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INNOVATION CAPABILITY: A KEY MECHANISM FOR ACHIEVING COMPETITIVE ADVANTAGE IN CONSTRUCTION BUSINESS

PITHAYAPORN PITHAYAWATANA
PH.D. CANDIDATES, DEPARTMENT OF BUSINESS ADMINISTRATION, KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG, PRINCE OF CHUMPHON CAMPUS, THAILAND.EMAIL: 66206014@kmitl.ac.th

MALLIKA SUBONGKOD, PH.D.
ASSISTANT PROFESSOR, PH.D., DEPARTMENT OF BUSINESS ADMINISTRATION, KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG, PRINCE OF CHUMPHON CAMPUS, THAILAND. EMAIL: mallika.su@kmitl.ac.th

APINYA INGARD, PH.D.
ASSISTANT PROFESSOR, PH.D., FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY, SILPAKORN UNIVERSITY, THAILAND.EMAIL: ingard_a@su.ac.th

ABSTRACT
This strategic article synthesizes evidence from the 2020–2025 literature to clarify "Innovation Capability" (IC) among Thai construction contractors, distinguish it from "Innovation Performance" (IPf), and explicate the mechanisms by which IC translates into sustainable competitive advantage. Guided by the Resource-/Knowledge-Based View and Dynamic Capabilities (sensing–seizing–transforming), the study adopts a systematic–scoping review, screening sources on quality and relevance and using thematic analysis to construct a logic chain that links capabilities, transmission mechanisms, and measurable outcomes.
The synthesis shows that IC is not a collection of isolated tools but an "architecture of capabilities" that can be replicated and scaled across projects. Six interlinked pillars emerge: (1) leadership and culture, (2) human competence and absorptive capacity, (3) digital enablement—BIM/CDE/AI, (4) supply-chain collaboration and IPD/partnering contracts, (5) innovation portfolio and governance, and (6) ESG/regulatory alignment. Core mechanisms that convert IC into IPf include a single source of truth via CDE and openBIM/IFC, coordination through BCF, 4D/5D gates before critical work, contractual levers that accelerate decisions (e.g., RFI SLA, data-sharing), a learning cycle from pilot to scale, and a shared KPI dictionary with project↔enterprise dashboards.
The measurable outcomes appear across time and cost (tighter schedule variance, lower % cost overrun and change-order exposure), quality and safety (reduced rework, NCR, and LTIR), customer experience (faster approvals, higher CSAT/NPS), and finance (higher bid–hit ratio and improved margin stability). When such results are achieved consistently and supported by innovation portfolio governance, they consolidate into sustainable competitive advantage.
Keywords: Innovation Capability, Competitive Advantage, Construction Business

I. INTRODUCTION

The global construction industry continues to face structural pressures: long-standing productivity stagnation, persistent cost and schedule overruns, and the complexity of coordinating multi-party supply chains. These factors erode gross margins and weaken contractors' competitiveness. Recent literature reviews indicate that root causes include insufficient front-end project planning, unclear contract management, and fragmented coordination, while macro indicators consistently show construction lagging other industries in productivity (Yeh, 2025; McKinsey, 2024).
On the other hand, new digital technologies—such as Building Information Modeling (BIM), Lean–BIM integration, Digital Twins, artificial intelligence (AI), and off-site construction (modular/prefabrication)—are reshaping industry competition by acting as capability-building mechanisms. Systematic studies confirm that BIM improves collaboration, reduces design errors, and compresses construction time; quantitative evidence further indicates that BIM/4D can reduce average project duration by about 20% and cut costs by roughly 15% (Doan et al., 2025; Rehman et al., 2025; Das et al., 2025). For off-site construction, recent research highlights significant potential to save time and cost and reduce waste (Zohourian et al., 2025). In Thailand, the country is accelerating investment in digital infrastructure—cloud and data centers—that supports data-intensive construction. However, the Thai construction industry remains in transition. Although BIM adoption is increasing on large projects, readiness in standards, human capital, and the organizational

development needed to move from a mere "modeling tool" to an organizational capability is still uneven (Udomdech et al., 2021; Sierra et al., 2023; Chatsuwan, 2024; Reuters, 2025). This raises a strategic question: how can contractors shift from competing on price to competing on speed, reliability, and customer experience in markets characterized by heightened risk, high costs, and rapid technological change? The Resource-Based View (RBV) and Dynamic Capabilities suggest that sustainable advantage arises when firms sense opportunities, seize them, and transform resources and processes—converting technologies into innovation capabilities that work in practice (Aghimien et al., 2023; Ruiz-Ortega et al., 2024; Hoang et al., 2025).
A literature review covering 2020–2025 reveals three critical research gaps: (1) most studies emphasize adoption of individual technologies (e.g., BIM) rather than examining how they interconnect into a system of innovation capabilities that drives strategic advantage (Rehman et al., 2025; Doan et al., 2025); (2) within the Thai context, empirical and policy research integrating data standards, workforce development, and public support to strengthen contractors' innovation capability remains limited (Udomdech et al., 2021; Sierra et al., 2023; Chatsuwan, 2024); and (3) strategic metrics that bridge "project-level to enterprise-level" outcomes—such as schedule variance, rework, bid–hit ratio, and margin stability—under mixed-technology contexts (BIM–Lean–Prefab–AI) have not been synthesized into a clear framework, even though many studies report partial outcomes (Alnajjar et al., 2025; Zohourian et al., 2025).
Accordingly, this strategic article synthesizes literature from 2020–2025 to explain and holistically understand Innovation Capability in construction contracting. It identifies the core components of such capability and explicates the mechanisms through which capabilities translate into tangible outcomes in cost control, schedule performance, quality and safety, margin stability, customer experience, and bid success. The article also proposes a practice framework and a set of strategic metrics aligned to Thai contractors, employing RBV and Dynamic Capabilities to convert digital investments into sustainable competitive advantage in practice. Finally, it addresses all three originally formulated review questions in full.

