cost, and redesign exposure across fiber programs, including utility-owned fiber built for grid automation, which broadband-focused policy discussion largely overlooks.
- For practitioners: the single highest-leverage habit the synthesis supports is pricing deferral: any decision to postpone right-of-way or permitting work should enter the risk register with its redesign, re-mobilization, and carrying-cost exposure stated.

➤ *Strengths and Limitations of the Review*

The review's strengths are its transparency, its integration of peer-reviewed, technical, artificial intelligence, and regulatory evidence that is usually read separately, and its grounding in a disclosed, multi-market delivery portfolio of the program type under discussion. It is a narrative review, not a systematic one, so source selection reflects judgment and is exposed to selection bias despite the documented search. It reflects a single practitioner's portfolio, and the case illustration is anonymized and non-quantitative by design, so the framework is a proposition to be tested rather than a validated instrument. The AI decision support layer is entirely proposal: it has not been built, deployed, or validated, its motivating evidence comes from adjacent construction settings rather than grid programs, and its reported metrics belong to the cited studies. The permitting evidence is drawn substantially from industry and regulatory sources whose institutional interests should be kept in view when weighing their findings. The framework itself also has boundary conditions. Its overhead is proportionate to the conditions that produced it: progressively released scope, multi-jurisdiction footprints, third-party crossings, and multi-year duration. For a short, single-site engagement with fully determined scope, a standing baseline register, a dedicated permitting owner, and release-level change control would be process for its own sake; in such settings the same principles collapse into lighter forms, an assumptions list agreed at kickoff, permitting checked once during feasibility, and ordinary contract change control. Where the threshold between these cases sits is an empirical question this paper does not answer.

V. CONCLUSION AND RECOMMENDATIONS

➤ *Conclusion*

The United States has committed capital, standards, and regulatory attention to grid modernization, but it has not yet developed a delivery literature commensurate with that commitment. This review synthesized maturity research, change-order research, permitting evidence, and applied artificial intelligence research into three themes and proposed a strategic project management framework spanning scope discovery, sequencing, adaptation, and delivery, grounded in direct experience managing utility fiber and substation programs across four states and two wholesale markets. It further proposed, as a conceptual extension for future adoption, an AI-enabled decision support layer mapped onto the four phases. Programs that reconcile scope continuously, sequence permits deliberately, price deferral explicitly, and adapt across jurisdictions systematically are the programs that turn grid modernization funding into energized infrastructure. Strengthening that delivery capability, and in time augmenting it with validated decision support, is itself a contribution to grid resilience.

➤ *Recommendations for Program Managers and Utilities*

Adopt a scope baseline register and assumptions log at program initiation, operate change control at the release level, size contingency to the undetermined share of scope, run right-of-way feasibility concurrently with preliminary engineering, assign permitting a dedicated workstream owner, and require that every deferral decision carry a priced risk entry before it is approved. Treat any AI decision support as a future capability to be piloted and validated against standard earned value metrics before it is relied upon.

➤ *Recommendations for Policymakers*

Prioritize predictability over speed alone in right-of-way reform. Deadlines and cost-based fee standards of the kind under consideration in WC Docket No. 25-253 would reduce the variance that forces conservative scheduling across fiber programs, and final rules should recognize utility-owned fiber built for grid automation alongside broadband access networks [3].

➤ *Recommendations for Future Research*

Three directions follow: empirical maturity assessment of U.S. utility program organizations using power-sector parameters of the kind Gareeb and Rwelamila proposed [15]; comparative delivery performance for equivalent programs across PJM and ERCOT; and controlled evaluation of the proposed AI decision support capabilities on real grid-infrastructure programs, since the motivating evidence to date comes from adjacent construction domains [23], [26], [28], [29].

➤ *Declarations*

- Competing interests: The author is employed in project management within the utility infrastructure sector.

- Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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