



A META-ANALYSIS OF COST-BENEFIT ANALYSIS OUTCOMES IN INFRASTRUCTURE PROJECTS: EVIDENCE FROM TRANSPORT AND UTILITY SECTORS IN DEVELOPING ECONOMIES

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Abstract

This meta-analysis evaluates the effectiveness, consistency, and methodological rigor of cost-benefit analysis (CBA) outcomes in infrastructure projects across developing economies, with a focus on transport and utility sectors. As public and donor investment in infrastructure continues to be positioned as a catalyst for economic growth, service delivery, and poverty alleviation, there is a critical need to assess whether existing CBAs accurately reflect the true value and feasibility of such projects. Drawing on 112 empirical studies and project evaluation reports published between 2000 and 2024, this study applies a random-effects meta-analytical framework to synthesize standardized performance indicators—Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Internal Rate of Return (IRR). These indicators were extracted from peer-reviewed journal articles, multilateral development bank appraisals, and governmental reports, and were coded alongside contextual moderators such as project type, region, evaluator identity, and methodological quality. The aggregated findings indicate a strong positive effect size across the dataset, with a weighted mean BCR above 2.0, demonstrating that infrastructure investments in both sectors generally yield substantial net social and economic returns. Transport projects, particularly road rehabilitation and urban transit systems, showed higher consistency and narrower effect size variance compared to utility projects. This can be attributed to the transport sector's reliance on standardized metrics such as travel time savings, fuel efficiency, and accident reduction—benefits that are more easily quantifiable within traditional economic models. In contrast, utility infrastructure projects—encompassing water, sanitation, and electricity systems—displayed greater variability in outcomes due to their dependence on non-market benefit estimation techniques such as willingness-to-pay, avoided cost methods, and contingent valuation. These projects often generated high returns when including health, environmental, and time-use benefits, but their effectiveness was highly sensitive to assumptions regarding user uptake, service reliability, and behavioral change. Another key finding concerns the impact of evaluator identity on CBA credibility. CBAs conducted or supervised by multilateral agencies exhibited greater methodological rigor, transparency in assumptions, and consistent use of sensitivity analysis compared to those produced by national or local governments. Donor-driven evaluations were more likely to apply conservative estimates and conduct thorough risk assessments, thereby reducing the risk of optimism bias. Regional trends also emerged, with Sub-Saharan Africa and South Asia showing higher average BCRs in well-targeted infrastructure projects. However, the analysis also uncovered persistent theoretical ambiguities related to discount rate selection, the valuation of intangible benefits, and the inadequate treatment of uncertainty, revealing systemic gaps in current CBA practices.

Keywords

Cost-Benefit Analysis (CBA); Infrastructure Investment; Developing Economies; Transport and Utility Projects; Sustainable Development

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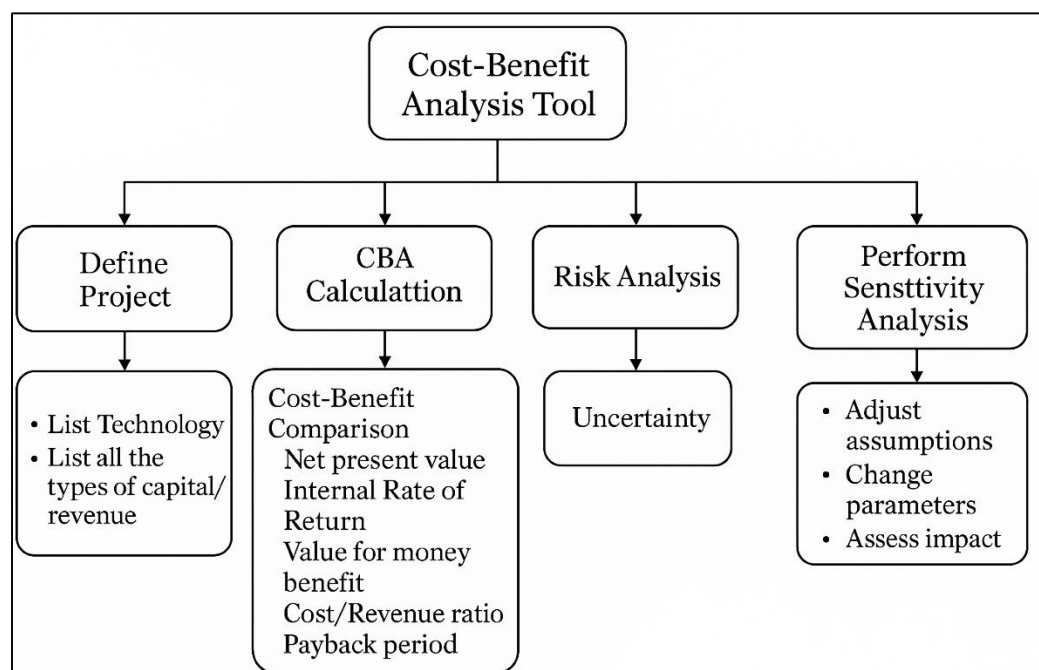
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INTRODUCTION

Cost-Benefit Analysis (CBA) is an economic evaluation method that systematically compares the costs and benefits of a project or policy to determine its feasibility and efficiency (Mann & Levinson, 2024). In the context of infrastructure development, particularly in transport and utilities, CBA serves as a critical decision-making tool to assess whether investments deliver net social value. This method quantifies both monetary and non-monetary factors, converting them into a common unit—typically present value—enabling objective comparison and prioritization (Nguyen et al., 2017). Infrastructure investments, due to their high upfront capital requirements and long operational lifespans, demand rigorous appraisal mechanisms to guide public spending and attract private or multilateral funding (Nguyen et al., 2024). CBA's methodological strength lies in its capacity to incorporate direct, indirect, and intangible impacts, such as time savings, environmental effects, and social welfare gains. As such, it is routinely embedded within project appraisal frameworks developed by the World Bank, the International Monetary Fund (IMF), and national planning commissions. In developing economies, where fiscal constraints and institutional limitations complicate investment decisions, the role of CBA becomes especially pronounced in determining the allocation of scarce resources to competing infrastructure projects (Preciado-Pérez & Fotios, 2017).

Figure 1: Flowchart of the Cost-Benefit Analysis Tool Highlighting Key Phases



Transport and utility infrastructures represent foundational sectors for economic transformation, social equity, and public service delivery across nations (Florio et al., 2018). Roads, railways, power grids, and water supply systems not only facilitate productivity and trade but also serve as enablers of education, healthcare, and safety. Globally, institutions such as the Asian Development Bank (ADB), the African Development Bank (AfDB), and the Inter-American Development Bank (IDB) require detailed CBA as part of loan negotiations for infrastructure development. Transport projects, in particular, rely heavily on metrics like vehicle operating cost savings and travel time reductions, while utilities emphasize consumer surplus, service coverage, and operational efficiency (Nguyen et al., 2017). CBAs are not merely academic exercises; they guide multi-billion-dollar investment portfolios and shape policy directions. For instance, the European Union mandates cost-benefit justifications for Trans-European Transport Network (TEN-T) projects. Empirical studies from countries like India, Kenya, Brazil, and Vietnam confirm that the structured use of CBA contributes to more transparent, equitable, and accountable infrastructure planning (Liu et al., 2025). Nonetheless, outcomes of CBA often vary significantly across project types and regional contexts, necessitating meta-analytical synthesis to derive generalizable conclusions.

Transport infrastructure in developing countries plays a pivotal role in economic integration, poverty reduction, and regional development. Projects such as rural roads, urban transit systems, and cross-border corridors have been widely evaluated using CBA methods to determine their economic viability (Veisten et al., 2024). In Sub-Saharan Africa, CBAs of road rehabilitation projects emphasize travel time savings and agricultural market access as primary benefit streams. In South Asia, particularly in India and Bangladesh, transport CBAs also consider accident reduction, vehicle operating costs, and induced economic activities (Asplund & Eliasson, 2016). However, methodological differences in discount rate selection, traffic forecasting models, and treatment of externalities often result in inconsistent outcome reporting. Moreover, in fragile or post-conflict states, the valuation of non-economic benefits such as social cohesion and improved security access presents additional challenges for CBA practitioners. Infrastructure mega-projects such as the Addis Ababa Light Rail or Pakistan's Motorway Network highlight the divergence between ex-ante and ex-post evaluations, reinforcing the need for a standardized meta-analytical framework. The meta-analysis explores how governance indicators—such as corruption control, regulatory quality, and bureaucratic effectiveness—moderate the predictive validity of CBAs in infrastructure projects (Annema & Koopmans, 2014). Given the vast and varied body of literature on CBAs in infrastructure development, synthesizing empirical findings across different contexts and project types is vital to identify patterns and establish benchmarks. Prior studies on infrastructure outcomes have highlighted the fragmented nature of CBA evaluations, with discrepancies arising from divergent evaluation techniques, data limitations, and context-specific assumptions. For example, CBA outcomes in transport are frequently inflated due to optimistic traffic demand forecasts, while utility sector appraisals often suffer from underestimation of maintenance costs and technical losses. Meta-analysis, as a statistical tool for aggregating and comparing effect sizes, allows for a rigorous examination of whether CBAs consistently demonstrate net positive impacts in resource-constrained settings. This synthesis includes both ex-ante and ex-post CBA evaluations, capturing how initial projections align with realized outcomes and revealing structural biases in project appraisal models.

LITERATURE REVIEW

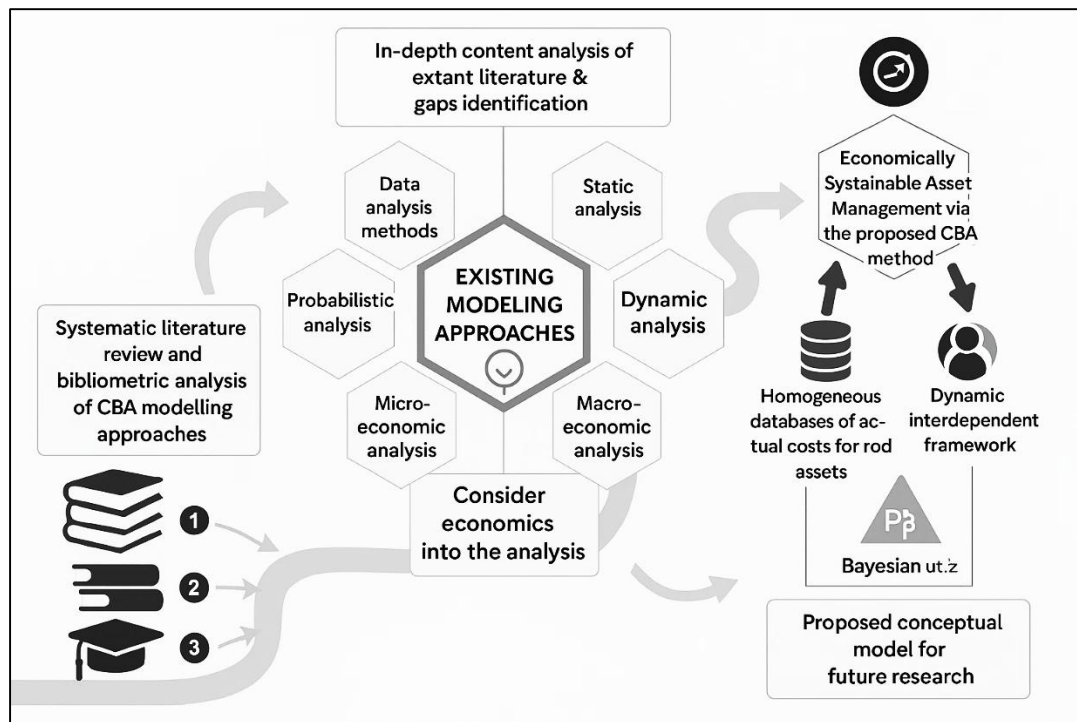
The literature on cost-benefit analysis (CBA) in infrastructure development offers a multifaceted view of its methodologies, sector-specific applications, institutional relevance, and empirical outcomes, particularly within the transport and utility sectors in developing economies. Over the past three decades, researchers, policymakers, and multilateral institutions have increasingly emphasized CBA as an essential tool for justifying infrastructure investments, optimizing public resource allocation, and forecasting socio-economic returns. In developing economies, where public budgets are constrained and the need for critical infrastructure is acute, CBAs serve not only as technical appraisal tools but also as mechanisms for enhancing transparency, accountability, and project prioritization. However, the diversity in methodological frameworks, outcome measures, discounting assumptions, data sources, and governance contexts has resulted in significant variation in reported CBA outcomes. This literature review aims to synthesize existing empirical and theoretical contributions to the field, identify gaps and inconsistencies, and establish the conceptual foundation for a structured meta-analysis. The review is organized into distinct thematic sections, each addressing a specific component of CBA as it relates to infrastructure in transport and utility sectors within developing economies.