II. REVIEW QUESTIONS

RQ1. What are the components of Innovation Capability (IC) in the construction contracting context, and how does IC differ from Innovation Performance (IPf)?
RQ2. How does IC translate into competitive advantage through mechanisms related to cost, time, quality–safety, reliability, customer experience, and bid-hit rate?
RQ3 (Thailand lens). How do Thailand's ecosystem factors—data standards, workforce skills, and government measures—enable or hinder the enhancement of Innovation Capability?

III. RESULTS

Building on a systematic review, analysis, and synthesis of recent scholarship, this study consolidates the core findings that directly address the three review questions. To make the contribution transparent and actionable, we present a mapping that links each review question (RQ1–RQ3) to its analytic scope and to the key deliverables generated by the synthesis. This mapping clarifies what evidence each question draws on, the lenses applied (RBV/KBV; Dynamic Capabilities), and the concrete outputs produced for practice and policy. The summary appears in Table 1.

TABLE 1 Mapping the Literature Review (Review Questions: RQ1–RQ3)

Review Questions	Scope	Key Deliverables
RQ1. What are the components of Innovation Capability (IC) in the construction contracting context, and how does IC differ from Innovation Performance (IPf)?	- Define the conceptual boundary of IC vs. IPf for contracting firms (enterprise–project–supply chain levels). - Identify IC components that can be replicated, scaled, and institutionalized (people–data–processes–partners–culture–governance). - Articulate the distinction between "capability" (IC) and "measurable outcomes" (IPf).	- Operational definitions of IC and IPf. - An inventory of IC components (six dimensions) with example behaviors / on-site evidence. - A preliminary conceptual model.
RQ2. Through which mechanisms does IC translate into competitive advantage across cost, time, quality–safety, reliability, customer experience, and bid-hit rate?	- Explain the transmission pathway (mechanisms) from IC → project/enterprise outcomes. - Anchor the analysis in the RBV/DC lens (sensing–seizing–transforming). - Specify tangible outcome metrics (cost, time, quality–safety, customer experience, financials).	- Logic chain: IC → data/processes → decision-making → outcomes. - Example dashboard linking project ↔ enterprise levels. - Playbook to upgrade Innovation Capability for sustained Innovation

Review Questions	Scope	Key Deliverables
		Performance.
RQ3 (Thailand lens). How do Thailand's ecosystem factors—data standards, workforce skills, and government measures—enable or hinder the enhancement of IC?	- Analyze the Thai context: readiness of data standards (CDE/BIM standards), digital skills of workers/engineers, and support mechanisms from government and industry/professional associations. - Identify gaps/bottlenecks and enabling conditions.	- Stakeholder map: Government – professional associations – contractors – academia – technology partners. - Policy & Practice Checklist for Thailand

3.1 First (RQ1) — This article identifies the components of Innovation Capability (IC) in the construction contracting context and clearly differentiates IC from Innovation Performance (IPf) in order to separate what constitutes an organization's embedded potential from the measurable outcomes produced by innovation. The literature reviewed is consistent with synthetic definitions in which IC is the organization's systemic capability to identify, integrate, and routinely deploy knowledge/technologies in ways that can be replicated, whereas IPf refers to the observable, measurable results that follow from exercising that capability (Saunila, 2020). In short, IC denotes the potential embedded within the firm, while IPf denotes the performance expressed in metrics. In construction, this view is anchored in the Resource-/Knowledge-Based View and Dynamic Capabilities, which posit that firms must sense–seize–transform to convert digital investments into measurable outcomes (Aghimien et al., 2023), and that ambidextrous culture and leadership are required to balance exploration (trying new approaches) and exploitation (amplifying what already works) on live projects (AlSaied, 2024).

