Public-private partnerships in infrastructure: examining operational models and implementation challenges

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Abstract

Public-Private Partnerships have emerged as an innovative mechanism to bridge the gap between pubic demand for infrastructure and limited government resources. PPPs provide an alternative model for the development and management of infrastructure projects. Various sectors, including transport, energy, healthcare, power, and education, widely use different modes of PPP, such as BOT (Build Operate Transfer), BOOT (Build Own Operate Transfer), and OMT (Operate Maintain Transfer). However, implementation of PPPs is not without challenges. Financial and economic constraints, legal and regulatory complexities, socio-political barriers and technology limitations often hinder project success. Understanding both the operational models and key challenges is critical for improving PPP frameworks and ensuring sustainable infrastructure development. This paper explores the different PPP models applied in infrastructure projects and critically examines the challenges that affect their effectiveness, with a view to suggesting strategies for enhancing project outcomes.

Keywords: Public-Private Partnership, Infrastructure, Sustainability and PPP models

Introduction

Infrastructure is often considered the backbone of economic development (PIB, 2025) [19]. In India, the demand for world-class infrastructure is increasing due to rapid economic growth, urbanization and population growth (C. Sharma, 2012) [22]. The growth of the economy is directly linked to infrastructure resources (Nguyen *et al*., 2017) [16]. Infrastructure resources have a positive impact on economic growth (Nguyen *et al*., 2017) [16]. After India's independence, to invest in the vital sectors of the economy (Unnikrishnan & Kattookaran, 2020) [25] like transport, energy and education, etc, became the government's responsibility. However, the situation has dramatically changed over the past few years. The belief that government is solely responsible for investing in society's well-being has faded. To address the significant investment gap (Raut & Vyas, n.d.; Sehgal & Dubey, 2019) [20], leading policymakers have adopted public-private partnerships as a solution. To bridging infrastructure gaps, PPPs have emerged as a strategic approach. Provide as a funding application across diverse sectors, including transport, environment, energy, health, and education (Palcic *et al*., 2022) [18]. PPPs are used as an effective tools for enhancing economic, social, and environmental sustainability (Ma *et al*., 2022). Consequently, many countries are compelled to transform their public infrastructure delivery by adopting Public Private Partnerships. PPPs provide an alternative financing and delivery model that combines the efficiency of private players with the social responsibility of the public sector. Private players provide various services like administration, supervision, building of various projects.

The investment required for a country's infrastructure development is substantial and often exceeds what the government can manage within its budget. India's infrastructure investment for FY2022 to FY2023 was around ₹7.5 trillion ($91.48 billion) and is anticipated to reach ₹10 trillion ($121.98 billion) for FY2024 (Development Bank, 2024) [8]. The National Infrastructure Pipeline (NIP) aims for a projected investment of ₹111 trillion ($1.35 trillion) from 2020 to 2025, focusing on energy, roads, urban infrastructure, and railways, funded by the central and state governments along with the private sector (Development Bank, 2024) [8].

(PPPs) Public-private partnerships have existed in many countries for a long time, but gained substantial momentum in the 1990s (Fefta Wijaya *et al*., 2023) [9]. Market-oriented approaches and corporate business practices were introduced to the public sector during this period. PPPs became a key element of privatisation and government reform efforts, based on the belief that private firms could deliver high-quality goods and services more efficiently and cost-effectively, thereby reducing the responsibilities of the government. PPPs offer a mechanism where the public and private sectors collaborate to plan, build, or manage infrastructure projects and services required to achieve the SDGs(Sharma & Garg, 2024) [23]. They share the responsibilities, costs, risks, and benefits involved in making these projects successful (Liu *et al*., 2024) [13]. Nevertheless, PPPs are not free from challenges, and their effectiveness

depends largely on the setting, the models adopted and the management of inherent risks.

Various PPP models (Table A) exist worldwide, each has unique characteristics of risk-sharing mechanisms and structural frameworks. For example, the Build, Operate and Transfer (BOT) model, which permits the private sector to finance, build and operate for a predetermined duration before relinquishing ownership to the public sector. Design, Build, Finance, and Operate (DBFO), which facilitates the private sector's responsibilities in designing, constructing, financing, and operating a project, while concurrently receiving compensation through fees from government entities before transferring the ownership to the government is another important model.