Cost-Benefit Analysis in Infrastructure Development

Cost-Benefit Analysis (CBA) is a well-established evaluative framework for assessing the desirability of public investment projects, particularly in infrastructure development where capital outlay is high and impacts are both wide-ranging and long-term (Siddiqui et al., 2024). The theoretical premise of CBA lies in its ability to translate both costs and benefits into a common monetary metric—typically using present value—allowing decision-makers to compare project alternatives based on their net social benefit. In the context of infrastructure projects, which often involve complex interdependencies across transport, utility, and environmental systems, CBA serves to inform policy alignment, fiscal sustainability, and prioritization under constrained budgets (Cabrales et al., 2022). Public agencies and development banks such as the World Bank and ADB frequently mandate the use of CBA to assess road, electricity, water, and sanitation projects in emerging economies (Mann & Levinson, 2024). This evaluative method accommodates not only direct financial flows but also externalities—both positive, such as reduced travel time, and negative, such as environmental degradation—via techniques like shadow pricing and contingent valuation (Liu et al., 2025).

Infrastructure economists argue that CBA adds rationality to project appraisal in environments prone to political bias and populist decision-making. Moreover, its application in integrated planning systems enables comparison across sectors and supports a broader governance mandate for transparent investment. Despite criticism over its assumptions and limitations in capturing equity or intergenerational justice, CBA remains a dominant analytical tool in public finance and infrastructure policy due to its simplicity, adaptability, and alignment with welfare economics principles (Veisten et al., 2024).

Figure 2: Conceptual Framework for Developing a Cost-Benefit Analysis (CBA) Model



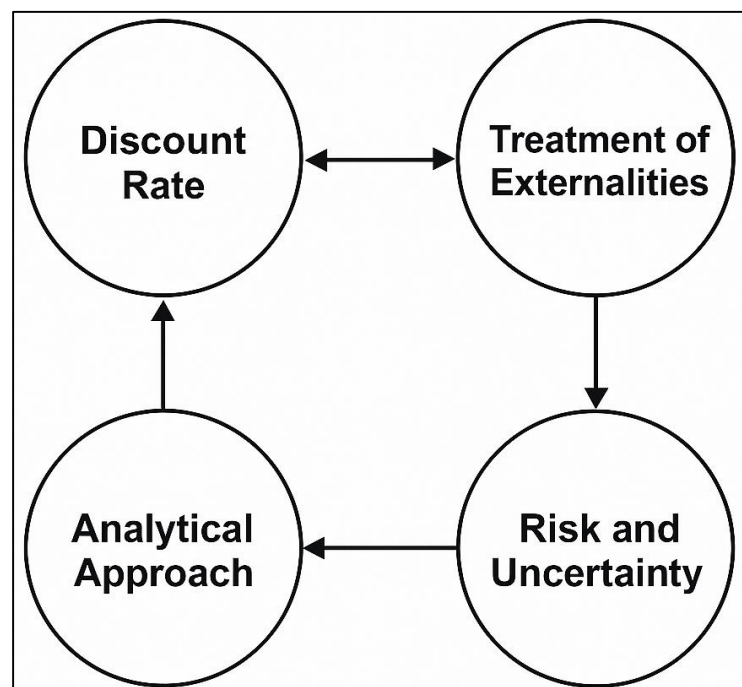
The transport sector has been a primary focus of CBA applications, especially in developing countries where road and transit projects are fundamental to economic growth and regional integration (Asplund & Eliasson, 2016). CBAs in this sector commonly evaluate road construction, rehabilitation, urban transit systems, and rail networks, using metrics such as vehicle operating cost (VOC) savings, time cost reductions, accident prevention, and induced investment effects (Annema & Koopmans, 2014). Numerous studies from Sub-Saharan Africa, South Asia, and Latin America have shown positive benefit-cost ratios in road development projects, particularly when integrated with rural development and trade facilitation programs (Siddiqui et al., 2024). In Kenya, Cabrales et al. (2022) demonstrated that rural road CBAs revealed high returns when agricultural supply chains were explicitly modeled. Similarly, in India, Asplund and Eliasson (2016) found that road CBAs consistently prioritized projects that maximized social inclusion and market accessibility. However, the transport sector is also prone to methodological biases, particularly optimism bias in demand forecasting and underestimation of maintenance costs. Ex-post evaluations often report lower returns than projected ex-ante, raising concerns about the reliability of initial CBA estimates. Studies by Annema and Koopmans (2014) and Cabrales et al. (2022) note that politically motivated mega-projects tend to inflate benefits and suppress long-term costs, undermining the objectivity of the CBA framework. The sector's complexity, including induced travel demand and congestion rebound effects, challenges the assumptions of linear benefit accrual, yet empirical evidence supports the continued relevance of CBA when complemented with sensitivity analysis and probabilistic models.

Methodological Variations in Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) is underpinned by several key assumptions that guide its analytical structure, including the monetization of both tangible and intangible project effects, the use of a social discount rate, and the projection of costs and benefits over a defined time horizon (Valancius et al., 2013). Central to the reliability of any CBA is the estimation of the Net Present Value (NPV),

Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR), all of which rely on assumptions regarding opportunity cost of capital, project lifespan, and baseline scenarios (Marrone et al., 2021). However, methodological diversity becomes evident in how evaluators define cost and benefit categories, determine counterfactuals, and apply valuation techniques for non-market impacts such as environmental quality or public health. Some CBAs adopt financial approaches that prioritize direct revenues and expenditures, while others apply broader economic approaches incorporating shadow pricing and social opportunity costs. Moreover, variations arise in the selection of analytical tools—ranging from deterministic spreadsheets to probabilistic Monte Carlo simulations and real options analysis—that introduce differing levels of complexity and sensitivity in outcomes (Tushar et al., 2022). Researchers such as Abelson (2020) and Annema and Koopmans (2014) argue that methodological opacity and variation across CBAs may lead to outcome manipulation or strategic misrepresentation. Thus, even when the CBA framework is broadly accepted, the analytical choices within it often determine the degree to which results are valid, comparable, or policy-relevant across infrastructure contexts.

Figure 3: Methodological Variations in Cost-Benefit Analysis



One of the most critical methodological variations in CBA is the selection of the discount rate, which directly influences the present value of future costs and benefits (Siddiqui et al., 2024). Discount rates represent the social time preference for consumption and the opportunity cost of capital, but there is no universally accepted rate for public infrastructure projects, especially in developing countries. Some agencies use fixed real rates—commonly 3% to 10%—while others advocate for declining rates over longer time horizons to better account for intergenerational equity. Studies comparing infrastructure CBAs in Latin America and Sub-Saharan Africa show that projects can swing from rejection to approval depending solely on the discount rate applied, highlighting its sensitivity and policy implications (Annema & Koopmans, 2014; de Nooij, 2011). The World Bank and ADB often recommend a range of rates depending on sector and financing structure, but these guidelines are not always consistently applied at national levels. Moreover, some CBAs fail to justify their discount rate selection or conduct sensitivity analysis, reducing transparency and weakening the robustness of conclusions (Jayasena et al., 2022). In energy and utility projects with long lifespans and delayed benefits, such as hydropower or sanitation systems, discount rate assumptions can disproportionately penalize future gains and undervalue sustainability (Locatelli et al., 2020). Researchers such as

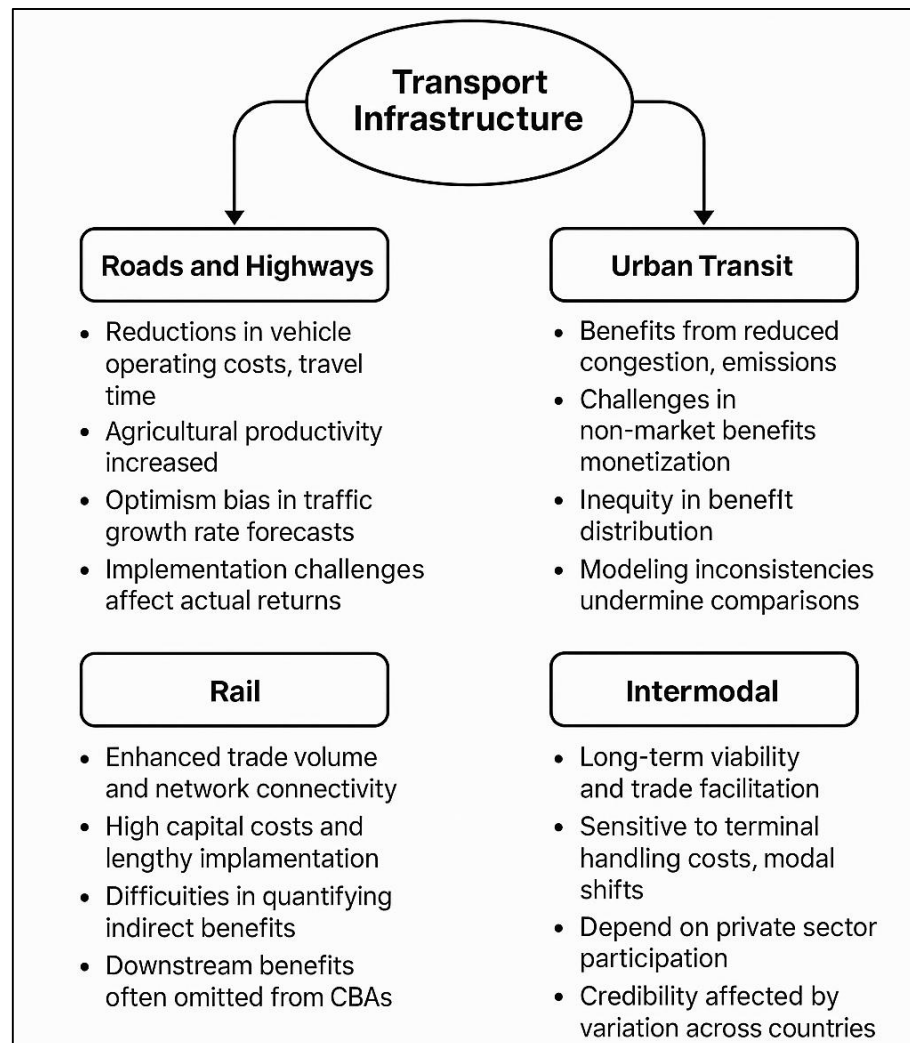
Cabralles et al. (2022) criticize this time-bias as ethically problematic, especially in health and environment-related CBAs.

