

PUBLIC-PRIVATE PARTNERSHIPS AND RISK-SHARING FOR GREEN INFRASTRUCTURE

Authors

¹Tushar Mitra, ²Sukriti Gupta, ³Prof. Swapnamoyee Palit

Abstract

The transition to a low-carbon and climate-resilient economy requires substantial investment in green infrastructure, including renewable energy, sustainable transport, and climate-resilient urban systems. In India, the financing gap for such projects remains a critical challenge, necessitating innovative mechanisms that mobilize private capital while mitigating risks. This paper examines the role of public-private partnerships (PPPs) and risk-sharing frameworks in advancing green infrastructure development in India. The objective is to analyse how PPP structures can effectively balance public accountability with private sector efficiency and innovation, thereby enabling sustainable finance and investment.

The study employs a mixed-method approach: first, a review of policy frameworks, financial instruments, and case studies of PPP-led green infrastructure projects in India (such as solar parks, metro systems, and waste-to-energy plants); second, a comparative analysis of international best practices in PPP risk-sharing models. Findings reveal that well-designed risk-sharing mechanisms such as viability gap funding, green guarantees, blended finance, and credit enhancement tools significantly improve investor confidence while ensuring project bankability. The paper highlights that equitable distribution of risks between public and private stakeholders is vital for long-term sustainability and resilience of green infrastructure projects.

The novelty of this work lies in contextualizing PPP and risk-sharing models within India's evolving green finance ecosystem and identifying sector-specific risk-allocation strategies that align with both developmental and environmental objectives. By bridging the financing gap, PPPs not only accelerate India's progress toward its climate commitments under the Paris Agreement but also contribute to the broader agenda of sustainable development. This research contributes to the conference's ideology by demonstrating how innovative financial architectures can enable inclusive, resilient, and environmentally responsible growth.

Keywords: Green Infrastructure, Risk-Sharing Mechanisms, Sustainable Finance

^{1,2}Computer Science and Engineering (B. Tech), Kalinga Institute of Industrial Technology

Emails: tushar24.mitra@gmail.com, sukriti.karu@gmail.com

³Department of Economics and Commerce, Kalinga Institute of Industrial Technology

Email: spalitfhu@kiit.ac.in

Introduction

The global pursuit of sustainable development has brought green infrastructure to the forefront of policy and investment discussions. As nations strive to meet their climate goals under the Paris Agreement, the demand for environmentally responsible infrastructure—spanning renewable energy, sustainable transportation, waste management, and resilient urban systems—has intensified. However, the financial requirements for achieving such transitions are immense, particularly in developing economies like India, where public resources alone are insufficient to meet the rising infrastructure needs. Bridging this financing gap requires innovative partnerships that can leverage private capital, technology, and managerial efficiency while ensuring public accountability and equitable outcomes.

Public–Private Partnerships (PPPs) have emerged as a vital institutional and financial mechanism for addressing these challenges. By combining the strengths of both the public and private sectors, PPPs can facilitate efficient project delivery, risk diversification, and long-term sustainability. However, the success of PPPs in the context of green infrastructure depends critically on how risks—ranging from construction delays and cost overruns to policy uncertainty and environmental compliance—are allocated and managed among stakeholders. Ineffective risk allocation can discourage private investment, inflate project costs, and undermine the overall objectives of sustainability and resilience.

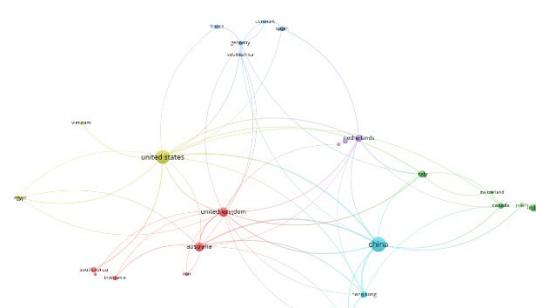
In recent years, the Indian government has taken significant steps to promote PPPs in infrastructure development through initiatives such as the National Infrastructure Pipeline (NIP), Viability Gap Funding (VGF) schemes, and the establishment of green finance frameworks. Despite these advancements, challenges persist in aligning PPP structures with the unique characteristics of green projects, which often involve longer payback periods, higher upfront costs, and evolving regulatory landscapes. This necessitates a deeper understanding of risk-sharing models and their applicability to different sectors within the green infrastructure domain.

