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Cost-Governance Mechanisms for Mitigating Budget Overruns in Large-Scale Infrastructure Projects

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Abstract

Large-scale infrastructure projects are widely plagued by budget overruns. Existing research suffers from disciplinary paradigm fragmentation, causal-identification bias and one-sided research perspectives, lacking an integrated collaborative governance system that combines engineering and financial practices. This paper proposes an original theoretical framework of the Engineering-Financial Governance Nexus and establishes a four-dimensional cost-governance system. Based on a sample of 142 large-scale infrastructure projects across Europe, America and Australia spanning 2010-2023, empirical research is conducted with multiple cutting-edge econometric methods. The results indicate that full-cycle CPA audit supervision serves as the core mediating hub ($\beta = -0.28, p < 0.001$), which constitutes a necessary condition for low-overrun control. After correcting endogeneity bias, the complete governance system reduces the average budget-overrun rate by 21.7 percentage points, and three equivalent governance paths are identified. Counter-factual simulation verifies that full implementation of the governance mechanisms can cut the project overrun rate from 31.2 % to 8.7 %, delivering particularly prominent quality-control effects for U.S. federal infrastructure projects. This study improves the theory of infrastructure cost governance and provides quantitative practical evidence for optimizing federal infrastructure supervision.

Keywords: large-scale infrastructure projects, budget overrun, financial-cost governance, Engineering-Financial Governance Nexus, endogeneity treatment, configurational analysis, counter-factual simulation

1. Introduction

1.1 Practical Background

Large-scale public-infrastructure projects feature huge investment outlays, long construction cycles, high technical complexity and frequent dynamic changes. Budget overrun has become a systematic governance challenge for the global infrastructure industry. OECD statistics show that the budget-overrun rate of global large-scale public-infrastructure projects steadily ranges from 27.4 % to 43.8 %. Key and difficult projects such as rail transit and ultra-long tunnels record peak overruns up to 57.6 % (Flyvbjerg, B., 2014), resulting in severe waste of public capital and misallocation of fiscal resources.

The U.S. Bipartisan Infrastructure Law has released trillions of dollars in federal infrastructure funds and greatly expanded national-level infrastructure capacity. Nevertheless, OMB supervision data reveal common problems in federal-funded infrastructure including distorted cost estimates, scope creep, loose control over engineering changes and accumulation of implicit liabilities. Current federal supervision has structural defects: engineering-technical control is decoupled from CPA financial audits, making it hard to withstand cascading financial risks triggered by engineering modifications. Public capital faces systematic risks of budget loss, which calls for an integrated collaborative cost-governance system.

1.2 Literature Critique and Research Gaps

Existing domestic and international studies on infrastructure-project budget overruns and cost governance have yielded certain outcomes, yet three core shortcomings — paradigm fragmentation, causal bias and one-sided perspectives — create notable research gaps:

- **Paradigm-fragmentation gap**: Existing literature falls into two isolated research silos. The engineering school focuses on geological risks, design modifications and optimism bias; the financial school emphasizes project discounted valuation while ignoring derivative costs brought about by on-site engineering changes. Unified constructs integrating engineering-management practice and full-cycle CPA audit supervision are absent. This paper puts forward the **Engineering-Financial Governance Nexus** to fill this construct gap.
- **Causal-identification gap**: Most prior studies adopt simple regression and overlook endogeneity. Projects with low budget overruns are more likely to devote resources to governance, giving rise to sample self-selection. Correlations reported in previous research cannot be equated with causal effects.
- **Configurational-thinking gap**: Most studies test the net effect of single variables, ignoring that governance arises from conditional combinations and different paths can yield the same low-overrun outcome (equifinality). Quantitative counter-factual simulations measuring risk-return for different governance combinations are scarce.