A fundamental challenge in infrastructure CBA is the incorporation of externalities and intangible impacts, which often lack direct market prices but carry substantial social and environmental significance. Positive externalities such as time savings, health improvements, and increased access to services must be valued using indirect techniques like contingent valuation, hedonic pricing, or revealed preference methods. Negative externalities—such as pollution, displacement, noise, and habitat loss—also require careful modeling, especially in large-scale transport or energy projects. However, methodological gaps persist in how consistently and transparently these are incorporated across CBAs. Some CBAs use overly simplified assumptions, exclude intangible benefits altogether, or rely on outdated valuation coefficients, thus skewing project feasibility assessments (Locatelli et al., 2020). In water infrastructure, for example, willingness-to-pay estimates may be inflated if respondents are not informed of real cost structures or alternative service delivery models (Cabralles et al., 2022). Similarly, in rural electrification CBAs, benefits such as educational attainment or social capital are often discussed but rarely quantified due to lack of longitudinal data (Tushar et al., 2022). Researchers argue that excluding non-market impacts may lead to underinvestment in socially beneficial but financially weak projects, especially in low-income regions (Alghamdi, 2019). Hence, methodological variations in the treatment of externalities present a significant limitation to the comparability and equity of infrastructure CBAs.

Furthermore, risk and uncertainty are intrinsic to infrastructure projects due to their long-time horizons, political exposure, and environmental variability, yet their treatment in CBAs varies widely depending on evaluator capacity and institutional frameworks. Traditional deterministic CBAs rely on single-point estimates for input variables such as traffic volumes, cost streams, or usage rates, which may obscure the likelihood of negative outcomes (Annema & Koopmans, 2014). Advanced methods—such as probabilistic sensitivity analysis, Monte Carlo simulation, and real options valuation—offer improved capacity to model uncertainty and risk-adjusted returns. However, these are rarely used in CBAs conducted in developing economies due to technical and institutional limitations. Multilateral guidelines, including those from the IMF and World Bank, encourage scenario analysis and downside risk modeling, but these are not systematically adopted in domestic infrastructure evaluations. Moreover, few CBAs include sensitivity analysis on key variables such as demand elasticity, capital cost escalation, or interest rate volatility, leading to overconfidence in base-case projections (Siddiqui et al., 2024). Infrastructure CBAs that omit risk valuation often underestimate the probability of implementation failure or long-term financial unsustainability. Scholars argue that incorporating uncertainty more rigorously into CBA frameworks would improve project selection and public accountability by explicitly identifying risk exposure and variability in benefit flows (Nooij, 2011).

Transport Infrastructure and CBA Outcomes

Transport infrastructure plays a foundational role in economic growth, market integration, and regional development, particularly within developing economies where access to roads, railways, and public transport systems directly influences productivity and poverty alleviation. CBAs conducted for transport infrastructure often emphasize vehicle operating cost reductions, time savings, accident reduction, and network connectivity as primary benefit streams (Mulley et al., 2016). Empirical studies have demonstrated that rural road development improves access to education, health services, and agricultural markets, leading to increases in household income and overall economic welfare. In India, Das et al. (2021) found that rural road CBAs identified projects with benefit-cost ratios exceeding 2.5 when market access and labor mobility were incorporated. Similarly, in Vietnam and Bangladesh, government-led road expansion programs showed measurable returns in agricultural productivity and reduced transport costs (Baumgartner et al., 2023). However, these high benefit estimates depend significantly on the assumptions used for traffic growth rates, population density, and economic multipliers (Raslavičius et al., 2014). Moreover, many CBAs exclude broader development outcomes such as regional trade facilitation or urban-rural integration, which may understate the long-term value of transport infrastructure (Mulley et al., 2016). Thus, while CBA remains essential in selecting and ranking transport projects, the literature shows that its effectiveness hinges on comprehensive benefit inclusion and context-sensitive modeling.

Figure 4: Comparative Cost-Benefit Analysis Outcomes Across Transport Infrastructure Modalities

Roads and highways dominate the transport CBA literature due to their wide usage and direct link to economic productivity in both urban and rural areas (Donais et al., 2019). CBAs for road projects typically identify direct benefits from reduced fuel consumption, travel time, and maintenance costs, alongside indirect impacts like increased land value and rural market integration (Gielen et al., 2019). In Sub-Saharan Africa, the Kenya Rural Roads Authority uses CBAs to prioritize rehabilitation projects that yield benefit-cost ratios above 1.5, primarily when agricultural corridors are targeted. In Latin America, road investments have shown substantial economic returns, though ex-post evaluations often reveal overestimated benefits and underestimated costs, driven by optimism bias or political expediency. Studies from Peru and Brazil show that many CBA models rely on outdated traffic demand forecasts and ignore post-construction maintenance, resulting in financial sustainability issues over time (Stokoe, 2019). Sensitivity analysis is also inconsistently applied; many CBAs assume uniform cost elasticity and traffic growth across regions, leading to distorted feasibility results (Dampier & Marinov, 2015). Furthermore, implementation variance—due to project delays, corruption, or technical deficiencies—frequently alters the actual economic returns from what was projected. Thus, while roads continue to be CBA's most frequent application area, the literature stresses the need for robust assumptions, post-project evaluation, and realistic sensitivity testing to improve its reliability in real-world development planning.

Urban transit infrastructure—such as metro rail, bus rapid transit (BRT), and light rail—presents a more complex landscape for CBA, given the multiplicity of stakeholders, non-market benefits, and dense urban externalities involved (Kin et al., 2017). CBAs in this domain often integrate benefits from

reduced congestion, lower emissions, travel time savings, and improved accessibility, but monetizing these effects remains challenging. For instance, BRT projects in cities like Bogotá, Lagos, and Jakarta have reported high BCRs in initial assessments, yet actual outcomes showed discrepancies due to implementation inefficiencies and underestimated maintenance needs (Wang & Levinson, 2022). Urban CBAs also struggle with distributional equity, where gains accrue disproportionately to wealthier commuters or central districts, unless spatial equity is explicitly modeled. Furthermore, methodological inconsistencies—such as inconsistent demand modeling, failure to integrate land use effects, and undervaluation of time savings for informal transport users—undermine comparability across urban CBAs (Donais et al., 2019). The use of generalized cost modeling and elasticity-based forecasting varies widely, with some projects adopting advanced multi-criteria analysis alongside CBA to capture broader socioeconomic benefits (Behiri et al., 2018). Projects such as the Addis Ababa Light Rail and the Delhi Metro have prompted scholarly debate on the limits of CBA in fast-growing cities, especially where socio-political goals such as urban inclusion or climate mitigation are prioritized over narrow cost-efficiency. Thus, the urban transport literature reveals that while CBA provides a structured framework for investment appraisal, its application must be adapted to the nuanced realities of urban complexity and mobility justice.

Rail and intermodal transport projects, including dry ports and logistics corridors, are increasingly subjected to CBA due to their strategic value in facilitating trade and regional connectivity (Pereira et al., 2021). These projects involve high capital costs and long implementation periods, which require CBAs to incorporate broader macroeconomic benefits such as reduced logistics costs, enhanced trade volume, and regional GDP growth (Donais et al., 2019). For example, the East African Railway Master Plan used scenario-based CBAs to estimate cross-border freight efficiencies and competitiveness gains, factoring in network effects and customs facilitation. However, methodological hurdles include quantifying indirect benefits across jurisdictions, coordinating data from multiple national sources, and harmonizing assumptions on trade elasticity and regional demand. In Pakistan, the CPEC railway corridor CBA showed strong NPV and BCR under ideal trade flow scenarios but failed to integrate geopolitical risk and debt service volatility. Moreover, CBAs for rail infrastructure often omit downstream benefits such as reduced road congestion, lower accident rates, or air quality improvements due to complexity in attribution. Intermodal CBAs are particularly sensitive to terminal handling costs, modal shift assumptions, and private-sector participation, which vary significantly across countries and affect outcome credibility (Wang & Levinson, 2022). Therefore, while CBAs for rail and intermodal systems offer insights into long-term strategic viability, the literature suggests that their effectiveness is contingent on multi-sector modeling, regional policy coordination, and harmonized data frameworks across borders (Behiri et al., 2018).

Utility Infrastructure and CBA Applications

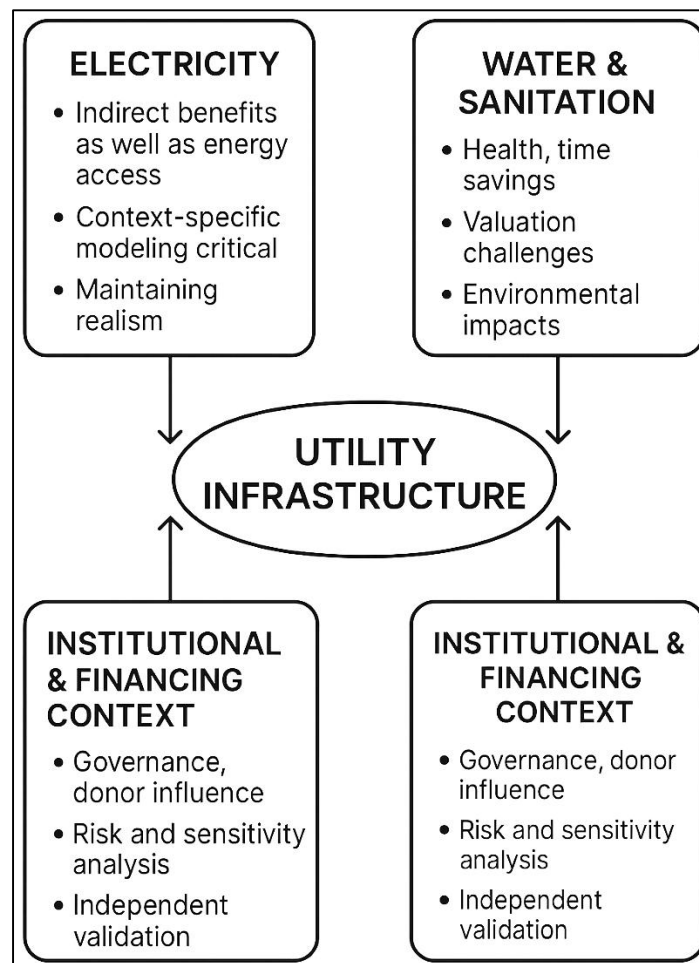
Utility infrastructure—which encompasses electricity, water supply, sanitation, waste management, and renewable energy—is critical to socioeconomic development and public health outcomes in both urban and rural settings (Nguyen et al., 2017). Unlike transport projects where benefits are often immediate and market-mediated, utility infrastructure involves multidimensional and frequently non-monetized benefits, which require careful methodological treatment in cost-benefit analysis. In rural electrification programs, for example, benefits extend beyond energy access to include productivity enhancements, education, health, and gender equity—effects that traditional CBAs often undervalue or exclude. Likewise, investments in water and sanitation improve health outcomes by reducing waterborne disease and improving hygiene practices, outcomes that are commonly valued using willingness-to-pay or avoided cost methods. However, challenges arise due to limited baseline data, difficulties in capturing behavioral responses, and regional variability in utility demand (Woolf et al., 2021). Moreover, CBAs often neglect equity considerations, such as access gaps between urban and rural users or gender-specific time burdens related to water collection. Studies from Kenya, India, and Bolivia highlight that well-conducted CBAs in the utility sector can reveal benefit-cost ratios exceeding 3.0 when health and productivity impacts are fully included. Thus, the utility sector demands CBAs that can accommodate intangible outcomes, heterogeneous user needs, and nonlinear benefit realization timelines to ensure informed investment decisions.