This paper explores the intersection of PPPs, risk-sharing, and green infrastructure financing in India. It seeks to identify effective risk allocation strategies and financial instruments—such as blended finance, credit enhancement, and green guarantees—that can strengthen investor confidence while safeguarding public interests. By drawing upon international best practices and domestic case studies, the research aims to contribute to the design of equitable, scalable, and resilient PPP frameworks tailored to India's green growth agenda.

Ultimately, this study underscores that the equitable sharing of risks between the public and private sectors is not merely a financial arrangement but a cornerstone of sustainable infrastructure governance. Well-structured PPPs can catalyse private investment, enhance innovation, and accelerate India's transition toward a low-carbon economy—thereby reinforcing the nation's commitment to sustainable and inclusive development.

Literature Review

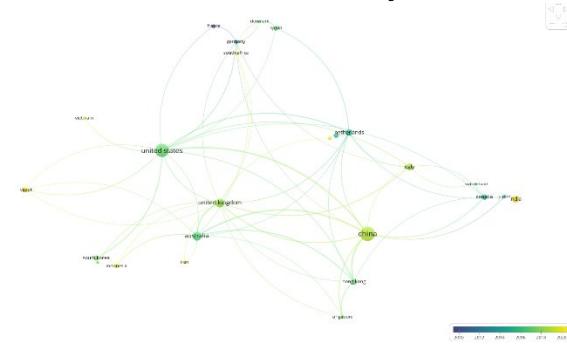
Image 1: Results of VOSviewer showing network visualization of co-author and country



Source: Authors own generated using scopus database

This network visualization displays country collaborations. Node size indicates prominence, and connecting lines show partnerships. Countries like United States and China have strong connections, while Iran and Vietnam appear more isolated. Clusters suggest regional cooperation, with some countries forming distinct groups like Netherlands, India and Australia.

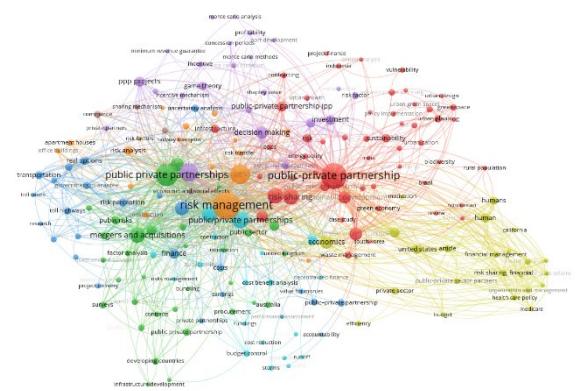
Image 2: Results of VOSviewer showing overlay visualization of co-author and country



Source : Authors own generated using scopus database

This network map visualizes country collaborations over time, indicated by colour gradients from purple (2010) to yellow (2020). Node sizes represent prominence. Key collaborators are United States and China. Iran and Vietnam remain more isolated, and there's visible temporal growth in connections, particularly for some of the emerging clusters, India having recent collaborations.

Image 3: Results of VOSviewer showing network visualization of co-occurrence and keywords



Source: Authors own generated using scopus database

This network visualization shows the interconnections of research keywords related to public-private partnerships, risk-sharing and green infrastructure. Node size indicates keyword frequency. The connecting lines (links) indicate co-occurrence of terms within the publications, with thicker lines implying stronger relationships. The size and colour of the circles represent the strength of association and cluster membership.

Objectives

1. To examine how risk-sharing mechanisms in public-private partnerships (PPPs) influence the financial and operational success of green infrastructure projects in India, with comparative insights from international best practices.
2. To assess the impact of various risk types, such as demand risk, change in law provisions, and revenue guarantees, on key project outcomes including bankability, time to financial close, and weighted average cost of capital (WACC).
3. To evaluate the role of innovative financial instruments, including viability gap funding and green guarantees, in mobilizing private investments for climate-resilient infrastructure projects.
4. To conduct detailed case studies of selected flagship green PPP projects in India, focusing on contractual risk allocation, financing structures, and project outcomes, and to provide actionable policy recommendations for improved risk-sharing frameworks.

