CHAPTER 6

Comprehensive Performance Indicators for Public Private Partnership Projects in India

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ABSTRACT

PPP projects have grown to be critical for the development of urban infrastructure across the world, enabling investment, innovation and risk sharing between public and private sectors. In India, urban infrastructure is being developed by the PPP-based metro projects as per National Metro Rail Policy- 2017. Investment has been substantial, however the risks of cost overruns, ridership shortfalls, delays over securing land and poor governance continue. This study constructs a thorough India-specific framework for evaluating the performance of PPP metro projects. This framework includes nine dimensions: financial performance, project performance, risk management, market viability, governance and compliance, environmentally sustainable development, stakeholder relations, innovation and technology adoption, and safety and health performance. Based on a comprehensive review of literature, consultation with 42 professionals, and AHP analysis, the KPIs were identified, weighted, and ranked. The results indicate that the Safety & Health, Governance & Compliance and Stakeholder Relations are the most influential factors to assess PPP metro performance in India. The framework helps to enhance planning, accountability, decision-making capabilities and gives practical guidelines. Future research could utilize this framework to test against real-world case studies to demonstrate its relevance and prioritize sub-factors according to contextual significance.

Keywords: Public Private Partnership (PPP), Metro Project, Framework, Analytic Hierarchy Process (AHP), Key Performance Indicators (KPI's).

1.0 Introduction

Public–private partnerships (PPPs) constitute a major mechanism for infrastructure

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development worldwide, wherein public authorities and private sector participants collaborate in the financing, design, construction, and operation of large and complex projects (Robert Marschinski, 2009). In India, programs like the National Infrastructure Pipeline as well as sector specific guidelines are actively encouraging PPPs in the country to attract additional funds by the private sector to support faster delivery.

During the time period of 2014-2024, India has settled on 1,825 PPP projects in the sectors of airports, electricity, information and communication technology and waste management and the total investments done in the projects have reached up to US$295.56billion. (Department of Economic Affairs, 2024). Nevertheless, with this large scale, systematic PPP performance assessment in India is still disjointed, thus hindering evidence-based governance and sustainability in the long term. One of the main weaknesses is the lack of an integrated, India-specific framework which is sensitive to the peculiarities of the regulatory, institutional and socio-economic environment of the country. Multidimensional factors are widely ignored by international structures that are usually finance-oriented and fail in the Indian setting that is marked by very different structures of governance, capacity limits and stakeholder interactions that do not match those seen in the advanced economies(Zhang, 2005) (Malaeb & Hamzeh, 2018).

This trend is particularly evident in the metro rail sector, where investments have reached ₹2.5 lakh crore (US$28.86 billion) over the past decade under the National Urban Transport Policy's Metro Rail Policy Component (2017), which explicitly mandates private sector participation. Still similar projects face high costs, low ridership, revenue deficit, delays due to land acquisition, poor governance and prevalent inefficiencies (Ministry of Housing and Urban Affairs, 2023) (Ahmad et al., 2022).

The current study fills this gap by developing a context-specific Performance Evaluation Framework (PEF) that fits in the context of an Indian PPP infrastructure with particular reference to metro rail. The framework generalizes best practices across the globe but incorporates India specific variables hence going beyond the traditional financial indices to include technical efficiency, quality of governance, stakeholder satisfaction and concerns to sustainability. The research has two major objectives. Firstly, it begins by reviewing and critically examining the existing PPP frameworks with the aim of coming up with transferable indicators that can be used to fit the Indian scenario. Second, it utilizes both the stakeholder consultations and the Analytic Hierarchy Process (AHP) to rank, weight, and combine indicators into 9 dimensions to create a valid, empirically based framework. These objectives will be achieved with the help of a mixed-methods design, comprising a systematic literature review, application of AHP, and consultations with stakeholders. The significance of the study lies in yielding scholarly innovation in a theoretically sound, empirically examined, multidimensional approach to Indian PPPs, to fresh financial biases and to scholarship in the

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field of emerging-economy governance. In a practical sense, the framework provides policymakers, regulators, and business parties with evaluation instruments that would boost the success of the projects, repair the gaps, and make investments of the metro rail sustainable. In terms of policy formulation, the framework can provide practical information that can fine-tune PPP in their plans; thus, enhancing further mobilization of the population of the privates and efficient infrastructure provision in the country.

2.0 Literature Review

2.1 Introduction and context

Key Performance Indicator (KPI) models are fundamental mechanisms that appraises the effectiveness and sustainability of Public-Privately-owned Partnership (PPP) infrastructure projects. In the last two decades of academic work, KPI systems have been broadened to include more than the traditional cost-time quality metrics, with aspects of governance, innovativeness, involvement of stakeholders, and sustainability being introduced. In this review, eight major frameworks (see Annexures) are evaluated:(Ahmad et al., 2022), (Yuan et al., 2009), (Yuan et al., 2012),(Ugwu & Haupt, 2007), (Muhammad & Johar, 2017),(Hossain et al., 2019), (Mohamad et al., 2018), and (JPR, 2022), which reflects the conceptual progress in the field of PPP performance measurement (Table 1). There is an acute gap between these international models and their pertinence to the unique institutional, regulatory and working environment in India. This Ambiguity can be attributed to the federal system of governance in India, legislation of land-acquisition, and institutions of varying capacities in different states and municipalities and ineffective data reliability at the public administration.

