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Public–private partnerships as catalysts for green infrastructure: a three-pronged analysis of economic, environmental, and institutional factors

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As cities contend with the escalating challenges of climate change, rapid urbanization, and resource depletion, the need for sustainable infrastructure solutions has never been more urgent. Cities account for 75% of global CO₂ emissions, yet efforts to implement green solutions remain fragmented. Green public–private partnerships (PPPs) offer a sustainable solution, but the mechanisms for effectively leveraging these collaborations remain underexplored. Despite growing interest in PPPs, a critical knowledge gap persists: how is PPP leveraged in tackling crucial urban challenges for advancing green infrastructure? This study critically examines how PPPs drive progress in six key sectors: renewable energy, sustainable urban mobility, water management, waste management, green building and urban greening. Through qualitative case studies, the study analyses flagship projects from cities in both developed and developing countries. The study presents that green PPPs will thrive when backed by strong institutional frameworks, long-term financial commitments, and adaptive collaborative environments. The key to sustainable urban futures lies not just in government action but in strategic PPPs. This study makes a call to rethink urban partnerships—aligning private sector innovation with public mandates. It offers actionable insights for policymakers, urban planners, and investors, demonstrating that green PPPs are catalysts for urban sustainability and if scaled effectively, they could redefine the trajectory of sustainable development.

KEYWORDS

green infrastructure, PPP, renewable energy, sustainable urban mobility, water management, waste management, urban greening

1 Introduction

For centuries, cities have been built for expansion, efficiency, and economic gain. Now, the focus is to build for resilience. As environmental crises intensify, partnerships must evolve to serve a more vital purpose—preserving the ecosystems that sustain urban life (Jamal et al., 2025). Urban areas around the globe are grappling with the dual challenges of rapid urbanization and environmental degradation, demanding transformative, forward-thinking approaches to sustainable development. The depletion of natural resources and the accelerating impacts of climate change have become central to this crisis, fundamentally reshaping global development trajectories (Bungau et al., 2022). The climate crisis, perhaps

the most urgent of all, is inextricably linked to socioeconomic instability, with rising global temperatures threatening to undermine decades of progress in poverty alleviation and development (Anwana and Owojori, 2023).

As the concentration of greenhouse gases (GHGs) continues to increase, the risks are no longer abstract; they threaten the very foundation of ecosystems and the stability of societies (Udeagha and Ngepah, 2023). Figure 1 highlights the stark reality of global emissions, illustrating how the per capita CO₂ emissions from fossil fuels and industrial processes have surged across regions and countries from 1750 to present. Despite growing awareness, global emissions remain alarmingly high, further exacerbated by unchecked industrialization. The figure shows that developed nations like the United States and Australia have historically exhibited the highest emissions per person, peaking above 20 tons. Europe shows an earlier rise and a steady decline from the 1970s, while China's emissions have rapidly increased in recent decades, surpassing the global average. In contrast, Africa and India have consistently low per capita emissions, highlighting global inequalities in historical responsibility for emissions.

A report by the Intergovernmental Panel on Climate Change (IPCC) revealed a concerning increase of $0.87^{\circ}\text{C} \pm 0.18^{\circ}\text{C}$ in global temperatures compared to the period between 1850 and 1900 (Forster et al., 2023; Intergovernmental Panel on Climate Change, 2018). This alarming rise in temperatures, compounded by rapidly growing urban populations, has placed immense strain on existing systems, exacerbating the frequency and severity of extreme weather events. This trend underscores the urgent need for innovative solutions such as green infrastructure to mitigate the cascading impacts of climate change, from flooding to heat islands. However, the discourse on sustainable urban development has often been narrowly focused, overlooking the interconnected approaches required to truly create resilient and sustainable cities. While green infrastructure is widely recognized as a vital component in fostering urban resilience, discussions around its widespread implementation remain limited and insufficient (Staddon et al., 2018). This gap in dialogue not only impedes progress but risks perpetuating unsustainable development practices that fail to address the scale and urgency of our climate crisis.

From the post-industrial era to today's smart cities, PPPs have long addressed urban challenges. But with mounting environmental pressures, a pressing question arises: can these partnerships evolve to meet both infrastructure needs and ecological sustainability? As the Brundtland Commission stated, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment Development, 1987). This highlights the urgency of reimagining PPPs for resilient, future-ready urban systems.

1.1 Research gap

The need for a paradigm shift has never been more pressing if cities are to withstand and adapt to the challenges of the 21st century. Creating sustainable green cities demands a

comprehensive strategy that goes beyond individual components. Yet, there has been limited emphasis on fostering collaborative frameworks that engage diverse stakeholders in advancing these initiatives. PPPs are essential in this context, offering a structured approach to integrating green infrastructure into sustainable city development and ensuring alignment of resources and expertise for long-term success (Cui et al., 2018; Koppenjan, 2015; Vassileva, 2022). Even with the significant media coverage and public discourse surrounding climate change, sustainable urban development and green cities, the research and green infrastructure to counteract the fallout of the climate menace remain underdeveloped in the PPP infrastructural sector. Scholarly work on addressing green-centric PPP infrastructure projects remains relatively underexplored. There is a lack of a comprehensive, integrated analysis of these drivers and barriers within the specific context of green infrastructure. In light of these pressing challenges, the overarching research question is: how are PPPs leveraged to tackle critical urban challenges and advance green infrastructure? This study seeks to address the following sub-questions:

- What constitutes critical green PPP infrastructure for sustainable urban development?
- What are the primary drivers enabling the development and implementation of green PPP infrastructure, and what barriers hinder their success?

This study aims to provide a detailed exploration of the unique drivers that influence green centric PPPs and the challenges that hinder their widespread implementation for urban infrastructure. Importantly, it is anticipated that this study will contribute to developing sustainable and resilient solutions that promote the successful integration of green infrastructure within PPP projects. This will not only enhance environmental stewardship but also support long-term economic and social sustainability. The remaining section of the study provides an overview of the research method underlying this study in Section 3. Section 4 discusses the critical green infrastructure for sustainable development, and section 5 highlights strategies for mitigating barriers and enhancing green PPPs while section 6 provides the conclusion, limitations and future directions of the study respectively.

2 Green PPP contextualization and research trends

Public-private partnerships have become a central mechanism for delivering infrastructure projects worldwide, particularly in the context of rapid urbanization and mounting environmental pressures. While traditional PPPs prioritized efficiency, fiscal prudence, and risk transfer (World Bank, 2020), the current global sustainability discourse calls for deeper transformation, where PPPs evolve into instruments for ecological resilience and social equity. PPPs operate at multiple levels: as project delivery mechanisms, policy tools, governance strategies, and within distinct cultural contexts (Darko et al., 2023). Despite their widespread adoption there remains no universally agreed definition of PPP. This conceptual fluidity has led to PPPs being framed as a "family of