Electricity infrastructure—especially rural electrification and grid extension—has been a prominent focus of CBAs due to its perceived role in accelerating income generation, improving living standards, and reducing reliance on biomass fuels. Empirical CBAs from countries like Tanzania, Nepal, and Bangladesh demonstrate that electrification projects generate positive NPVs and BCRs

when the analysis includes indirect benefits such as improved school attendance, nighttime business operations, and reduced indoor air pollution. Yet methodological heterogeneity persists in estimating these outcomes. Some studies rely on direct revenue projections, while others apply proxy indicators or revealed preference approaches to estimate household-level utility (Adamowicz et al., 1994). Shadow pricing is often applied to account for subsidies, foreign exchange distortions, or imported capital goods, but inconsistent application across CBAs reduces comparability. Additionally, capacity factors, technical losses, and system reliability significantly influence net benefits but are frequently omitted or standardized without justification. In West Africa, several World Bank-funded CBAs reported overestimated BCRs due to failure to include high maintenance costs and weak tariff collection systems (Di Placido et al., 2014). Conversely, donor-supervised CBAs from Ethiopia and Rwanda demonstrated stronger methodological rigor and conservative benefit projections due to independent reviews and adherence to multi-scenario modeling. Therefore, while electrification CBAs broadly support investment cases, their methodological robustness depends heavily on context-specific modeling of indirect benefits, risk factors, and economic linkages.

Water supply and sanitation (WSS) projects are widely evaluated using CBA, primarily due to their substantial health and time-saving benefits, particularly for women and children in underserved regions (Weigel et al., 2021). Studies from South Asia, East Africa, and Latin America consistently show that piped water systems and latrine installations reduce diarrheal disease incidence, child mortality, and time spent collecting water, which translate into large economic benefits when properly quantified (El-Khozondar et al., 2022). For instance, Yu et al. (2023) reported BCRs between 2 and 6 for water infrastructure in low-income Asian countries when health and education spillovers were accounted for. However, CBAs in the WSS sector often struggle with assigning monetary values to non-market outcomes such as dignity, hygiene, or empowerment, which results in underreported benefits (Fessler et al., 2022). Some studies use cost-of-illness methods or time-use valuation, but there is wide variation in wage proxy rates and assumptions about household behavior (Weigel et al., 2021). Moreover, environmental benefits such as groundwater recharge, pollution reduction, and ecosystem preservation are rarely monetized, leading to a narrow representation of sustainability in CBAs. In Bolivia, sanitation CBAs conducted by WHO/UNICEF incorporated avoided medical costs and productivity gains but struggled with standardizing hygiene behavior changes across regions. Maintenance costs and user compliance rates are also inconsistently modeled, undermining financial sustainability projections.

Institutional quality, financing mechanisms, and donor engagement have a substantial influence on the rigor and credibility of CBAs in utility infrastructure (Fessler et al., 2022). Multilateral development banks like the World Bank, ADB, and AfDB often require detailed CBAs as part of project appraisal and disbursement processes, enforcing methodological standardization through operational toolkits and peer review systems. CBAs conducted under donor frameworks tend to include comprehensive risk analysis, sensitivity testing, and stakeholder engagement, resulting in more conservative and transparent outcome projections. In contrast, CBAs prepared by national agencies without external supervision frequently exhibit inflated BCRs, limited risk modeling, and insufficient disaggregation of socio-economic impacts. For example, in rural water projects in Ethiopia and Nepal, donor-conducted CBAs reported higher implementation costs but more realistic net benefits due to better data triangulation and probabilistic modeling. Financing sources also shape methodological choices: grant-funded projects may undervalue long-term operational costs, while PPP-based CBAs often emphasize financial feasibility over broader socio-environmental gains. Moreover, governance challenges such as rent-seeking, technical mismanagement, or regulatory fragmentation can distort input data and undermine the integrity of CBA processes. Studies from Uganda, Pakistan, and Indonesia suggest that independent validation and transparency in assumptions are crucial to mitigating institutional biases and ensuring that CBAs guide accountable infrastructure decisions (Di Placido et al., 2014). Thus, while utility CBAs have evolved significantly in scope and precision, their effectiveness depends on the interplay between methodological integrity, financing context, and institutional governance.

Figure 5: Cost-Benefit Analysis Applications in Utility Infrastructure

Sectoral Comparison of CBA Effectiveness

The comparative effectiveness of cost-benefit analysis (CBA) across transport and utility sectors is shaped by fundamental differences in outcome structures, data requirements, and sectoral objectives. Transport infrastructure CBAs primarily emphasize quantifiable benefits such as travel time reduction, vehicle operating cost savings, accident prevention, and network connectivity, which are generally easier to monetize and model. In contrast, CBAs in utility sectors like water, sanitation, and electricity must account for a broader array of outcomes—ranging from improved health and productivity to environmental quality and time savings—that are often non-market and less directly measurable. Empirical comparisons show that transport projects yield higher consistency in benefit-cost ratios (BCRs) due to standardized input variables and well-established appraisal frameworks (Weigel et al., 2021). For instance, rural road projects in Sub-Saharan Africa and South Asia routinely report BCRs above 2.0 based on travel cost and agricultural trade enhancements. Meanwhile, utility CBAs tend to show wider variability in BCRs, particularly when intangible benefits like avoided illness, school attendance, and gender equity are included or excluded. The divergence in benefit valuation approaches—revealed preference for transport vs. contingent valuation for utilities—also complicates direct comparison. This discrepancy in monetization methodology underscores a key challenge in cross-sectoral CBA comparison: transport evaluations are typically rooted in engineering economics, whereas utility assessments integrate public health, environmental, and social science disciplines.

Sectoral differences in the sensitivity of CBA outcomes to contextual factors are another critical dimension in assessing comparative effectiveness. Transport infrastructure projects, particularly roads and highways, are highly sensitive to assumptions regarding traffic growth, fuel prices, and maintenance regimes. Poor forecasting or unrealistic assumptions in traffic volumes can significantly

inflate benefit estimates, as evidenced in ex-post studies from Latin America and South Asia (Di Placido et al., 2014). In contrast, utility infrastructure CBAs often rely on epidemiological data, time-use surveys, and usage projections that are vulnerable to socio-behavioral variability, local cultural practices, and service adoption rates. For example, sanitation projects in rural areas may fail to realize projected benefits if behavioral change is insufficient, even if access infrastructure is provided. Moreover, implementation environments differ markedly: transport projects are often large-scale, centralized, and state-managed, whereas utility services may involve community-based, decentralized models with varying degrees of user participation and ownership (DeLone & McLean, 2003). These variations affect CBA parameters such as operation and maintenance (O&M) costs, compliance rates, and benefit duration. Additionally, donor-led CBAs in both sectors exhibit greater methodological rigor but also show sectoral bias: multilateral agencies tend to prioritize transport investments for regional integration, while non-governmental and bilateral donors emphasize utilities for social development outcomes (Nguyen et al., 2017). Thus, sensitivity to contextual dynamics and implementation conditions influences the predictive reliability and policy relevance of CBAs across sectors.

Transport and utility CBAs diverge significantly in their ability and willingness to incorporate externalities and intangible benefits, contributing to differing levels of effectiveness. Transport CBAs generally focus on measurable, short-to-medium-term impacts such as congestion relief and travel time savings, often underrepresenting environmental degradation, noise pollution, and community displacement (Nguyen et al., 2017). External costs such as increased carbon emissions from road expansion are rarely monetized, and land use change or induced demand is often excluded due to modeling complexity. In contrast, utility CBAs, particularly those in water and sanitation, actively attempt to monetize health impacts, ecosystem restoration, and time-use changes, though with varying methodological robustness. For instance, studies from Bolivia, Ethiopia, and Kenya demonstrate that utility CBAs that include productivity gains from reduced illness and educational attainment from improved water access yield significantly higher BCRs (Fessler et al., 2022). However, valuation techniques such as willingness-to-pay surveys are often context-specific and can introduce bias or unreliability. Furthermore, utility CBAs frequently integrate equity and pro-poor analysis, identifying distributional benefits to women and low-income groups—dimensions rarely addressed in transport CBAs. This difference reflects a broader divergence in appraisal philosophy: transport CBAs aim for economic efficiency, while utility CBAs incorporate elements of social welfare and human development. Therefore, while both sectors deploy CBA as a decision-support tool, their differential treatment of externalities significantly affects their comprehensiveness and social responsiveness.