2.2 Comparative framework analysis

The structures have developed into primitive cost- time- quality indicators to multidimensional frameworks that involve governance, sustainability, stakeholder participation, and innovation.

Table 1: Review of 8 Selected Frameworks

Framework	Authors (Year)	Paper Title	Core Focus Areas	Key Contribution
Framework 01	Ahmad et al. (2022)	Developing a Performance Evaluation Framework for PPP Projects	Contract design, cost-time performance, service quality, stakeholder relations, sustainability	Provides one of the most comprehensive, contract-centric KPI sets (40 KPIs) linking operational performance with socio-economic and sustainability outcomes

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Framework 02	Yuan et al. (2012)	Developing KPIs for PPP Projects: Questionnaire Survey and Analysis	Project basics, finance, innovation, stakeholder satisfaction, project processes	Empirically validated KPIs (41 KPIs) integrating governance, innovation, and learning into PPP performance; includes fuzzy TOPSIS analysis for lifecycle phase prioritization
Framework 03	Ugwu & Haupt (2005)	KPIs and Assessment Methods for Infrastructure Sustainability	Environmental, social, resource utilization, health & safety	Introduces sustainability-driven KPIs (44 KPIs) emphasizing lifecycle environmental and social impacts; pioneering framework for developing-country infrastructure contexts
Framework 04	Yuan et al. (2009)	Selection of Performance Objectives and KPIs to Achieve VfM	Governance, finance, innovation, stakeholder management, project process	Strong focus on value-for-money through balanced managerial and financial indicators; emphasizes governance and risk management integration
Framework 05	Zayyanu & Johar (2007)	Conceptual Framework for Evaluating PPP Success	Governance, procurement, investment climate, risk allocation	Emphasizes institutional and governance conditions over operational metrics; highlights success factors approach rather than performance measurement
Framework 06	Hossain et al. (2018)	Performance Indicators of PPP in Bangladesh	Planning, financing, transparency, lifecycle performance, socio-economic impact	Developing-country-oriented framework (42 KPIs) addressing implementation and institutional capacity gaps; closest to Indian context in global literature
Framework 07	Mohamad et al. (2018)	Performance Indicators for PPP Projects in Malaysia	Financial sustainability, marketability, innovation	Focuses on financial robustness and innovation but limited coverage of social and governance aspects
Framework 08	Nuno & de Gaia (2022)	Performance Measurement and Evaluation of PPPs: A Systematic Review	Traditional KPIs, stakeholder, lifecycle, innovation, accountability	Synthesizes global PPP KPIs and introduces emerging dimensions such as BIM utilization and accountability; reflects latest thinking on infrastructure digitalization

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2.3 Conceptual evolution and key patterns

Initial studies such as Ugwu and Haupt (2005) emphasized environmental, social, and financial dimensions of project performance. Later works by Yuan et al. (2009, 2012) expanded this scope by incorporating governance, risk management, and learning within value-for-money assessments in developed contexts like Australia, Canada, and the United States. Recent frameworks (Hossain et al., 2019; JPR, 2022) recognize institutional capacity and socio-economic outcomes in developing economies but still treat them as secondary factors. The Bangladesh framework by Hossain et al. (2019), while similar to India's context, prioritizes governance processes over regulatory and institutional barriers.

2.4 KPI analysis and local adaptation

Analysis of eight frameworks revealed convergence across 17 KPI pairs and 48 clusters among 251 indicators, primarily focusing on project management (29.9%) and financial performance (17.9%). Core KPIs such as cost, time, quality, risk, and environmental management are consistent, whereas innovation, social impact, and safety remain underrepresented.

Existing frameworks emphasize isolated dimensions, often ignoring local regulatory capacity and institutional diversity. In India, KPI adaptation must reflect specific legal and financial contexts—such as RFCTLARR (2013), VGF, InvITs—and align with oversight from NGT, SEBI, RBI, and CAG to address socio-political and environmental factors absent in global PPP frameworks.

2.5 Consolidated Indian specific framework

The proposed framework identifies four guiding principles that collapse shifts 12 categories into 9 to get rid of 23% of redundancies without covering essential aspects (Table 3):

- Principle 1: Operational Integration- Combines time, quality and facility measurements to Project Performance and introduces land acquisition delay and monsoon-impact measures.
- Principle 2: Financial Consolidation unites Value for Money, marketability and tariff measures to Financial Performance with an Inflation Sensitivity Index and a VGF Ratio.
- Principle 3: Governance Convergence- absorbs contract execution into Governance Compliance, such as RTI rates and monitoring amendments.
- Principle 4: Risk Specialization—Standalone due to India's political/regulatory risks.