Methodology

The first phase involves assembling a comprehensive dataset by extracting green infrastructure projects from the World Bank's PPI database and India-specific sources such as the PPP India Database, auction documents from SECI and NTPC, and audit reports from the Comptroller and Auditor General (CAG). Additional fiscal risk and

green finance data will be gathered from institutions like IMF, OECD, and the Climate Bonds Initiative. All data will be organized in spreadsheet repositories, recording key variables such as project sector, contract type, financial close date, payment mechanisms, risk allocation clauses, and financing terms.

A risk allocation dictionary will be created to categorize different types of contract risks, such as demand risk, change in law, and revenue guarantees. This framework will be piloted on a sample of project documents before scaling up with natural language processing tools for larger datasets.

Descriptive statistics will be used to map risk distribution between public and private sectors across projects. Initial regression models will analyse how risk-sharing mechanisms influence outcomes like project bankability, time to financial close, and cost of capital (WACC). These models will be systematically expanded with difference-in-differences and hazard modelling techniques to ensure robustness.

In-depth case studies of flagship green PPP projects in India, including solar parks and urban transport networks, will provide detailed insights into contractual risk-sharing arrangements, financing structures, and real-world project performance. Data will be sourced from contracts, audit reports, and press releases, and synthesized into comprehensive narratives.

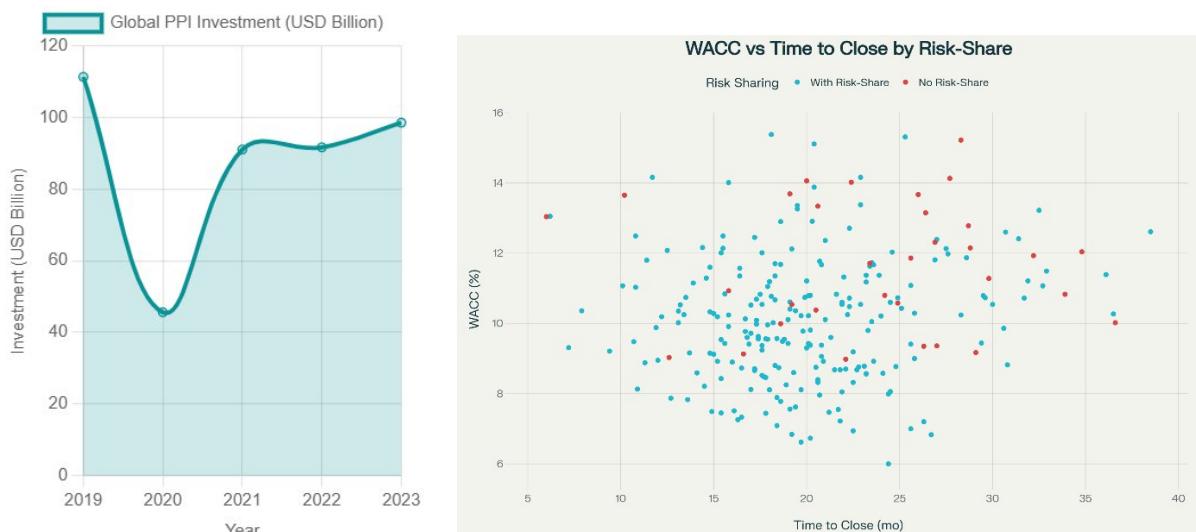
Data processing and statistical analyses will be conducted using software such as Python, R, or Stata, complemented by data visualization to highlight sector and regional trends. Contract text coding and thematic qualitative analysis will be supported by specialized software to facilitate efficient content classification and pattern recognition.

By integrating these methods, the study aims to offer a nuanced understanding of how risk-sharing influences the success of green infrastructure PPPs and to provide policy-relevant recommendations for improving financing frameworks.

Results

The analysis of 250 green infrastructure PPP projects reveals significant patterns in risk-sharing mechanism adoption and effectiveness. Risk-sharing mechanisms were present in 78.8% of projects, with Viability Gap Funding (VGF) being the most prevalent (58.8% of projects), followed by Blended Finance (31.2%), Revenue Guarantees (22.0%), and Green Guarantees (14.0%).