This paper examines the leading models utilised for public-private partnerships across several infrastructure sectors and investigates the barriers faced by diverse parties in executing these projects. Before implementing the projects, the government and other stakeholders must anticipate the potential challenges in this and develop strategies to address these constraints, ensuring that the partnership operates effectively.

Review of literature

In 1977, Uk was initially used the public-private partnership-based model and is now widely applied across the world in infrastructure sectors such as highways, healthcare, power, airports, seaports and education. In various sectors, different types of PPP models like BOT, BOOT, OMT, DBFO and BOLT, etc. is used according to their unique characteristics. (Akhtar *et al*., 2023) [1].

According to the Zakharina *et al*. (2020) [26] found that the selection of an appropriate model and a partnership framework influence the success of PPP projects, which serve as an effective alternative to traditional approaches in managing strategic economic sectors. According to Liu *et al*. (2021) [14] DBFO (Design- Build-Finance-Operate) and BOT models are also implemented for the smart city projects, where the private sector develops smart facilities and provides smart services for a predetermined time period and after this is transferred to the public sector. The selection of an appropriate PPP model is largely determined by the type of projects and services to be provided.

In greenfield projects, the BOT model is commonly and widely used in the world (Akhtar *et al*., 2023) [1]. However, Balasingh (2024) [4] states that India has implemented PPP models for the supervision, administration and building of national roads, which are annuity and (BOT) Build Operate Transfer model. The annuity model lets the concessionaire to be compensated through fixed annuity payments or early toll revenues provided by the government, while the BOT model involves realising the concessionaire's investment by imposing tolls on road users. To address the global challenges, scope of partnership mis further evolving. Choi *et al*. (2020) [6] analysed the evolution of (PPPs) public-private partnerships within the partnership for Green Growth and Global Goals 2030 (P4G), examines stakeholder relationships and their development over time. The increasing involvement of Ros (Research organisation) in connecting with NPOs/NGOs, (Governments) GOVs, international organisations (IOs), and companies reflects the pilot nature of P4G start-up projects. This evolution underscores P4G's role in fostering multi-stakeholder collaborations for sustainable development, with clear roles emerging for participants at different stages. The study differentiates between the summation network, showing overall stakeholder participation, and the normalised network, which reveals the effectiveness of these partnerships. This highlights a shift from binary public private contracts towards complex, multi-stakeholder collaborations for achieving sustainable development goals (SDGs).

Apart from the model selection, a robust body of literature identifies the factors that underpin PPP success, encompassing financial, legal and project management dimensions. Kumar *et al*. (2022) [12] investigated the various infrastructure sectors profitability in India. In this investigation, the variable has an impact on PPPs profitability and results showed that firm-specific factors like leverage, size, non-debt tax shield, growth, and risk positively impact PPPs' profitability. In contrast, macroeconomic factors like inflation have a significant positive relationship. The study highlights the importance of identifying factors determining profitability for researchers, practitioners, policymakers, and fund providers. This indicates that the financial health and strategy of the private partner are crucial for project viability. Geng *et al*. (2022) [10] explored the influence of completion risk and project profitability on private-sector investment decisions in PPP infrastructure projects. It uses a continuous real option method to analyse investment and default boundaries under various risk conditions. His study showed that an increase in completion risk depends on the private sector risk tolerance limit but doesn't necessarily increase the investment boundary. The optimal debt level increases with the tax rate but decreases with the default loss rate. Their findings suggest that risk allocation must be carefully adjusted to the private sector's capacity to bear it.

Synthesizing these points, (Olusola Babatunde *et al*. 2012) [17] states that while PPP can be suitable for various infrastructure types, their performance depends on well-structured success factors. They examined the most suitable types of infrastructural projects using public-private partnerships (PPP) and identified critical success factors that are essential for developing the necessary rule, regulations, laws and guidelines. However, ensuring well-structured success factors for successful implementations is important for optimum performance. Identifying critical factors in PPP can help develop a body of PPP knowledge, which can be used to establish relevant rule, regulations, and guidelines. The eventual justification for public-private partnership often lies in its broader economic impact. Chotia and Rao (2018) examined that the Indias GDP have most positively influenced be the public-private partnerships (PPP). It includes private financing in the roads, energy, and telecom sectors having a particularly

impactful effect. This study also suggests that benefits are not same across sectors, with the seaport sector, for instance, deriving optimal benefits from this mode of financing.