From the synthesis, the literature indicates that Innovation Capability comprises at least six interlinked pillars that must operate as a system for innovation to be "repeatable, scalable, and transferable," as follows:

1. Digital enablement. A shared information environment (e.g., a Common Data Environment—CDE), common data standards, and controls for access/quality are required so that information serves as a "single source of truth" for all parties (Seyis & Özkan, 2024).
2. Human competence and absorptive capacity. Teams need cross-functional skills in BIM/VDC, data & analytics, AI/automation, and lean/prefab methods so they can "see the model—see the data—decide" on a shared basis in the field (AlSaied, 2024).
3. Innovation portfolio and governance. A clear pathway from idea → pilot → evaluation → scale, together with systematic lessons-learned/case repositories, in order to drive down rework and shorten the RFI cycle on subsequent projects.
4. Supply-chain collaboration. Use IPD/partnering arrangements or shared agreements on data/standards so that design–data–field execution ("model–data–the real work") flows smoothly across designers, contractors, fabricators, and suppliers (Niazmandi et al., 2024).
5. Leadership and culture. Leaders must create safe-to-try yet accountable space, make data-driven decisions, reward improvements in ways of working, and maintain the exploration–exploitation balance (AlSaied, 2024).
6. ESG/regulatory alignment. Clear ownership of digital policy, an innovation plan/portfolio, and regular metrics/monitoring so that what works is codified as organizational standards rather than remaining tied to any single team or project (Aghimien et al., 2023).

All six interlinked pillars can be summarized into an infographic as shown in Figure 1.

Figure 1. Innovation Capability-six interlinked pillars (Generated by Google Gemini)

Conversely, Innovation Performance (IPf) refers to the actual, measurable outcomes achieved within a specified period or project. Examples include shorter construction durations; reduced total costs or lower risk of budget overruns; improved quality and safety; shorter RFI cycles; lower rework rates; higher customer satisfaction and repeat business; higher bid-win rates; and steadier margins. Recent empirical evidence supports this view: adoption of BIM/4D–5D is associated with statistically significant reductions in project time and cost (Rehman et al., 2025; Das et al., 2025); implementing a Common Data Environment (CDE) enables "single-source-of-truth" information management linked to project success indicators (Seyis et al., 2024); and Integrated Project Delivery (IPD) practices correlate with fewer time- and cost-related claims due to improved coordination (Niazmandi et al., 2024).

In sum, Innovation Capability (IC) denotes internal readiness and routines—a long-term capacity—whereas Innovation Performance captures visible performance figures at the project or period level. Organizations that cultivate end-to-end IC are more likely to deliver consistently strong IPf across multiple projects and years. By contrast, occasional spikes in IPf—e.g., driven by a special-purpose team or a favorable project context—do not by themselves indicate high IC if effective practices cannot yet be replicated, scaled, and institutionalized (Rehman et al., 2025; Das et al., 2025; Seyis et al., 2024; Niazmandi et al., 2024).

To present the findings in a coherent and systematic way, the results are summarized as shown in Table 2, which illustrates the linkage between digital technologies, logistics activities, and their impacts on key performance indicators (KPIs). The comparison underscores how different clusters of technologies-such as AI/ML, IoT/RFID, blockchain, cloud computing, big data analytics, robotics and automation, AR/VR, and digital twins-yield distinct performance outcomes when applied across the nine fundamental logistics activities. By mapping each technology to its relevant operational domain, the table offers an integrated perspective that clarifies how digital transformation most effectively enhances efficiency, accuracy, resilience, customer satisfaction, and sustainability within the logistics sector.

3.2 Second (RQ2) — Innovation Capability (IC) links to competitive advantage through mechanisms spanning cost, time, quality–safety, reliability, customer experience, and bid-win rates. The literature indicates that contractors gain real advantage not merely by acquiring new technologies, but by making those technologies work as an integrated system across successive projects. This is the role of IC: a bundle of capabilities that enables organizations to "see opportunities—seize them—and transform them into routines," in line with the Dynamic Capabilities framework (sensing–seizing–transforming) under RBV/KBV foundations (Kump et al., 2019; Saunila, 2020; Aghimien et al., 2023). In construction contexts, IC operates through a small set of powerful mediating mechanisms—shared data across the team, rapid and transparent joint decision-making, reduction of design/work discrepancies, and cross-project learning. When these mechanisms flow smoothly, outcomes (IPf) in time, cost, quality–safety, customer experience, and finance improve together (Ellström et al., 2022), as follows:

First, sensing—anticipating opportunities and risks. Digital capabilities such as BIM 4D/5D, CDE, and AI/analytics interlink design–schedule–budget and provide a "single source of truth" for all parties. This allows clashes to be detected before fieldwork, reduces RFIs, and improves bottleneck prediction. The resulting effects are clear: reduced time and cost (e.g., narrower schedule variance, lower % cost overrun, shorter RFI cycle time). Recent reviews and case studies consistently support this picture (Rehman et al., 2025; Das et al., 2025; Seyis & Özkan, 2024).

Next, seizing—acting decisively through coordinated decisions and execution. Collaboration capabilities in the supply chain—such as IPD/partnering and early contractor involvement—help stakeholders "see–understand–decide" in alignment, reducing disputes and claims while keeping change-order costs and contract values within bounds. Paired with a transparent CDE, this mechanism accelerates approval cycles, enables faster change implementation, and still manages risk (Matysiak et al., 2018; Niazmandi et al., 2024; Seyis & Özkan, 2024).