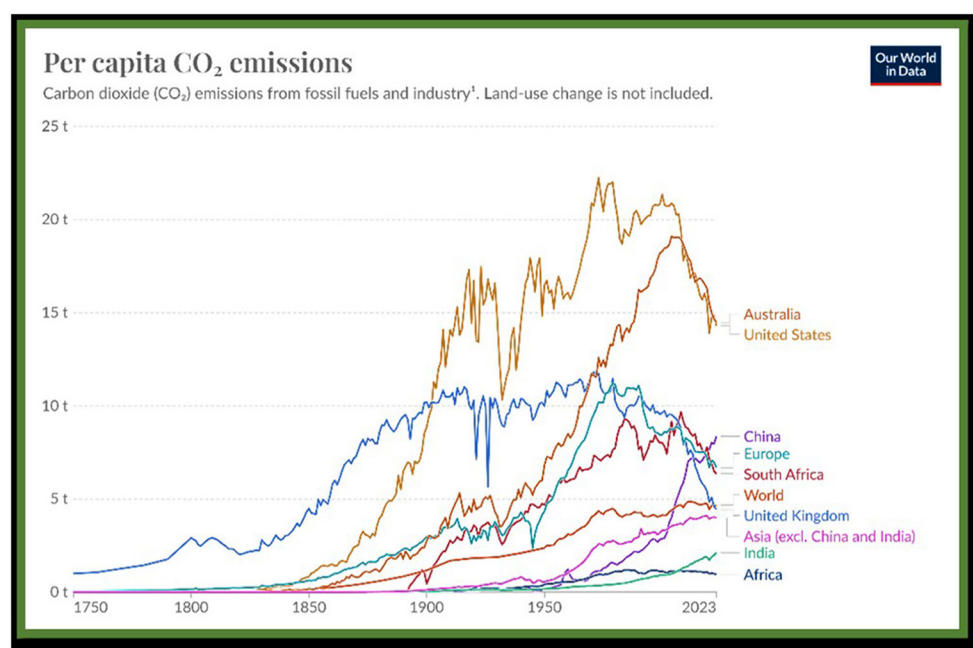


FIGURE 1

Per capita CO₂ emissions across countries from 1750 to 2023 (Source: Ritchie et al., 2023).

concepts,” each interpreted and implemented based on institutional maturity, political ideology, and developmental priorities (Cai et al., 2021).

Western applications of PPPs typically reflect neoliberal governance paradigms—marked by transparent procurement processes, standardized procedures, long-term contractual arrangements, and risk-sharing frameworks based on mutual benefit (Aydin and Altindag, 2024; Pianezzi et al., 2023; Darko et al., 2023). However, the growing urgency of climate change and the UN Sustainable Development Goals (SDGs) has shifted expectations. PPPs are now increasingly called upon not just to deliver infrastructure, but to advance environmental outcomes and promote socio-spatial equity. In the context of advancing sustainable development, Vassileva (2022) examines the transformative role of Green PPPs as innovative investment mechanisms. It explores their application in global and European contexts and highlights how these partnerships serve as effective tools for achieving SDGs. In the Global South, particularly African cities, scholars such as Mudau (2022) and Akomea-Frimpong et al. (2023) emphasize the need for PPPs to be explicitly aligned with developmental imperatives—including pro-poor urban integration and environmental justice. This necessitates the contextual adaptation of PPP models, moving away from imported frameworks toward those responsive to local institutional capacities and community needs.

Recent scholarship further illustrates this paradigmatic shift. Adegun et al. (2021) and Essuman-Quainoo and Jim (2023), for example, explore how green infrastructure—such as parks, urban forests, and rooftop vegetation—can be advanced through collaborative financing models. Their work underscores the role of green infrastructure in achieving sustainable urbanization in

rapidly growing African cities. Similarly, Owojori and Okoro (2023) advocate repositioning PPPs as “resilience partnerships,” highlighting their potential to strengthen systemic risk governance, especially in infrastructure systems vulnerable to climate shocks. Ning et al. (2023), focusing on Pakistan, examined the role of green innovation in PPP frameworks and call for strategic investments in renewable energy to achieve the SDGs. Their study illustrates the need to embed green innovation into environmental planning for sustainability. Adelakun et al. (2024) also conducted an insightful analysis of the role of PPPs in advancing renewable energy projects across Africa. Their findings also report increasing optimism among stakeholders about green PPPs while they highlighted that weak regulatory institutions and inadequate risk-sharing mechanisms present significant challenges to attracting private sector investment. The study argues for stronger multi-stakeholder platforms and capacity-building aligned with green infrastructure goals.

Barriers to green PPP implementation are also gaining scholarly attention. Uzuegbunam (2024), in a cross-country study of renewable energy PPPs, finds that cultural factors significantly affect investment scale—particularly in culturally tight societies where strict norms inhibit flexibility. Nobles and Moore (2024), focusing on Philadelphia, expose systemic obstacles to equitable urban greening and call for policy reforms that center environmental justice, especially where public–private interests intersect. Collectively, these studies reframe PPPs not merely as financing tools, but as co-governance mechanisms shaped by policy, culture, and sustainability mandates. They reveal an evolving understanding of PPPs as institutional arrangements that must be recalibrated to meet the complex demands of green and inclusive urban development.

While the majority of existing green PPP applications are concentrated in the renewable energy sector, there is growing recognition of their potential across a broader range of urban infrastructure (Vassileva, 2022). Building on this foundation, the present paper explores the distinctive drivers and barriers shaping green-centric PPPs across six key infrastructure domains: renewable energy, sustainable urban mobility, water and wastewater management, solid waste management, green buildings, and urban greening. This exploration is grounded in interdisciplinary perspectives that span economic, environmental, and institutional dimensions.

3 Methods

This study employs a multi-case synthesis approach to examine existing green PPP infrastructure solutions and identify the critical drivers and barriers to their development. A multi-case synthesis is well-suited for exploring phenomena where the boundaries between the phenomenon and its context are unclear (Yin, 2014). This approach allows for an in-depth empirical review of actual interventions, enabling the identification of linkages and patterns (Yin, 2014). The selection process follows a structured roadmap derived from Patton and Appelbaum (2003), which includes several key steps. First, the object of study is determined—green infrastructure projects delivered via PPPs. Next, initial concepts are developed through a comprehensive literature review, focusing on green PPP, its typology, drivers and barrier factors. A data extraction matrix is used to systematically catalog key variables, ensuring consistency. Relevant cases that align with the established criteria of green PPPs are then selected. Data collection includes secondary sources from authoritative databases such as the PPP Knowledge Lab, the Global Infrastructure Hub, academic journals, the UNEP, and the World Bank. Finally, the collected data are analyzed to uncover patterns, drivers, and barriers in these green infrastructure projects. Analysis follows an iterative pattern, technique, combining cross-case synthesis, and thematic coding to report patterns in driving mechanisms, and implementation challenges. Triangulation from multiple sources ensures the reliability and validity of the findings. Figure 2 presents a funnel diagram representing the structured methodological framework utilized for analyzing green PPP infrastructure projects. Starting with broad scoping, the framework narrows through case selection, thematic categorization (e.g., renewable energy, urban mobility), and pattern recognition to identify key drivers and barriers. The final stage produces strategic recommendations at economic, environmental, and institutional levels. The approach ensures robust, context-sensitive insights to support the development and scaling of green PPPs.

