Dynamic Modeling of Governance and Corruption Vulnerabilities in Infrastructure Public-Private Partnerships and Optimal Control A Review of Kampala Capital City Authority

Kenneth Okello Othieno, Twizeere Harrimah, Muhumuza Adam, Prof. Margaret Kareyo

Kampala International University, Kampala

DOI: https://doi.org/10.51584/IJRIAS.2026.11100082

Received: 26 October 2026; Accepted: 31 October 2026; Published: 12 November 2026

ABSTRACT

Infrastructure public-private partnerships (PPPs) involve complex governance arrangements that can expose projects to corruption, weak accountability and poor performance. This paper examines the relationships among governance capacity, corruption vulnerability, PPP implementation and infrastructure performance, using Kampala Capital City Authority (KCCA) as the institutional context. A qualitative integrative literature review synthesizes scholarly studies, Ugandan legislation, KCCA documents and institutional guidance. The synthesis indicates that governance vulnerabilities can develop across project identification, procurement, implementation, contract management and renegotiation. Weak institutional capacity, limited competition, information asymmetry and inadequate monitoring may reinforce one another over time. The paper develops a conceptual Dynamic Governance Optimal-Control Framework linking these vulnerabilities to project performance and governance responses.

Sector-specific applications distinguish the capital, construction and renegotiation risks of transport assets from the recurrent verification and payment risks of waste collection service contracts. A proposed operationalization pathway specifies system boundaries, measurable indicators, longitudinal data requirements, stock-and-flow relationships, parameter estimation, calibration and validation. The framework is conceptual: it neither estimates causal effects nor establishes an empirically optimal control policy. Its contribution is to provide a basis for testing how the timing and intensity of governance interventions can respond to changing project risks. Effective PPP governance therefore requires lifecycle oversight, sector-sensitive controls and evidence-based institutional learning.

Key words: Public-Private Partnerships, Governance, Corruption Vulnerability, Infrastructure Performance, Dynamic Modeling, Optimal Control, Kampala Capital City Authority

Background

Public-private partnerships (PPPs) enable governments to combine private capital, technical expertise and management capabilities with public infrastructure objectives. Their value depends on appropriate project selection, contractual arrangements and the capacity to manage long-term obligations (Burke & Demirag, 2019; World Bank, 2017).

Governance is an integral component of successful PPPs. It encompasses all components of the partnership including institutions involved in planning and decision-making, the contractual structure used by the parties involved in the partnership, organizational ability to implement plans and programs, communication among partners and stakeholders, transparency regarding all aspects of the partnership, the allocation of risk among partners and managers, and management practices (Burke & Demirag, 2019). Therefore, it is logical to assume that differences in governance arrangements would likely result in varying degrees of success when employing PPPs.

Despite the benefits of PPPs, they present several challenges. Due to their long-duration nature, PPPs

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

inherently produce complex financial arrangements that allow for information asymmetry among participants. They require coordination among multiple stakeholders who have competing interests, thereby producing incomplete contracts. Consequently, PPPs provide many opportunities for opportunism among participants. Opportunistic behaviors include but are not limited to theft of funds intended for use in public sector projects, diversion of monies intended to pay contractors working on public sector projects to other uses. Opportunistic behavior also includes delaying payments owed to contractors until after completion of their work; diverting materials purchased for public sector projects to other uses; engaging in false reporting to conceal underperformance and mismanagement. All of these behaviors represent a form of weak accountability that leads to suboptimal project performance (Burke & Demirag, 2019; World Bank, 2017; Wang et al., 2020).

Given that PPPs create several potential pathways for governance-related risks, it is essential to treat corruption vulnerability as a process that evolves over the lifetime of a project rather than simply as a procurement stage issue (Burke & Demirag, 2019). Corruption has become one of the most significant obstacles hindering the delivery of large-scale public sector projects (World Bank, 2017).

PPP governance therefore requires attention to the interaction of institutional arrangements, organizational capacity, contractual incentives and managerial practices (Xiong et al., 2019).

Moreover, corruption has created an added layer of complexity for addressing governance problems since large-scale public sector projects are typically characterized by considerable financial transactions and large amounts of discretionary power exercised by those individuals or organizations undertaking the project (World Bank, 2017). Project selection; procurement; contracting; land acquisition; financing; implementation; and contract renegotiation are examples of project activities that involve substantial financial resources and discretionary decisions made by either public or private entities (Burke & Demirag, 2019). The World Bank has indicated that project selection; procurement; contract administration; renegotiation; and disclosure are primary areas requiring anti-corruption measures in PPPs where low transparency and inadequate institutional capacity provide private or public actors with ample opportunity to take advantage of informational advantages and discretionary authority (Burke & Demirag, 2019).

Empirical evidence supports the existence of common risk factors associated with PPP projects in Uganda. Those risk factors include governmental corruption; procurement risk; inadequate tender competition; project approval delays; construction cost overruns; etc. (Bagenda & Ndevu, 2024).