Then, transforming—embedding changes into organizational standards. This depends on leadership and an ambidextrous culture that permits responsible experimentation, together with innovation-portfolio governance that scales what works across sites. The result is more stable earnings (e.g., lower variance in gross margin) and an organization that can "repeat at will," independent of any single individual or project (AlSaied & McLaughlin, 2024; McKinsey, 2024). On quality–safety, strengthening absorptive capacity and institutionalizing lessons-learned cycles drive continued reductions in rework rates, NCRs per 100k hours, and LTIR (Aghimien et al., 2023).

From the customer's vantage point, the same mechanisms translate into a better, more predictable experience. 4D/5D simulations and CDE dashboards enable faster owner decisions and tighter alignment between expectations and reality, boosting satisfaction (CSAT/NPS) and repeat business. Because the organization can present credible data and plans during bidding, bid-hit ratios (win rates) also increase—especially when ESG readiness and standards are in place under modern procurement requirements (Sierra et al., 2023; Seyis & Özkan, 2024).

Summary Playbook — Uplift Innovation Capability for Sustained Innovation Performance

1. Phase 0–90 Days (Stabilize & Sense)

- 1) Baseline & Targets: Assess IC maturity; set 6–12 month OKRs (e.g., SV ≤ ±5% in 70% of projects).
- 2) Data Foundation (CDE-first): Define folder/version/permission structures; establish KPIs and accountable owners.
- 3) Quick Wins: Enable 4D look-ahead on flagship projects; set RFI SLAs; open a centralized lessons-learned log.

Artifacts: IC baseline report; KPI dictionary; CDE playbook; RFI SLA.
2. Phase 90–180 Days (Seize & Prove at Scale)
- 4) Bundles: BIM-4D + CDE + digital QA/QC across 2–3 projects of different types; adopt IPD-lite rituals.
- 5) Enable People (ACAP): Stand up CoPs for BIM/VDC/PMO; micro-learning; skills matrix.
- 6) Governance & Funding: Innovation Board with stage-gate; value cases for pilots (target KPIs + success criteria).

Artifacts: Pilot charters; CoP plan; stage-gate checklist; value-case templates.
3. Phase 180–360 Days (Transform & Institutionalize)
- 7) Scale & Standardize: Convert winning pilots into SOPs/standards; reach ≥90% CDE compliance; require a 4D gate before major works begin.
- 8) Portfolio & Finance Loop: Track Pilot→Scale funnel; % innovation spend/revenue; margin stability (σ).
- 9) ESG / Qualification Readiness: LCA/carbon basics; HSE checklist; bid pack (BIM extracts, 4D, ESG evidence).

Artifacts: SOPs/standards; incentive model; ESG/bid pack; quarterly portfolio review.

When specifying tangible outcome metrics (cost/time/quality–safety/client & market/financial stability), the results can be explained in five outcomes—summarized in Table 2—as follows:
1. Time: Improvements in schedule variance (±%), RFI cycle time, and approval turnaround (Rehman et al., 2025; Seyis & Özkan, 2024).
2. Cost: Reductions in % cost overrun, change-order cost/contract value, and material waste (Das et al., 2025).
3. Quality & Safety: Reductions in rework rate, NCR per 100k hours, and LTIR (Aghimien et al., 2023; Seyis & Özkan, 2024).
4. Client & Market: Higher NPS/CSAT, greater % repeat business, and more dispute-free delivery (Rehman et al., 2025; Seyis & Özkan, 2024).
5. Financial Stability: Higher bid-hit ratio, greater margin stability, and improved qualification success (ESG/data-ready bids) (McKinsey, 2024; Sierra et al., 2023).
Therefore, to secure competitive advantage, contractors should architect their Innovation Capability to support the sensing–seizing–transforming cycle end to end: digital (BIM/CDE/AI) as the lever; IPD-style collaboration as the accelerator; leadership, culture, and the innovation portfolio as the rails; and ESG as the license to operate. When these elements work in concert, outcome metrics improve together, and competitive advantage ceases to be a one-off product of an individual project and becomes an enduring organizational capability (Saunila, 2020; Aghimien et al., 2023; Rehman et al., 2025; Das et al., 2025; Seyis & Özkan, 2024; Niazmandi et al., 2024; McKinsey, 2024; Sierra et al., 2023).

TABLE 2 Dashboard Template Linking Project-Level ↔ Organizational-Level

Dimension	Project-level KPIs (with formulas)	Organization-level KPIs (Org-level Roll-up)
Time	- Schedule variance (SV%) = (Planned − Actual) / Planned × 100 - RFI cycle time (days) - Approval turnaround (days)	- % of projects with SV within ±5% (mean + σ) - RFI P90 (90th percentile) - % of critical-path activities completed on schedule
Cost	- Cost overrun (%) - Change-order cost / Contract value (%) - Productivity (units per person-hour)	- % of projects completed at or under budget - 6-month change-order trend
Quality & Safety	- Rework rate (%) - NCRs per 100k hours - LTIR (Lost-Time Injury Rate)	- 12-month trend + Top 5 root causes (Pareto) - NCR/LTIR reduction rate
Client & Market	- CSAT/NPS - Dispute-free delivery (%)	- Repeat business (%) - Bid-hit ratio (%) (quarterly)
Financial Stability	- Gross margin (%) per project	- Margin stability = standard deviation of per-project margins per year (lower is better