4 Conceptualization of PPPs

PPPs are a pivotal mechanism in infrastructure development and the provision of public services globally. Their evolution reflects the dynamic interplay between globalization, economic pressures, and the growing emphasis on sustainable development (Cui et al., 2018; World Bank, 2024). Originating in early infrastructure collaborations during the 19th and early 20th

centuries, PPPs have grown from their historical roots in transport, utilities, and industrial projects to encompass a wide range of sectors, including healthcare, education, and environmental management. Historically, PPPs served as a pragmatic solution to address resource limitations in the public sector, leveraging private sector investment and expertise to deliver essential infrastructure (Owojori and Okoro, 2023). The scope of these partnerships has expanded significantly over time to respond to increasingly complex global challenges, including climate change, urbanization, and resource scarcity. The evolution of PPPs can be divided into three distinct phases, as presented below:

4.1 Emergence and early adoption (1980s–1990s)

The modern concept of PPPs gained prominence during the 1980s and 1990s, particularly in developed countries like the United Kingdom. Governments faced fiscal constraints and sought to improve public service delivery by leveraging private sector efficiency and investment (Lorman, 2018). A notable example from this era is the UK's Private Finance Initiative (PFI), introduced in 1992, which aimed to engage private sector resources in financing, designing, constructing, and managing public infrastructure projects. PFI was utilized for various projects, including the construction of schools, hospitals, and transportation infrastructure (Bovis, 2006).

4.2 Expansion and diversification (2000s)

The 2000s witnessed a significant expansion in the scope and application of PPPs, driven by globalization, urbanization, and the increasing complexity of development challenges. During this period, the adoption of PPPs extended beyond traditional infrastructure sectors to encompass healthcare, education, social housing, and environmental services (Global Alliance, 2024). This diversification was fueled by growing recognition of the need for integrated solutions to address multifaceted challenges such as urban growth, technological advancements, and sustainability. Emerging economies also began to adopt PPP frameworks as a means to bridge infrastructure gaps and stimulate economic development. Governments in regions such as Asia, Latin America, and Africa increasingly turned to PPPs to attract private capital and expertise, particularly in sectors like energy, transportation, and water management (Global Alliance, 2024; World Bank, 2024). The rise of multilateral development banks and international organizations promoting PPPs further accelerated their global proliferation.

4.3 Integration with sustainable development (2010s–present)

In recent years, PPPs have increasingly been aligned with SDGs. The focus has shifted toward creating projects that not only provide economic benefits but also address social and environmental challenges (World Bank, 2024; Vassileva, 2022). The 2010s marked

Green-centric PPP infrastructure categorisation



Key Barriers and Drivers

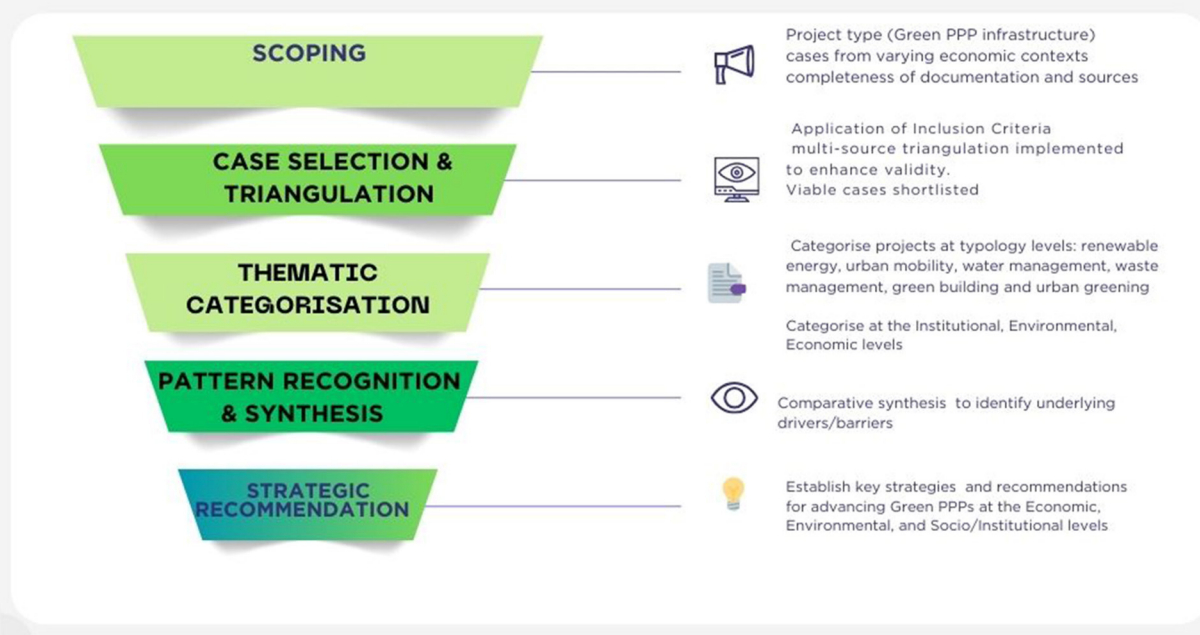


FIGURE 2
Flowchart with key phases. Source: Author's compilation.

a shift toward integrating sustainability into PPP projects, aligning with global efforts to address environmental challenges and promote sustainable development. PPPs began to focus on projects that incorporated renewable energy, green infrastructure, and environmentally friendly technologies. For example, in various cities, PPPs have been instrumental in developing sustainable public transportation systems, such as light rail and bus rapid transit, aimed at reducing carbon emissions and improving urban mobility (Global Alliance, 2024). These projects not only address infrastructure needs but also contribute to broader environmental and social goals.

4.4 Green infrastructure in the context of sustainable development

The landmark report *Our Common Future* (Brundtland et al., 1987) emphasized the interconnected nature of social, economic, and ecological challenges. Humanity's wellbeing and survival hinge on the environment, necessitating a new approach to

economic growth that meets human needs while respecting environmental constraints. The Sustainable Development Goals (SDGs) adopted in 2015, aim to address global challenges and create a sustainable future by 2030. Green infrastructure, which integrates nature-based solutions and environmentally friendly systems, plays a crucial role in advancing multiple SDGs (Hanna and Comín, 2021; Vassileva, 2022), especially Goals 6, 11, 13, and 15. Goal 6 focuses on clean water and sanitation, where green infrastructure like constructed wetlands and rain gardens enhance water quality, manage stormwater runoff, and reduce pollution, supporting sustainable water management. Goal 11 aims for sustainable, resilient cities, with green infrastructure such as urban parks and permeable pavements mitigating heat, reducing air pollution, and increasing biodiversity, while fostering social equity. Goal 13 calls for climate action, with green corridors and living shorelines acting as buffers against climate change impacts, helping cities adapt to extreme weather and rising sea levels. Goal 15 promotes ecosystem protection, with green infrastructure projects like reforestation and habitat restoration supporting biodiversity and combating deforestation and desertification (United Nations, 2015).

4.4.1 Green infrastructure: concept and elements

Green infrastructure is a term that takes on diverse meanings depending on the perspective of the researcher or practitioner. For example, conservationists tend to focus on the ecological benefits and biodiversity that these systems promote (Filazzola et al., 2019), while urban developers often approach green infrastructure through the lens of urban planning and policy implementation (Van Oijstaeijen et al., 2020). Similarly, experts in green spaces or recreational areas stress the social and health benefits of providing residents with access to nature (Sokolova et al., 2024). This broad range of interpretations reflects the inherent complexity and multifaceted nature of green infrastructure, making it difficult to pin down with a singular definition (Adesoji and Pearce, 2024).