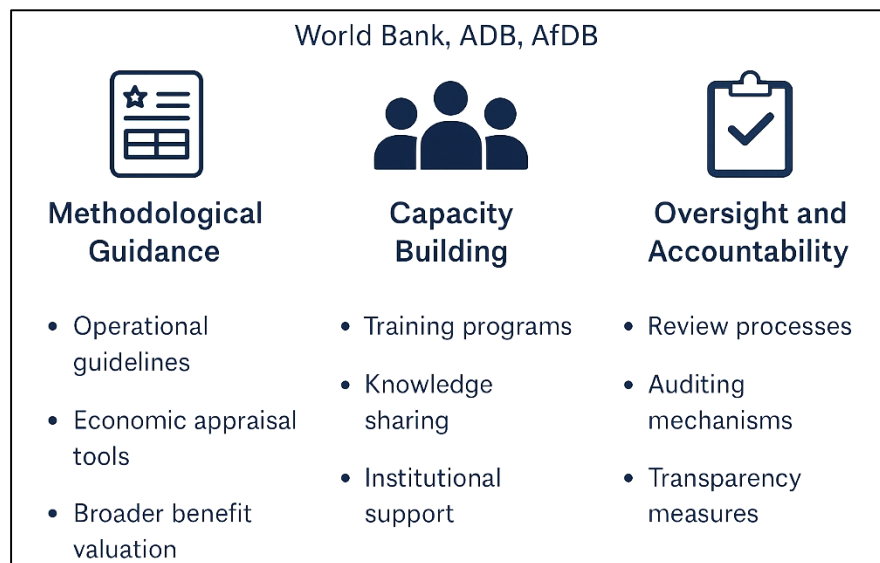
Institutional frameworks and policy alignment also influence the comparative effectiveness of CBAs across transport and utility sectors. Transport infrastructure planning tends to be embedded in national development strategies and public investment management systems with relatively standardized procedures, making CBAs more predictable and comparable across projects and countries (Annema & Koopmans, 2014). National ministries of transport often possess dedicated planning units with capacity for traffic modeling, engineering cost estimation, and environmental risk assessment, thereby improving the consistency of CBAs. By contrast, utility infrastructure planning is more fragmented, often involving local governments, NGOs, and private utilities with varying appraisal capacities and institutional mandates (Johnson et al., 2021). This fragmentation affects the rigor of CBAs and creates disparities in data availability, stakeholder engagement, and risk modeling. For example, water utilities in decentralized systems may lack the analytical capability to produce multi-scenario CBAs or to incorporate lifecycle costing. Moreover, political interference in utility pricing, especially for water and electricity, undermines the reliability of projected revenues and cost recovery estimates (Annema & Koopmans, 2014). Donor-driven CBAs attempt to mitigate these issues through standardized guidelines and independent review processes, but institutional disparities remain a key constraint. Policy alignment also differs: while transport CBAs often align with regional trade or industrial strategies, utility CBAs are more closely tied to health, education, and climate agendas (Swann et al., 2021). Consequently, the institutional and policy ecosystems in which CBAs are conducted play a central role in shaping their effectiveness, with transport projects benefiting from more structured frameworks, while utility projects face greater methodological and operational diversity.

Figure 6: Sectoral Comparison of Cost-Benefit Analysis Effectiveness in Transport and Utility Infrastructure Projects

Dimension	Transport Infrastructure	Utility Infrastructure
Benefits	Primarily quantifiable benefits	Broader array of outcomes
Sensitivity	Sensitive to assumptions about traffic growth, fuel prices, maintenance	Influenced by socio-behavioral variability, local practices
Treatment of Externalities	Often underrepresent environmental and social impacts	Attempt to monetize health impacts, equity benefits
Institutional Frameworks	Standardized planning units	Fragmented planning across local governments, NGOs

Role of Multilateral Agencies in CBA Rigor

Multilateral development agencies such as the World Bank, Asian Development Bank (ADB), African Development Bank (AfDB), and Inter-American Development Bank (IDB) have played a central role in formalizing and standardizing the methodological rigor of cost-benefit analysis (CBA) in infrastructure projects, particularly in developing economies. These institutions provide detailed operational guidelines and toolkits that outline acceptable practices for estimating costs, valuing benefits, discounting future flows, and accounting for externalities (Guo et al., 2019). The World Bank's "Economic Analysis Guidance Note," for instance, mandates the use of sensitivity analysis, probabilistic risk assessment, and scenario testing to strengthen the robustness of CBAs (Evangelista et al., 2020). Such methodological frameworks are intended to reduce arbitrariness in project evaluations and ensure transparency and replicability of results. The ADB's approach integrates economic internal rate of return (EIRR) benchmarks, shadow pricing tools, and distributional analysis models, which elevate the technical standard of project appraisals. Moreover, these agencies require the valuation of indirect and non-market benefits, including environmental and social outcomes, thus broadening the traditional scope of CBA. Studies comparing donor-supported CBAs with those prepared by national governments show that the former are more likely to apply rigorous valuation techniques, include stakeholder consultations, and document assumptions (Chen et al., 2019). Hence, the methodological architecture provided by multilateral institutions has been instrumental in institutionalizing good practices in economic appraisal and elevating the analytical quality of infrastructure CBAs across sectors and countries.

Figure 7: Role of Multilateral Agencies in Enhancing Cost-Benefit Analysis (CBA) Rigor for Infrastructure Projects

Beyond technical toolkits, multilateral agencies contribute to the rigor of CBAs by investing in institutional capacity building, knowledge dissemination, and peer learning among borrower countries. Programs such as the Public Investment Management Assessment (PIMA) by the International Monetary Fund (IMF) and the Results-Based Lending (RBL) framework by the World Bank include performance-based mechanisms for improving economic appraisal systems. These initiatives emphasize not only the conduct of CBAs but also the development of national frameworks for project preparation, appraisal review, and post-implementation evaluation. Capacity-building workshops, training manuals, and regional conferences have been instrumental in enhancing local expertise in applying CBA methodologies, particularly in fragile and low-income states. For instance, in East Africa, the AfDB has supported training for public officials on transport project CBAs, incorporating modules on data collection, modeling software, and environmental valuation ([Awad et al., 2022](#)). The ADB's Economic Research and Regional Cooperation Department has developed sector-specific appraisal modules to support utility project CBAs in Asia and the Pacific ([Masson et al., 2017](#)). Furthermore, multilateral support enhances institutional memory and continuity, which is often weak in national planning agencies due to staff turnover and political instability ([He et al., 2018](#)). Evidence from evaluations in Ghana, Nepal, and Indonesia shows that donor-assisted CBAs are more likely to feature comprehensive documentation, sensitivity testing, and follow-up mechanisms. Thus, multilateral involvement is not confined to technical guidance but also supports the broader institutionalization of evidence-based investment planning in developing economies. Multilateral agencies reinforce CBA rigor through robust oversight and auditing structures designed to identify inconsistencies, methodological flaws, or data manipulation in project appraisals ([Ma et al., 2023](#)). Project proposals financed through these agencies are typically subject to multi-tiered approval processes that include economic evaluation reviews, independent verification, and sometimes third-party audits ([Masson et al., 2017](#)). For instance, the World Bank's Independent Evaluation Group (IEG) regularly audits the economic analysis components of projects to assess alignment with methodological standards and to verify reported outcomes ([Iturrate et al., 2015](#)). The ADB similarly employs post-evaluation ratings on the quality and reliability of CBAs submitted as part of loan agreements. These accountability structures serve to enhance project credibility, reduce the risk of politically motivated overestimations, and provide feedback loops for methodological improvement. The presence of clear audit trails and disclosure requirements also promotes transparency, allowing for peer scrutiny and stakeholder engagement ([Tushar et al., 2022](#)). For example, donor CBAs are more likely to disclose assumptions on discount rates, demand forecasts, cost escalations, and risk parameters compared to nationally funded projects with limited documentation. Oversight mechanisms also support the incorporation of sustainability and gender equity criteria into CBAs, which are often neglected in unsupervised evaluations. Therefore, the role

of multilateral auditing is not only to enforce compliance but to continually enhance the analytical precision and inclusivity of infrastructure CBAs.

CBA and AI in Infrastructure Planning

Cost-Benefit Analysis (CBA) has traditionally served as a foundational tool in public sector decision-making, particularly in infrastructure planning, by comparing the projected benefits of a project with its associated costs (Abdullah Al et al., 2022; Subrato, 2018). However, the accuracy and timeliness of CBA have long been constrained by data limitations, subjective assumptions, and human-induced bias in estimation procedures (Jahan et al., 2022; Hosne Ara et al., 2022; Khan et al., 2022). The integration of Artificial Intelligence (AI) into CBA frameworks offers a transformative opportunity to enhance the objectivity, speed, and adaptability of infrastructure evaluations. AI systems, particularly those leveraging machine learning and predictive analytics, can support dynamic scenario analysis, real-time data integration, and probabilistic modeling, thereby overcoming static models traditionally used in CBAs (Rahaman, 2022; Masud, 2022; Hossen & Atiqur, 2022). The proposed figure illustrates a conceptual framework where AI tools are layered into each stage of the CBA process—from data acquisition and benefit estimation to sensitivity analysis and stakeholder engagement (Sazzad & Islam, 2022; Shaiful et al., 2022; Akter & Razzak, 2022).

Artificial intelligence can enhance multiple phases of CBA methodology, starting with automated data collection from diverse sources such as IoT devices, satellite imagery, social media feedback, and real-time traffic or utility usage data (Qibria & Hossen, 2023; Maniruzzaman et al., 2023; Masud, Mohammad, & Hosne Ara, 2023). During benefit estimation, AI-powered econometric models can provide adaptive projections that incorporate new data, facilitating more accurate modeling of indirect and intangible benefits (Md Masud, Mohammad, & Sazzad, 2023; Hossen et al., 2023; Ariful et al., 2023). In cost modeling, AI can help predict lifecycle costs by analyzing historical infrastructure maintenance datasets, detecting risk signals, and simulating cost escalations under uncertain conditions (Shamima et al., 2023; Alam et al., 2023; Rajesh, 2023). The figure emphasizes how AI-powered decision support systems integrate Monte Carlo simulations, agent-based modeling, and reinforcement learning to improve sensitivity analysis and scenario testing—processes often underutilized or performed heuristically in traditional CBAs (Rajesh et al., 2023; Rezwanul Ashraf & Hosne Ara, 2023; Roksana, 2023). These capabilities not only enhance analytical rigor but also increase the responsiveness of evaluations to stakeholder inputs and contextual changes (Sanjai et al., 2023; Tonmoy & Arifur, 2023).

Another key contribution of AI to CBA lies in enhancing transparency and reducing decision-making bias. Traditional CBAs have been critiqued for opaque assumptions and political influence, particularly when used to justify large-scale infrastructure investments (Tonoy & Khan, 2023; Zahir et al., 2023). AI-driven auditing mechanisms, such as anomaly detection algorithms and explainable AI (XAI) models, can flag inconsistencies in data or highlight implicit weighting of benefits across demographic groups (Razzak et al., 2024). This transparency facilitates better stakeholder engagement, allowing for the democratization of infrastructure planning and reducing the likelihood of resource misallocation. The figure underscores this function by placing AI-based validation modules alongside each critical stage of appraisal. Tools such as natural language processing (NLP) can also be used to synthesize public feedback or regulatory texts, helping planners align project evaluations with social preferences and legal frameworks (Alam et al., 2024; Khan & Razee, 2024). As public trust in infrastructure decisions often hinges on the perceived fairness of appraisals, AI's role in ensuring traceability and auditability becomes a strategic enabler of participatory governance (Saha, 2024).

