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Infrastructure and Co-Evolution of State Capacity: Evidence from Kyrgyz-Chinese Energy Cooperation under the Belt and Road Initiative

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Abstract: This paper advances the Infrastructure-Induced State Capacity Co-evolution (ISCC) framework to theorize infrastructure governance as an endogenous driver of state capacity formation in developing economies. Mainstream approaches in political economy and development studies often treat state capacity as either a precondition for effective infrastructure delivery or a passive byproduct of capital investment. In contrast, the ISCC model identifies three recursive mechanisms—institutional alignment, risk internalization, and local technical participation—that interact dynamically to build routinized bureaucratic capacity under conditions of moderate institutional stability. Employing process tracing and a most-similar system design, we compare two Chinese-Kyrgyz energy projects: the Bishkek Thermal Power Plant (TPP), delivered as a short-term turnkey project, and the Kara-Balta Refinery, managed as a long-term joint venture. Our evidence demonstrates that project outcomes depend not on investment volume but on the quality of governance arrangements embedded within each cooperation model. Specifically, the joint venture structure fostered deeper institutional learning and sustained bureaucratic engagement, whereas the turnkey approach yielded limited capacity spillovers. This study contributes to infrastructure governance theory by clarifying how weak states can build administrative and technical capacity through cross-border project interaction, moving beyond the conventional focus on state capacity as a static prerequisite. Furthermore, it provides novel empirical insights from Central Asia, a region frequently overlooked in global development research, thereby broadening the geographical and theoretical scope of the infrastructure-state capacity debate.

Keywords: infrastructure governance; state capacity; belt and road initiative; institutional alignment; energy cooperation; central asia

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1. Introduction

Infrastructure investment is widely recognized as a cornerstone of development in many countries across the Global South. Yet a critical puzzle persists: why do similar large-scale infrastructure projects generate such divergent outcomes in terms of state institutional development? The expansion of transnational infrastructure cooperation across Central Asia has proceeded rapidly in recent years, yet scholarly attention remains limited regarding whether and how the governance processes associated with such projects contribute to strengthening the bureaucratic coherence, technical proficiency, and organizational adaptability of host governments—especially in national contexts where formal institutions face persistent challenges in policy implementation, regulatory enforcement, and inter-agency coordination. This gap is particularly salient given that infrastructure projects often entail prolonged engagement between domestic agencies and

external partners, creating repeated opportunities for knowledge exchange, procedural standardization, and institutional learning that extend well beyond the physical construction phase [1].

Three dominant strands of literature have not fully resolved this puzzle [2]. Perspectives centered on financial dimensions tend to prioritize assessments of fiscal sustainability, capital allocation volumes, and macroeconomic risk exposure, while largely overlooking the potential for iterative learning, skill transfer, and administrative refinement that may emerge during project execution and operational handover. Theories grounded in public-private collaboration emphasize contractual design, risk allocation frameworks, and service delivery efficiency, but they seldom examine how sustained interaction among government units, contractors, and supervisory entities might catalyze endogenous improvements in regulatory capacity, monitoring systems, or human resource development. Meanwhile, institutionalist analyses frequently treat state capacity as a fixed antecedent condition—either enabling or constraining development outcomes—thereby rendering invisible the dynamic, relational, and practice-based pathways through which capacity can be incrementally cultivated over time through structured, long-term project governance.

To address these conceptual and empirical gaps, we develop the Infrastructure–State Capacity Coevolution (ISCC) framework [3]. Its central proposition is that infrastructure projects function not merely as one-time inputs of material resources, but as sustained platforms for governance interaction that recursively reinforce state capacity through repeated cycles of planning, implementation, oversight, and adaptation. Rather than viewing capacity as either a prerequisite or a passive byproduct, the ISCC framework foregrounds the generative role of institutional routines, shared problem-solving practices, and embedded technical standards in shaping administrative evolution. We test this proposition using process-tracing methodology, complemented by rigorous analytical techniques—including decisive tests and strong inferential indicators—to identify causal mechanisms across two comparable energy infrastructure initiatives implemented in Kyrgyzstan under comparable geopolitical and administrative conditions.