From the standpoint of urban sustainability, this study defines green infrastructure as an interconnected network of nature-based solutions and adaptive designs that seek to integrate natural ecological processes with the functionality of urban systems. This network fosters resilience, equity, and environmental stewardship, addressing both the immediate and long-term challenges posed by urbanization and the global climate crisis. It emphasizes that the benefits of green infrastructure extend beyond environmental preservation, as it also enhances the quality of life by promoting social inclusion, equity, and access to essential resources in rapidly urbanizing regions. This approach aligns with the United Nations' SDGs, which stress the need for inclusive urban development and sustainable cities that ensure equitable access for all urban residents (United Nations, 2015).

Access to green infrastructure plays a pivotal role in improving urban residents' physical, mental, and social health. Proximity to green spaces has long been associated with numerous health benefits, including reduced stress, enhanced social cohesion, and healthier lifestyles (Jennings and Bamkole, 2019; Wilson et al., 2024). In fact, living near green spaces can lower risks related to urban health challenges such as obesity, depression, and cardiovascular diseases. On the other hand, a lack of access to green areas often correlates with poorer health outcomes and higher mortality rates. A striking study by Marques Dda Costa and Kállay (2020) found that individuals who lived more than 1 km away from green spaces reported elevated stress levels compared to those residing within 300 meters, highlighting the crucial role proximity to these spaces plays in human wellbeing. This role in human wellbeing underscores the importance of integrating green infrastructure into urban planning, not just for environmental reasons but for the collective health and resilience of urban populations. Table 1 below presents a synthesis of green infrastructure typologies and their associated criteria derived from a review of existing literature.

International policy frameworks have recognized the value of green infrastructure and set benchmarks to encourage its integration into urban environments. For example, the European Environment Agency advocates for green spaces to be within a 15-min walking distance for urban residents, while the UK government suggests a more specific target of no more than 300 meters from one's home (Dias, 2023). At the global level, the World Health Organization (WHO) has proposed a standard of at least 9 m² of green space per urban resident to promote healthier and more livable cities (World Health Organization, 2017). Some cities in the Global North have exceeded these recommendations, such as Vienna, which offers 120m² of green space per capita, followed

by Copenhagen at 42.4 m², and London at 27 m² (Husqvärna, 2021). These benchmarks demonstrate the commitment of certain nations to advancing urban sustainability, yet they also highlight the disparities between regions, particularly in the Global South.

Urban green space accessibility remains a challenge in many parts of the Global South. In South Africa, a significant portion of urban areas is deprived of green infrastructure, with many cities dedicating less than 10% of their total land area to green spaces (Girma et al., 2019). In Accra, Ghana, the situation is particularly alarming, as the city's green space cover dropped dramatically from 41% in 1991 to just 15% in 2018 (Duku et al., 2023). In Lagos, Nigeria, the situation is even worse, with green spaces accounting for less than 3% of the city's urban area. This stark contrast between the Global North and South highlights the urgent need for sustainable urban planning that prioritizes green infrastructure as a key element in addressing both environmental degradation and social inequalities in the face of rapid urbanization. Table 1 categorizes the types of green infrastructure—from urban greening (parks, green roofs) and sustainable drainage systems to renewable energy installations, urban agriculture, low-carbon transport networks, green buildings, carbon sequestration projects, water management systems, circular-economy/waste management, and wildlife corridors—and pairs each with its defining performance criteria.

4.5 Partnerships for green infrastructure development

Partnerships between the public and private sectors have emerged in advancing sustainable infrastructure, a necessity underscored at landmark global summits like the 1992 Rio Earth Summit and reiterated in subsequent frameworks, including the United Nations' SDGs (Marx, 2019). The fragmented and multifaceted nature of infrastructure projects demands collaboration across sectors, particularly to address environmental challenges while simultaneously fostering socio-economic growth (World Bank, 2024). These partnerships, often involving community alongside public and private stakeholders, exemplify the type of multi-stakeholder collaboration emphasized during Rio+20 as essential for achieving "The Future We Want" (UNEP, 2012).

PPPs play a strategic role in integrating sustainability into urban planning, with each sector contributing distinct strengths. Governments provide essential resources, such as land allocation, research funding, and regulatory frameworks, ensuring alignment with long-term societal objectives. Conversely, the private sector brings innovative solutions, investment, and operational efficiency, making it a critical ally in implementing resilient, scalable projects. This synergy not only aligns with the SDGs but also catalyzes economic and environmental benefits, as PPPs enable green infrastructure to enhance community resilience and competitiveness (Sokolova et al., 2024).

The potential of such partnerships extends beyond infrastructure delivery; they act as mechanisms for fostering local economic growth while promoting environmental stewardship. The integration of private sector expertise, particularly in deploying innovative green technologies and securing capital, complements

TABLE 1 Green infrastructure typology concepts/criteria.

Elements or typology of green infrastructure	Criteria for green infrastructure	Authors
Urban greening (parks, urban forests, green roofs)	Enhancing biodiversity, carbon sequestration, air quality improvement, urban cooling	Adegun et al. (2021); Essuman-Quainoo and Jim (2023); Kowarik et al. (2019); Laforzezza et al. (2017)
Sustainable urban drainage systems	Managing stormwater, reducing urban flooding, improving water quality	Green et al. (2021); Hettiarachchi et al. (2022); La Rosa and Pappalardo (2021)
Renewable energy infrastructure	Reducing carbon emissions, integrating clean energy into urban systems	Al-Thani et al. (2022); Harahap et al. (2024); Jena and Meattle (2020)
Urban agriculture (community gardens, vertical farming)	Enhancing local food security, promoting green jobs, and urban ecosystem services	Kowarik et al. (2019); Khan et al. (2024); Lin et al. (2017)
Green transport and urban mobility systems	Promoting low-carbon transport, reducing urban traffic congestion	Al-Thani et al. (2022); Trapani et al. (2021); Zawawi et al. (2020)
Green buildings	Energy efficiency, use of sustainable materials, enhancing occupant health	Bungau et al. (2022); Nain et al. (2021); Owoha et al. (2022)
Carbon Sequestration Projects	Increasing green cover, reducing atmospheric CO ₂ , supporting ecosystem services	Adegun et al. (2021); Lin et al. (2017); Udeagha and Ngepah (2023)
Water management systems	Efficient water use, reducing water wastage, addressing water scarcity	Green et al. (2021); Cousins and Hill (2021); Hettiarachchi et al. (2022)
Circular economy/waste management	Minimizing waste, recycling, reusing resources	Bansal et al. (2025); Owojori and Okoro (2023); Pearlmutter et al. (2019)
Wildlife corridors and habitat conservation	Preserving biodiversity, ensuring ecological connectivity	Laforzezza et al. (2017); Wang et al. (2024)

Source: Based on author's compilation.

the public sector's capacity to ensure accountability and equitable resource distribution (United Nations, 2015). Together, they produce transformative solutions that address urban challenges, from climate adaptation to biodiversity enhancement, reaffirming the centrality of cross-sectoral collaboration in global sustainable development efforts (Adegun et al., 2021; Wang et al., 2024). As partnerships continue to drive innovation and sustainability, they underscore the critical need for unified, action-oriented approaches to building resilient, inclusive urban environments

4.6 Critical green PPP infrastructure for sustainable urban development

Green-centric PPPs are focused on integrating environmental considerations into infrastructure development. These initiatives aim to leverage the strengths of both sectors—public regulation and policy alongside private sector expertise and capital—to promote eco-friendly urban development and sustainable resource management. The findings below identify key categories of green infrastructure where PPPs are leveraged effectively, supported by case studies and implications for broader implementation.