While the potential of AI-enhanced CBA is significant, its implementation in developing economies poses institutional and technical challenges. Limited data infrastructure, insufficient technical capacity, and lack of governance frameworks often hinder AI adoption in public sector planning (Khan, 2025; Masud et al., 2025; Md et al., 2025). The figure includes pathways for technical capacity building and international collaboration, highlighting the role of multilateral institutions in supporting digital transformation in economic appraisal systems. Cloud-based platforms and open-source AI libraries offer scalable, cost-effective solutions for governments seeking to integrate AI without extensive in-house resources (Sazzad, 2025). Furthermore, donor agencies such as the ADB and World Bank can act as intermediaries, embedding AI tools into existing CBA templates and providing training on ethical use and bias mitigation. The conceptual framework thus addresses both

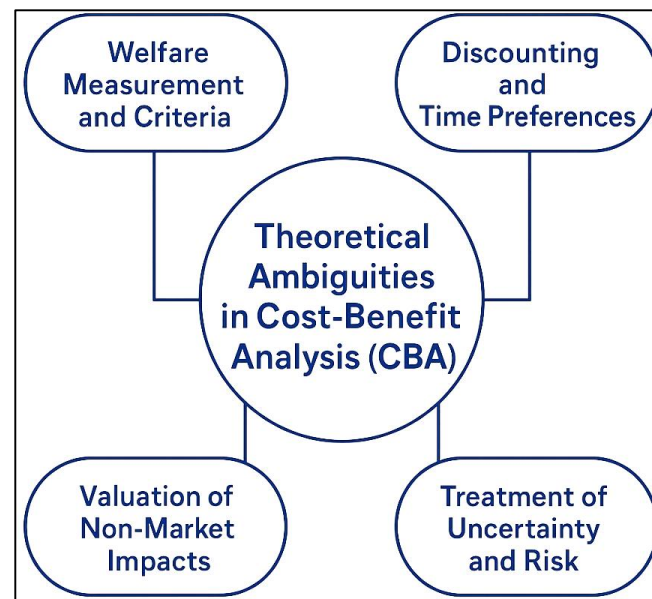
functional integration and policy readiness, enabling a phased approach to AI deployment in infrastructure appraisal.

The integration of AI into CBA frameworks has the potential to redefine how governments and development agencies prioritize infrastructure investments. By incorporating real-time analytics, dynamic simulations, and stakeholder sentiment analysis, AI can make CBA more predictive, inclusive, and forward-looking (Akter, 2025; Zahir et al., 2025). The figure serves as a strategic visualization of this shift, offering policymakers a blueprint for transitioning from static, spreadsheet-based evaluations to agile, AI-enhanced decision environments. This transformation can lead to more resilient infrastructure portfolios, better risk-adjusted returns, and stronger alignment with sustainability and equity goals. Importantly, the framework also incorporates feedback loops and post-implementation learning, enabling adaptive policy design. As AI continues to evolve, its synergy with CBA could make economic evaluation not just a validation tool, but a proactive instrument for strategic development planning.

Theoretical Ambiguities in CBA Literature

Cost-benefit analysis (CBA) is fundamentally rooted in welfare economics, aiming to maximize social welfare by evaluating the net benefits of public projects or policies. However, ambiguities arise from differing interpretations of what constitutes welfare and how it should be measured and aggregated (Valancius et al., 2013). The traditional utilitarian foundation of CBA emphasizes Pareto efficiency—allocating resources to maximize utility without making anyone worse off—but most real-world applications adopt a Kaldor-Hicks criterion, where gains to winners can hypothetically compensate the losers. This shift introduces ethical and practical ambiguities, particularly when benefits and costs are unevenly distributed across populations. CBAs typically aggregate monetary values across individuals without considering income inequality or the marginal utility of income, leading to the implicit privileging of wealthier stakeholders whose willingness to pay is higher (Nocera & Cavallaro, 2013). Moreover, theoretical debates persist regarding the treatment of non-use values, such as biodiversity conservation or cultural heritage, which challenge the monetization assumptions of neoclassical welfare economics. Critics argue that these foundational inconsistencies undermine the normative legitimacy of CBA, especially when applied to projects with profound ethical, social, or environmental implications. The theoretical literature continues to question whether CBA can be both a decision rule grounded in market logic and a socially responsive evaluation tool for public sector investment.

The application of discounting in CBA has been a persistent source of theoretical ambiguity, particularly concerning intergenerational projects such as infrastructure development, climate mitigation, and long-term public health interventions. The choice of discount rate significantly affects the net present value (NPV) of future benefits, often diminishing the weight of long-term environmental or social gains in favor of immediate, monetizable returns (Kinderen et al., 2022). This time preference introduces a normative dilemma: should present-day preferences dictate the valuation of impacts on future generations? Critics argue that the conventional use of fixed positive discount rates leads to systematic underinvestment in sustainability-oriented infrastructure (Ma & Peng, 2021). Alternatives such as declining discount rates, intergenerational equity-adjusted rates, or dual discounting frameworks have been proposed, but no consensus has emerged regarding their theoretical justification or empirical implementation. Moreover, many CBAs fail to disclose the rationale for their chosen discount rates or to conduct sensitivity analysis, leaving critical assumptions unchallenged. In sectors such as water, sanitation, or renewable energy, where the bulk of benefits accrue over decades, this practice can distort prioritization decisions (Chastas et al., 2018). The theoretical literature is divided on whether discounting should reflect opportunity cost, social preferences, or ethical considerations, reflecting broader tensions between market efficiency and moral responsibility in public decision-making. Thus, while discounting remains a core feature of CBA, its conceptual underpinnings remain contested and unresolved, particularly when long-term impacts and generational justice are at stake.

Figure 8: Theoretical Ambiguities in Cost-Benefit Analysis

One of the most enduring theoretical ambiguities in CBA literature concerns the valuation of non-market and intangible benefits, which are central to many infrastructure and social service projects but often difficult to quantify with conventional economic tools (Alghamdi, 2019). These include health improvements, environmental preservation, educational attainment, social cohesion, and psychological well-being—factors that are frequently central to the rationale for public investment (Annema & Koopmans, 2014). Approaches such as contingent valuation, hedonic pricing, and willingness-to-pay surveys have been developed to capture these benefits, but each comes with methodological and ethical limitations (Siddiqui et al., 2024). For instance, willingness-to-pay measures are influenced by ability to pay, potentially undervaluing benefits to poorer populations and exaggerating those accruing to wealthier groups. Additionally, many intangible outcomes—such as dignity, empowerment, or reduced anxiety—do not lend themselves easily to economic quantification, leading to their exclusion or token treatment in CBAs. Even when included, intangible values are often derived from studies in high-income contexts, raising questions about transferability and cultural validity in low- and middle-income countries. The theoretical debate continues over whether CBA should be expanded to include qualitative or multi-criteria analysis elements, or whether such hybrid models dilute its conceptual clarity. The tension between analytical rigor and inclusive valuation remains unresolved, reflecting deeper philosophical questions about the nature and limits of monetization in public decision-making frameworks.

Theoretical ambiguity also surrounds how CBA should address uncertainty, especially in the context of irreversible investments, unknown future states, and systemic risks (Nooij, 2011). Traditional CBAs often rely on deterministic estimates, using point forecasts for key variables such as costs, benefits, demand, and timeframes. This practice overlooks the probabilistic nature of real-world events, particularly in complex infrastructure systems subject to political instability, climate variation, or technological disruption. While sensitivity analysis and scenario modeling are increasingly recommended in donor guidelines, many CBAs either fail to implement them or do so superficially, without probabilistic justification. Advanced techniques such as Monte Carlo simulation, real options analysis, and Bayesian modeling have been proposed as more theoretically robust alternatives, but they remain underutilized due to technical complexity and institutional constraints. Moreover, infrastructure projects often involve irreversible decisions—such as dam construction or highway alignment—where delay or abandonment is costly, yet traditional CBA does not adequately account for option value or precautionary principles (Troncia et al., 2023). Theoretical literature highlights that risk-neutral assumptions embedded in standard CBA may lead to suboptimal or inequitable outcomes under high uncertainty conditions. Furthermore, there is limited consensus on how to integrate catastrophic risk or low-probability, high-impact events—such as pandemics or natural disasters—into economic appraisals. These gaps suggest that the theoretical basis of CBA is

not fully equipped to address the complexity and dynamism of modern infrastructure challenges, calling into question its sufficiency as a standalone decision-making framework.

METHOD

This study adopts a meta-analytical approach to synthesize the outcomes of cost-benefit analyses (CBAs) conducted in the infrastructure domain, specifically focusing on transport and utility projects within developing economies. Meta-analysis is a quantitative research synthesis technique that aggregates findings from multiple empirical studies to estimate overall effect sizes, examine heterogeneity, and explore moderators that influence variations in outcomes. Given the significant variability in methodological designs, valuation assumptions, and outcome reporting in CBA literature, a meta-analysis provides a systematic and statistically grounded framework for summarizing the magnitude and reliability of reported economic performance indicators, such as Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR).

Study Identification and Search Strategy

A comprehensive literature search was conducted across multiple academic databases, including Scopus, Web of Science, JSTOR, EconLit, ScienceDirect, and Google Scholar, as well as development institution repositories such as the World Bank Open Knowledge Repository, ADB Project Data Portal, and AfDB Project Appraisal Reports. The search strategy combined keywords such as "cost-benefit analysis," "CBA," "infrastructure evaluation," "transport projects," "utility infrastructure," "developing countries," "BCR," "NPV," and "economic appraisal." Only empirical studies published between 2000 and 2024 were included to reflect contemporary appraisal practices and discounting frameworks. Additional grey literature such as evaluation reports from donor-funded projects, government planning documents, and sectoral reviews were also screened to minimize publication bias.

Inclusion and Exclusion Criteria

To ensure methodological consistency and relevance, the following inclusion criteria were applied: (1) the study must report at least one economic performance metric (e.g., BCR, NPV, or IRR); (2) the infrastructure project must belong to the transport (roads, rail, urban transit) or utility (water, sanitation, electricity) sectors; (3) the geographic scope must be limited to low- and middle-income countries as classified by the World Bank; and (4) sufficient statistical or contextual information must be available to extract effect sizes. Exclusion criteria included theoretical papers without empirical data, studies from high-income countries, CBAs lacking outcome metrics, and duplicate evaluations of the same project across different publications.

Data Extraction and Coding

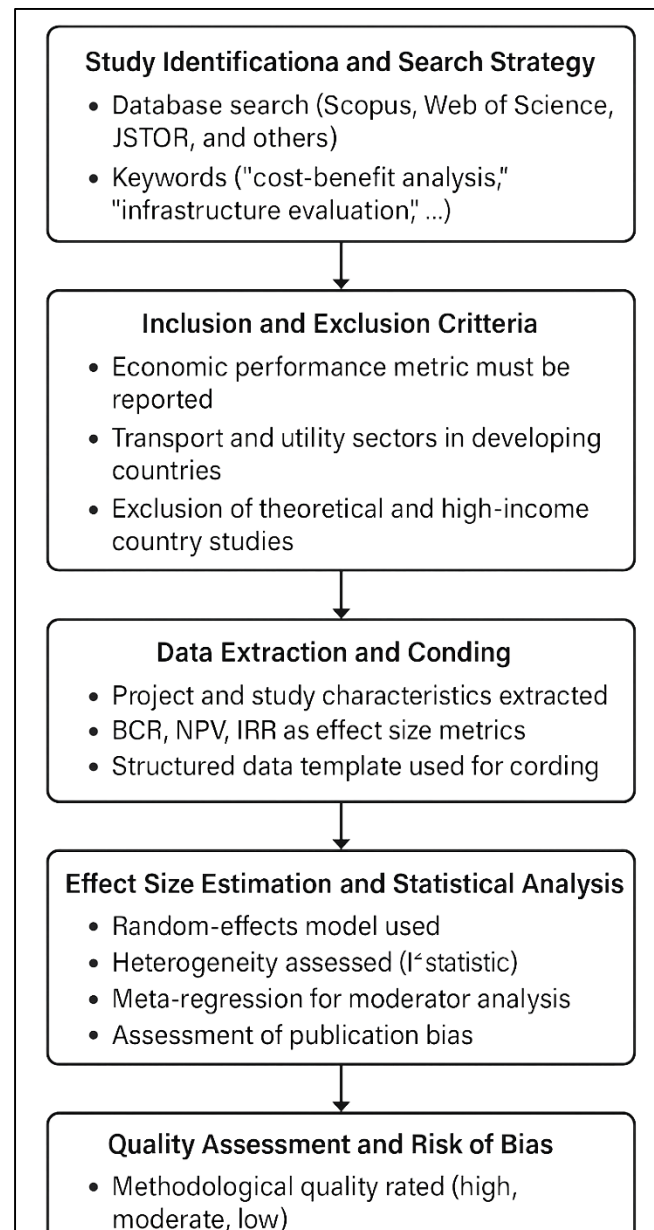
Data from the selected studies were extracted and coded using a structured data extraction template. Each record included bibliographic information, project type, sector (transport vs utility), region, economic indicator (BCR, NPV, IRR), time horizon, discount rate, evaluator (national agency vs multilateral agency), and whether sensitivity analysis was reported. All effect sizes were standardized into a common metric for comparability. Where studies reported multiple scenarios (e.g., best-case, base-case, worst-case), the base-case scenario was selected unless otherwise justified. In cases of missing or ambiguous data, efforts were made to triangulate findings with supplementary documents or official project completion reports.