Research methodology

The research is descriptive research based on secondary data. The literature is retrieved from Scopus and Web of Science for the comprehensive coverage of public-private partnerships and infrastructure development. The study analysed the predominant models utilised for public-private partnerships across several infrastructure sectors and investigated the challenges faced by stakeholders in the implementation of the project.

Table A: Shows the types and models of PPPs

Model	Description	Private sector role	Asset ownership	Key contributors
BOT	Build, Operate and Transfer	Finance, build, and transfer after the concession period, but continue to operate it for a fee on behalf of the government.	Public	Water and sewerage (Babatunde *et al*., 2014) [3], Toll and Highway Roads (Akhtar *et al*., 2023) [1] and Airports
BOO	Build, Own, Operate	Financing, Building, and operating a facility for indefinite periods and getting financial incentives such as tax-exempt status	Private	Airports, Roads and highways(Akhtar *et al*., 2023) [1]
BOOT	Build, Own, Operate and Transfer	Financing, Building, and operating a facility for a set period and transferring at an agreed-upon and market price.	Public	Education (Babatunde *et al*., 2014) [3], Power and Healthacare
BOLT	Build, Operate, Lease and Transfer	Builds and operates a facility, leasing it to the public sector for a specific period and then transferring ownership	Public	Transportation (Akhtar *et al*., 2023 [1])
DBFO	Design, Build, Finance, and Operate	Design, construct, Finance and operate a project and get fees from the government	Public	Education (Babatunde *et al*., 2014) [3], Healthcare
OMT	Operate, maintains/modernize and transfer	Operating and maintaining a public asset or service for a set period	Public	Railways and Bridges

Source: Compiled by Author

Challenges faced by PPP infrastructure projects in India financial and economic issues: This issue impacts both the public and private sectors. For the private sector, high participation costs (Malek & Gundaliya, 2023) [15], bidding process, complicated requirements, and meanwhile, the public sector faces difficulties due to the size and complexity of the projects, as well as the need for external requirements in the early stages.

Legal and regulatory hurdles

PPP often encounter legal disputes and a lengthy approval process (Singh & Kadam, n.d.) involving multiple government agencies. This includes challenges such as obtaining environmental clearances, weak institutional capacity, and weak enabling policies (Babatunde *et al*., 2014) [3] and navigating regulatory uncertainties.

Technological hurdles

Poor strategic partners in advanced technology development in infrastructure projects, along with a lack of capacity to keep pace with completion timelines, expertise requirements, and architecture of ICT infrastructure, create hurdles in projects (Ibrahim & Jantan, 2024) [11] implementation.

Socio-political barrier

The Central and state government makes many rules and regulations in countries like India, which have to fulfilled before starting the projects and during the projects. Many issues such as land acquisition delays (Babatunde *et al*., 2014) [3], political interference, public opposition, unstable of government, bribery in system (Bramhankar & Devalkar, n.d.) and a lack of support from stakeholders further complicate the implementation of PPPs.

Project management

Coordination difficulty (Ibrahim & Jantan, 2024) [11] is a significant issue in PPPs. The involvement of various stakeholders, such as contractors, lenders, and public and private authorities, often leads to divergent interests and complicates partnership dynamics, especially considering the long-term nature of these collaborations. Poor network coordination, lack of PPP experience, lack of integrated communications between industry partners and government (Ampratwum *et al*., 2023) [2], shows issues in coordination.

Conclusion

Public-Private Partnerships have become an essential tool for bringing private resources, knowledge, creativity and skills to address public infrastructure needs. The PPP model from the transportation sector to healthcare, education and the power sector has proven effective. Despite their benefits, PPPs implementation continues to face significant challenges. Issues such as unclear risk allocations, lack of transparency, funding constraints, high participation costs, political interference, etc., remain unsolved. This paper concludes that there are more challenges to PPPs project implementation in developing

countries. Effective PPPs require a transparent mechanism, technological advancement, improved financing structuring, a stable regulatory framework, a stable government and reform of land acquisition policies. These solutions not only address immediate issues but also align with India's long-term vision of sustainable and resilient infrastructure under the National Infrastructure Pipeline (NIP) and Gati Shakti Master Plan.

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