Additionally, Uganda has formally established an institutional framework for PPPs. Specifically, Uganda enacted the Public-Private Partnerships Act in 2015. The act sets forth the role of the PPP Committee; establishes the PPP Unit; defines roles for contracting authorities and project teams; prescribes procurement procedures; provides guidance for feasibility studies; outlines provisions for project agreements; establishes methods for monitoring; and describes techniques for managing PPPs (Government of Uganda, 2015). The PPP Unit provides technical assistance; financial analysis and evaluation; legal advice to contracting authorities; maintains records of all PPP projects; facilitates collaboration among stakeholders; promotes transparent processes for identifying, evaluating, procuring, implementing and monitoring PPP projects; etc. (Government of Uganda, 2015). Overall, Uganda's PPP framework emphasizes governance and risk allocation at each phase of the PPP project lifecycle. Governance refers to the establishment of rules governing conduct within the partnership (Government of Uganda, 2015). Risk allocation refers to establishing responsibility among partners for losses incurred as a result of errors in design or construction specifications (Government of Uganda, 2015).

Therefore, Kampala is an especially suitable location for studying the aforementioned constructs given KCCA's current Strategic Plan clearly articulates PPPs as one possible funding vehicle for delivering KCCA's programmatic commitments to deliver infrastructure and service delivery programs for Kampala residents (Kampala Capital City Authority [KCCA], 2025). KCCA's FY2025/26–FY2029/30 Strategic Plan lists Waste Management; Street Lighting; Administrative Buildings; Public Transportation; Parking Facilities as possible subject matters for KCCA to utilize PPPs. Also included is a list of KCCA's necessary

infrastructure financing needs (KCCA, 2025). Past experience also demonstrates that KCCA has pursued PPP-type initiatives for infrastructure development. For example, KCCA has proposed a Waste Management PPP that will feature privately funded infrastructure with public sector support (KCCA, 2020). Thus KCCA has already engaged in utilizing private sector participation as part of KCCA's overall strategy to fund new infrastructure development.

Given that Kampala faces tremendous pressures on its budgetary resources and infrastructure financing needs — KCCA will need to prioritize effective management practices if it expects to successfully develop its extensive urban infrastructure agenda. One such priority area for KCCA will be enhancing its ability to govern itself effectively and manage corruption risks associated with its infrastructure investments. KCCA currently views "strengthening" its internal oversight/governance functions as one of its strategic priorities. KCCA also connects infrastructure investment with multiple sources of financing including central government appropriations; climate finance funding; P3 funding; innovation financing models etc. (KCCA, 2025). Presently, KCCA engages in very large-scale procurements for projects such as constructing major roads and bridges in addition to other urban infrastructures that require KCCA to supervise contractors performing these works. Moreover, KCCA has significant numbers of land acquisitions required for new urban developments as well as environmental-social safeguards associated with many types of urban infrastructure projects. These activities create many opportunities for institutional failures or non-compliance with applicable laws and regulations that could arise from inadequate oversight or failure to ensure accountability among KCCA employees or third-party consultants contracted by KCCA (KCCA, 2025). Prior audits conducted by Uganda's Office of the Auditor General have evaluated the financial management practices of KCCA in terms of its compliance with financial policies; performance of KCCA's mission objectives and other aspects of KCCA's business operations including donor-funded projects (Office of the Auditor General, 2025).

A limitation of static risk assessment is that it can obscure interactions among decisions made at successive project stages. A dynamic approach examines how limited transparency, weak institutional capacity, procurement deficiencies and inadequate monitoring may reinforce one another. It also allows researchers to investigate the timing and combination of controls needed to reduce vulnerability while sustaining project delivery (Wang et al., 2020).

This paper conceptualizes governance and corruption vulnerability in infrastructure PPPs as an interconnected system. Drawing on PPP governance literature, Ugandan evidence and KCCA's institutional context, it develops a framework linking governance capacity, corruption vulnerability, project performance and control interventions (Bagenda & Ndevu, 2024; Wang et al., 2020; Xiong et al., 2019). Its contribution is a context-sensitive explanation of these relationships and a pathway for future empirical testing.

Problem Statement

Although Infrastructure PPPs are able to provide additional financing, experience and alternatives for providing public infrastructures to governments, the complicated nature of their governance structure makes them vulnerable to potential corruption, information asymmetry, opportunistic behavior, procurement fraud and problems with renegotiating contracts. These vulnerabilities are especially pronounced when large amounts of capital are committed to a project, the duration of the contract is lengthy, there are many decision makers involved and there is limited knowledge regarding future costs, risks and performance (Burke & Demirag, 2019; Wang et al., 2020). In response, Uganda has developed a statutory PPP framework that covers all aspects related to project appraisal, procurement, risk allocation, contract management, monitoring and institutional oversight of PPPs (Government of Uganda, 2015). However, empirical evidence shows that government corruption, procurement risk, lack of tender competition, project approval delays, excessive construction costs and financial risks associated with PPPs in Uganda are some of the most important identified vulnerabilities in the use of PPPs (Bagenda & Ndevu, 2024).

Therefore, due to KCCA's increased reliance on PPPs as a method for funding its infrastructure development needs, there exists a need for stronger analytical methods which will allow researchers to

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

investigate how governance failures interact and evolve throughout the life cycle of a project (KCCA, 2025). Past research on PPPs have primarily focused on assessing individual risk factors and governance structures and contractual relationships as well as project performance. While this research area has provided little comprehensive analysis of the interactive relationship between governance failures and corruption vulnerability within urban infrastructure PPPs in Uganda (Xiong et al., 2019; Bagenda & Ndevu, 2024), this gap is highly relevant to KCCA given that the Authority's current infrastructure plan includes using PPPs in several sectors such as waste management, street lighting, public transportation, parking and administrative buildings (KCCA, 2025). This paper fills this gap by creating a dynamic conceptual model linking governance failures, corruption vulnerability, infrastructure PPP performance and optimal control interventions within the KCCA context.