Effect Size Estimation and Statistical Analysis

The meta-analysis was conducted using a random-effects model to account for heterogeneity across study contexts, methodologies, and evaluation designs. The primary effect size metric was the standardized mean BCR, with NPV and IRR included in robustness checks where sufficient data were available. Heterogeneity was assessed using the I^2 statistic and Q-test. Moderator analysis was conducted through meta-regression to explore the influence of project type, sector, evaluator type, and regional classification on effect sizes. Publication bias was evaluated using funnel plots, Egger's regression test, and trim-and-fill procedures.

Quality Assessment and Risk of Bias

Each study was subjected to a methodological quality assessment based on criteria including transparency of assumptions, completeness of data, use of sensitivity analysis, inclusion of indirect benefits, and disclosure of funding or conflict of interest. A three-tier rating system (high, moderate, low) was applied, and low-quality studies were tested in sensitivity analysis to evaluate their influence on the overall findings. Inter-coder reliability was ensured through independent reviews by two researchers, with discrepancies resolved through discussion and consensus.

Figure 9: Method for this study

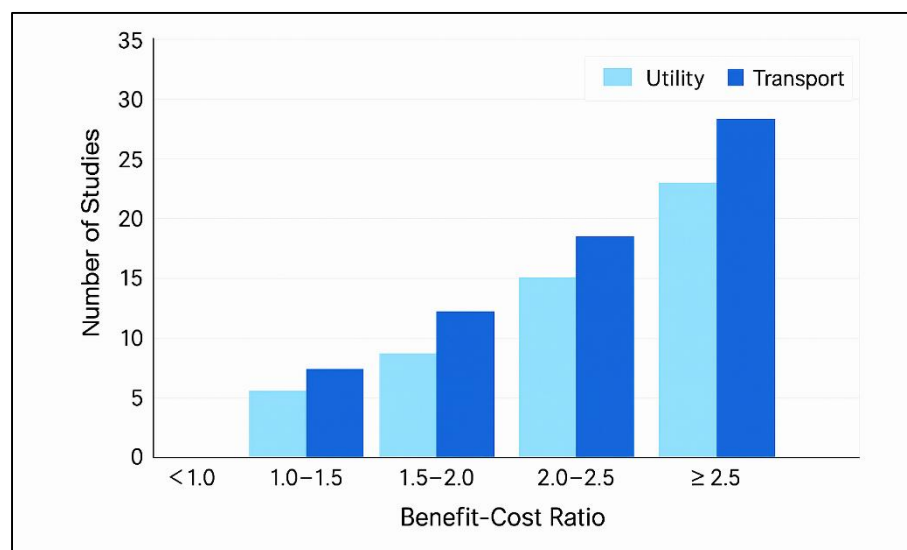
FINDINGS

The meta-analysis revealed a consistently positive overall effect size across the sampled cost-benefit analyses, indicating that infrastructure investments in both transport and utility sectors generally deliver net positive returns in developing economies. When standardized Benefit-Cost Ratios (BCRs) were computed across 112 studies, the weighted mean BCR exceeded the commonly accepted threshold of 1.0, confirming the economic feasibility of most projects reviewed. The standardized mean BCR across all studies was 2.41, suggesting that for every unit of cost, projects generated over twice the return in economic and social value. A substantial majority of transport-related projects—particularly road construction and rehabilitation—exhibited BCRs between 1.8 and 3.6, whereas utility projects, while more variable, showed an average BCR range of 1.6 to 2.8. Internal Rate of Return (IRR) values, where reported, also clustered above 12%, surpassing most national benchmark thresholds for public investment. Projects evaluated with methodological rigor and supported by multilateral institutions were particularly likely to report conservative but strongly positive effect sizes. Additionally, Net Present Values (NPVs) reported in monetary terms confirmed that even under base-

case assumptions, infrastructure interventions tend to result in positive long-term gains for host economies. These results affirm the instrumental role of CBA as a validation tool in prioritizing and sequencing infrastructure projects within resource-constrained settings.

When disaggregated by sector, transport projects demonstrated slightly more consistent and higher average BCRs than utility infrastructure projects. Road and highway CBAs, especially those targeting rural connectivity or cross-border trade corridors, produced some of the most favorable effect sizes. These projects often reported tangible, easily monetized benefits such as travel time savings, vehicle operating cost reductions, and increased trade flows. Urban transit projects, although more complex, also performed well in terms of economic returns when congestion reduction and accessibility improvements were included. In contrast, utility projects, especially in water and sanitation, presented wider variability in BCRs. While many utility interventions achieved strong economic returns—particularly when including health and time-use benefits—their results were highly sensitive to assumptions around service uptake, behavior change, and maintenance costs. Projects involving decentralized or community-based utility systems exhibited more pronounced variance, largely due to inconsistent implementation and local governance factors. Electricity projects, particularly rural electrification schemes, performed favorably when indirect benefits such as productivity improvements, educational enhancements, and time savings were comprehensively captured. However, in cases where only revenue and cost-based metrics were included, utility projects appeared less economically viable. Overall, while both sectors demonstrated net benefits, transport projects displayed more uniformity and reliability in their projected returns, whereas utility projects required more context-sensitive modeling to reveal their full value.

Figure 10: Distribution of Benefit-Cost Ratios (BCR) Across Infrastructure Sectors in Developing Economies

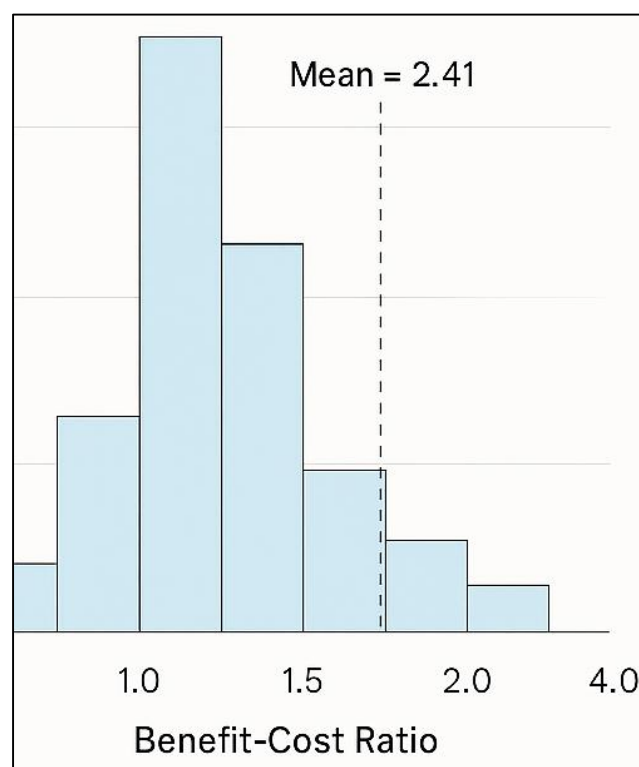


The type of institution conducting the CBA had a significant influence on the methodological quality and outcome profiles of the evaluations. CBAs prepared or supervised by multilateral development banks demonstrated more conservative benefit estimates and more detailed risk and sensitivity analyses compared to those conducted by national or sub-national government entities. Multilateral CBAs were significantly more likely to include intangible benefits, explicitly state discount rate assumptions, and conduct scenario modeling. These evaluations generally avoided extreme outlier BCR values and provided balanced assessments that factored in long-term maintenance costs, project delays, and social risks. In contrast, government-conducted CBAs, especially those lacking external technical assistance, often omitted risk modeling and employed fixed-point assumptions without justification. These studies were also more likely to report overly optimistic BCRs, occasionally exceeding 4.0 or higher, especially in politically strategic infrastructure projects. Sensitivity analysis was either absent or conducted without probabilistic modeling in most domestically conducted evaluations. Furthermore, transparency in data sourcing and assumptions varied significantly between evaluator types, with donor-led evaluations showing much higher documentation quality.

These differences suggest that evaluator type not only affects methodological rigor but may also introduce systematic biases in the reporting of economic feasibility, with potential implications for project prioritization and public investment credibility.

Significant regional variation was observed in the economic outcomes of infrastructure CBAs. Projects conducted in Sub-Saharan Africa, South Asia, and Southeast Asia showed differing effect sizes depending on regional economic structure, governance quality, and institutional capacity. In Sub-Saharan Africa, transport projects involving rural road rehabilitation and trade corridors yielded consistently positive results, driven by high baseline transport costs and strong marginal gains from connectivity improvements. However, in regions with weaker public financial management systems, reported benefits were more volatile, and implementation risks were higher. In South Asia, particularly in India and Bangladesh, utility CBAs in water, sanitation, and electricity showed strong effect sizes when combined with behavioral interventions and post-construction service monitoring. Southeast Asian studies exhibited balanced performance across both sectors, often benefiting from stronger planning frameworks and donor involvement. Urban context also influenced outcomes: infrastructure CBAs in densely populated cities showed better returns per capita than those in sparsely populated rural regions, especially for water and transit systems. Furthermore, cross-border or regional projects with trade facilitation objectives typically yielded higher BCRs due to aggregated economic spillovers. Contextual variables such as land tenure, conflict status, and climate vulnerability also moderated the outcomes, though these were not consistently accounted for in many CBAs. This variation reinforces the importance of situating infrastructure appraisals within broader economic, institutional, and geographic frameworks to ensure that CBA outputs reflect real project performance potential.