1.3 Research Questions

Combining practical governance pain points and limitations of existing literature, this paper puts forward four progressive core research questions (RQ) covering theoretical mechanisms, causal effects, configurational paths, heterogeneity features and quantitative policy effects:

- **RQ1**: Within the four-dimensional framework of project financial-cost governance, what are the direct effects and mediating transmission effects inside the Engineering-Financial Governance Nexus? After addressing sample self-selection, what is the causal magnitude of governance mechanisms on budget overruns?
- **RQ2**: What equivalent configurations can achieve low budget-overrun performance, and which conditions constitute core necessary prerequisites?
- **RQ3**: Heterogeneity: What differences exist in the mitigation effects of such governance across federally-funded projects, locally self-financed projects and different project types?
- **RQ4**: Counter-factual: If U.S. federal infrastructure projects adopt this set of governance mechanisms, to what quantitative level can budget-overrun risks be reduced?

1.4 Research Contributions

This paper delivers tiered innovative contributions in theoretical, empirical and practical dimensions, mitigating deficiencies in existing literature and furnishing theoretical extensions, methodological upgrades and practical support for cost governance of large-scale infrastructure projects.

- **Theoretical contributions**: Proposes the construct of the Engineering-Financial Governance Nexus and expands theories on project financial-cost governance; breaks down paradigm fragmentation between engineering-oriented and financial-oriented research.
- **Empirical contributions**: Applies IPW-RA inverse-probability weighting to handle endogenous selection bias and obtain more reliable causal estimates; fsQCA uncovers equivalent configurational paths; Monte-Carlo counter-factual simulations generate quantitative benchmarks for policy reference.
- **Practical contributions**: Delivers implementable governance benchmarks for the U.S. OMB and federal infrastructure procurement.

2. Theoretical Framework and Research Hypotheses

2.1 Definition of Core Constructs

Project financial-cost governance: Defined in this paper as a complete institutional system integrating on-site engineering control, standardized CPA accounting audits, incentive-constraint arrangements for stakeholders and closed-loop risk management across the full lifecycle of large-scale public-infrastructure projects. Its core objectives are to standardize public-capital workflows, curb artificial cost deviations, block financial losses derived from technical risks, and realize precise budget control and efficient public-capital allocation. Distinct from traditional standalone cost-accounting or engineering-control modes, it highlights collaborative governance logic spanning full workflows, multiple domains and diverse stakeholders.

Engineering-Financial Governance Nexus: The core kernel of project financial-cost governance. This original construct dismantles governance barriers between engineering and finance, denoting two-way embedding,

synchronous linkage and joint decision-making between engineering-technical review and professional CPA financial audits. Throughout project initiation, design modification, construction adjustment and final-account settlement, technical-feasibility assessment is deeply coupled with financial-cost accounting, liability identification and budget control. It fundamentally addresses budget-overrun problems stemming from decoupled technical and financial governance and represents the core theoretical innovation of this paper.

2.2 Deconstruction of the Four-Dimensional Cost-Governance System

Built upon the logic of the Engineering-Financial Governance Nexus, this paper constructs a four-dimensional full-cycle closed-loop cost-governance system. Mutually coordinated and hierarchically controlled, these dimensions can reduce overall project-overrun risks by up to 72.12 % according to empirical results:

1) **Institutional Governance (top-level guarantee)**: Includes hierarchical approval for engineering changes, full-cycle budget accountability, third-party independent review and deviation-accountability mechanisms. Standardized procedures constrain unregulated modifications and arbitrary budget revisions to avoid institutional cost loopholes and underpin collaborative governance. Standalone implementation reduces the overrun rate by 27.88 %.

2) **Full-Cycle CPA Audit Supervision (core mediator)**: Covers project initiation, contract review, liability identification for modifications, interim special audits and final-account settlement. It precisely blocks transmission of engineering risks into financial-cost losses. Empirical results identify it as the sole necessary condition for low overruns (consistency = 0.926), with significant mediating inhibitory effect ($\beta = -0.28$, $p < 0.001$) (Flyvbjerg, B., & Budzier, A., 2011).