Overall Objective

Develop a conceptual dynamic model of governance and corruption vulnerabilities in infrastructure public-private partnerships within Kampala Capital City Authority, and specify how alternative governance-control strategies could be evaluated.

Specific Objectives

- Assess governance structures and corruption vulnerabilities associated with infrastructure PPPs within the KCCA context.
- Analyze dynamic interactions among governance failure conditions, corruption vulnerabilities and infrastructure PPP performance.
- Develop a conceptual optimal-control framework and outline the empirical steps needed to assess governance interventions across the infrastructure PPP lifecycle.

Research Questions

- What governance structures and corruption vulnerabilities exist in terms of infrastructure PPPs within the KCCA?
- How do governance conditions and corruption vulnerabilities interdependently affect infrastructure PPP performance?
- What governance-control mechanisms would optimize reduction of corruption vulnerabilities while effectively implementing infrastructure PPPs?

Scope

From a geographical standpoint this study investigates governance of infrastructure PPPs at Kampala Capital City Authority in Uganda. From a subject matter viewpoint this study analyzes institutional governance, transparency, procurement, accountability, risk allocations, contract management, corruption vulnerabilities, PPP performance and optimal control measures. Finally, from a temporal point-of-view this study emphasizes empirical data from studies conducted from 2018-2026. Empirical data collected from prior studies was used to demonstrate Uganda’s existing PPP governance framework. In addition to empirical data from prior studies this paper utilizes the Public-Private Partnerships Act 2015 and other key statutes to describe Uganda’s present-day PPP governance architecture (Government of Uganda, 2015; KCCA, 2025).

Justification

This paper is justified by the increasingly greater emphasis placed upon PPPs in KCCA’s current infrastructure investment strategy and documented instances of both corruption and governance risks experienced with PPP projects in Uganda (KCCA, 2025; Bagenda & Ndevu, 2024). By adopting a dynamic analytical perspective, this paper may assist in supplementing traditional risk registers by demonstrating how governance weakness may be interdependent with each other over time. Additionally, by employing an

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

optimal control perspective this paper will assist in identifying where preventative measures, monitoring requirements, transparency procedures, procurement processes and accountability measures should be implemented during the life cycle of a PPP (Wang et al., 2020; World Bank, 2017).

LITERATURE REVIEW

Public-private partnerships establish contractual responsibilities for public and private participation in infrastructure financing, development and operation. Their long-term nature makes governance a continuing process: decisions during appraisal, procurement and implementation can affect later operation and renegotiation. Governance analysis must therefore consider relationships across the contract lifecycle rather than focus solely on contract award (Xiong et al., 2019).

Uganda's Public-Private Partnerships Act, 2015 establishes the PPP Committee and PPP Unit and allocates responsibilities across contracting authorities and oversight institutions. These arrangements create multiple accountability relationships in project development, procurement and implementation (Government of Uganda, 2015).

Formal institutions alone do not ensure effective governance. Xiong et al. (2019) identify institutional, organizational, contractual and managerial dimensions whose interaction influences PPP outcomes. Their analysis directs attention to trust, communication, monitoring capability, transparency and risk allocation, as well as the capacity to adapt relationships when conditions change.

In Uganda, Bagenda and Ndevu (2024) identify 34 principal PPP risks, including government corruption, procurement risk, inadequate tender competition, delayed approvals and construction cost overruns. These findings establish the relevance of governance vulnerabilities, but risk rankings alone do not estimate the causal feedback relationships required by a dynamic simulation.

For KCCA, this issue of governance becomes increasingly pertinent due to the fact that the Authority's current Strategic Plan outlines PPPs as one method available for funding and delivering infrastructure in meeting the large investment needs of Kampala. Additionally, KCCA's Strategic Plan identifies several possible applications for PPPs such as: waste management; street lighting; public transportation; car parks; and administrative buildings (KCCA, 2025). Thus, the governance capacity related to selecting, acquiring, managing contracts, monitoring and holding accountable the use of funds for PPPs directly affects the success of infrastructure investments in Kampala.

Risk of corruption along the entire PPP lifecycle

Corruption vulnerability can arise during project selection, procurement, implementation and renegotiation. Complex technical information and substantial financial commitments may limit public scrutiny and create opportunities for opportunistic conduct. The present framework treats these as potential vulnerabilities, not as evidence that corruption has occurred in any particular KCCA project.

At project selection, unclear appraisal criteria may allow political or private interests to displace public value. Weak preparation can also create commitments that become difficult to revise after investment begins. Transparent appraisal and scrutiny of long-term obligations are therefore relevant before procurement commences (World Bank, 2014).

Competitive tendering can be undermined by favoritism, collusion and manipulation of evaluation criteria. Inadequate competition and procurement risk were prominent in the Ugandan evidence reviewed by Bagenda and Ndevu (2024). Such conditions may affect contractor selection and subsequent delivery, although these effects require project-level investigation.

After contract signature, private partners may possess superior information about costs, technical conditions and service delivery. Public authorities need independent verification to distinguish genuine changes in operating conditions from inaccurate reporting or opportunistic claims (Xiong et al., 2019).