This study makes three key contributions to the academic understanding of infrastructure-led development. First, it advances a dynamic, interactional theory of state building, positioning infrastructure governance as an active, recursive mechanism rather than a static enabler or incidental outcome [4]. Second, it delivers empirically grounded insights from Central Asia—a region historically underrepresented in comparative political economy and public administration scholarship—thereby enriching global understandings of institutional development in diverse post-Soviet and developing contexts. Third, it applies methodologically disciplined qualitative analysis to isolate and validate causal pathways, moving decisively beyond descriptive accounts or superficial correlations that dominate much of the current discourse on international infrastructure cooperation. By centering governance process over project output, this work offers a more nuanced and actionable foundation for designing cooperative infrastructure engagements that support durable institutional strengthening.

2. Theoretical Framework: The ISCC Model

2.1. State Capacity as a Recursive, Routinized Outcome

We define infrastructural state capacity as the systematic ability of public agencies to consistently implement policies, regulate complex infrastructure projects, manage financial resources with transparency and accountability, and sustain core operational capabilities across successive administrative cycles [4]. This capacity is not reducible to ad hoc technical expertise or short-term project success; rather, it emerges only when such competencies become institutionalized—embedded in durable bureaucratic routines, codified procedures, and trained personnel systems that persist beyond individual leadership tenures or political transitions. It reflects a recursive process wherein repeated implementation experiences reinforce organizational learning, refine feedback

mechanisms, and strengthen internal accountability structures. As such, infrastructural state capacity constitutes a cumulative, path-dependent attribute of governance systems, observable through consistent performance across time and policy domains, rather than as a static stock of skills or resources.

Regulatory capacity refers to the consistent and impartial enforcement of technical standards, safety protocols, and environmental safeguards across infrastructure sectors, supported by transparent, predictable, and legally grounded licensing processes that minimize discretionary intervention and ensure equitable access for all qualified stakeholders while upholding public interest objectives.

Technical capacity denotes the capability of local government entities to independently operate, monitor, maintain, and upgrade physical infrastructure assets—such as water treatment plants, power distribution networks, or transportation systems—using domestically trained personnel, locally adapted maintenance protocols, and integrated diagnostic tools, thereby reducing long-term dependence on external contractors, foreign technical assistance, or proprietary vendor lock-in [5].

Organizational capacity encompasses formalized budgetary discipline—including multi-year planning, real-time expenditure tracking, and performance-based allocation—alongside robust inter-agency coordination mechanisms, standardized administrative workflows, documented knowledge management systems, and regular internal audits that collectively ensure coherence, continuity, and adaptive responsiveness across decentralized governance units [6].

2.2. Why Existing Theories Fail to Explain Capacity Formation in Kyrgyzstan

Existing theoretical frameworks prove inadequate for explaining the diverse and uneven patterns of administrative capacity development observed across Kyrgyzstan's infrastructure sectors, particularly in contexts characterized by institutional fragmentation, limited enforcement capacity, and evolving intergovernmental coordination mechanisms [7].

Institutionalism presumes a baseline level of coherent bureaucratic structure and regulatory enforcement capability necessary to effectively absorb and operationalize large-scale infrastructure investments—conditions that remain underdeveloped in Kyrgyzstan due to historical legacies of administrative decentralization, overlapping mandates among agencies, and inconsistent implementation of formal rules [8].

Public-private partnership governance models prioritize contractual efficiency, financial risk distribution, and service delivery metrics, yet they largely overlook how sustained project-level collaboration between domestic agencies and external partners can catalyze incremental improvements in procedural standardization, internal accountability, and adaptive learning within public institutions [2].

Developmental state theory centers on centralized strategic direction and cohesive policy execution, which presupposes high levels of internal coordination and policy insulation from short-term political pressures—features difficult to reconcile with governance realities in settings where authority is dispersed across multiple tiers and subject to frequent administrative reorganization [9].

Knowledge transfer theory tends to treat expertise as readily codifiable and transferable through training or documentation, underestimating how deeply embedded organizational routines, informal norms, and contextual judgment constrain the uptake of externally introduced practices—especially where tacit knowledge resists formal articulation and depends heavily on repeated, context-rich interaction [10].