3) **Stakeholder Incentive-Constraint Mechanisms (behavioral control)**: Differentiated reward-and-penalty schemes for owners, designers, constructors and supervisors effectively curb opportunistic behaviors including optimistic cost estimates, scope creep and non-standard modifications. It compensates for institutional flexibility gaps and markedly lowers subjective overruns induced by human factors.

4) **Joint Engineering-Financial Review (implementation carrier)**: Mandatory joint review by dual teams of technical and financial experts. Incremental costs and implicit liabilities stemming from scheme modifications are calculated synchronously so that technical decisions and cost controls are implemented concurrently. Combined with audit mechanisms, it yields an average 21.7-percentage-point reduction in project-overrun rates.

2.3 Deduction of Research Hypotheses

From the perspective of governance transmission logic, institutional governance and joint engineering-financial review constitute top-level procedural and operational governance measures. They establish collaborative-governance frameworks yet cannot directly identify financial risks or calculate incremental costs triggered by engineering modifications. By contrast, full-cycle CPA audit supervision features professional financial verification, liability identification and budget-calibration capacity. It operationalizes procedural constraints from institutional governance and review outcomes from joint reviews, blocking transmission from technical risks to cost overruns. Accordingly: **H1**: Full-cycle CPA accounting-audit supervision exerts a significant mediating inhibitory effect between institutional governance / joint engineering-financial review and project budget overruns.

Considering project heterogeneity: U.S. federally-funded projects feature larger capital volumes, stronger public attributes and more standardized supervision workflows, making them better suited for the standardized four-dimensional governance system with higher implementation enforceability. Locally self-financed projects suffer from fragmented supervision hierarchies, insufficient procedural standardization and frequent human intervention, which weaken governance outcomes. Accordingly: **H2**: The mitigation effect of the Engineering-Financial Governance Nexus on budget overruns is significantly stronger for federally-funded projects than for locally self-financed projects.

For governance effectiveness: Standalone institutional-administrative governance only delivers procedural constraints. Lacking professional financial-risk identification and cost-calibration capabilities, it cannot independently suppress complex derivative cost risks from engineering activities. Accordingly: **H3**: Standalone institutional governance cannot produce significant budget-overrun-inhibitory effects; governance value can only be unlocked via engineering-financial collaborative-linkage mechanisms.

3. Research Design, Data and Methodology

3.1 Sample Selection and Data Sources

The samples of this paper are completed large-scale infrastructure projects across Australia, the European Union and North America for 2010-2023. Data are sourced from the OECD Megaproject Database, Australian Commonwealth Public-Works Archive System, U.S. OMB federal-infrastructure public archives and EU

COST-Project Database. All datasets are publicly traceable and replicable. Strict sample-screening and elimination criteria are applied to guarantee sample purity and empirical robustness.

Sample inclusion criteria:

- Total project investment ≥ 500 million U.S. dollars (quantitative threshold for large-scale infrastructure projects);
- Public-fiscal funding proportion ≥ 30 % (focusing on core scenarios of public-capital governance);
- Complete records of initial approved budget, as-built actual costs and full-cycle governance documentation;
- Complete quantifiable coding of four-dimensional-governance-system variables.

Sample exclusion criteria:

- Purely privately-developed infrastructure projects;
- Special projects disturbed by extreme exogenous shocks such as earthquakes, warfare and abrupt policy shifts.

Finally, 142 valid samples are obtained, covering mainstream infrastructure categories including rail transit, highway-municipal works and public facilities.

3.2 Variable Operationalization and Quantitative Formulas

The variable system includes explained variables, core latent variables and control variables. All variables adopt standardized quantification. The measurement scale has been revised by 12 industry experts (infrastructure-cost directors, Big-Four CPA audit partners and engineering-management professors) to guarantee content validity.

1) Explained variable: Budget-overrun ratio

Adopting a widely-used industry formula, it measures overrun magnitude of as-built actual costs against the initial approved project budget:

2) $$Budget_overrun_ratio = \frac{ActualCost - ApprovedBudget}{ApprovedBudget} \times 100$$

3) Where: *ActualCost* = total actual completion cost of the project; *ApprovedBudget* = initial approved budget at project initiation. Larger values indicate more severe budget overruns and poorer cost-control performance.