Renegotiation may be necessary when economic, regulatory or operational conditions change. It creates additional vulnerability where proposed variations lack transparent justification, independent assessment or fiscal scrutiny (World Bank, 2017).

Institutional Capacity, Governance Failure and Risk Allocation

Risk allocation should reflect each party's capacity to manage a particular risk, rather than maximize the amount transferred to the private partner. Inappropriate allocation can encourage disputes, renegotiation and underperformance; its consequences must be assessed alongside institutional capacity (World Bank, 2017).

Wang et al. (2020) have demonstrated that PPP risk management can evolve as policy modifications, contractual terms and operational circumstances can both redistribute risks over time and produce differing consequences. Causal-loop modeling, employed by the authors, demonstrates that risk allocation and contract management provisions can directly impact financing terms, service quality, project revenue and potential dispute resolution. This represents a perspective relevant to the current investigation due to its critique of static views where governance risk is viewed as a constant characteristic of the PPP contract.

Similarly, evidence from developing countries has illustrated that the relationship between risk transfer and PPP performance is neither direct nor unconditional. A large-scale cross-country comparative study on infrastructure PPPs indicated that the assignment of more responsibility for managing risk to private entities was positively correlated with successful PPP performance and that the effectiveness of institutions and economic conditions were influential factors in determining outcomes (Fleta-Asín & Muñoz, 2020). As such, risk transfer should not be assessed in isolation from the institutional environment in which the PPP exists.

Therefore, institutional capacity is a significant intermediate condition. Public officials capable of evaluating complex financial models, assessing VfM, negotiating contracts, monitoring performance by the private partner and identifying emerging risks are required for effective PPP governance. Weak technical capacity can lead to increased reliance upon private partners and/or transaction advisors, thereby increasing informational asymmetry relative to the ability of the government to defend public interests (Xiong et al., 2019). The Ugandan PPP framework recognizes this capacity requirement by designating the PPP Unit as responsible for technical expertise, capacity-building programs, research, project development and support to contracting authorities (Government of Uganda, 2015).

KCCA's responsibilities span transport, waste management, environmental management and urban development. Governance capability must therefore combine common accountability standards with sector-specific technical expertise (KCCA, 2025).

Interactions Between Governance Failures and Infrastructure Performance Over Time

The proposed dynamic interpretation is that weak preparation increases uncertainty, uncertainty encourages contract variation, and poorly scrutinized variations create further discretion. If unresolved problems consume oversight resources, they may weaken the authority's capacity to prevent subsequent failures. These are hypotheses for empirical testing rather than causal effects established by this review.

Dynamic modeling makes these proposed relationships explicit by identifying feedback direction, accumulation and delay. Project preparation can shape procurement quality; contractual arrangements determine monitoring demands; and monitoring outcomes influence subsequent intervention and renegotiation. The framework therefore examines how vulnerabilities accumulate and how controls may interrupt their reinforcement (Wang et al., 2020).

Optimal Control Theory as Analytical Approach to PPP Governance

Optimal control provides an analytical perspective for selecting time-varying interventions within resource and institutional constraints. In this framework, controls include procurement scrutiny, independent

monitoring, audit intensity, disclosure and capacity development. An optimal policy can only be identified after the model's relationships, objective function and constraints have been specified and tested.

The central question is how control intensity should change across the project lifecycle. Additional scrutiny at procurement, construction or renegotiation may produce different benefits and costs. Future analysis should compare these alternatives rather than assume that uniform oversight is efficient.

Thus, the proposed analytical methodology conceives of KCCA's PPP governance environment as a dynamic system characterized by interactions between governance capacity/corruption vulnerability/project performance/control interventions over time. The intention is not to suggest that an optimal solution exists without empirical validation but to develop a theoretically and empirically grounded framework through which future KCCA PPP data can be used to estimate system behavior and identify possibly efficient control strategies.

Empirical and conceptual gap

The literature establishes the relevance of PPP governance and risk interdependence, but three gaps motivate this paper. First, risk identification does not by itself explain feedback between governance weaknesses, corruption vulnerability and performance. Second, governance controls require greater attention to their timing, intensity and sectoral context. Third, a KCCA-focused framework needs an explicit route from conceptual relationships to measurable variables and simulation. This review addresses these gaps through conceptual integration; it does not claim to resolve them through primary empirical testing.

THEORETICAL FRAMEWORK

The study draws on principal-agent theory and systems thinking. Jensen and Meckling (1976) explain how delegated responsibilities can generate problems when actors have divergent interests and unequal information. In PPPs, public authorities delegate delivery responsibilities to private partners, while citizens rely on public officials to safeguard public value. Information advantages and discretionary powers can create opportunities for opportunistic behavior where monitoring and accountability are weak. Principal-agent theory helps identify these vulnerabilities; systems thinking examines how they interact over time.

Systems thinking provides additional support to principal-agent theory by providing an explanation for how individual governance problems can interact and produce wider system effects. Instead of treating corruption, poor monitoring, lack of competition in procurement processes and institutional capacity as independent factors systems thinking provides a basis for representing them as interconnected variables generating feedback over time (Wang et al., 2020).