4.6.1 Renewable energy systems

Over recent years, the shift toward renewable energy has become a central focus of urban sustainability efforts. This transition not only aims to reduce carbon emissions but also to enable cities to become more resilient to the impacts of climate change. PPPs in renewable energy often involve the development

of solar, wind, and hydroelectric power plants. These projects aim to increase the share of renewable energy in the energy mix, reduce greenhouse gas emissions, and promote sustainable energy sources. Trafigura's 2,000 MW Green Energy Initiative, launched in July 2024, is a green PPP involving Trafigura, ProMarks, and the Angolan government. The project develops a high-voltage interconnector to transport renewable energy from Angola's hydropower to Zambia, the DRC, and the Southern Africa Power Pool (Trafigura Group, 2025). Similarly, a 580 MW concentrated solar power plant, Noor Ouarzazate is a PPP between the Moroccan government (via MASEN) and private firms like ACWA Power. The government provided land, guarantees, and regulation, while private partners managed design, construction, and operation. Funded through public investment and loans from the World Bank and others, it powers 1 Million+ homes and supports Morocco's goal of sourcing 52% of electricity from renewables by 2030 (Global Infrastructure Hub, 2018). Another is the São Gonçalo Solar Power Project in Brazil, which involves the Brazilian government providing financial support through low-interest loans, while the private sector, led by Enel Green Power (2023), manages the development, operation, and maintenance of the solar farm. In India, the Rewa Ultra Mega Solar Park showcases the potential of green PPPs. The 750 MW solar park, a collaboration between the Madhya Pradesh government and private developers like Mahindra Renewables, supplies clean energy to the Delhi Metro and other consumers, setting a benchmark for future projects (Vyas et al., 2022). As a cornerstone of green infrastructure, renewable energy PPPs embody the transformative potential of collaborative models to advance sustainable urbanization.

4.6.2 Urban mobility systems

One of the most impactful applications of green PPPs is in green transportation in areas of development of electric public transit systems enabling cities to decarbonise transportation infrastructure while improving efficiency and accessibility. One notable example is Santiago Metro in Chile, which has integrated electric buses through partnerships with private operators. In Santiago's model, the private sector finances and manages the electric bus fleet, while the government provides regulatory oversight and subsidies (Orbea, 2018). This collaboration has significantly reduced fossil fuel reliance, improved air quality, and positioned Santiago as a leader in sustainable urban mobility in Latin America. Similarly, the Delhi Metro Rail Corporation (DMRC) in India has leveraged PPPs to expand metro services and integrate solar energy into operations. Through strategic private-sector investment, the DMRC has enhanced energy efficiency while reducing its carbon footprint, serving as a model for other cities seeking sustainable transit solutions (Gulati, 2011; Teng, 2023).

In the United States, Los Angeles has adopted a PPP model to develop e-scooter sharing programs, integrating last-mile mobility solutions into public transit networks. Companies like Lime and Bird operate the e-scooter fleets, while the city provides infrastructure and policy support. This initiative has reduced traffic congestion and private car dependency, demonstrating the role of PPPs in fostering multimodal, low-carbon urban transport (Latinopoulos et al., 2021). Beyond transit vehicles, PPPs are also shaping urban infrastructure, in Copenhagen, Denmark, the City and Port Development Corporation has collaborated with private investors to create extensive cycling infrastructure, pedestrian-friendly streets, and car-free zones. This initiative has made Copenhagen one of the world's most bike-friendly cities, with over 60% of residents commuting by bicycle (UNEP, 2021). These partnerships not only enhance transport efficiency but also contribute to broader urban resilience and environmental sustainability.

4.6.3 Water management and green stormwater systems

Water management and green stormwater systems are crucial for achieving urban sustainability, and addressing water scarcity, flooding, and pollution while enhancing climate resilience. The increasing frequency of extreme weather events, such as floods, has heightened the need for innovative solutions (Anwana and Owojori, 2023). For example, the "Green City, Clean Waters" program in Philadelphia emerged as a response to the U.S. Clean Water Act, which mandated the reduction of combined sewer overflows. This PPP-driven initiative integrates green stormwater systems, such as bioswales, permeable pavements, and rain gardens, improving water quality while mitigating flooding risks (Philadelphia Water Department, 2023). Similarly, in Melbourne, Australia, the city has collaborated with private developers to integrate green roofs and walls into new buildings. These features not only manage stormwater but also enhance urban biodiversity and reduce the urban heat island effect (Bush et al., 2021). Mexico City provides another example, where recurring water crises and flood risks led to the Nature-Based Solutions for Water Security

program. This PPP initiative employs rainwater harvesting, green roofs, and reforestation to address water retention challenges and reduce groundwater extraction, which has led to land subsidence (Chen et al., 2024). In Singapore, the NEWater project exemplifies a successful PPP in water recycling, addressing national water scarcity while ensuring climate resilience (Gheraout et al., 2019). This project, combining public and private investments, treats wastewater for industrial and potable uses, advancing both SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action).

4.6.4 Waste management and circular economy

The circular economy systems have emerged as vital green infrastructure, addressing the global waste crisis and its environmental impact. PPPs are increasingly deployed to drive innovative waste reduction, recycling, and resource recovery systems, aligning with the principles of sustainability and urban resilience. The urgency for green waste management systems stems from mandates such as the European Union's Circular Economy Action Plan, which emphasizes reducing landfill dependency, improving recycling rates, and fostering resource efficiency (Owojori and Okoro, 2023). Many countries have adopted similar frameworks, creating opportunities for PPPs to advance these goals.

For instance, in Amsterdam, Netherlands, the city has partnered with private companies to implement circular economy strategies, such as repairing and refurbishing products, sharing resources, and designing for recyclability. These initiatives are supported by public policies that incentivise sustainable practices (Baumert and Commins, 2023). The Indore Municipal Corporation in India is another example of collaboration with private firms under a PPP to implement the Indore Clean India Mission, which transformed the city's waste management system. Through source segregation, organic waste composting, and biogas production, this initiative reduced landfill dependency and positioned Indore as India's cleanest city for five consecutive years (Saifi and Jha, 2023).

4.6.5 Green buildings and urban development

Green buildings have become a cornerstone of sustainable urban development, offering solutions to mitigate the environmental impact of the construction sector, which contributes approximately 40% of global carbon emissions (UNEP, 2022). PPPs have played a pivotal role in scaling green building projects by integrating private-sector innovation, financing, and technology with public mandates and policies aimed at reducing energy consumption, enhancing resource efficiency, and promoting urban sustainability. Globally, mandates such as the Paris Agreement (2015) and the UN SDG 11 emphasize sustainable urbanization, including energy-efficient buildings. National green building standards, such as the Leadership in Energy and Environmental Design (LEED) in the United States, Green Star in Australia, and EDGE (Excellence in Design for Greater Efficiencies) in developing countries, further bolster the need for PPP-driven green building initiatives. Globally, governments have collaborated with private developers to integrate green building solutions into urban planning, ensuring a balance between economic development and environmental stewardship. One prominent

example is the Re:New Paris Project in France, where the City of Paris partnered with private firms to retrofit existing buildings for energy efficiency. This initiative leveraged private investment to enhance insulation, install renewable energy systems, and reduce carbon emissions, aligning with France's ambitious climate goals (C40 Cities Climate Leadership Group, 2020). In the United States, the Empire State Building Retrofit Project, executed under a PPP model, involved partnerships between the New York City government, Johnson Controls, and the Clinton Climate Initiative to implement energy-efficient upgrades. This initiative resulted in a 38% reduction in energy use, setting a precedent for sustainable high-rise retrofits (De la Garza, 2021). Whether through retrofitting existing structures or constructing new buildings with sustainable designs, PPPs facilitate the scalability and financial viability of these projects.