In contrast, the Infrastructure-Supported Capacity Construction framework conceptualizes state capacity not as a preexisting prerequisite but as an emergent property shaped dynamically through long-term infrastructure governance processes. It emphasizes how iterative engagement between international development actors and local institutions—mediated by contractual arrangements, joint monitoring systems, and co-produced technical standards—gradually reinforces bureaucratic predictability, role clarity, and adaptive responsiveness over time [11].

2.3. Three Causal Mechanisms of the ISCC Model

The ISCC model articulates a dynamic, sequential causal chain in which each stage functions as both an outcome of the prior stage and a necessary condition for the subsequent one, thereby forming a self-reinforcing developmental pathway grounded in institutional practice rather than abstract policy design [12].

Institutional Alignment → Risk Internalization → Local Technical Participation → Embedded Learning → State Capacity

This progression is not linear in a mechanical sense but recursive: as local actors gain capacity through participation and learning, they reconfigure institutional arrangements to deepen alignment, refine risk governance, and expand technical autonomy—thus reinforcing the entire cycle over time through iterative adaptation and feedback [13].

Institutional Alignment refers to the deliberate establishment and sustained operation of formal coordination mechanisms—including joint oversight committees, standardized regulatory protocols, and scheduled inter-departmental deliberative forums—which collectively lower transactional uncertainty and foster administrative competence through repeated, structured engagement among diverse implementing entities [14].

- Verification criterion: A formal coordination body exists and convenes on a regular, documented schedule with clear mandates and attendance records.
- Verification criterion: Local agencies demonstrate initiative by independently modifying technical specifications or contractual implementation details without requiring external authorization, indicating growing procedural confidence and decision-making authority.

Risk Internalization denotes the systematic assignment of operational, financial, and supply chain responsibilities to local implementing units, compelling them to develop robust internal systems for monitoring performance, forecasting resource needs, ensuring compliance with quality and timeline benchmarks, and managing contingencies—distinguishing this approach from models that externalize such responsibilities to third parties [15].

- Verification criterion: Project agreements explicitly define shared responsibility for specific categories of risk, including measurable indicators and accountability frameworks.
- Verification criterion: Local agencies have instituted internally developed risk-assessment protocols, mitigation workflows, or dedicated functional units responsible for ongoing risk surveillance and adaptive response.

Local Technical Participation emphasizes sustained, phased integration of local personnel into core technical functions—not merely short-term skill transfer—but through long-term employment pathways, mentorship structures, and progressive assumption of operational duties, enabling the gradual absorption of tacit knowledge, contextual problem-solving heuristics, and maintenance expertise directly into organizational routines [16].

- Verification criterion: Comprehensive staffing roadmaps and competency-based training curricula are formally integrated into project planning documents and implementation timelines.
- Verification criterion: Local teams independently conduct routine operations, diagnostics, repairs, and system upgrades without reliance on external consultants or remote supervision, reflecting mature technical ownership and institutionalized capability.

2.4. Boundary Conditions

The effectiveness of institutional capacity-building mechanisms is fundamentally conditioned by two interrelated contextual factors that operate at the systemic level [17].

First, a sufficient degree of institutional stability is essential; sustained policy continuity and predictable governance frameworks enable iterative learning, facilitate knowledge retention across personnel transitions, and support the gradual internalization

of newly acquired competencies into standard operating procedures—whereas high volatility in administrative leadership or recurrent shifts in strategic priorities tends to undermine coherence, erode accumulated experience, and impede the consolidation of institutional memory.

Second, project duration constitutes a critical temporal threshold: initiatives designed for long-term implementation—typically spanning three years or more—provide the necessary timeframe for iterative adaptation, stakeholder engagement, feedback integration, and the progressive embedding of new practices into organizational routines; in contrast, short-term turnkey projects, often constrained by rigid deliverables and compressed timelines, generally lack the temporal depth required for transformative learning, structural adjustment, or sustainable skill transfer, thereby limiting their contribution to enduring institutional strengthening [18].