3.3 Third (RQ3) — Thailand lens: How do Thai ecosystem factors (data standards, workforce skills, and government measures) enable or impede the upgrading of Innovation Capability (IC)? A review of the 2021–2025 literature indicates that Thailand has digital momentum driven by large-scale projects and national investments in data infrastructure. At the same time, constraints persist in shared data standards and workforce skills—especially among SMEs in design/engineering and subcontracting—resulting in IC (particularly Digital/CDE + Collaboration) "rising unevenly" between large organizations and the downstream tiers of Thailand's construction supply chain.

For Thailand's construction industry to translate IC into sustained, real outcomes (IPf), it cannot be just a single contractor's technology story; it must be an ecosystem effort that aligns the roles and incentives of the state, professional associations, contractors/owners, academic institutions, and technology partners. Crucially, the three most powerful levers—data standards, workforce skills, and government measures/digital infrastructure—all rely on collaboration: so that sensing emerges from shared data (CDE/openBIM), seizing is enabled by contracts and shared incentives (e.g., IPD/partnering), and transforming occurs by embedding what works as industry standards. Accordingly, the stakeholder map serves as an integrated operating picture, as detailed in Table 3.

TABLE 3 Stakeholder Map

Group	Primary role	Needs from others	Expected outcomes
State (Ministry of Industry; Ministry of Transport; Cabinet/NESDC; BOI; Ministry of Commerce; Ministry of Finance; Local governments)	Set industry data standards (openBIM/IFC/CDE protocols); mandate data-driven procurement and inspection/acceptance; create IPD/partnering sandboxes; offer tax incentives	Technical input from associations/universities; CDE platforms/nodes from the private sector	Uplift IC across the value chain; reduce delays/disputes in public works; raise overall construction-sector productivity
Professional/industry associations (engineering, architecture, contractors, property developers)	Co-develop Thai standards/guidelines; certify competencies in BIM/CDE/PM/HSE; run CoPs and benchmarking	Policy frameworks/training budgets from the state; content/technology from universities/partners	Practical, usable standards; practitioner networks; private-sector benchmarking indicators
Contractors / Owners / Consultants	Deploy CDE + BIM-4D/5D in real projects; set RFI/approval SLAs; act as IPD-lite pilots; capture KPIs	Unified standards/TOR requirements from government and owners; training resources	Better IPf: time/cost/quality/safety/customer/financial outcomes
Academic institutions / Centers of Excellence	Project-based upskilling/reskilling curricula; competency testing centers; research/testing of Thai standards	Real-world problem data from industry; funding support	Job-ready talent; policy-relevant evidence
Technology partners (CDE/BIM/AI/IoT/Prefab)	Provide Thai-standard solution bundles; ensure interoperability/openBIM; data residency/compliance; support pilots	Sandboxes/standards from the state; pilot cases from contractors	Scaled real-world adoption with measurable value

In addition, upgrading Innovation Capability (IC) so that it converts into practical outcomes (time–cost–quality/safety–customer–financial) requires shared rules and tools across the entire system—not just the efforts of a single contractor, but a "policy–practice package" that links data standards ↔ skills development ↔ contract forms/collaboration mechanisms ↔ state incentives and procurement, all working in concert. This can be explained as follows.

Start with data standards (Data standards & CDE), which serve as the "rails" that keep a single stream of information flowing throughout the contract. A National CDE Protocol enables all parties to store and version documents under common rules—with a clear folder structure separating WIP/Shared/Published/Archive, role-based access control, and an auditable revision trail. Paired with openBIM/IFC for cross-platform model delivery and BCF for issue/clash records that include images, coordinates, responsible owner, and due dates, information becomes "portable and verifiable," independent of any specific tool. At the contract level, we must define Thailand's LOD/LOI—i.e., the minimum model/detail and data attributes required at each phase. For example, at the For Construction stage, material codes and O&M tags must be complete so that handover constitutes a true digital asset. All of this must be tied to a central KPI Dictionary specifying formulas/data sources for indicators such as SV%, % cost overrun, rework, and RFI cycle time, so results can be benchmarked across projects. Finally, these requirements should be translated into public-sector TORs that "deliver and accept on the basis of data"—mandating submission of IFC/BCF/asset data as per LOD/LOI, along with a CDE report confirming ≥90% completeness of latest documents and RFI closure within SLA (e.g., ≤5 days). This is how we lock "standards → real-world use" together (CEN, 2020; UK BIM Framework, 2020, 2021).

Next, upskilling/reskilling is the multiplier that lets people "do it and do it repeatedly." Project-based upskilling is not slide-deck lectures, but hands-on work on real projects: setting 4D look-ahead, operating the CDE per protocol, executing digital QA/QC, and delivering a measurable capstone (e.g., shorter RFI cycles, more clashes resolved pre-site). In parallel, establish Competency Standards with levelled certifications (Beginner–Advanced) and link them to contractor selection and personnel requirements in TORs, so incentives line up. At the industry level, monthly Communities of Practice (CoPs) and platforms for sharing lessons/templates/model QA scripts help knowledge circulate quickly and cut down on repeated trial-and-error (Udomdech, 2021; Sierra, 2023).