This style combines international best practices with Indian needs producing an integrated but rational framework.

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Table 2: Consolidated Framework for Indian Metro PPP projects

Core Category	Subcategory (KPI)	KPI (Global + India-Specific)	Significance
Financial Performance	Cost Management	- Construction Cost Variance & Growth	Controls budget overruns and enhance financial predictability for stakeholders.
		- Operational Cost	Ensures long-term financial sustainability and service quality maintenance.
		- Inflation Sensitivity Index	Critical for managing India's volatile inflation environment.
		- Subsidy Dependency Ratio	Indicates financial reliance on public funding and affects project sustainability.
		- Local Currency Financing Ratio	Reduces foreign exchange risk in financial planning.
	Profitability & Value for Money	- Sustainable Profitability	Ensures private-sector viability and attractive investment.
		- Value for Money Test	Validates the efficiency and appropriateness of PPP approach.
	Tariff & Subsidy Mechanisms	- Tariff/Toll Adjustment Mechanism	Balances affordability for users and financial viability for operators.
		- Viability Gap Fund Utilization	Ensures optimal allocation of public resources.
Project Performance	Schedule & Delays	- Construction Time Variance & Growth	Identifies bottlenecks and facilitates improved project delivery.
		- Project & Concession Period Duration	Ensures effective resource utilization and timely project handover.
		- Land Acquisition Delay Days	Critical in India where land acquisition often causes major project delays.
		- Monsoon Delay Days	Supports seasonally adjusted planning and risk mitigation.
	Coordination & Interfaces	- Agency Coordination Index	Reduces bureaucratic delays and improves multi-stakeholder cooperation.
		- Interface Management	Minimizes conflicts and smooths transition across project lifecycle stages.
	Quality & Facilities	- Quality Control	Maintains asset integrity and minimizes rework/maintenance costs.
		- Facility Management	Prolongs asset life and sustains service quality.
		- Safety & Health Management Systems	Protects worker welfare and ensures regulatory compliance.
Risk Management		- Risk Management System	Improves project resilience and risk awareness.

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	Risk Identification & Mitigation	- Force Majeure Incident Frequency	Measures vulnerability to external shocks.
		- Policy Change Impact Score	Essential for managing regulatory risk, especially in emerging markets.
		- Credit Quality Index	Helps evaluate financial risk and partner reliability.
		- Fair Risk Allocation	Prevents scope creep and cost disputes.
Environment & Sustainability	Environmental Compliance	- EIAR Compliance	Ensures environmental protection and legal compliance.
		- NGT Compliance Rate	Mitigates legal risks related to environmental issues.
		- Local Biodiversity Impact Index	Demonstrates commitment to ecological sustainability.
	Resource & Emissions	- Waste Management	Minimizes environmental pollution and regulatory penalties.
		- Renewable Energy Integration Ratio	Supports carbon reduction and operational cost savings.
	Long-Term Sustainability	- Benefit Sustainability (Long-Term vs Short-Term)	Aligns project objectives with sustainable development goals.
		- Scalability & Replicability	Maximizes knowledge transfer and investment efficiency.
Stakeholder Relations	Community Engagement	- Community Involvement	Builds social acceptance and minimizes resistance risks.
		- Panchayat Consultation Score	Ensures grassroots democratic participation and transparency.
		- Local Employment Ratio	Promotes inclusive economic development.
		- Displacement Compensation Timeliness	Helps maintain community goodwill and legal compliance.
	Satisfaction & Trust	- Stakeholder Satisfaction	Drives continuous improvement and accountability.
		- Public Client Satisfaction	Ensures alignment with public policy and expectations.
		- Trust Building	Strengthens partnership and cooperation.
		- Responsiveness to Complaints	Maintains service quality and reputation.
Innovation & Technology	Technology Adoption & R&D	- Technology Innovation	Improves efficiency, reduces costs, and enhances service quality.
		- Local Technology Adoption Rate	Supports local industry and aligns with 'Make in India' policies.
		- R&D Investment	Drives innovation and competitive advantage.

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		- R&D Collaboration Count	Accelerates knowledge transfer and innovation diffusion.
	Digitalization	- Digitalization Index	Enhances transparency, monitoring efficiency, and data accuracy.
		- Technology Transfer	Builds capacity and supports sustainability.
		- Learning Organization Setup	Fosters innovation culture and process improvement.
Governance & Compliance	Transparency & Accountability	- Good Governance	Builds stakeholder confidence and supports ethical project management.
		- RTI Compliance Rate	Empowers public oversight and trust.
		- Disclosure of Project Information	Increases transparency and stakeholder engagement.
		- Audit Finding Closure Time	Ensures proper control and accountability improvements.
	Contract Governance	- Contract Framework & Flexibility	Supports project adaptability and risk management.
		- Contract Amendment Frequency	Reflects contract robustness and operational adaptability.
		- Dispute Resolution Provisions	Minimizes disputes and project delays.
Safety & Health	Occupational Health & Safety	- Health and Safety Management Systems	Protects workforce and reduces legal/operational risks.
		- National Injury Frequency Rate	Tracks safety culture maturity and effectiveness.
		- Accidents, Injuries & Fatalities	Monitors risk control and continual improvement.
Market & Commercial	Market Viability & Financial Health	- Increased Marketability	Ensures revenue generation and commercial success.
		- Shareholders' Financial Ability	Reduces financial risks and supports project completion.
		- Availability of Financial Market	Enhances financial agility and cost optimization.
		- EIRR Variance	Indicates accuracy of economic forecasting and long-term value creation.