Therefore, the combined theoretical perspective provided support for the study's central proposition: PPP corruption vulnerability is shaped by agency relationships within a broader dynamic governance system and the effectiveness of anti-corruption controls depends partially on their timing, intensity and interaction with other governance mechanisms. This proposition provided the conceptual link between the reviewed evidence and the proposed dynamic-control model for KCCA infrastructure PPPs.

METHODOLOGY

This study adopted a qualitative integrative literature review approach which enables evidence from multiple scholarly and documentary sources to be synthesised to develop an integrated understanding of complex public management phenomena (Snyder, 2019).

The literature review was based on peer-reviewed journal articles, legislation and policy documents published by the Government of Uganda, strategic and institutional documents published by KCCA, guidelines relating to PPPs, publications produced by reputable international institutions.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

The review emphasized literature published between 2018 and 2026, supplemented by earlier legislation, institutional guidance and foundational theory where relevant.

Searches focused primarily on terms including public-private partnerships, PPP governance, infrastructure corruption, Uganda PPPs, Kampala infrastructure, risk management of PPPs, system dynamics and optimal control.

Sources were selected for relevance to the objectives, institutional or scholarly credibility, methodological quality and traceable bibliographic information.

Evidence was organized around governance structures, corruption vulnerabilities, institutional capacity, procurement, risk allocation, contract management, infrastructure performance and control interventions.

The analysis used thematic synthesis, critical comparison and conceptual integration to identify convergent findings, differences and gaps.

Triangulation was achieved by comparing evidence across peer-reviewed studies, Ugandan legal and policy sources, KCCA documentation and authoritative institutional publications.

Synthesized evidence was then integrated into a conceptual dynamic governance and optimal-control framework which links governance capacity, corruption vulnerability, performance of infrastructure projects and control interventions throughout the lifecycle of a PPP.

The review did not collect primary project data, estimate feedback coefficients or solve an optimal-control problem. Its findings are a conceptual synthesis. Because a complete search log and source-screening counts are not reported, the review should not be interpreted as an exhaustive systematic review. The proposed sectoral mechanisms and simulation pathway are analytical extensions requiring independent empirical validation.

RESULTS AND FINDINGS

Three primary results were derived from the integrative review regarding the research goals: the governance structure of infrastructure PPPs; the types of corruption vulnerabilities and their interactions; and the use of dynamic modeling and optimal-control principles in PPP governance at KCCA.

Structure of Governance Arrangements for Infrastructure PPPs

The synthesis indicates that PPP governance involves interacting institutional, organizational, contractual and managerial arrangements. Xiong et al. (2019) show why contractual provisions should be examined alongside cooperation, communication, capacity, risk allocation and transparency.

In Uganda, a formal institutional framework for PPPs exists through the Public-Private Partnerships Act 2015 and the PPP Committee and PPP Unit. The framework establishes formal accountability structures between contracting parties, private sector partners and public oversight bodies to manage the procedures for identifying, developing, procuring, implementing and monitoring PPP projects.

Kampala is a place where PPP governance is becoming increasingly relevant because KCCA's FY2025/26–FY2029/30 Strategic Plan lists public-private partnerships as one of the funding mechanisms for its development program.

A list of major infrastructure priorities including roadways, street lighting, public transportation, waste collection, markets and other urban infrastructure will demonstrate the scope and complexity of the governance environment in which PPPs are managed.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

Therefore, KCCA's PPP governance challenge is primarily one of managing multiple institutional, contractual and administrative controls throughout each stage of the project life cycle as opposed to creating new formal regulations.

Corruption Vulnerabilities Throughout Each Phase of the PPP Life Cycle

The Ugandan study by Bagenda and Ndevu (2024) identifies corruption alongside procurement, competition, approval, construction and financing risks. This supports examining governance vulnerabilities across project stages rather than treating them as a single procurement concern.

Accordingly, findings suggest that corruption vulnerability is present throughout multiple stages of the PPP process. At the initial stages of a PPP project, corrupt individuals may influence discretionary decision-making regarding project selection. Procurement-related corruption vulnerabilities include bribery, bid manipulation, collusion, limited competition or favoritism. Asymmetrical access to information may limit public authority's ability to ensure that contractors perform as required.

Contract variations and changes in financing or operating conditions may create further opportunities for discretionary decisions. The framework therefore treats vulnerability as evolving across the lifecycle. It does not interpret risk rankings as proof of causal relationships or verified misconduct.

Interactions Among Governance Factors and Changes Over Time

The reviewed literature supports considering governance issues jointly. Xiong et al. (2019) emphasize their interrelationships, while the present framework proposes that these relationships can produce feedback across project stages.

Pagoni and Georgiadis (2020) review system dynamics applications to PPP problems. Their work provides methodological support for representing complex interactions through feedback structures, while leaving the relationships proposed here to be specified and tested with local evidence.

As a result of this evidence, the authors identify four key dynamic variables specific to the KCCA context: governance capacity, corruption vulnerability, infrastructure performance and control interventions. Weak governance capacity increases exposure to both corruption and procurement risks; increasing corruption vulnerability affects project cost, competition, and implementation; declining project performance creates pressure for control intervention or contractual adjustments; effective governance controls reduce vulnerability and enhance accountability.