To make collaboration real in contracts, we need sandboxes/commitments (Collaboration). Begin with a Regulatory IPD Sandbox for large public projects to pilot contracts with shared incentives (pain/gain share) and CDE-based data sharing—mirroring proven private-sector practice—together with model contract clauses that set RFI SLAs, require a 4D gate before critical works, and mandate openBIM/BCF data sharing, thereby accelerating decisions and reducing disputes. Coupled with a Dispute Avoidance Board that treats "data from the CDE" as the common factual baseline, this helps prevent protracted conflicts and resolves issues before they escalate (Niazmandi et al., 2024; OECD, 2024).

On policy drivers, use tax/procurement incentives as levers. The state can offer super-deductions for CDE/BIM/training investments to lower entry costs, and deploy Green/Innovation procurement to award extra points to bidders with BIM maturity/ESG readiness and clear 4D/IFC plans—so that "doing it right" gains a competitive edge. Augment this with grants/matching funds for pilot projects that specify clear KPIs (time/cost/quality/safety) and have a post-proof scaling plan, accelerating the transition from pilot to organizational standard (OECD, 2025).

When these four dimensions move together, they complete the sensing–seizing–transforming cycle: data standards and CDE enable sensing of issues/opportunities from real data; collaborative contracts and workflows enable seizing through faster decisions; and skills plus tax/procurement incentives enable transforming into routine practice. The results will be visible in tangible KPIs—narrower time and cost variance, reduced rework and disputes, improved safety, higher customer satisfaction, and steadily improving margin stability—at both organizational and industry levels.

IV. KEY MECHANISMS FOR COMPETITIVE ADVANTAGE

The competitive advantage of Thai construction contractors over the next decade will not come from "having the latest technology," but from "organizing technology to work as a system" together with contracts, ways of working, and people's skills across the supply chain—until these become an Innovation Capability (IC) that is replicable, scalable, and measurably effective across multiple consecutive projects. This logic aligns with the RBV/DC lens, which holds that firms must sense opportunities, seize them, and transform in a sustained manner, leveraging resources, knowledge, and collaboration as key levers.

The first game-changing mechanism is a "single set of data rails" via national data standards and a Common Data Environment (CDE). When design–schedule–budget are linked through openBIM/IFC and managed in a CDE with clear folder structures, version control, role-based permissions, and auditable revisions, both site-level and upstream decisions are anchored to a "single source of truth." This shortens RFI cycles and reduces misinterpretation and rework—paving the way for 4D/5D simulation that makes plans, resources, and risks genuinely visible in advance. The key to keeping this tool-agnostic is defining LOD/LOI as the common information language for each contract phase, and issuing a central KPI dictionary (e.g., SV%, % cost overrun, rework, RFI cycle) so different clients and contractors can compare and learn fairly across projects. When public-sector TORs mandate "data-based delivery and acceptance," this loop is locked into the contract chain, rather than left to the goodwill of any single team.

The second mechanism is "contract-anchored collaboration" through IPD/partnering. In Thailand, an IPD sandbox for large public works (infrastructure/utilities) provides the proving ground that shared incentives, CDE-based information sharing, and model contract clauses—from RFI SLAs and a 4D gate before critical works to using BCF as factual evidence—can significantly reduce disputes and time costs. Shifting from post-event claims to pre-event visibility and correction raises delivery reliability. Outcomes show not only in narrower SV% or lower change-order spending, but also in customer-facing indicators such as shorter approval cycles, higher satisfaction, and issues closed before litigation.

The third mechanism is "people who can do it—and do it again," especially among SMEs, the backbone of Thailand's supply chain. Project-based upskilling ties training to actual project tasks: building a 4D look-ahead, operating the CDE per protocol, performing digital QA/QC, and submitting a measurable capstone (e.g., lower RFI P90, more clashes resolved pre-site). When competency standards and tiered certifications (Beginner–Advanced) are linked to contractor selection, market incentives push everyone in the same direction. Monthly Communities of Practice (CoPs) plus a shared repository of templates/scripts/lessons accelerate knowledge circulation, cut the cost of repeated trial-and-error, and raise the success rate from pilot to scale.

The fourth mechanism is "innovation-portfolio governance," the long track that sustains results. Contractors that set up an Innovation Board, run a clear stage-gate (Idea → Pilot → Scale), and tie budgets to measurable value know where to double down and when to stop. A central dashboard connecting project-level KPIs to organizational KPIs (e.g., margin stability: the standard deviation of per-project gross margins per year) gives leaders a view of reality rather than instincts. When what works is converted into SOPs/data standards and CDE forms, success no longer depends on a single "hero" team, but becomes a predictable routine.