Source: Created by authors

3.0 Methodology

The proposed research design is a mixed-method research design combining systematic literature review, framework synthesis, expert consultation, and quantitative analysis via the Analytic Hierarchy Process (AHP) to create an inclusive performance measurement framework of Public- Private Partnership (PPP) metro projects in India (Figure

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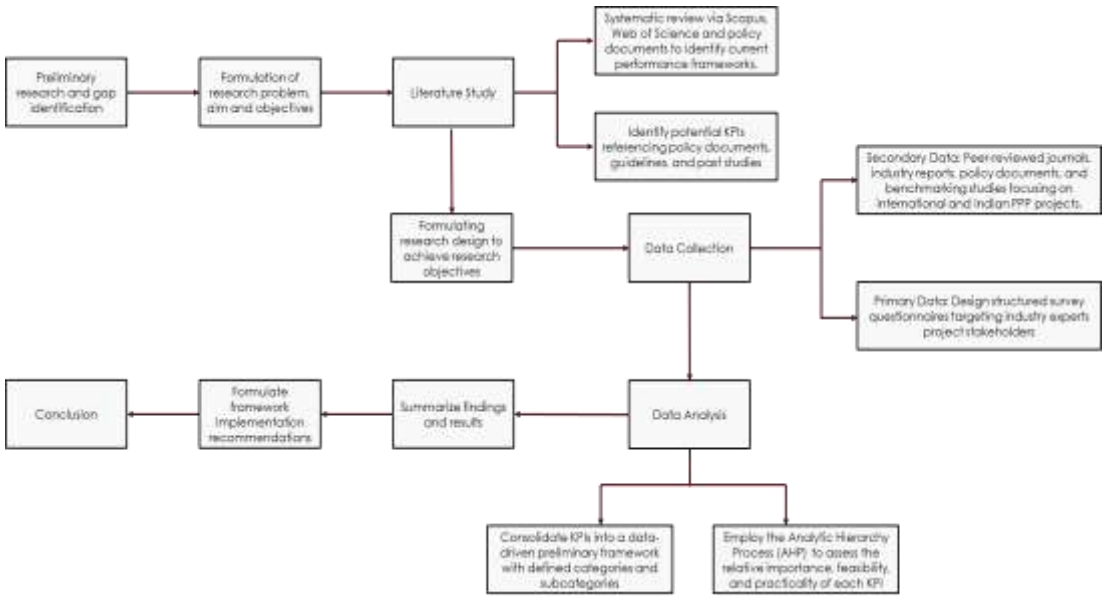
1). The nine-phase approach guarantees the rigor, reproducibility and applicability to the Indian infrastructure situation. Key Performance Indicators (KPIs) are empirically weighted using the quantitative approach based on structured expert judgment and conceptually define and make them related to their context using the qualitative validation approach.

Figure 1: Research Methodology Framework for PPP Project Performance Evaluation



Source: Created by authors

3.1 Literature review and framework development (Phases 1-3)

A systematic review was conducted using Scopus and Web of Science databases covering 2005–2025. The keywords "Public–Private Partnership KPIs," "PPP performance indicators," and "infrastructure project performance measurement" were used. Papers were selected based on direct relevance, methodological transparency, and quantifiable indicators, resulting in 38 screened studies. Of these, 18 empirically verified frameworks were analysed through standardized extraction templates, revealing eight comprehensive frameworks with common focus areas such as financial performance, operational efficiency, stakeholder satisfaction, risk management, and value for money.

Findings from these frameworks were synthesized into 12 KPI packages encompassing 59 individual performance indicators. To adapt the framework to India's context, policies such as the National PPP Policy, Infrastructure Vision 2025, and National Metro Rail Policy 2017 were integrated. These ensured inclusion of social impact

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measurement, environmental sustainability, and community engagement dimensions. The final KPI packages included: Financial Performance, Project Performance, Risk Management, Environment and Sustainability, Stakeholder Relations, Innovation and Technology, Governance and Compliance, Safety and Health, and Market and Commercial Dimensions.