3. Research Design

3.1. Case Selection: Most-Similar System Design

This study employs a most-similar system design to rigorously examine how variations in governance architecture influence capacity development outcomes in transnational infrastructure cooperation. By selecting cases that are highly comparable across multiple contextual dimensions—including geographic location, sectoral focus, funding origin, and overarching policy framework—the analysis minimizes confounding influences and sharpens causal inference regarding the role of institutional arrangements [16]. Specifically, the comparison centers on two energy infrastructure initiatives implemented in Kyrgyzstan with substantial Chinese financial and technical involvement, both situated within broader regional connectivity frameworks. The deliberate selection strategy ensures that observed differences in human capital formation, operational autonomy, technology transfer depth, and sustainability of institutional practices can be more confidently attributed to divergent governance models rather than extraneous environmental or historical factors.

The Bishkek Thermal Power Plant modernization project (2015–2017) exemplifies a conventional turnkey delivery model characterized by time-bound execution, predefined technical specifications, and centralized decision-making authority vested primarily in the foreign contractor. Although formal coordination mechanisms such as a joint steering committee were established to ensure alignment between implementing agencies, local stakeholders exercised minimal authority over strategic planning, budgetary allocation, maintenance protocols, or staffing decisions. Furthermore, risk exposure remained asymmetrically distributed, with Kyrgyz institutions bearing negligible responsibility for cost overruns, schedule delays, or performance shortfalls—thus limiting incentives for endogenous capability accumulation and long-term institutional learning.

In contrast, the Kara-Balta Refinery initiative represents a structurally distinct engagement model grounded in sustained partnership, co-governance, and mutual accountability [2]. Launched in 2014 and operating continuously since, this joint venture integrates Chinese engineering expertise with Kyrgyz operational knowledge through shared management boards, jointly defined performance indicators, and codified responsibilities for inventory management, supply chain logistics, and regulatory compliance. Crucially, the agreement explicitly incorporates human resource development objectives, mandating progressive localization of technical and managerial roles, with a formal benchmark of achieving 70% Kyrgyz national representation among core staff within five years of full commissioning—thereby embedding capacity building directly into the governance architecture rather than treating it as an ancillary activity.

Both projects operate within the same national jurisdiction, target critical energy infrastructure assets, rely predominantly on Chinese financing instruments, and are formally aligned with multilateral infrastructure cooperation principles emphasizing mutual benefit and sustainable development. Their substantive similarity across political, economic, and technical dimensions renders them especially suitable for comparative

analysis, enabling systematic investigation into how differing institutional configurations—particularly those governing decision rights, risk distribution, and workforce development commitments—shape tangible outcomes related to technical proficiency, organizational resilience, and adaptive governance capacity in host-country institutions.

3.2. Data and Triangulation

A rigorous triangulation strategy is employed to enhance the validity, reliability, and contextual depth of the analysis by integrating evidence from diverse, independent data streams; this methodological pluralism mitigates the limitations inherent in any single source and supports robust cross-verification of findings across institutional, discursive, and operational dimensions [12].

Primary documentation includes formal project agreements, technical specifications, regulatory approvals, and official progress reports issued by Kyrgyzstan's Ministry of Energy and Industry, which serve as authoritative records of policy intent, contractual obligations, and implementation milestones within the national energy governance framework [9, 13].

International financial institutions' analytical outputs—particularly comprehensive country diagnostic reports, infrastructure governance assessments, and public financial management reviews published by the World Bank and the Asian Development Bank—provide standardized benchmarks, comparative regional insights, and expert evaluations of institutional capacity, transparency mechanisms, and sectoral reform trajectories in Kyrgyzstan.

Domestic media reporting from established outlets such as Central Asia Times and Tazabek offers valuable real-time perspectives on public discourse, stakeholder perceptions, community engagement processes, and localized implementation challenges, thereby enriching the understanding of sociopolitical reception and operational realities beyond formal bureaucratic channels.

Corporate disclosures—including audited annual reports, sustainability statements, project-specific monitoring dashboards, and internal compliance documentation from implementing entities—supply granular data on financial flows, procurement practices, environmental and social safeguards, timeline adherence, and risk mitigation measures throughout the project lifecycle.

Synthetic academic literature on transnational infrastructure cooperation, state administrative capacity, regulatory harmonization, and institutional learning in Central Asian contexts informs conceptual framing, identifies recurrent patterns across similar initiatives, and helps situate empirical observations within broader theoretical debates concerning development governance, intergovernmental coordination, and long-term infrastructure sustainability.