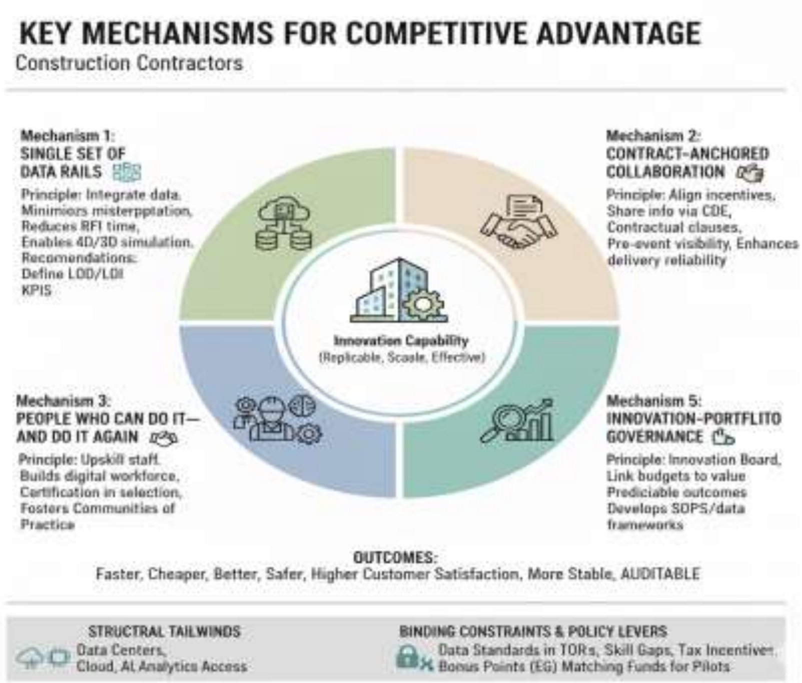

Figure 2. Key Mechanisms for Competitive Advantage (Generated by Google Gemini)

Thailand also enjoys structural tailwinds from investments in data centers/cloud and data-platform readiness, which lower AI/analytics access costs for both large players and SMEs. Yet two binding constraints—shared data standards not yet embedded widely in TORs and skill gaps—must be addressed with a bundle of policy and procurement levers: tax incentives for CDE/BIM/training, bonus points for BIM maturity/ESG readiness/4D in bidder evaluation, and matching funds for pilots with clear KPIs and post-proof scaling plans. These shifts help the entire market move together, not just a few front-runner firms.

When the four mechanisms—shared data, contract-anchored collaboration, people who can do and repeat, and innovation-portfolio governance—operate in harmony under sensing–seizing–transforming, results appear simultaneously as faster–cheaper–better–safer–higher customer satisfaction–more stable, and crucially, auditable: schedule variance within bounds, RFIs closed within SLA, rework and disputes down, bid-hit ratio up, and margin volatility shrinking. Competing on price alone gives way to competing on delivery reliability and consistent customer experience. This is the essence of a Thai-specific competitive advantage—not tied to any single technology, but to the capability of the entire ecosystem to keep digital–contract–skills–incentives moving in step, and to sustain that momentum over time.

V. CONCLUSION

This article clarifies how Innovation Capability (IC)—conceived as a capability architecture spanning leadership & culture, people/absorptive capacity, digital enablement (BIM/CDE/AI), supply-chain collaboration, portfolio governance, and ESG alignment—translates into Innovation Performance (IPf) when managed as an end-to-end system. Grounded in RBV and Dynamic Capabilities, we show that four mechanisms are pivotal: (1) a single source of truth via CDE/openBIM and 4D/5D gates; (2) contract-anchored collaboration (IPD/partnering) that accelerates decisions and reduces disputes; (3) project-based upskilling that raises SME absorptive capacity; and (4) innovation-portfolio governance that scales what works and stabilizes margins. We operationalize these ideas through a three-phase playbook and a dashboard that links project-level to organization-level KPIs across time, cost, quality/safety, client/market, and financial stability. For Thailand, we propose a policy–practice package coupling a National CDE Protocol and Thai LOD/LOI with regulatory sandboxes and targeted tax/procurement incentives so the whole ecosystem—public buyers, associations, contractors, academia, and technology partners—moves in step. The contribution is a practical separation of IC from IPf, a set of measurable mediators (e.g., RFI cycle, clashes resolved pre-site, CDE compliance, pilot→scale rate), and implementation guidance that shifts competition from price alone to reliable delivery and superior client experience. Future research should test these mediators causally (e.g., PLS-SEM, panel data), extend SME evidence, and track interoperability/compliance and cybersecurity as technologies and standards evolve.

VI. IMPLICATION

6.1 Theoretical implications

The article's central proposition—separating Innovation Capability (IC) from Innovation Performance (IPf) and articulating the transmission mechanisms—helps fill a gap in construction research that tends to measure project-level outcomes rather than organization-wide capability systems. Defining IC as a "capability architecture" (leadership & culture; human/absorptive capacity; digital/BIM–CDE/AI; supply-chain collaboration; portfolio & governance; ESG/compliance) turns RBV/DC into an actionable lens: sensing on shared data, seizing through joint contractual commitments, and transforming via standards and an innovation portfolio. This yields a set of mediating variables (e.g., RFI cycle, clashes resolved pre-site, CDE compliance, pilot→scale rate) that more clearly link the digital layer to economic outcomes and provide a basis for future causal/SEM studies.