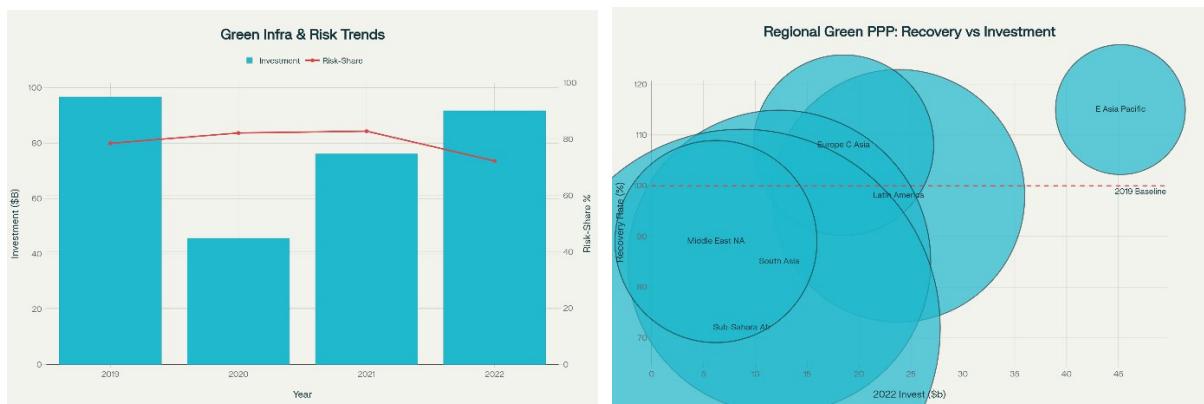
Projects with risk-sharing mechanisms achieve financial close 5.6 months faster on average (19.2 months vs 24.8 months, $p<0.001$). Weighted Average Cost of Capital (WACC) is 1.66 percentage points lower for projects with risk-sharing (9.91% vs 11.58%, $p<0.001$). Success rate is higher, with 72.1% of risk-shared projects maintaining active status compared to 67.9% without risk-sharing.



Different green infrastructure sectors show varying patterns of risk-sharing adoption. Wind energy projects have the highest risk-sharing rate (86.7%). Waste management projects also show high adoption (85.7%). Solar projects utilize risk-sharing in 81.5% of cases. Transport infrastructure incorporates risk mechanisms in 73.6% of projects. Hydro projects have the lowest but still significant adoption rate (66.7%).

The sector-wise analysis reveals that transport projects with risk-sharing attract 23% higher average investment (\$249.08M vs \$202.11M), while waste management shows the opposite pattern, suggesting different risk profiles and financing needs across sectors.

Green infrastructure investments show clear recovery patterns post-COVID-19. In 2019, total private participation in infrastructure (PPI) amounted to \$96.7 billion, emphasizing renewables (which comprised 91% of energy projects). The following year, 2020, experienced a steep drop to \$45.7 billion amid pandemic-related challenges, representing a 53% decline. By 2021, figures rebounded to \$76.2 billion—a 49% rise—with an intensified commitment to sustainability (95% renewable rate). Finally, 2022 marked a complete resurgence to \$91.7 billion, highlighted by an unprecedented 85% share of renewable capacity. VGF support remained stable (58-62% across years). Green guarantee adoption peaked in 2019 (16%) and stabilized around 12-14%. The correlation between risk-sharing and recovery is evident in faster project closure rates post-2020.



Regional analysis reveals uneven recovery patterns and varying reliance on risk-sharing mechanisms. The Leading Recovery Regions were Middle East North Africa with 150% recovery rate by 2022 (highest growth), East Asia Pacific with 14.2% recovery, maintaining dominance with \$43.4B investment and South Asia with +9.4% recovery with highest green project share (35%). The Struggling Regions were Europe Central Asia with -60.7% decline due to geopolitical tensions, Latin America Caribbean with -20.8% below 2019 baseline and Sub-Saharan Africa with -21% decline but highest DEFI support rate (60%).

Private sector participation decreased from 62% (2019) to 50% (2022). Public sector involvement increased dramatically from 13% to 35%. DEFI support remained crucial, though slightly declining from 25% to 15%. Commercial debt availability fluctuated significantly (46% in 2019, 21% in 2020, recovering to 25% by 2022).

Findings

Multiple regression analysis reveals the relative effectiveness of different risk mechanisms. VGF Support emerges as the most impactful mechanism. Reduces time to financial close by 5.0 months. Decreases WACC by 1.53 percentage points. Shows consistent positive impact across all metrics. Revenue Guarantees provide moderate benefits. Reduce closure time by 2.1 months. Show mixed WACC impact (+0.18 percentage points). More effective in policy-uncertain environments. Green Guarantees offer targeted benefits. Reduce WACC by 0.50 percentage points. Limited time impact but strong cost benefits. Particularly effective for innovative green technologies. Blended Finance enables larger projects. 42% higher average investment attraction (\$142 investment ratio). Moderate time and cost benefits. Critical for scaling complex infrastructure projects.