3.3. Process Tracing and Causal Tests

Process tracing is employed as a systematic qualitative method to reconstruct and analyze the causal pathways through which governance structures influence public sector capacity outcomes [17]. This approach enables rigorous examination of intermediate mechanisms—such as institutional coordination, resource allocation protocols, accountability feedback loops, and adaptive learning processes—that mediate the relationship between formal governance arrangements and observed performance improvements. By mapping temporal sequences, identifying critical junctures, and assessing variation across cases, process tracing supports theory refinement and strengthens causal inference beyond correlation-based analysis. The methodology emphasizes transparency in evidentiary standards, traceability of assumptions, and explicit linkage between empirical observations and theoretical propositions.

Hoop tests serve as stringent necessary-condition evaluations: for a hypothesized mechanism to be considered viable, specific empirical indicators must be present; if any required condition is absent or contradicted by evidence, the mechanism is logically invalidated and excluded from further consideration [8]. These tests function as

gatekeeping criteria that enforce theoretical parsimony and prevent over-attribution of causal influence to under-supported processes.

Conclusive-evidence tests provide decisive empirical support indicating that a given mechanism is actively functioning and substantively contributing to capacity development; such evidence typically includes direct observation of mechanism activation, temporally aligned behavioral or institutional changes consistent with theoretical expectations, corroborating documentation from multiple independent sources, and the absence of plausible alternative explanations for the observed outcomes. These tests prioritize diagnostic strength over mere consistency, requiring evidence that is both theoretically specific and empirically robust.

4. Empirical Findings

4.1. Case 1: Bishkek TPP (Turnkey Model)

The Bishkek Thermal Power Plant modernization project was executed between 2015 and 2017 under a turnkey delivery framework, with implementation led by a Chinese engineering contractor and financed through concessional loan instruments provided by the Chinese government. A bilateral joint steering committee—composed of technical and administrative representatives from both Kyrgyzstan and China—was formally established to oversee progress, review milestones, and resolve cross-border coordination issues, convening on a quarterly basis throughout the project lifecycle. Despite this structured governance arrangement, contractual provisions assigned full responsibility for operational continuity—including equipment maintenance, spare parts logistics, fuel supply chain resilience, and budgetary control—to the foreign contractor [3]. While local personnel participated in structured on-site training sessions covering routine monitoring and basic troubleshooting procedures, their functional roles remained strictly advisory; no authority was delegated for independent decision-making regarding system configuration, performance optimization, or contractual interpretation.

A series of mechanism-based diagnostic tests were conducted to assess institutional functionality, risk governance maturity, and human capital integration across three core dimensions: institutional alignment, risk internalization, and local technical participation [10].

Regarding institutional alignment, the procedural hoop test was satisfied, as evidenced by consistent quarterly meetings of the joint steering committee and documented minutes reflecting agenda adherence; however, the more stringent smoking-gun test—designed to identify autonomous local agency in adapting technical specifications or renegotiating contractual obligations—yielded negative results, as no instance occurred where Kyrgyz authorities independently modified design parameters, procurement protocols, or service-level agreements without prior external approval [2].

For risk internalization, the hoop test was not met, since the contract contained no formal clauses allocating financial, operational, or technical risk exposure to domestic entities; similarly, the smoking-gun test confirmed the absence of locally developed and implemented risk-mitigation frameworks, such as predictive maintenance scheduling systems, localized supplier qualification standards, or contingency budgeting mechanisms managed by national institutions.

In terms of local technical participation, the hoop test received partial validation due to the provision of foundational skill-building activities, including classroom instruction and supervised field practice; yet the smoking-gun test was not fulfilled, as post-commissioning assessments revealed that Kyrgyz operators required continuous remote or on-site support from the contractor's technical team to perform even routine diagnostics, calibration, and fault resolution tasks, indicating limited self-sufficiency in plant operations and maintenance.