6.2 Policy implications

At the national level, procurement and standards should be the primary levers: promulgate a National CDE Protocol and Thai openBIM/IFC + LOD/LOI, then link them to public-sector TORs that "deliver and accept with data." This moves digital capability along the whole chain, not just in frontrunner firms. In parallel, establish a regulatory sandbox (IPD/partnering) for large public projects to demonstrate benefits in time–cost–disputes, then codify results into Thai guidelines. Tax incentives / matching funds for CDE/BIM/training lower SMEs' entry costs and align market incentives for broad-based IC upgrading.

6.3 Managerial/operational implications

Contractors should shift from "occasional good projects" to "reliable year-on-year performance" through innovation-portfolio governance: set up an Innovation Board; run a stage-gate (Idea→Pilot→Scale) with value cases and target KPIs; stop low-value efforts and scale what works. Tie team bonuses to composite indicators (SV%, Rework, RFI SLA, Safety, Margin stability) rather than silo metrics. Establish a single source of truth on the CDE (structure–versioning–permissions–audit trail) and use 4D/5D as a gate before critical works to de-risk time/cost. Build project↔ organization dashboards (RAG + control charts) so decisions are evidence-driven, not intuition-led.

6.4 People & ecosystem implications

Thailand's bottleneck lies with SMEs and subcontractors. Pursue project-based upskilling (BIM-4D/5D, CDE workflows, Digital QA/QC, IPD-lite, HSE) with competency standards and tiered certifications linked to contractor selection. Launch monthly Communities of Practice (CoPs) and a shared repository of templates/scripts to reduce the "cost of learning by oneself" and accelerate the pilot→scale conversion rate. Collectively, this raises the industry's absorptive capacity, not just within large firms.

6.5 Measurement & transparency implications

To avoid "pretty numbers that don't change behavior," create a central KPI Dictionary (definitions–formulas–data sources–owners) and conduct random data audits from the CDE/RFI logs. Establish industry-level indices (BIM maturity, CDE adoption, Safety index, Productivity proxy, Margin stability) quarterly, and publish a public Industry Benchmark Dashboard (heatmaps/trends) to incentivize quality-based competition and feed evidence back into policy (a policy feedback loop).

6.6 Technology & risk implications

Adhering to openBIM/IFC/BCF and contractual data-sharing reduces vendor lock-in and improves cross-platform data exchange. In parallel, manage cybersecurity, data residency/compliance, and a data exit plan from day one so scaling is not derailed when tools or contract forms change.

Overall implication; The contribution is about "systematizing" how digital–contracts–skills–incentives move in step under sensing–seizing–transforming. When policymakers lay the rails with standards and procurement, executives build portfolio governance and data-linked dashboards, and the education/association system develops SME capabilities via project-based methods, the outcomes are shorter time, lower cost, better quality/safety, higher customer satisfaction, and steadier margins—auditable and sustained. This becomes a sector-level competitive advantage for Thai contractors, rather than ad hoc successes confined to a few projects or firms.

VII. LIMITATION OF THE STUDY

This work is an evidence-based synthesis that seeks to link the mechanisms from Innovation Capability (IC) to Innovation Performance (IPf) in the Thai context. Accordingly, it has the following limitations and caveats:

1. Scope of content. The focus is primarily on construction contractors. Owners/designers/suppliers are covered only insofar as they relate to the mechanisms, not as a complete picture of the entire value chain

across all work categories (e.g., post-handover asset maintenance, real-estate operations). The discussion emphasizes core digital tools (BIM/CDE/4 D–5 D/IPD) rather than the full universe of specialized technologies.
2. Evidence timeframe. The review relies on literature from 2020–2025. As such, it may miss classic earlier studies and very recent publications that appeared after this window, including in-press/early-access work.
3. Heterogeneity of definitions/metrics. Definitions of IC and IPf vary across studies (e.g., how rework, schedule variance, or change-order % are computed). Cross-case/cross-country comparisons therefore require caution, and reported effects may be contingent on project/contract contexts.
4. Technology velocity. Standards (openBIM/IFC), CDE versions, and AI/analytics capabilities evolve rapidly. Recommendations suitable today may require adjustment within 6–12 months, particularly regarding interoperability, data residency/compliance, and cybersecurity.
5. SME translation. Much of the evidence comes from large contractors/flagship projects. Adoption by SMEs may be constrained by resources, skills, and contracting systems.

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VIIII. COMPLIANCE STATEMENT

The author discloses the use of generative AI tools (GPT-5, Google Gemini, and Grammarly, accessed on 21 September 2025) solely for language editing, infographic generation, and text organization. These tools were not used to generate data, perform analyses, or produce scholarly conclusions. All content, data, and references were independently reviewed and authored by the author, who assumes full responsibility for the accuracy and integrity of the article. No confidential or personally identifiable information was entered into the AI systems. The AI tools are not listed as authors or co-authors.

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