3.2 Sample design and data collection (Phases 4-6)

A purposive sampling method was adopted to ensure representation of diverse stakeholder perspectives. Forty-two respondents were selected based on their involvement in PPP infrastructure projects, knowledge of metro systems, and understanding of performance measurement techniques. Respondents had between 1 and 30 years of relevant experience and represented major metro projects across Delhi, Mumbai, Pune, Hyderabad, Bangalore, and Nagpur. This diversity enhanced the reliability and generalizability of responses.

Primary data were collected via a web-based survey that included two core components: (1) KPI definitions and operational descriptions, and (2) hierarchical AHP pairwise comparison matrices. A three-level hierarchical structure was applied with the overall objective—PPP metro performance evaluation—at Level 1, nine KPI categories at Level 2, and their respective indicators at Level 3. Saaty's 1–9 scale was used to assess relative importance, while reciprocal values (1/3, 1/5, 1/7, 1/9) were applied for inverse comparisons. The questionnaire was pre-tested for clarity and consistency. Supplementary information was gathered from peer-reviewed journals, government documents, industry reports, and benchmarking studies to strengthen validation.

3.3 AHP Computation and Validation (Phases 7-9)

AHP calculations were performed using Microsoft Excel's matrix functions. The Consistency Ratio (CR) was computed for each respondent as CR = CI/RI, with a threshold of 0.20 deemed acceptable per Saaty's guideline. Out of 42 responses, 34 exhibited consistent judgments, indicating reliability and producing a retention rate of 80.95%. The geometric mean method aggregated individual priority vectors, preserving the ratio-scale character of AHP data. Derived normalized weights reflected expert consensus and were classified into four priority tiers: High (>15%), Medium–High (10–15%), Medium (5–10%), and Low (<5%).

3.4 Framework integration and limitations

Quantitative AHP results were integrated with qualitative feasibility assessments to refine the framework. Indicators with high weights but low practicality were reviewed and adjusted. The final framework presented a hierarchically structured, data-centric synthesis

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reflecting both international benchmarking and Indian stakeholder priorities. However, limitations include the narrow focus on Indian PPP metro projects, restricting broader generalizability. The purposive sampling, while ensuring expert input, may introduce selection bias. Finally, the dependability of AHP outcomes rests on the coherence of expert judgments. Despite these limitations, the approach ensures methodological rigor and contextual validity for evaluating PPP metro performance in India.

4.0 Data Analysis

4.1 Data transformation and processing

Raw pairwise comparison judgments were transformed analytically into measurable priorities, integrating expert knowledge with mathematical processing (Decision Making Using Analytical Hierarchy Process, 2025). Forty-two AHP questionnaires were converted into a group consensus priority vector over nine performance indicators. Respondents, stratified by career experience (1–10, 11–20, and 21+ years), rated comparisons using Saaty's 1–9 scale. The process involved: (1) building positive reciprocal matrices, (2) normalizing columns and averaging rows to approximate eigenvectors, and (3) aggregating results via the geometric mean.

Table 2: Construction of Positive Reciprocal Pairwise Comparison Matrices for Respondent 32 (R32)

COMPARISON MATRIX									
	Financial Performance	Project Performance	Risk Management	Environment & Sustainability	Stakeholder Relations	Innovation & Technology	Governance & Compliance	Safety & Health	Market & Commercial
Financial Performance	1.00	5.00	3.00	5.00	3.00	0.33	1.00	1.00	0.20
Project Performance	0.20	1.00	1.00	3.00	1.00	0.20	1.00	3.00	0.20
Risk Management	0.33	1.00	1.00	3.00	1.00	0.20	1.00	3.00	0.20
Environment & Sustainability	0.20	0.33	0.33	1.00	0.20	0.14	0.20	1.00	0.11
Stakeholder Relations	0.33	1.00	1.00	5.00	1.00	0.20	5.00	5.00	0.20
Innovation & Technology	3.00	5.00	5.00	7.00	5.00	1.00	5.00	7.00	1.00
Governance & Compliance	1.00	1.00	1.00	5.00	0.20	0.20	1.00	3.00	0.20
Safety & Health	1.00	0.33	0.33	1.00	0.20	0.14	0.33	1.00	0.20
Market & Commercial	5.00	5.00	5.00	9.00	5.00	1.00	5.00	5.00	1.00
Sum	12.07	19.67	17.67	39.00	19.60	3.42	19.53	29.00	3.31

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Table 3: Matrix Normalization and Priority Vector Calculation