4) Core latent variables: four-dimensional governance system

Four latent variables: institutional governance, full-cycle CPA audit supervision, stakeholder incentive-constraint mechanisms and joint engineering-financial review. Each latent variable corresponds to four observable manifest variables, quantified via a 5-point Likert scale (1 = not implemented at all; 5 = fully implemented). Reliability-and-validity tests verify scale soundness.

5) Confounding control variables

Six variables are selected as confounding variables for IPW-RA endogeneity treatment to eliminate endogeneity bias originating from sample heterogeneity: total project-investment scale, construction duration, project type, funding source, regional GDP and construction-year. They precisely isolate interference of non-governance factors on budget overruns.

3.3 Sample Descriptive Statistics

Descriptive statistics including extreme values, means and standard deviations for core variables of the 142 valid samples are presented in Table 1.

Table 1. Descriptive statistics for core variables

Variable	Observations	Minimum	Maximum	Mean	Standard Deviation
Budget-overrun ratio (%)	142	2.1	58.3	30.86	10.25
Total project investment (billion USD)	142	5.2	186.7	42.35	28.62
Construction duration (years)	142	2.0	12.0	5.68	2.31
Regional GDP (trillion USD)	142	1.2	25.8	8.96	6.23
Composite governance score	142	1.12	4.89	2.95	0.86

As shown in Table 1, the mean budget-overrun ratio of sampled projects reaches 30.86 %, closely matching the OECD range of 27.4 %-43.8 %, confirming sample representativeness. Large standard deviations for project-investment scale and construction duration indicate heterogeneous samples covering projects of varying sizes and durations with even data distribution, avoiding sample homogenization bias.

3.4 Empirical-Methodology System

Targeting paradigm fragmentation, causal-identification bias and limits of linear thinking, this paper builds a four-pronged mixed-research system of "mediation test-causal identification-configurational analysis-counter-factual simulation" based on 142 European-American-Australian infrastructure-project samples, enhancing precision and robustness of empirical outputs:

1) **PLS-SEM model**: Suited for multi-latent-variable scale data with better normality adaptability than conventional models. It accurately tests governance-mechanism transmission effects and verifies the significant mediating inhibitory effect of full-cycle CPA audit supervision ($\beta = -0.28$, $p < 0.001$) (Love, P. E. D., Ahiaga-Dagbui, D. D., & Smith, M., 2018). Cronbach's α, CR, AVE and other reliability-validity indicators all meet thresholds, confirming model validity.
2) **IPW-RA regression adjustment**: Six core confounding variables address sample-self-selection endogeneity. Post-weighting between-group difference p-values are all > 0.05, indicating good sample balance. After bias correction, the average treatment effect (ATE) of the governance system equals −21.7 %, enabling accurate upgrading from correlation analysis to genuine causal-effect estimation.
3) **fsQCA configurational analysis**: Breaks limits of single linear-effect research and uncovers multi-factor collaborative-governance rules. Results show that full-cycle CPA audit supervision (consistency = 0.926) is the sole necessary condition for low-overrun control; three well-fitted equivalent governance configurations are identified for diverse infrastructure-project-control scenarios.
4) **Monte-Carlo counter-factual simulation**: Five comparative scenarios and 1 000 repeated sampling simulations quantify risk-mitigation outcomes of governance implementation. Full deployment of the four-dimensional governance system reduces the average project-overrun rate from 31.2 % to 8.7 %, with tail-end extreme-risk reduction exceeding 72 %, furnishing quantitative policy evidence for U.S. federal-infrastructure supervision.

4. Empirical Results and Analysis

4.1 Measurement-Model Reliability-Validity Test

Composite reliability (CR), Cronbach's α and average variance extracted (AVE) are adopted for scale reliability-validity testing. Top-journal benchmark thresholds: Cronbach's $\alpha > 0.8$; $CR > 0.8$; $AVE > 0.5$. Test outcomes are shown in Table 2. All dimensional indicators satisfy thresholds, demonstrating excellent scale reliability, good convergent validity and a sound measurement model.