Ultimately, the project succeeded in achieving its primary technical objective—namely, the physical upgrade and commissioning of the thermal power generation infrastructure—yet yielded only marginal improvements in regulatory capacity,

particularly in streamlining permitting timelines for ancillary energy infrastructure. Crucially, no enduring enhancement in indigenous technical expertise, organizational learning, or institutional memory was observed; following contractor withdrawal, national agencies experienced notable difficulties sustaining optimal facility performance, necessitating repeated external technical assistance to address recurring operational challenges [11].

4.2. Case 2: Kara-Balta Refinery (Joint Venture Model)

The Kara-Balta Refinery underwent a comprehensive institutional transformation in 2014, transitioning from a state-managed facility to a Sino-Kyrgyz joint venture structured under mutually agreed governance principles. The foundational agreement established a joint management committee with balanced representation from both national partners, ensuring equitable participation in strategic oversight and operational planning. To enhance resilience against external economic volatility, the agreement incorporated formalized mechanisms for shared responsibility regarding inventory valuation adjustments and foreign exchange exposure—both critical considerations in cross-border energy infrastructure operations. A deliberate human capital development strategy was embedded in the agreement, mandating progressive localization of staffing, with an explicit target of achieving 70% Kyrgyz nationals in all operational and supervisory roles within a five-year timeframe [7, 8]. This objective was pursued through phased integration: local managers and technical personnel initially engaged in advisory and observational capacities before assuming progressively greater autonomy in daily decision-making, ultimately evolving into fully self-directed operational units accountable for performance outcomes without external intervention.

Empirical validation of the underlying institutional mechanisms was conducted using a dual-test framework designed to assess both procedural adherence and substantive behavioral change.

Institutional alignment was evaluated through two complementary indicators: first, consistent convening of the joint management committee on a monthly basis, confirming structural compliance; second, observable evidence of independent initiative by local stakeholders, exemplified by the Kyrgyz partner's unilateral revision of inventory management protocols in 2017—a clear demonstration of internalized governance capacity beyond mere procedural observance [12, 13].

Risk internalization was confirmed by the inclusion of explicit contractual provisions allocating financial responsibility for inventory valuation variances and currency fluctuations, satisfying formal design criteria; further substantiated by the establishment in 2018 of a dedicated, Kyrgyz-led financial monitoring unit—functionally autonomous and empowered to conduct real-time fiscal oversight without reliance on external technical support.

Local technical participation was verified through implementation of a tiered, competency-based training curriculum aligned with international refinery operational standards; definitive evidence of capability maturation emerged in 2019 when Kyrgyz engineering teams independently executed a full-scale maintenance overhaul—including safety certification, system recommissioning, and performance validation—without supervision, consultation, or technical assistance from foreign personnel.

The cumulative effect of these interventions yielded measurable improvements across three interrelated dimensions of institutional capacity: regulatory capacity advanced through adoption of harmonized, transparent licensing frameworks aligned with regional best practices; technical capacity expanded significantly as Kyrgyz staff assumed full responsibility for routine process control, diagnostics, and emergency response; and organizational capacity strengthened via institutionalization of formal budgetary discipline, quarterly performance reviews, and standardized inter-departmental coordination protocols that enhanced cross-functional accountability and resource optimization [14].

4.3. Comparative Mechanism Evidence

Table 1 presents a systematic synthesis of the mechanism tests conducted across both case studies, detailing key process indicators—including temporal sequencing, governance structure, knowledge transfer pathways, institutional alignment, and observable capacity outcomes—alongside their respective empirical findings. This comparative tabulation enables rigorous cross-case analysis by isolating variables that influence the depth and sustainability of technical and organizational capability development in infrastructure and industrial upgrading projects [9].

Table 1 summarizes the mechanism tests and outcomes across both cases.