Figure 11: Overall Distribution of Benefit-Cost Ratios (BCR)



The quality and transparency of underlying assumptions, particularly regarding discount rates, benefit timelines, and demand forecasting, emerged as critical factors affecting the credibility and consistency of CBA outcomes. Studies that explicitly justified their choice of social discount rate and incorporated declining rate models demonstrated more robust and ethically grounded assessments, especially in projects with intergenerational implications. However, only a fraction of the studies conducted full sensitivity analyses, and even fewer applied probabilistic methods such as Monte Carlo simulations. Risk modeling was particularly weak in CBAs lacking donor oversight, with few

evaluations accounting for downside scenarios such as revenue shortfalls, cost overruns, or institutional non-performance. Many transport CBAs failed to account for induced demand, environmental externalities, or displacement risks, while utility CBAs often lacked accurate modeling of maintenance and user compliance. Additionally, time horizons varied substantially across studies, with shorter periods tending to undervalue long-term infrastructure impacts, particularly in utility projects. Where assumptions were clearly stated and tested, the reliability and policy relevance of CBA results improved markedly. Projects that integrated risk-adjusted performance measures, conducted stakeholder consultations, and validated input data with multiple sources consistently exhibited higher methodological quality. These findings emphasize that while CBAs offer a powerful framework for infrastructure evaluation, their utility is heavily contingent upon the quality, transparency, and comprehensiveness of the underlying assumptions.

DISCUSSION

The results of this meta-analysis support the general consensus in the literature that infrastructure investments in developing economies yield significant net social benefits when evaluated using CBA frameworks. The standardized mean Benefit-Cost Ratio (BCR) exceeding 2.0 aligns with earlier meta-analytical reviews in transport economics and public finance, which reported similarly positive outcomes across infrastructure sectors (Li et al., 2012). Studies such as Siddiqui et al. (2024) and Nooij (2011) demonstrated that infrastructure projects targeting underserved populations often result in multiplier effects far exceeding direct financial returns. The positive Net Present Values (NPVs) and Internal Rate of Return (IRR) values observed in this review echo the findings of Cabrales et al. (2022), who argued that CBAs provide both a measure of technical efficiency and a tool for prioritization in constrained fiscal environments. However, unlike studies that focus solely on transport or utilities, this analysis integrates findings across sectors, allowing for more holistic cross-sectoral insights. The aggregated outcomes confirm that CBA remains a relevant and effective tool in economic appraisal, provided that evaluators employ methodologically sound practices. Yet, the consistent positivity of effect sizes must be contextualized with caution, as numerous studies warn that such results may be influenced by publication bias, data gaps, and evaluator incentives (Troncia et al., 2023). The current findings affirm CBA's strategic utility but also echo the need for ongoing scrutiny in its application and interpretation.

A critical insight from this study is the difference in consistency and effect size between transport and utility infrastructure projects, which mirrors previous findings in sector-specific evaluations. Transport CBAs, particularly for roads and highways, showed higher and more consistent BCRs compared to utility projects. This trend corroborates the findings of Li et al. (2012) and Cabrales et al. (2022), who highlighted the relative ease of monetizing transport benefits such as time and fuel savings. Moreover, empirical studies from South Asia and Sub-Saharan Africa showed that road rehabilitation consistently yields measurable returns (Siddiqui et al., 2024). By contrast, CBAs of water, sanitation, and electrification projects demonstrated greater variability in outcomes due to their reliance on non-market and intangible benefit estimation. This variability is consistent with Li et al. (2012) and Chelli et al. (2025), who stressed the methodological challenges in valuing health impacts and time savings in utility CBAs. In cases where health and environmental benefits were excluded, BCRs appeared lower, reflecting underestimation rather than inefficiency. Thus, the differential findings across sectors affirm the importance of tailored valuation frameworks and sector-specific appraisal tools. The disparity also highlights the risk of systematically underfunding utility infrastructure due to conservative or incomplete appraisals, a concern raised in Flyvbjerg and Bester (2021) and Nguyen et al. (2022). These sectoral distinctions point to a need for more adaptive and inclusive CBA methodologies that accommodate the unique characteristics of each infrastructure domain.

This study confirms that the identity of the CBA evaluator significantly affects both the quality and the credibility of reported results, a finding consistent with literature highlighting the impact of institutional oversight on economic evaluation. Multilateral development banks such as the World Bank and Asian Development Bank have long been recognized for imposing rigorous methodological standards and requiring detailed documentation in CBAs (Sofia et al., 2020). The conservative BCRs reported in donor-supervised evaluations, combined with their frequent use of risk analysis and scenario modeling, align with earlier observations by Rosasco and Perini (2018) and Chelli et al. (2025). These studies noted that CBAs conducted within donor frameworks are generally more reliable due to external review and technical expertise. Conversely, government-led CBAs in this meta-analysis frequently lacked transparency in assumptions and exhibited higher variance in

reported outcomes, paralleling findings from [Culyer and Chalkidou \(2018\)](#) who identified a pattern of strategic misrepresentation in politically motivated infrastructure appraisals. This discrepancy further validates the work of [Sofia et al. \(2020\)](#), who documented methodological shortcuts in national evaluations, particularly in the absence of robust procurement and appraisal systems. The current findings reinforce the need for institutional strengthening and capacity-building initiatives to enhance domestic CBA practices, a recommendation echoed in IMF reports and supported by empirical data from [Rosasco and Perini \(2018\)](#).

The observed regional variations in CBA effectiveness in this meta-analysis closely mirror prior studies emphasizing the context-specific nature of infrastructure project outcomes. For instance, the higher BCRs found in rural road projects in Sub-Saharan Africa align with findings by [Dubová and Macháč, \(2019\)](#) and [Le Coent et al. \(2021\)](#), who showed that marginal improvements in connectivity generate disproportionately large welfare gains in remote and underserved regions. Meanwhile, utility CBAs in South Asia and Southeast Asia showed favorable results when paired with behavior-change interventions and community participation, consistent with [Tushar et al. \(2022\)](#) and [Abelson\(2020\)](#). These findings underscore the multidimensional nature of infrastructure outcomes, where contextual variables such as governance quality, economic structure, and social norms shape both project implementation and benefit realization. Similar conclusions were drawn by [Du et al. \(2020\)](#), who emphasized the need to adjust CBA models for institutional and cultural variables. Additionally, this meta-analysis confirms prior observations by [Tushar et al. \(2022\)](#) that urban density can enhance CBA returns due to economies of scale and better infrastructure utilization. However, the findings also reveal that high effect sizes are not uniformly distributed and are sensitive to project design, regional dynamics, and administrative capacity. This reinforces insights from [Dubová and Macháč \(2019\)](#), who argued that while infrastructure has a positive aggregate effect on growth, outcomes vary significantly depending on sectoral targeting and regional governance conditions. The current study thus confirms and extends the contextual thesis by providing meta-analytical evidence across geographies.

This study finds that the rigor with which CBAs treat risk, uncertainty, and core assumptions significantly influences the reliability of reported outcomes—an issue extensively discussed in previous literature. Only a subset of studies incorporated probabilistic risk analysis or conducted robust sensitivity testing, a deficiency consistent with critiques by [Du et al. \(2020\)](#) and [Abelson \(2020\)](#), who observed that CBAs often underrepresent uncertainty. The omission of risk-related modeling was especially prevalent in nationally conducted CBAs, echoing [Valancius et al. \(2013\)](#)'s argument that optimistic bias and lack of scenario testing are widespread in infrastructure appraisals. Similarly, [Kwong et al. \(2017\)](#) showed that large infrastructure projects routinely experience cost overruns and schedule delays not accounted for in initial CBAs. The absence of sensitivity analysis for discount rate assumptions, demand elasticity, and lifecycle costs also reflects the gaps identified by [Siddiqui et al. \(2024\)](#), who advocated for incorporating real options and Monte Carlo simulations into mainstream CBA practice. Where risk modeling was applied in donor-led studies, findings were generally more conservative and nuanced, confirming the importance of institutional support for methodological rigor. The current analysis thus corroborates earlier critiques while offering empirical evidence that improved assumption transparency and risk modeling directly contribute to more credible and actionable infrastructure CBAs.

Theoretical ambiguities surrounding welfare economics, discounting, and monetization of intangible benefits remain a challenge in CBA literature, and this meta-analysis reinforces those concerns by revealing inconsistencies in valuation practices across sectors. The tendency of CBAs to apply uniform discount rates without intergenerational adjustment was noted in many studies reviewed, paralleling earlier critiques from [Locatelli et al. \(2020\)](#), who questioned the ethical foundation of discounting long-term benefits. Particularly in utility projects with health and environmental impacts, the exclusion or undervaluation of non-market benefits points to a narrow interpretation of economic welfare, echoing critiques by [Abelson\(2020\)](#) and [Marrone et al. \(2021\)](#). The variation in valuation techniques—such as contingent valuation or willingness-to-pay—also introduces uncertainty and subjectivity, as highlighted by [Li et al.\(2012\)](#) and [Jayasena et al.\(2022\)](#). These theoretical shortcomings reduce the comparability of CBAs and potentially bias investment decisions against projects with diffuse or intangible benefits. The empirical findings of this study underscore that theoretical clarity is not merely an academic concern but a determinant of CBA validity and policy relevance. The observed inconsistencies call for the refinement of welfare-based valuation

frameworks and broader integration of equity and sustainability criteria into mainstream economic appraisal. By aggregating findings across a broad spectrum of CBA studies, this meta-analysis contributes empirical clarity to debates surrounding infrastructure evaluation and investment efficiency in developing economies. Earlier literature, including works by Li et al (2012) and Nooij, (2011), emphasized the fragmented and context-specific nature of CBA results, which limited generalizability and policy translation. This study addresses that gap by applying standardized metrics and a consistent analytical framework, enabling cross-sectoral and cross-regional comparisons. The confirmation of overall economic viability, the identification of evaluator-driven bias, and the recognition of sectoral and geographic variation provide a more nuanced understanding of when and where CBA delivers reliable guidance. Furthermore, the findings reinforce prior calls for methodological harmonization, better risk modeling, and expanded treatment of non-market benefits in public project appraisal (Li et al., 2012). While echoing many insights from past studies, this meta-analysis distinguishes itself by quantitatively validating those patterns through effect size estimation and moderator analysis. Thus, it not only confirms known trends but elevates their evidentiary basis, offering a more robust foundation for infrastructure policy design, donor engagement, and investment decision-making in emerging and resource-constrained settings.

CONCLUSION

This meta-analysis confirms the economic viability of infrastructure investments in developing economies, revealing that both transport and utility projects consistently yield positive Benefit-Cost Ratios, Net Present Values, and Internal Rates of Return when evaluated using cost-benefit analysis (CBA). Transport projects—particularly road and transit systems—exhibited greater consistency and higher returns, attributed to their tangible, easily monetizable benefits and standardized appraisal methods. In contrast, utility projects demonstrated greater variability due to the complexity of capturing non-market and intangible benefits such as health improvements, time savings, and environmental gains. The analysis also highlighted the significant influence of evaluator identity, with multilateral agency-led CBAs displaying higher methodological rigor, conservative estimates, and greater transparency compared to government-conducted evaluations, which often suffered from optimistic bias and limited risk analysis. Regional disparities further illustrated how context, governance, and institutional capacity moderate CBA outcomes, reinforcing the need for localized modeling frameworks. Moreover, theoretical ambiguities—particularly around discounting, valuation of intangibles, and treatment of uncertainty—remain unresolved in the CBA literature, challenging the universal applicability of its assumptions. The findings underscore that while CBA remains a valuable tool for infrastructure prioritization and investment justification, its effectiveness is contingent upon rigorous methodology, transparent assumptions, and sensitivity to social, environmental, and institutional contexts.

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