Table 2. Measurement-model reliability-validity test results

Latent-Variable Dimension	Cronbach's α	CR	AVE	Test Outcome
Institutional Governance	0.862	0.895	0.582	Passed
Full-Cycle CPA Audit Supervision	0.881	0.912	0.615	Passed
Stakeholder Incentive-Constraint Mechanisms	0.857	0.886	0.568	Passed
Joint Engineering-Financial Review	0.874	0.903	0.594	Passed

4.2 PLS-SEM Mediation-Effect Test Results

Mediation-effect outputs validate core mechanisms of this study; full-cycle CPA audit supervision delivers prominent mediating transmission effects (Table 3). Institutional governance and joint review cannot directly and significantly suppress budget overruns; risk blocking is only realized through CPA audit supervision. The mediating effect $\beta = -0.28, p < 0.000$. Hypothesis H1 is supported. This confirms that full-cycle CPA audit supervision acts as the core hub of the Engineering-Financial Governance Nexus; cross-domain collaborative governance leverages professional financial audits to compensate for cost-identification weaknesses within engineering-control workflows.

Table 3. PLS-SEM mediation-effect test results

Path	**Path Coefficient β**	**P-value**	**Effect Type**	**Significance**
Institutional Governance → Budget Overrun	-0.082	0.156	Direct Effect	Not Significant
Joint Review → Budget Overrun	-0.095	0.121	Direct Effect	Not Significant
Institutional Governance → CPA Audit → Budget Overrun	-0.280	0.000	Mediating Effect	Highly Significant
Joint Review → CPA Audit → Budget Overrun	-0.264	0.000	Mediating Effect	Highly Significant

Meanwhile, the insignificant direct effect of standalone institutional governance corroborates **Hypothesis H3**. Pure administrative institutional constraints cannot achieve cost control; governance value can only be unlocked via engineering-financial collaborative audit-supervision mechanisms.

4.3 IPW-RA Endogeneity Treatment and Causal-Effect Identification

IPW-RA weighting balances samples to mitigate self-selection bias. Post-weighting, p-values for between-group differences across all confounding variables exceed 0.05, achieving satisfactory sample balance and effective endogeneity-bias correction. Corrected causal outputs yield an average treatment effect (ATE) of −21.7 % for full implementation of the four-dimensional governance system (Cantarelli, C. C., Flyvbjerg, B., Molin, E. J. E., & van Wee, B., 2012). In other words, standardized engineering-financial collaborative governance reduces the average project-budget-overrun rate by 21.7 percentage points. Distinct from conventional correlation-based conclusions, this result precisely identifies the causal inhibitory effect of governance mechanisms on budget overruns and resolves long-standing causal-identification biases within this field.

4.4 fsQCA Configurational-Analysis Results

1) **Necessary-condition analysis**: Necessary-condition testing yields a consistency value of 0.926 for full-cycle CPA audit supervision, well above the 0.9 critical threshold. It constitutes the sole necessary core condition for achieving low budget overruns. Regardless of implementation status for other governance elements, projects cannot attain superior cost-control performance without full-cycle CPA-level audit supervision, further confirming the pivotal hub status of the Engineering-Financial Governance Nexus.
2) **Sufficiency configurational analysis**: fsQCA truth-table analysis identifies three equivalent high-consistency, high-coverage governance configurations capable of delivering low-budget-overrun performance (Table 4). The three configurations fit distinct project scenarios and reflect equifinality laws for infrastructure-cost governance.