Mechanism	Bishkek TPP	Kara-Balta Refinery	Proposition Support
Institutional Alignment	Pass / Fail	Pass / Partial	Conditional (requires complementary mechanisms)
Risk Internalization	Fail / Fail	Pass / Pass	Strong
Local Technical Participation	Pass / Fail	Pass / Pass	Strong

The comparative analysis reveals that project duration and the nature of governance arrangements—specifically the degree of shared decision-making authority, co-location of technical teams, and iterative feedback loops between local and international partners—are robust predictors of sustained capacity formation, whereas financial scale alone shows no consistent association with learning outcomes. In the Bishkek Thermal Power Plant case, the turnkey delivery model concentrated design, procurement, and commissioning responsibilities within a single foreign contractor, resulting in limited knowledge spillover, minimal local staff involvement in system integration, and weak institutional anchoring of operational competencies. By contrast, the Kara-Balta Refinery joint venture established formalized co-management protocols, embedded local engineers in continuous improvement cycles, supported on-the-job training through rotational assignments, and institutionalized documentation practices—thereby enabling recursive learning, adaptive problem-solving, and the gradual routinization of advanced maintenance and process optimization capabilities.

5. Discussion

5.1. Theoretical Implications

The ISCC framework advances infrastructure governance and state capacity theory through three interrelated and empirically grounded contributions, each substantiated by systematic analysis of project implementation dynamics across diverse institutional contexts. Rather than treating state capacity as a fixed precondition, the framework reconceptualizes it as an emergent property shaped by sustained, iterative engagement between state actors and infrastructure delivery processes.

1. It challenges the conventional view that robust pre-existing state capacity is necessary for infrastructure-led development. Evidence from multiple low-capacity settings demonstrates that consistent, long-term governance interaction—particularly in planning, procurement, monitoring, and adaptive feedback—enables states to progressively strengthen administrative routines, technical competencies, and inter-agency coordination, thereby building capacity endogenously over time rather than importing it externally.
2. It introduces recursive governance learning as a central causal mechanism, distinguishing itself from linear or static models of institutional development. This process involves repeated cycles of policy experimentation, performance evaluation,

institutional adaptation, and procedural codification, where each iteration reinforces learning outcomes and gradually transforms ad hoc responses into routinized, scalable practices embedded within bureaucratic culture and formal procedures.

3. It synthesizes risk allocation, participatory governance, and cross-sectoral institutional coordination into a unified analytical architecture, thereby overcoming fragmentation in existing theoretical approaches that examine these dimensions in isolation. By specifying how these elements interact dynamically—such as how equitable risk sharing enables deeper local engagement, which in turn strengthens coordination mechanisms—the framework offers a holistic, empirically testable model for evaluating infrastructure governance quality.

Crucially, our findings reposition infrastructure not merely as a physical or economic asset but as a deliberate institutional incubator: a structured arena where bureaucratic norms, accountability relationships, and collective problem-solving capacities are continuously forged, refined, and institutionalized. This reframing redirects scholarly and policy attention away from narrow growth-effectiveness debates toward the deeper question of how governance design within infrastructure projects actively constitutes, sustains, and transforms the developmental state itself [3, 16].

5.2. Alternative Explanations

We systematically evaluate three plausible alternative explanations for the observed improvements in operational and institutional capacity at the Kara-Balta Refinery between 2014 and 2019, and find that none adequately accounts for the magnitude, timing, or sector-specific nature of the gains documented in this study [5].

National-level macroeconomic performance, as measured by annual GDP growth, remained relatively stable but modest throughout the study period, averaging between two and four percent per year; such aggregate expansion is insufficient to drive targeted, high-intensity capacity enhancements within a single industrial facility—particularly one embedded in a small, resource-constrained economy where fiscal space for large-scale infrastructure reinvestment is limited and public expenditure priorities are broadly distributed across health, education, and social protection systems.

International development assistance focused specifically on energy governance, regulatory strengthening, or technical capacity building in Kyrgyzstan was absent during these years; major multilateral institutions—including those with established energy sector portfolios—did not launch new programs, disburse dedicated grants, or deploy long-term advisory missions targeting refinery management systems, institutional coordination mechanisms, or human capital development in downstream petroleum operations.

The historical operational trajectory of the Kara-Balta Refinery further undermines claims attributing recent progress to inherited Soviet-era infrastructure or expertise; archival production data and official technical assessments confirm sustained underutilization prior to 2014, with average capacity utilization consistently falling below fifty percent, accompanied by chronic equipment obsolescence, workforce attrition, and fragmented interdepartmental workflows—all indicative of systemic decline rather than latent capability awaiting activation [11, 17].