NORMALIZED DATA										
	Financial Perfromance	Project Perfromance	Risk Management	Environment & Sustainability	Stakeholder Relations	Innovation & Technology	Governance & Compliance	Safety & Health	Market & Commercial	Priority Vector
Financial Perfromance	0.08	0.25	0.17	0.13	0.18	0.10	0.05	0.03	0.06	**0.12**
Project Perfromance	0.02	0.05	0.06	0.08	0.06	0.06	0.05	0.10	0.06	**0.06**
Risk Management	0.03	0.05	0.06	0.08	0.06	0.06	0.05	0.10	0.06	**0.06**
Environment & Sustainability	0.02	0.02	0.02	0.03	0.01	0.04	0.01	0.03	0.03	**0.02**
Stakeholder Relations	0.03	0.05	0.06	0.13	0.06	0.06	0.26	0.17	0.06	**0.10**
Innovation & Technology	0.25	0.25	0.28	0.18	0.30	0.29	0.26	0.24	0.30	**0.26**
Governance & Compliance	0.08	0.05	0.06	0.13	0.01	0.06	0.05	0.10	0.06	**0.07**
Safety & Health	0.08	0.02	0.02	0.03	0.01	0.04	0.02	0.03	0.06	**0.03**
Market & Commercial	0.41	0.25	0.28	0.23	0.30	0.29	0.26	0.17	0.30	**0.28**
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: Created by authors

4.2 Consistency assessment and data quality control

Matrix consistency was tested through the Consistency Index (CI) and Consistency Ratio (CR), with CR < 0.20 considered acceptable. For $\lambda_{max} = 10.11$ and $n = 9$, $CI = 0.14$ and $CR = 9.6\%$, indicating reliable coherence. Of 42 responses, 34 met the threshold (mean CR = 11.94%), yielding an 80.95% retention rate. The eight inconsistent responses (CR = 22.6–79.2%) were excluded to preserve methodological integrity.

Table 4: Consistency Analysis - Lambda Max Calculation

LAMBDA CALCULATION										
Financial Perfromance	Project Perfromance	Risk Management	Environment & Sustainability	Stakeholder Relations	Innovation & Technology	Governance & Compliance	Safety & Health	Market & Commercial	Sum	Consistency Vector
0.12	0.30	0.18	0.12	0.29	0.09	0.07	0.03	0.06	1.25	10.61
0.02	0.06	0.06	0.07	0.10	0.05	0.07	0.10	0.06	0.59	9.91
0.04	0.06	0.06	0.07	0.10	0.05	0.07	0.10	0.06	0.60	9.97
0.02	0.02	0.02	0.02	0.02	0.04	0.01	0.03	0.03	0.22	9.53
0.04	0.06	0.06	0.12	0.10	0.05	0.34	0.17	0.06	0.99	10.22
0.35	0.30	0.30	0.16	0.48	0.26	0.34	0.24	0.28	2.72	10.37
0.12	0.06	0.06	0.12	0.02	0.05	0.07	0.10	0.06	0.65	9.72
0.12	0.02	0.02	0.02	0.02	0.04	0.02	0.03	0.06	0.35	10.17
0.59	0.30	0.30	0.21	0.48	0.26	0.34	0.17	0.28	2.93	10.53
Lambda										10.11

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4.3 Pairwise comparison matrices, priority weights and aggregation

The aggregated 9×9 reciprocal matrix ($a_{ij} \times a_{ji} = 1$) gave stable eigenvalues with tolerable deviations. Using Saaty's invariance principle ($Aw = \lambda w$), normalized eigenvectors produced the priority weights. Group-level aggregation through geometric mean preserved ratio-scale properties. Final weights ranked Safety and Health (25.14%) and Governance and Compliance (18.99%) highest, reflecting strong coherence and prioritization of safety and regulatory compliance in India's PPP infrastructure context.

Table 5: Aggregation of Individual priorities using geometric mean approach

Aggregation of Individual Priorities (AIP)																																										
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30	R31	R32	R33	R34	Geometric Mean	Normalized Weights
Financial Perfromance	0.11	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.27	0.32	0.35	0.36	0.03	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.39	0.12	0.14	0.03	0.047	5.61%
Project Perfromance	0.06	0.04	0.05	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.25	0.17	0.20	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.24	0.18	0.06	0.17	0.02	0.036	4.35%
Risk Management	0.04	0.08	0.09	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.15	0.10	0.11	0.14	0.07	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.07	0.05	0.15	0.05	0.06	0.16	0.05	0.066	7.89%
Environment & Sustainability	0.02	0.07	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.11	0.05	0.09	0.04	0.05	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.10	0.11	0.02	0.05	0.06	0.058	6.97%
Stakeholder Relations	0.08	0.11	0.17	0.14	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.11	0.08	0.08	0.07	0.08	0.09	0.12	0.10	0.11	0.12	0.10	0.10	0.11	0.11	0.12	0.11	0.11	0.11	0.09	0.09	0.10	0.11	0.11	0.105	12.65%
Innovation & Technology	0.03	0.07	0.05	0.07	0.08	0.09	0.05	0.06	0.06	0.07	0.07	0.07	0.09	0.05	0.06	0.05	0.02	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.02	0.06	0.26	0.08	0.05	0.056	6.74%
Governance & Compliance	0.32	0.27	0.26	0.25	0.25	0.24	0.21	0.21	0.21	0.22	0.22	0.21	0.12	0.04	0.03	0.03	0.04	0.22	0.23	0.21	0.21	0.23	0.22	0.22	0.21	0.22	0.21	0.20	0.23	0.11	0.04	0.07	0.14	0.23	0.158	18.99%
Safety & Health	0.08	0.26	0.20	0.23	0.25	0.25	0.37	0.36	0.36	0.36	0.36	0.35	0.22	0.03	0.14	0.06	0.13	0.33	0.34	0.35	0.35	0.33	0.35	0.33	0.35	0.33	0.35	0.36	0.34	0.21	0.05	0.03	0.04	0.34	0.209	25.14%
Market & Commercial	0.27	0.08	0.08	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.33	0.03	0.06	0.03	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.11	0.03	0.02	0.28	0.10	0.11	0.097	11.67%
SUM																																			0.832	100.00%