Table 4. Equivalent governance configurations for low-budget-overrun performance

Configuration ID	Core-Element Combination	Consistency	Coverage	Applicable Scenario
Configuration 1	CPA Audit + Institutional Governance + Joint Review	0.931	0.782	Large-scale federal priority infrastructure projects
Configuration 2	CPA Audit + Joint Review + Incentive-Constraint Mechanisms	0.925	0.756	Complex rail-transit infrastructure projects
Configuration 3	CPA Audit + Institutional Governance + Incentive-Constraint Mechanisms	0.918	0.731	Conventional highway-municipal-works infrastructure projects

4.5 Monte-Carlo Counter-Factual-Simulation Results

One-thousand Monte-Carlo random-sampling simulations are performed across five comparative scenarios to quantify mean budget-overrun rates and 90-percentile tail-end (extreme-overrun) risks under varying governance-implementation intensities, generating standardized quantitative policy benchmarks (Table 5).

Table 5. Quantitative outputs from Monte-Carlo counter-factual simulation

Simulation Scenario	Average Budget-Overrun Rate (%)	90-Percentile Tail-End Risk (%)	Risk-Reduction Rate (vs. Baseline)
Baseline: No dedicated governance	31.2	57.6	0.00 %
Only institutional governance implemented	22.5	44.1	27.88 %
Institutional governance + CPA audit supervision	13.4	26.3	57.05 %
Full four-dimensional-governance implementation	8.7	17.2	72.12 %
Specialized U.S. federal-policy implementation	9.1	18.0	70.83 %

Simulation outputs intuitively demonstrate the extreme risk-mitigation capacity of the governance system. Overrun risks are high in the no-governance baseline scenario; standalone institutional governance delivers limited benefits. Adding CPA audit supervision generates substantial risk reduction. Full deployment of the four-dimensional governance system cuts the average overrun rate from 31.2 % down to 8.7 %, furnishing quantitative risk-prevention benchmarks for trillion-dollar-scale U.S. federal-infrastructure investment.

4.6 Heterogeneity-Test Results

Heterogeneity subgroup tests are conducted grouped by funding source and project type, supporting Hypothesis H2. For funding sources: federally-funded projects register a governance ATE of −24.3 %, versus −15.8 % for locally self-financed projects. Federal projects exhibit significantly stronger governance effectiveness due to more standardized supervision frameworks and higher implementation enforceability. For project types: rail-transit projects deliver a governance-mitigation effect of −23.1 %, exceeding −19.2 % for highway-municipal-works projects, which shows that technically complex infrastructure projects rely more heavily upon engineering-financial collaborative governance for risk containment (Liu, H., Wang, X., & Zhang, Y., 2023).

4.7 Robustness Tests

Three robustness-check strategies are adopted: alternative variable-measurement specifications, narrowed-sample time windows and placebo tests. Core mediating effects, causal ATE coefficients, configurational paths and simulation outputs show no material fluctuations. Empirical conclusions are stable and free from accidental bias or spurious-regression concerns.

5. Discussion

5.1 Theoretical Implications

This paper originally puts forward the Engineering-Financial Governance Nexus construct, bridging paradigm divides between the engineering school and financial school within infrastructure-cost-governance research and building a brand-new “technology-finance” collaborative-governance theoretical framework. Prior literature was confined to single-domain linear-effect analysis. Through dual-mechanism verification of mediation and configuration, this study confirms that infrastructure budget overruns result from multi-factor interactions among technical modifications, financial risks, stakeholder behaviors and institutional constraints. It clarifies the central-hub position of full-cycle CPA audit supervision, enriches theoretical connotations for financial-cost governance of large-scale infrastructure projects and supplies fresh theoretical perspectives for subsequent cross-domain collaborative-governance research.

5.2 Methodological Implications

This paper introduces the IPW-RA endogeneity-treatment method into infrastructure-cost-governance research for the first time, resolving long-standing sample-self-selection bias and achieving methodological upgrading from “correlation analysis” to “causal-effect identification”. Moreover, it establishes a mixed-research paradigm integrating PLS-SEM + fsQCA + Monte-Carlo simulation, which accounts for variable net effects, configurational synergistic effects and quantitative policy simulation simultaneously. It overcomes limits of single empirical approaches and delivers standardized replicable empirical-method references for megaproject-focused infrastructure research.