This leads to a conceptual representation of relationships as follows:

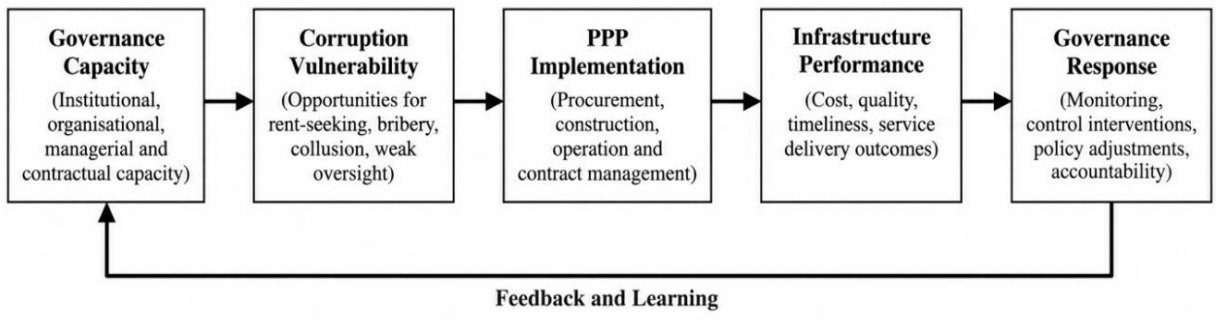

Figure 1: Dynamic Relationship among Governance, Corruption Vulnerability, PPP Implementation, Infrastructure Performance and Governance Response

This relationship provides the foundation for applying dynamic modelling to KCCA's infrastructure PPP environment.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

DISCUSSION

The conceptual framework connects governance capacity, corruption vulnerability, implementation and infrastructure performance. Its usefulness depends on explaining how these relationships differ across municipal projects and how they can be tested.

Governance Beyond Contractual Compliance

Contractual compliance is one component of governance. Institutional capacity, communication, transparency and managerial coordination also influence whether public authorities can identify and respond to emerging problems (Xiong et al., 2019).

Sector-Specific Adaptation of the Dynamic Governance Framework

The same core relationships apply across municipal sectors, but the dominant vulnerabilities, indicators and response delays vary. The following contrasts are analytical applications of the framework, not findings from primary investigation of specific KCCA contracts. Project classification should follow its actual contractual and financing arrangements: a routine service contract should not automatically be treated as a statutory PPP.

For high-capital transport assets, substantial upfront expenditure and long contract horizons make appraisal assumptions, land acquisition, design specifications and construction certification important points of vulnerability. Private partners may hold information advantages concerning engineering costs, asset quality and demand forecasts. In the proposed model, weak appraisal can increase variation requests; poorly scrutinized variations can raise fiscal pressure; and fiscal pressure may constrain subsequent oversight. Appropriate controls include independent design and cost review, milestone-based certification and scrutiny of changes to guarantees or concession terms. Relevant indicators include variation value relative to the original contract, verified physical progress, defects, cost deviations and asset availability. These relationships should be estimated with construction and operational delays represented separately.

For waste collection service contracts, vulnerability may arise through recurrent transactions and dispersed service delivery. Claimed tonnage, completed routes, collection frequency and billed services may be difficult to verify independently. The proposed feedback mechanism is that inaccurate reporting supports inappropriate payment, weakens incentives for reliable collection and increases complaints or unserved areas. Controls should therefore connect weighbridge records, route logs, spot checks and complaint resolution to payment verification. Indicators include discrepancies between billed and verified quantities, missed collections, coverage and payment-adjustment rates. Monitoring may need daily or weekly operational observations aggregated to a monthly simulation interval. The distinction is contractual rather than simply sectoral. A waste treatment plant or waste-to-energy concession can involve capital, construction and financing risks similar to transport infrastructure, alongside service-verification and environmental obligations. Each application should retain the common governance structure but revise its performance variables, feedback strengths, delay assumptions and control costs. Coefficients estimated for one project type should not be transferred unchanged to another.

Systemic Corruption Vulnerability

The framework proposes that procurement weaknesses, implementation difficulties and constrained oversight may reinforce one another. Uganda's risk evidence motivates this proposition, but project-level longitudinal data are needed to establish its strength and direction. For example, weak competition may reduce the quality of contractor selection, contributing to implementation difficulties and pressure for contract revisions. Where revisions escape independent scrutiny, they may create further vulnerability. Technical failure, inflation or legitimate scope changes can produce similar outcomes, so performance deterioration alone is not evidence of corruption.

A dynamic interpretation is useful because it separates proposed mechanisms from observed outcomes and makes alternative explanations testable.

Dynamic modeling methodology

System dynamics offers a way to translate the conceptual relationships into stocks, flows, decision rules and time delays. Its application to PPPs is documented by Pagoni and Georgiadis (2020). In this study, the contribution remains a proposed governance structure rather than an estimated simulation.

Corruption vulnerability is represented as a condition influenced by institutional capacity, contractual incentives and control actions. Its measurement must distinguish exposure to misconduct from detected cases, because stronger monitoring can increase detection even when underlying vulnerability is declining.

Optimal-Control Implications

The control perspective asks how much oversight should be applied, when it should be intensified and how its costs compare with expected reductions in vulnerability and service failure. These decisions require explicit objectives and constraints.

Controls should reflect project phase and sector. Procurement may require competition and conflict-of-interest checks; transport construction may require engineering verification; and recurrent waste collection may require frequent service and payment reconciliation. Major contract revisions warrant independent technical and financial scrutiny.