4.6.6 Urban greening and carbon sequestration

Urban greening involves adding more plants and green spaces to cities, such as through tree planting and creating parks. This can greatly aid in carbon sequestration, which is the process of capturing and storing carbon dioxide from the air in plants and soil. In the United States, the Million Trees NYC initiative is an exemplary PPP effort to green urban spaces in New York City. The project, a collaboration between the City of New York, non-profits, and private companies, has planted over a million trees, improving air quality and increasing the city's carbon absorption capacity. This initiative aligns with New York City's PlaNYC sustainability plan (NYC Parks Department, 2024). The project has become a model for urban greening initiatives worldwide and continues to contribute to the ecological health of New York City. In China, the Million Trees Project in Shanghai illustrates the role of PPPs in large-scale urban greening for carbon sequestration. Spearheaded by the government in partnership with non-profits and private organizations, the project has restored degraded lands, planted millions of trees, and enhanced the city's resilience to climate change by reducing carbon emissions and improving biodiversity (Zhao et al., 2024). Similarly, in Mexico, the Bosque de Chapultepec Restoration Project leverages PPPs to preserve and enhance one of the largest urban parks in Latin America. The project incorporates tree planting, green infrastructure, and carbon management strategies to combat air pollution and urban heat stress (Barba, 2023). These examples highlight the ability of PPPs to align urban greening efforts with social and environmental goals, enhancing liveability and community wellbeing.

5 Drivers and barriers to green-centric ppps for sustainable infrastructure

To examine the major drivers and barriers to developing and implementing green PPPs for sustainable infrastructure, this study adopts a hybrid analytical framework that integrates the Triple Bottom Line (TBL) and the Institutional Analysis and Development (IAD) Framework. Grounded in the works of Elkington (1994), Ostrom (2005), and subsequent scholars who have advanced these models in sustainability and governance research. Recent studies (e.g., Akomea-Frimpong et al., 2022;

Casady, 2021) demonstrate the value of integrating sustainability and institutional perspectives in analyzing PPPs. The TBL framework, emphasizes the interconnected dimensions of economic viability, environmental integrity, and social equity. The IAD framework examines the institutional arrangements and governance structures that influence collaborative actions. The exploration of the economic, environmental, social, and institutional factors as presented below.

5.1 Economic drivers and barriers

5.1.1 Key economic drivers

The economic drivers of green PPP-centric infrastructure are deeply interconnected. At the core is cost efficiency, achieved through risk-sharing between governments and private entities. By leveraging private sector expertise in project management and innovation, green PPPs reduce overall costs and ensure timely delivery. As Love et al. (2021) argue, this risk-sharing mechanism is particularly critical in large-scale PPP projects, where upfront costs and uncertainties are high. For instance, Morocco's Noor Ouarzazate Solar Complex exemplifies this, as private financing and technology made the project financially feasible while distributing risks between the government and private partners (Global Infrastructure Hub, 2018). The lifecycle cost savings of green infrastructure often outweigh the initial investment, making it a financially prudent choice for governments. This efficiency is further bolstered by access to private capital, which addresses government budget constraints and unlocks funding for ambitious green projects. According to Pambudi et al. (2023), private investors are drawn to green infrastructure due to its alignment with environmental, social, and governance (ESG) goals and its potential for stable, long-term returns. Economic incentives such as tax breaks, grants, and subsidies reduce upfront costs, while long-term returns like increased property values, job creation, and tourism bolster financial viability (Le et al., 2024; Braga and Ernst, 2023). It is important to recognize that while ESG-driven investments are growing, the financial returns of green infrastructure are often realized over extended periods, which may not align with the investment horizons of some private sector actors. Furthermore, reliance on government incentives, such as subsidies and grants, can create risks if policy frameworks shift or if governments face budgetary constraints. Thus, while the economic case for green infrastructure is compelling, the risk of long payback periods and policy uncertainty must be carefully managed.

The availability of diverse financial mechanisms and incentives is a driving force where instruments like green bonds, environmental impact bonds, incentivise private sector participation and ensure the financial viability of long-term green projects (Zhao et al., 2022) enabling governments to leverage private sector capital for large-scale, high-impact green infrastructure projects.

5.1.2 Key economic barriers

Economic barriers significantly hinder the implementation of PPPs in urban green infrastructure, particularly in developing

countries. High initial capital costs, exceeding the fiscal capacity of many local governments and private sector stakeholders, remain a critical challenge (Masuda et al., 2022). Although green infrastructure offers long-term benefits, the immediate financial burden deters investment, especially without innovative financing mechanisms. As noted by Le et al. (2024), the initial investment required can deter private investors, particularly in regions with limited financial resources.

Uncertain revenue streams further complicate these projects, as the economic value of green infrastructure is often intangible and difficult to quantify (Pasquini and Enqvist, 2020). However, this also reflects a broader limitation in how value is defined and measured in infrastructure planning. Conventional financial models often overlook environmental and social co-benefits, which, if integrated through innovative valuation methods or blended financing mechanisms, could help de-risk green investments. Thus, while revenue uncertainty is a critical barrier, it also signals the need for evolving financial tools that better capture the multifaceted value of sustainable infrastructure.

Additionally, limited access to affordable financing stalls progress. With municipal budgets stretched and competing priorities, green initiatives are frequently deprioritized. Small and medium-sized private sector partners often struggle to secure low-interest loans or other funding, restricting their ability to scale green projects (Owojori and Okoro, 2023). Green projects often struggle to secure funding at competitive interest rates, especially in developing countries where financial markets are less mature. According to Lavitt and Sargeant (2024), private investors may perceive green infrastructure as high-risk due to uncertainties in revenue streams and regulatory environments. This perception can lead to higher borrowing costs, making projects less economically viable (Lavitt and Sargeant, 2024). However, this barrier is not solely a function of market immaturity. It also reflects the current lack of tailored financial instruments and risk mitigation mechanisms that align with the unique nature of green projects. Finally, market limitations can hinder the scalability of green PPPs. In some regions, the absence of a robust market for green products or services, such as recycled materials or renewable energy, can limit revenue potential. According to Pasquini and Enqvist (2020), this is particularly challenging in developing economies, where demand for sustainable infrastructure may be low due to economic or cultural factors. Without targeted policy interventions such as credit enhancement tools, green bonds, or concessional financing, even viable projects may fail to reach financial closure. Therefore, the barrier lies not just in the inherent risk of green infrastructure, but in the gap between conventional financing norms and the emerging needs of sustainable development.