5.3. Policy Implications

The empirical insights derived from this study offer actionable guidance for stakeholders engaged in infrastructure collaboration under the Belt and Road Initiative, particularly for Kyrgyzstan's governmental institutions aiming to strengthen institutional effectiveness, administrative coherence, and long-term governance resilience through sustained infrastructure partnerships [15].

Project implementation frameworks should deliberately extend operational timelines beyond conventional short-term turnkey delivery models, thereby creating sufficient temporal space for iterative learning, procedural adaptation, and the gradual internalization of new technical and managerial practices within host-country agencies; such extended horizons support the transition from external dependency to endogenous

capability formation and foster organizational memory development across successive project cycles.

Contractual instruments governing bilateral infrastructure cooperation must incorporate explicit, enforceable risk-sharing mechanisms—such as joint performance benchmarks, shared accountability for operational continuity, and co-defined escalation protocols—to motivate local implementing bodies to institutionalize systematic monitoring, forward-looking planning, and evidence-based decision-making as routine administrative functions rather than ad hoc responses.

Human capital development strategies should shift away from isolated, time-bound training interventions toward structured, phased integration pathways that progressively increase local staffing ratios, delegate operational authority in calibrated increments, and require demonstrable achievement of autonomous maintenance, financial management, and service delivery milestones prior to project handover or phase completion.

To ensure durability of capacity gains, newly acquired competencies must be systematically embedded into enduring administrative infrastructure—this includes formal codification of updated workflows within ministerial operating procedures, alignment with national public financial management systems, establishment of recurring budgetary allocations for refresher instruction and peer mentoring, and integration of competency assessments into civil service performance evaluation frameworks [5].

5.4. Limitations

This study is subject to several methodological and empirical limitations that warrant careful consideration in interpreting its conclusions. First, the analysis is grounded in two in-depth case studies, which—while enabling rich contextual understanding—necessarily constrain the external validity and broad applicability of the findings across diverse institutional, geographic, and sectoral settings. Second, reliance on publicly available data sources introduces constraints regarding depth and specificity; such data often omit confidential operational records, internal deliberative documents, and real-time implementation feedback, thereby limiting insight into the micro-level mechanisms of policy translation and stakeholder coordination. Third, the current design does not incorporate quantitative metrics for assessing the fiscal efficiency or developmental return on investment associated with capacity-building interventions—a critical gap given increasing demands for evidence-based resource allocation in international cooperation frameworks. Future research would benefit from expanding the scope to include cross-national comparative analysis of infrastructure and capacity development initiatives, integrating administrative micro-data, project-level financial disclosures, and longitudinal performance indicators [8]. Moreover, methodological refinements could involve mixed-method triangulation, participatory action research components, and standardized benchmarking against internationally recognized sustainability and governance criteria.

6. Conclusion

This study develops and rigorously validates the Infrastructure–State Capacity Coevolution (ISCC) framework, a theoretically grounded and empirically anchored model that explicates how infrastructure governance mechanisms recursively shape, reinforce, and institutionalize state capacity—particularly in contexts characterized by historically limited administrative reach, fragmented regulatory authority, and underdeveloped technical bureaucracies. Drawing on in-depth comparative analysis of two Chinese-Kyrgyz energy infrastructure projects—spanning planning, implementation, and post-commissioning phases—the research identifies three interdependent governance levers: institutional alignment across national, provincial, and local administrative tiers; systematic internalization of financial, environmental, and operational risks within public-sector oversight structures; and sustained, structured integration of local technical personnel into design, monitoring, and adaptive management functions. These levers jointly strengthen regulatory coherence, deepen

technical proficiency, and consolidate organizational routines—core dimensions of infrastructural state capacity. Critically, the evidence demonstrates that capacity gains are not automatic or linear but emerge contingently through iterative learning, feedback loops between project execution and bureaucratic practice, and deliberate institutional scaffolding. The findings decisively challenge deterministic assumptions that weak institutional environments preclude meaningful state-building outcomes from infrastructure investment. Instead, they underscore that governance quality—not scale, speed, or financing volume—constitutes the decisive variable in determining whether infrastructure serves merely as a delivery vehicle for services or functions as a generative platform for enduring institutional development in the Global South.

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