For KCCA, the practical implication is to link oversight decisions to documented risk signals, while preserving mandatory controls and recording the reasons for intervention.

Implications for public administration theory

The framework connects principal-agent theory with systems thinking. The former identifies information asymmetries and divergent incentives; the latter explains how these conditions may accumulate, interact and respond to intervention.

Their integration produces testable propositions about governance over time. It does not establish causal effects without longitudinal evidence or remove the need to account for political, economic and sectoral conditions.

Path Toward Empirical Operationalization

The following steps are proposed for future research and municipal application. They were not undertaken in this conceptual review. The pathway builds on the use of system dynamics in PPP research while specifying the additional measurement and validation needed for the present governance model (Pagoni & Georgiadis, 2020).

First, define the decision problem and system boundary. Select the project type, contract phases, decision-makers, observation interval and simulation horizon. A transport model should encompass construction and relevant operating obligations; a waste collection model should capture recurrent service and payment cycles. Distinguish endogenous governance responses from external influences such as inflation, demand changes and political transitions. Record the reference behavior to be explained, such as recurring variations, delayed corrective action or persistent service shortfalls.

Second, operationalize the constructs and assemble longitudinal data. Governance capacity can be represented through qualified oversight staff, caseloads, inspection completion and corrective-action closure times. Vulnerability indicators may include unexplained variations, reporting discrepancies, procurement red flags and unresolved audit findings; they measure exposure rather than proven corruption. Link procurement

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

records, signed contracts, amendments, invoices, inspection reports, audit follow-up and service records through stable project identifiers and dates. Record control expenditure and staff time as well as performance. Document missingness, reporting changes and any normalization or weighting used to construct indices. A single cross-sectional questionnaire is insufficient to estimate feedback timing.

Third, translate the conceptual framework into a causal-loop diagram and a stock-and-flow structure. Stakeholder workshops can test the plausibility of proposed links, but agreement does not establish causality. Candidate stocks include trained oversight personnel, unresolved governance deficiencies and accumulated physical assets or service backlogs. Flows include recruitment, attrition, new deficiencies, corrective-action completion, construction and deterioration. Vulnerability may be modeled as an index derived from these stocks and other risk conditions rather than assumed to be an accumulating quantity. Distinguish stocks from rates and specify consistent units for every equation.

An illustrative accounting relationship is: unresolved deficiencies at time $t + \Delta t$ = unresolved deficiencies at time $t + \Delta t \times$ (new deficiencies per period − resolved deficiencies per period). Resolution must be bounded by the available backlog and oversight capacity. The recorded inflow also depends on detection intensity: more inspections can initially reveal more deficiencies without implying that underlying misconduct has increased. Separate this observation process from the modeled incidence of new problems, and keep all stocks non-negative.

Fourth, identify parameters and quantify feedback. Estimate incident rates, resolution rates, staff attrition and response delays from dated records where possible. For each causal link, specify its expected sign, functional form, units, lag and plausible range. Test whether deteriorating performance predicts later intervention and whether intervention predicts subsequent resolution, controlling for project phase and external conditions. A reinforcing loop may connect unresolved weaknesses, implementation problems and overloaded oversight; a balancing loop may connect detected problems, corrective effort and resolution. Represent delays explicitly and examine nonlinear effects such as monitoring saturation. Use structured expert elicitation for unobserved parameters, label those values as assumptions and test them over wide ranges.

Fifth, calibrate and validate the simulation. Fit parameters against several observed trajectories, such as backlog, expenditure and service performance, using a stated error criterion. Reserve later observations or comparable projects for validation rather than using all observations for calibration. Check dimensional consistency, extreme conditions, conservation relationships and sensitivity to the numerical time step. Examine whether multiple parameter combinations reproduce the same history; weakly identifiable relationships should be simplified or reported as uncertain. Conduct sensitivity and uncertainty analyses and compare alternative feedback structures. Historical fit alone does not validate a causal mechanism.

Sixth, compare feasible controls and formulate an optimization problem. Begin with a baseline reflecting actual governance practice and compare preventive, targeted and combined strategies. Define the objective as a weighted reduction in service shortfall, fiscal exposure and vulnerability, balanced against oversight costs. State how unlike outcomes are normalized or monetized and justify the weights with decision-makers. Constrain expenditure, staff availability, intervention intensity and mandatory procedures. Search for time-varying control schedules and test their performance across plausible parameter ranges. Report trade-offs and robust strategies; an apparent optimum is conditional on the chosen objective, constraints and model assumptions.

Finally, pilot the model and document its limits. Publish the data dictionary, equations, parameter sources, calibration procedure and validation results, with appropriate protection for confidential information. Compare prospective predictions with new observations and update the model at agreed intervals. Data access, inconsistent records, underreporting and the distinction between detected irregularities and underlying vulnerability may limit inference. Until these requirements are met, the framework should support structured discussion and hypothesis generation rather than automated decisions or claims of proven optimality.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

CONCLUSION

This review develops a conceptual explanation of governance and corruption vulnerability as interdependent processes across the infrastructure PPP lifecycle. The central implication is that oversight should respond to changes in project conditions, institutional capacity and performance rather than rely exclusively on periodic compliance assessment.