Source: Created by authors

5.0 Results

Analytical Hierarchy Process (AHP) analysis of pairwise comparisons with nine evaluation criteria monitored resulted in a normalized distribution of the weight that confirmed the relative importance of each individual criterion to outcomes of the success of PPP projects in the Indian infrastructure scenario. The results indicate that there is a stratified priority system through the evaluation system, and this is systematically explained as follows.

5.1 High-priority criteria (≥15% Weight)

- **Safety & Health** turned out to be the most significant evaluation criterion with normalized weight of 25.14% with over a quarter of the total evaluation weight. This finding indicates acknowledgment of stake holders that occupational health and safety measures, hazard controls, risk mitigation measures and welfare of workers are major success factors in the PPP infrastructural projects. The strong focus on Safety and Health takes the traditional financial measures out of the respondent list, which points to a paradigm shift toward triple-bottom-line assessment approaches that encompass both social and occupational aspects along with financial feasibility. The observation is in line

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with the modern days practice of infrastructure management that is more focused on the protection of human capital.

- **Governance Compliance** was rated second with a normalized weight of 18.99 %, which points to the extreme significance of regulatory compliance, openness of decision-making procedures, and institutional accountability systems in PPP systems. This weighting was based on the fact that in Indian context there is special focus on compliance with the provisions of the Right to Information (RTI), regulations of the audit frameworks, and governmental multi-layered approval. As a requirement to deliver partnership success and sustainable value delivery within a project, stakeholders clearly emphasize the elements of clarity in the contractual governance schemes and institutional settings.

5.2 Medium-high priority criteria (10–15% weight)

- **Stakeholder Relations** with the weight of 12.65% emphasizes the great importance of community involvement, trust-building in relations between the public and the partner companies, and institutional attention to the stakeholder reactions. This is a criterion in Indian PPP context that covers the compulsory consultation in panchayats, compensation mechanisms on displacement and the community benefit-sharing. The stakeholder weightings revealed in the weighting are that there is great stakeholder relations to reduce the effects of social risks and increase the project legitimacy among the larger public constituency.
- **Market Commercial** considerations were given a weight of 11.67%, the balance to be between commercial viability and protection of the public interest. This package includes financial capacity evaluation of the shareholders, market attractiveness evaluation and the financing methods. The specified weight reflects the fact that involvement in the private sector requires the established capacity to achieve sustainability of returns and guarantee consistency of revenue streams due to the necessary use of relevant mechanisms of adjusting tariffs and implementing strict demand forecasting procedures.

5.3 Medium priority criteria (5–10% Weight)

- **Risk Management** has a weight of 7.89% and it deals with the organized approach of identifying, assigning, and eliminating risks in the project within the partnership lifecycle. The moderate weighting does not diminish the risk management aspect of the entire evaluation setup as it represents the trust of stakeholders towards contractual and institutional arrangements that they have in addressing the overall risks holistically. The comparatively less priority than governance and safety can indicate that the respondents perceive risk management as an institutional facilitator but not an independent source of success.

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- **Environment Sustainability and Innovation Technology** are the ones that belong to the medium-priority band with the weight of 6.97% and 6.74% respectively. Environmental factors, such as adherence to regulations of the National Green Tribunal (NGT), integrated waste management, and protection of ecosystem, are mandatory compliance factors, but are rated lower than the safety and governance factors. Likewise, the innovations in technology and research and development investment are considered as enabling capabilities that improve the project delivery, instead of being the major determinants of evaluation, perhaps based on the stakeholder perception that the adoption of technology is situational and secondary to institutional maturity.

5.4 Lower priority criteria (<5% Weight)

- **Financial Performance**, with a weight of 5.61, had a surprisingly small prioritization, appearing as the eighth in the list of the nine evaluation criteria. This finding is a marked contrast to the traditional practice of infrastructure evaluation, which has long held cost management and return on investment as the key success metrics. The reduced weighting can be seen as the trust that stakeholders have in existing financial assessment tools (Internal Rate of Return, Net Present Value and debt-service-coverage-ratio calculations) and their acknowledgment that monetary analysis, needed as it is, remains an inadequate single measure of success evaluation. Alternatively, the same result could also reflect stakeholder acknowledgement that financial sustainability is a by-product of good governance, stakeholder management and strong risk mitigation instead of a standalone cause.
- **Project Performance**, which includes schedule adherence and cost variance indicators, had the lowest weight at 4.35 or under 5 percent of total evaluation weight. Although the operational factors, performance metrics also seem to be regarded as end measures of the effectiveness of antecedent success factors, and not as evaluation drivers. This weighting implies that the stakeholders will be more interested in preventative and foundational measures (safety, governance, stakeholder relations) rather than reactive outcome measures because it is an advanced evaluation philosophy that values root causes of success over symptom-based metrics.