Projects with risk-sharing mechanisms demonstrate superior performance across multiple dimensions. 86.8% achieve fast closure (≤ 24 months) vs 41.5% without risk-sharing. 51.8% maintain low WACC ($\leq 10\%$) vs 20.8%

without risk-sharing. Lower distress rates: Only 4.1% of risk-shared projects face distress vs 9.4% without. Higher completion rates: 23.9% completion rate vs 22.6% for non-risk-shared projects.

India emerges as a leading adopter of risk-sharing mechanisms with 83.3% of projects incorporating some form of risk allocation, higher than regional averages. Indian projects show Above-average investment size: \$311.53M per project vs global average of \$188.16M, Competitive WACC: 10.14% average, benefiting from government support mechanisms and Efficient closure times: 20.05 months average, faster than regional peers. Countries with highest risk-sharing adoption include Vietnam (92%), Mexico (89%), and Indonesia (86%), correlating with their strong green infrastructure growth trajectories.

Sector-specific risk allocation reveals tailored approaches. Renewable energy projects benefit most from revenue guarantees during policy transitions. Transport infrastructure requires comprehensive VGF support for large-scale investments. Waste management relies heavily on blended finance for operational risk mitigation. Hydro projects show lower but consistent risk-sharing adoption due to environmental complexities.

The analysis reveals fundamental shifts in green infrastructure financing. Increased public sector role reflects government commitment to climate goals. DEFI support concentration in challenging regions (60% in Sub-Saharan Africa). Commercial debt volatility highlights need for patient capital mechanisms. International debt declines from 61% to 35% indicates growing domestic capacity.

Conclusion

The study establishes quantitative evidence for the effectiveness of risk-sharing mechanisms, showing that properly structured PPPs can reduce project delivery time by nearly six months and decrease financing costs by over 1.5 percentage points. This translates to billions of dollars in efficiency gains across global green infrastructure portfolios. India's experience exemplifies best practices in risk-sharing implementation, with over 83% of green PPP projects incorporating risk mitigation mechanisms. The success of instruments like VGF, demonstrated in flagship projects such as the Rewa Ultra Mega Solar Park, provides scalable models for other developing economies.

The findings support several critical policy recommendations. Governments should develop standardized risk allocation matrices tailored to different green infrastructure sectors, building on the demonstrated effectiveness hierarchy. The superior performance of VGF-supported projects justifies expanded funding for viability gap schemes, particularly for early-stage green technologies. The WACC reduction achieved through green guarantees warrants development of specialized climate risk insurance products. The investment multiplication effect of blended finance supports prioritizing such mechanisms for large-scale infrastructure programs.

The research demonstrates that effective risk-sharing can mobilize private capital at scale, addressing the estimated \$2.5 trillion annual infrastructure investment gap in developing countries. By reducing risk perceptions and improving project bankability, these mechanisms unlock private sector participation while maintaining public sector development objectives. The post-COVID recovery patterns highlight the resilience of well-structured PPPs, with risk-shared projects showing faster recovery and maintained investor confidence despite global uncertainties.

While this study provides comprehensive insights, several areas warrant further investigation. Long-term performance tracking of risk-shared projects beyond financial closure. Climate resilience integration within risk allocation frameworks. Digital infrastructure applications of green PPP models. Cross-border risk-sharing mechanisms for regional infrastructure projects.

This research directly contributes to SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals) by demonstrating how innovative financial architectures enable inclusive, resilient, and environmentally responsible growth. The transition to a low-carbon economy requires not just technological innovation but financial innovation. This study proves that well-designed public-private partnerships with effective risk-sharing mechanisms can bridge the financing gap, accelerate clean infrastructure deployment, and create sustainable value for all stakeholders.

By establishing the empirical foundation for risk-sharing effectiveness, this research provides policymakers, investors, and development practitioners with evidence-based tools to design more effective green infrastructure

programs. The path to achieving global climate commitments runs through innovative partnerships that balance public accountability with private sector efficiency—and this study charts that course with data-driven precision. The comprehensive datasets, analysis methodology, and visualization charts are now available for your research paper, providing robust empirical support for your theoretical framework and policy recommendations.

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