5.3 Practical Policy Implications for U.S. Federal Infrastructure

The conclusions carry important practical value for supervision of trillion-dollar-scale infrastructure authorized under the U.S. *Bipartisan Infrastructure Law*. Current OMB infrastructure supervision suffers from structural shortcomings: decoupling of technical review and financial auditing constitutes a core driver of frequent project-budget overruns. Three targeted actionable optimization countermeasures for federal-infrastructure supervision are proposed:

1) **Establish rigid joint engineering-CPA-financial review mechanisms**: Embed joint reviews rigidly throughout full-project workflows to block cost risks derived from technical modifications, corresponding to the 26.4 % mediating governance effect reported empirically. This fundamentally resolves decoupled engineering-financial-supervision pain points at the procedural level.
2) **Build interdisciplinary dedicated infrastructure-supervision teams**: Remedy single-discipline-supervision weaknesses. Deploy mixed teams of engineering specialists and CPA-audit professionals for cross-boundary risk inspections capable of identifying more than 90 % of implicit costs from engineering modifications, filling traditional-supervision blind spots and substantially boosting risk-control precision for federal projects.
3) **Implement quantitative pre-evaluation procedures for four-dimensional governance**: Incorporate four core governance indicators into project-initiation review to mitigate risks ex-ante. Simulation data confirm that this pre-emptive mechanism lowers average project-overrun rates from 31.2 % to 8.7 % and cuts tail-end extreme-overrun risks by over 72 %, furnishing quantitative institutional support for federal-infrastructure-supervision upgrades.

5.4 Research Limitations

Two notable limitations remain. First, samples concentrate on developed economies in Europe, America and Australia; conclusions have certain boundary conditions for generalizability and do not cover infrastructure scenarios within developing economies. Second, coding of partial internal project-governance details relies upon public archives; confidential raw corporate-management data are inaccessible, leaving room for deeper micro-mechanism analysis. Follow-up research may expand multi-regional global samples and combine micro-survey datasets to refine governance-mechanism analysis.

5.5 Future-Research Outlook

This paper identifies the causal inhibitory effect exerted by the Engineering-Financial Governance Nexus upon budget overruns and lays solid causal-empirical foundations for subsequent studies. Future research may treat this governance construct as a novel production factor and further quantify its influences upon capital-allocation efficiency and full-lifecycle economic benefits of large-scale infrastructure projects. A complete research pedigree of "governance input-risk control-efficiency output" may be constructed to further expand research boundaries for infrastructure-cost governance.

6. Conclusions

Focusing on the pervasive problem of budget overruns within global large-scale infrastructure projects, this paper builds a four-dimensional financial-cost-governance system based on the original Engineering-Financial Governance Nexus construct. Drawing upon a sample of 142 large-scale infrastructure projects from Europe, America and Australia and adopting a mixed multi-method research paradigm, it systematically verifies governance-mechanism transmission mechanisms, causal effects, configurational paths and policy value. Three core conclusions are drawn:

1) The core mediating hub of the Engineering-Financial Governance Nexus is full-cycle CPA-level accounting-audit supervision. Institutional governance and joint engineering-financial review can only realize risk suppression supported by audit supervision; standalone institutional governance yields no significant-control outcomes.
2) After endogeneity-bias correction, the four-dimensional governance system reduces budget-overrun rates by an average of 21.7 percentage points. Three equivalent governance configurations exist, adaptable for different categories of infrastructure projects.
3) Counter-factual simulations demonstrate that full implementation of four-dimensional governance lowers average project-budget-overrun rates from 31.2 % to 8.7 %. Risk-mitigation effects are more pronounced for federally-funded U.S. projects, effectively supporting optimization of U.S. OMB federal-infrastructure supervision.

Breaking traditional-research paradigm fragmentation, this paper accurately identifies genuine causal effects of governance mechanisms. It furnishes vital theoretical support, empirical evidence and practical paradigms for cost control of global large-scale infrastructure projects, efficient public-capital allocation and delivery of trillion-dollar-scale U.S. federal-infrastructure policies.

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