Sectoral adaptation is essential. High-capital transport assets require attention to appraisal, construction certification, financing and long-term renegotiation, while waste collection service arrangements require frequent verification of outputs, coverage and payments. Waste treatment infrastructure may combine both risk profiles. Common accountability principles should therefore be implemented through different indicators and response intervals.

For KCCA, the framework provides a basis for organizing project evidence and designing prospective governance interventions. It does not demonstrate that particular projects are corrupt, estimate feedback coefficients or identify an already optimal policy.

Empirical implementation requires a documented project database, validated indicators, explicit stock-and-flow equations and estimated delays. Researchers should calibrate sector-specific parameters, test the model against withheld observations and examine uncertainty before comparing alternative controls. The methodological pathway outlined above converts the conceptual contribution into a reproducible research agenda.

The next practical step is a bounded pilot involving a capital-intensive project and a recurrent service arrangement, subject to data access and appropriate classification. Municipal staff and researchers should jointly verify the causal structure, evaluate predictive limitations and revise the model as evidence accumulates. Any policy conclusions should remain conditional on data quality, validated relationships and feasible oversight resources.

RECOMMENDATIONS

Lifecycle governance of PPPs

KCCA should assess governance and corruption vulnerability across identification, appraisal, procurement, construction, operation, renegotiation and closure, with documented responsibility for acting on identified risks.

Risk monitoring

KCCA should maintain a project-level monitoring system linking procurement anomalies, contract variations, expenditure, implementation delays, service indicators and audit follow-up. Risk signals should trigger verification, not automatic allegations of corruption.

Enhanced integrity in procurement process

Competitive procurement should be supported by transparent evaluation criteria, conflict-of-interest disclosure and independent review of suspected collusion or bid manipulation.

Matching control measures to emergent risk profiles

Oversight should respond to unusual cost changes, repeated variations and deteriorating performance. Sector-specific triggers should distinguish transport construction and asset availability from waste collection coverage and verified service outputs.

Development of institutional capacity

KCCA should strengthen technical, financial, legal, procurement and contract-management skills, with staffing and training plans aligned to the complexity of its project portfolio.

Contract and performance monitoring

Contracts should specify measurable indicators, reporting responsibilities and independent verification procedures. Transport indicators may include certified progress, defects and asset availability; waste-service indicators may include verified tonnage, completed routes, missed collections and complaint resolution.

Increased transparency-disclosure

Disclosure should cover project-selection reasons, procurement decisions, material contract amendments, public financial commitments and performance outcomes, subject to applicable confidentiality requirements.

Development of an Optimal control model based on data

KCCA and relevant national institutions should establish a linked longitudinal dataset, document indicator definitions and estimate sector-specific parameters before calibrating the model. Validation, sensitivity analysis and transparent reporting of assumptions should precede any claim that a governance strategy is optimal.

Integration of dynamic modeling into Future studies of PPPs

Future studies should test the proposed feedback relationships using repeated project observations from Kampala and, where comparable, other Ugandan urban authorities. A pilot should publish its data dictionary, equations, calibration criteria, uncertainty ranges and validation results, while protecting confidential records.

REFERENCES

1. Bagenda, B., & Ndevu, Z. (2024). Principal risks associated with public-private partnership projects in Uganda. Public Works Management & Policy, 29(2), 183–230. https://doi.org/10.1177/1087724X231167326
2. Burke, R., & Demirag, I. (2019). Risk management by SPV partners in toll road public private partnerships. Public Management Review, 21(5), 711–731. https://doi.org/10.1080/14719037.2018.1523450
3. Fleta-Asín, J., & Muñoz, F. (2020). How does risk transference to private partner impact on public-private partnerships' success? Empirical evidence from developing economies. Socio- Economic Planning Sciences, 72, 100869. https://doi.org/10.1016/j.seps.2020.100869.
4. Government of Uganda. (2015). Public Private Partnerships Act, 2015. Government of Uganda.
5. Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. Journal of Financial Economics, 3(4), 305–360. DOI: 10.1016/0304-405X(76)90026-X.
6. Kampala Capital City Authority. (2020). Public-private partnership project: Waste management infrastructure. Kampala Capital City Authority.
7. Kampala Capital City Authority. (2025). Kampala Capital City Authority strategic plan FY2025/26–FY2029/30. Kampala Capital City Authority.
8. Office of the Auditor General. (2025). Report of the Auditor General on the financial statements of Kampala Capital City Authority for the year ended 30 June 2024. Office of the Auditor General.
9. Pagoni, E. G., & Georgiadis, P. (2020). System dynamics approaches to public–private partnerships: A literature review. Systems Research and Behavioral Science, 37(2), 277–291. https://doi.org/10.1002/sres.2626.

10. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039
11. Wang, H., Xiong, W., Wu, G., & Zhu, D. (2020). Public–private partnerships: Implications from policy changes for practice in managing risks. Engineering, Construction and Architectural Management, 27(9), 2253–2269. https://doi.org/10.1108/ECAM-09-2018-0400
12. World Bank. (2014). Public-private partnerships: Reference guide version 2.0. World Bank.
13. World Bank. (2017). Public-private partnerships: Reference guide version 3.0. World Bank.
14. Xiong, W., Chen, B., Wang, H., & Zhu, D. (2019). Governing public–private partnerships: A systematic review of case study literature. Australian Journal of Public Administration, 78(4), 567–585. https://doi.org/10.1111/1467-8500.12343