5.2 Environmental drivers and barriers

5.2.1 Key environmental drivers

Environmental drivers play a pivotal role in shaping the development and success of PPP projects. Stringent environmental regulations, particularly those addressing carbon emissions and renewable energy targets, are among the most influential factors. Policies such as the European Union's Green Deal and its ambitious climate action plans have created a regulatory environment that

pushes both public authorities and private firms to collaborate on green infrastructure solutions. These regulations are a driving force for green PPP projects where compliance with emission reduction targets incentivises innovation and investment in green initiatives (Maharjan, 2024; Sokolova et al., 2024). Simultaneously, growing market demand for sustainability is pushing green infrastructure to the forefront. Consumers, businesses, and investors are prioritizing environmentally friendly practices, creating opportunities for projects like electric vehicle charging networks. According to Ahmed et al. (2025), this demand is driven by increasing awareness of climate change and the economic opportunities associated with the green transition. Another critical driver is the need for resource conservation and the transition to a circular economy. As natural resources become increasingly scarce, green PPPs are developing innovative solutions to recycle, reuse, and recover materials. Owojori and Okoro (2023) argue that PPPs are essential for creating closed-loop systems that minimize waste and maximize resource efficiency. Moreover, global commitments to sustainability goals, including the United Nations' SDGs, have been crucial in shaping the environmental landscape for PPPs. The drive for climate resilience and resource efficiency, framed within global agreements like the Paris Agreement, has fostered cross-sectoral collaboration in urban infrastructure projects (Hussein et al., 2024). These international commitments create shared priorities, uniting private and public stakeholders in the common goal of reducing environmental impacts and improving urban resilience. Policies as outlined earlier have created a regulatory environment that drives collaboration on green infrastructure initiatives, however, the impact of such environmental drivers can vary across regions, with some areas lacking the regulatory frameworks or financial resources to fully leverage these policies. Over-reliance on external regulations may also limit innovation, particularly in regions with weaker enforcement or where market conditions are under-developed. Despite challenges, the increasing market demand for sustainability offers opportunities for innovation and collaboration, even in resource-constrained regions.

5.2.2 Key environmental barriers

One significant challenge lies in navigating regulatory and compliance requirements, which can be complex and vary widely across local, national, and international contexts. Urban PPP projects often face stringent environmental standards aimed at preserving ecological balance and reducing environmental harm, yet the diverse and evolving regulatory frameworks make it difficult for stakeholders to ensure full compliance. Adherence to these regulations requires substantial resources, and any misalignment with legal requirements could lead to delays or project cancellations (Vale de Paula et al., 2022). As Maharjan (2024) argue, the complexity of obtaining environmental clearances and complying with stringent regulations can deter private investors, particularly in regions with inconsistent or opaque regulatory frameworks. However, while regulatory complexity is a clear barrier, which signal an opportunity for harmonization and standardization across relatively close jurisdictions, potentially streamlining processes in the future.

Public perception also represents a critical barrier, particularly in projects that transform local landscapes. The benefits of green

infrastructure are often not immediately visible to the public, which can lead to skepticism. Public opposition can arise from concerns about aesthetic changes, potential disruptions during construction, and the perceived high costs of implementing green solutions. Engaging communities in the early stages of project development and fostering transparent communication about long-term benefits are essential to securing public support and reducing resistance (Pasquini and Enqvist, 2020; Zhao et al., 2022).

5.3 Social and institutional drivers and barriers

5.3.1 Key social and institutional barriers

The successful implementation of green infrastructure through PPPs often faces significant institutional barriers that hinder its potential to promote sustainable urban development. One of the key institutional challenges is the inadequacy of policy and regulatory frameworks. While strong policies and regulations are critical in promoting sustainability, many developing countries and even some developed nations still lack comprehensive frameworks that explicitly support green infrastructure initiatives. Inadequate or ambiguous policy directions lead to uncertainties for both private investors and public authorities, making it difficult to align efforts and resources toward sustainability goals (Braga and Ernst, 2023; Corfee-Morlot et al., 2012). This regulatory gap may also be partly due to a lack of political will or competing priorities, which can slow down the adoption of green initiatives. Moreover, in some cases, existing frameworks may not be tailored to the specific needs of green infrastructure, limiting their effectiveness in driving long-term sustainability. However, it can be argued that the inadequacy of these frameworks may reflect the early stages of policy evolution, offering an opportunity for development. The challenge lies not only in the creation of policies but in ensuring they are adaptable to rapidly changing environmental and economic contexts. Another critical barrier is institutional inefficiencies and lack of capacity. Effective implementation of green PPPs requires strong institutional frameworks, skilled personnel, and efficient governance structures. However, many governments, particularly in developing countries, lack the capacity to design, manage, and monitor complex PPP projects. Weak institutional capacity can lead to delays, cost overruns, and poor project outcomes (Akomea-Frimpong et al., 2022; Owojori and Okoro, 2023). This limitation highlights the importance of long-term capacity-building strategies, rather than short-term fixes, in strengthening institutional frameworks. Therefore, training government staff, fostering innovation, and cultivating a culture of sustainability within both public agencies and private entities is essential as institutional capacity ensures that projects are well-maintained and integrated into urban development planning.

Furthermore, the absence of clear roles, responsibilities, and accountability mechanisms between public and private partners is essential for ensuring efficient decision-making, effective risk management, and the achievement of sustainability targets. However, in practice, PPP projects often suffer from fragmented governance structures that lack coordination and transparency (Cui et al., 2018; Dewulf and Garvin, 2020). This challenge is

exacerbated when multiple stakeholders with differing interests must collaborate to achieve green infrastructure goals which can create tensions that delay or derail projects. Another significant institutional barrier is the limited capacity for cross-sectoral partnerships. While collaboration among public agencies, private firms, and Non-government Organisations (NGOs) can align goals and resources effectively, institutional fragmentation and sectoral silos often inhibit the formation of robust partnerships. Successful green infrastructure projects show the potential of multi-stakeholder partnerships in driving environmental sustainability. However, these partnerships require not only shared objectives but also the establishment of trust, long-term commitments, and mechanisms for resolving conflicts (Cui et al., 2018). In the absence of such integrative approaches, green PPPs may struggle to achieve their intended impact.

Political and economic instability, as well as short-term political cycles, further exacerbate the challenges of institutional coordination in green infrastructure projects. In some cases, political leaders may lack the long-term vision needed for sustainable urban development, opting for short-term infrastructure projects that do not prioritize environmental considerations (Qamruzzaman and Karim, 2024). As such, the success of green PPPs is not only contingent on the alignment of policy, governance, and partnerships but also on the political will to support long-term, sustainable urban planning initiatives. Finally, governance and corruption issues can create significant barriers to green PPPs. Corruption and lack of transparency in procurement processes can deter private investors and undermine project credibility (Dewulf and Garvin, 2020). Good governance and anti-corruption measures are essential for the success of green PPPs.

5.3.2 Key social and institutional drivers

One of the primary social drivers is growing public awareness and demand for sustainability. As communities become more conscious of environmental issues such as climate change, pollution, and resource depletion, there is increasing pressure on governments and businesses to adopt sustainable practices (Ahmed et al., 2025). This shift in public sentiment has created a favorable environment for green PPPs, as they are seen as a viable solution to address these challenges. However, while public awareness is rising globally, the depth and nature of this awareness vary significantly across regions. The extent to which this social pressure translates into actionable change can also vary. In some cases, public support is strong in rhetoric but weak in practice—particularly when green solutions involve trade-offs such as higher upfront costs or changes in behavior. Moreover, awareness alone may not be sufficient without enabling platforms for public participation and inclusive decision-making. Societal enthusiasm can also be uneven across socio-economic groups, with more affluent communities often having greater access to green infrastructure benefits than marginalized or low-income populations.