5.5 Framework validation against extant literature

The priorities obtained using Analytic hierarchy Process are quite consistent with the findings provided in the academic literature, at the same time providing significant results which are specific to the situation of the Indian public-private partnership. The following comparative analysis reveals the trends of corroboration and dissimilarities which are local to the setting:

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5.6 Alignment with existing frameworks

The existing research by Ahmad et al. (2022), Yuan et al. (2012), and Kukah et al. (2024) is consistent and unanimous regarding the factors that determine the success of PPP projects is the presence of governance structures, risk allocation mechanisms, and managing relationships with stakeholders. These results are corroborated by the high weightings of Governance Compliance (18.99 %) and Stakeholder Relations (12.65 %) in the current study, and the findings can be generalized to the wider applicability of the principles across geographical and sectoral frontiers.

5.7 Context specific insights

Safety and Health (25.14 %) attract such strong weight that it can be inferred that the regulatory priority in India differs, and this weight is further increased by the labor-intensive character of urban infrastructure projects, particularly those which are carried out in metropolitan construction. This greater focus on Governance Compliance is in tune with that of India, with its multilayered system of approval, with central government, state governments and municipalities, and compulsory transparency provisions created under the Right to Information Act of 2005. These situational determinants support the relevance of the appraisal framework in the Indian PPP system.

5.8 Divergence from traditional practice

The somewhat low weight given to Financial Performance (5.61%) is a significant deviation of the traditional paradigm of infrastructure analysis, in which the traditional concern of cost management and pay back is always the major issue. This finding is an implication that the stakeholders involved in the Indian PPP milieu, faced with the challenge of overrating a critique of holistic success, are more likely to deemphasize financial performance in favor of institutional and social aspects. The identified trend is conditioned by the development of PPP policy frameworks, gradually incorporating the mechanisms of social accountability and sustainability as the direct policy requirements, thus indicating the shift in the direction of the development of a multidimensional evaluation of the achievements in the sphere of the public-private partnership.

6.0 Conclusion

Public-Private Partnership (PPP) development of urban transport infrastructure via metro projects has evolved to be a major strategy in India. Nevertheless, the existing performance assessment remains disjointed, with existing frameworks, in the majority, being restricted to financial measurements and the conventional Value-for-Money (VfM) measures.

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These tools fail to reflect crucial dimensions like governance, sustainability and stakeholder issues. The paper fills this gap by advancing a context-bounded model of performance evaluation of PPP metro projects in India, built on the basis of a thorough mixed-method methodology.

The study is based on the institutional, regulatory and socio-economic reality of India including land acquisition inefficiencies, contractual uncertainty and invariable small ridership-issues usually omitted in global PPP models. Applying a systematic synthesis of eight globally accepted assessment frameworks, with a nine-phase research process through the systematic literature review, framework synthesis, and expert judgement using the Analytic hierarchy Process (AHP), the research determined 251 Key Performance Indicators (KPIs) as falling into 13 themes. These have been summarized into 9 KPI packages with 59 indicators that are specific to the metro PPP environment of India.

The results of the AHP indicate a change in the perception regarding the determinants of PPP success by experts. The highest weighted criterion was Safety and Health (25.14) then Governance and Compliance (18.99) and Stakeholder Relations (12.65) with a total significance of over 56. More conventional metrics like Financial Performance (5.61%) and Project Performance (4.35) were slightly lower, and a paradigm shift in thinking about evaluating only financial and delivery-specific measurements to multidimensional measurements with greater emphasis on institutional governance, workforce safety, community and sustainability.

The suggested framework will help policymakers and practitioners with a solid base to prioritize investments, distribute risk, and evaluate performance in its entirety. It can enhance more accountability in government-private relations, help in the early detection of risks in projects, encourage the long-term social and environmental benefits, and empower the PPP governance institutional capabilities in India.

The study is confined to metro projects only and bases its analysis on expertise perception and not longitudinal outcome data, but such limitations raise potential opportunities to future studies. The possible leads are: empirical testing with operational metro case studies, comparative analysis of South Asian PPP transit systems, machine learning based on dynamic KPI weighting and longitudinal assessment of framework efficacy in enhancing project results.

Comprehensively, this research has created a scientific and policy-relevant basis on how to enhance PPP performance assessment in the Global South. It gives India the flexibility, transparency, and multidimensional structure that has the potential to enhance economic efficiency, social equity, and environmental sustainability in the development of urban infrastructure.

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