Government support and leadership also play a critical role in driving the success of urban green infrastructure through strategic policy, funding, and the establishment of task forces or agencies dedicated to these projects. Strong government commitment enables the effective alignment of green infrastructure goals

with national and local sustainability targets (Braga and Ernst, 2023). For instance, the establishment of green building codes or urban regeneration policies directly influences the scaling and success of green initiatives in cities (Owojori and Okoro, 2023). Government policies and regulations are pivotal in shaping this landscape, and as affirmed by Franco et al. (2021), such policies create a stable investment environment, reducing uncertainties for private investors.

Moreover, strong governance and institutional capacity are also key drivers of green PPPs. Effective governance structures, transparent procurement processes, and skilled personnel are essential for the successful implementation of green infrastructure projects (Qamruzzaman and Karim, 2024). Nonetheless, formal governance frameworks do not always guarantee effective implementation. In some contexts, transparency mechanisms may exist on paper but lack enforcement, or skilled personnel may be concentrated in urban centers while local governments remain under-resourced. Moreover, institutional strength must be complemented by political will and public trust; without these, even well-designed systems may struggle to achieve meaningful outcomes. Thus, governance quality must be assessed not only by its structure but also by its functionality and responsiveness to diverse stakeholder needs.

Strong institutional frameworks reduce risks for private investors and ensure efficient project delivery. Collaboration across sectors is also indispensable for realizing green infrastructure. Effective coordination between various government agencies, private companies, NGOs, and local communities leads to more efficient and sustainable outcomes (Cui et al., 2018), ensuring that green infrastructure serves diverse urban needs.

5.4 Mitigating barriers and enhancing success factors in green PPPs

Table 2 presents strategic approaches to support green-centric PPP infrastructure by addressing economic, environmental, and institutional/social barriers. Economically, it recommends using green bonds, risk-sharing mechanisms, and government incentives to attract private investment. Environmentally, it promotes integrating ecosystem services and applying recognized sustainability standards. Institutionally and socially, it emphasizes capacity building, community engagement, and collaboration among government, private sector, and NGOs to ensure effective and inclusive project development.

6 Conclusion

This study has explored the evolving role of public-private partnerships (PPPs) in advancing green infrastructure, focusing on the key environmental, social, and economic drivers and barriers that influence their success. The study of PPPs in green infrastructure remains in its early stages, yet its significance for sustainable urban development cannot be overstated. While green PPPs have the potential to contribute significantly to sustainable urban development, they face considerable challenges, ranging

TABLE 2 Strategic approaches to mitigate barriers and promote green-centric PPP infrastructure development.

Category	Strategies	Description
Economic	Innovative financing mechanisms	Utilize green bonds, environmental impact bonds, and blended finance to attract private investment and ensure financial viability.
		Cost-benefit analyses that include environmental externalities
	Risk allocation and sharing	Allocate risks equitably between public and private sectors to reduce burden and promote investment security.
		Provide government subsidies or tax incentives to make green infrastructure projects more attractive to private investors.
	Public subsidies and incentives	Establish performance-based incentives.
		Independent audit and evaluation frameworks reinforcing investor confidence and public support.
Environmental	Integrating ecosystem services	Design projects that consider the full value of ecosystem services to justify their environmental and economic benefits.
	Sustainability standards and green certifications	Implement internationally recognized sustainability frameworks to standardize environmental outcomes.
Institutional/ social	Capacity building and knowledge sharing	Enhance the technical expertise of government agencies and private partners through training, workshops, and cross-sector knowledge exchange.
	Stakeholder engagement and community participation	Engage local communities and stakeholders early in the planning and decision-making processes to ensure that green infrastructure meets local needs and priorities.
	Interagency and cross-sector collaboration	Foster collaboration between various government agencies, private sector players, and NGOs to co- create integrated solutions for green infrastructure.
	Governance and policy alignment	Define clear green objectives
		Develop standardized contracts
		Set sustainable regulatory frameworks
	Operational efficiency	Establish dedicated institutions for streamlined permitting and inter-agency coordination for green infrastructure projects
		Leverage green technologies and best practices

(Continued)

TABLE 2 (Continued)

Category	Strategies	Description
		Conduct feasibility studies and environmental impact assessments
		Embed performance targets into operations.
		Establish clear KPIs across environmental, social, and economic performance

Source: Author's work.

from regulatory complexities to financial barriers and governance issues. However, these challenges also present opportunities for innovation in policy, financing, and institutional capacity that could accelerate the adoption of green infrastructure solutions.

As cities grapple with escalating climate crises, resource depletion, and rapid urbanization, the future of urban sustainability depends not just on ambitious policies but on the ability to forge strategic, high-impact partnerships. This study underscores that while green PPPs offer immense potential, their success hinges on three critical factors: robust governmental regulatory frameworks, sustained private sector investment, and adaptive collaborative mechanisms that foster green innovation. By examining the typologies of green-centric infrastructure developments, this study has highlighted the essential principles and systemic approaches necessary for integrating green infrastructure into urban enterprises. To optimize their implementation, cities must enhance institutional capacity, establish clear risk-sharing mechanisms, and foster multi-stakeholder collaboration. Additionally, incentivising private sector engagement through fiscal policies, streamlining regulatory approvals, and embedding long-term environmental commitments into contracts can create a more enabling environment for green PPPs. The implications of this research extend beyond urban green infrastructure, offering insights into how PPPs can be leveraged to tackle broader sustainability challenges. As governments worldwide adopt more aggressive climate goals, the success of green PPPs could serve as a blueprint for future sustainable projects, shaping the way cities address their environmental footprint. Moreover, these findings highlight the need for an ongoing dialogue between policy-makers, private sector actors, and local communities to ensure that the benefits of green infrastructure projects are equitably distributed.

Despite its contributions, this study has some limitations that warrant acknowledgment. First, it primarily focuses on key drivers and barriers of implementing green infrastructure PPPs, without an exploration of sector-specific complexities. Future research could benefit from granular analyses of different infrastructure typologies—such as renewable energy, green mobility, or urban water systems—to uncover sector-specific challenges and best practices. Additionally, regional variations in green PPP implementation require closer investigation, particularly in Global South cities, where infrastructure needs, governance structures, and financial ecosystems differ significantly

from those in developed economies. Technological innovation is emerging as a key driver in the effectiveness of green PPPs. Future studies should explore the integration of smart and predictive technologies to enhance the monitoring and management of green infrastructure. Understanding how these technologies interact with traditional systems will be crucial for optimizing resource efficiency, improving system performance, and scaling urban sustainability initiatives.

Future research should also focus on understanding how the drivers interact across different geographies and sectors, and what incentives are needed to foster sustainable partnerships in regions where such drivers are weak or underdeveloped. Nevertheless, this research provides a structured analysis of the socio-institutional, economic, and environmental dimensions shaping green PPP success. If harnessed effectively, green-centric PPPs can catalyze systemic urban transformation, shifting sustainability from rhetoric to reality. Moving forward, the challenge is not merely to expand PPP adoption but to redefine their role in shaping inclusive, resilient, and climate-positive cities.

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