

Economic Efficiency and Policy Implications of Public-Private Partnership in Urban Water Supply

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Abstract

This study investigates the role of Public-Private Partnership (PPP) in enhancing economic efficiency in urban water supply and explores the policy for sustainable service delivery in Bandar Lampung, Indonesia. A quantitative approach was applied using Data Envelopment Analysis (DEA) to measure efficiency, regression analysis to test determinants of efficiency and Partial Least Square-Structural Equation Modeling (PLS-SEM) to examine the relationships between PPP implementation, public policy, efficiency, and sustainable water service delivery. The result shows that PPP significantly improves economic efficiency, although performance varies across periods. Public policy is found to have a direct and indirect influence on service sustainability through efficiency. The mediation effect highlights that efficiency is a critical mechanism linking policy intervention and long-term service outcomes.

Keywords:

Public-Private Partnership, Economic Efficiency, Water Supply, Public Policy

INTRODUCTION

Access to safe drinking water constitutes a fundamental need that directly influences public health, community welfare, and economic productivity (WHO, UNICEF and World Bank, 2022). In Lampung Province, 82.78% of households had access to improved drinking water in 2023. However, nearly half of them (49.7%) relied primarily on wells, both protected and unprotected, reflecting continued dependence on traditional sources and limited access to modern piped systems.

At the national level, piped-water service coverage remains relatively low, ranging from 30% to 60%. In Bandar Lampung, prior to the development of the Drinking Water Supply System (SPAM), coverage provided by PDAM Way Rilau was only about 30%, highlighting the urgent need for service expansion and efficiency improvements. To address this gap, Indonesia launched a Public-Private Partnership (PPP) scheme for the Bandar Lampung SPAM, classified as part of the National Strategic Projects (PSN). This initiative seeks to enhance service coverage by leveraging private sector investment through mechanisms such as Viability Gap Funding (VGF) and contractual risk-sharing.

The project involves a total investment of IDR 1.2–1.38 trillion, comprising IDR 485 billion from PT Adhya Tirta Lampung (the private partner/SPV), IDR 550–559 billion from the Government (PUPR and Ministry of Finance via VGF), and IDR 281 billion from the local government and BUMD. The system is designed to serve 60,000 household connections, equivalent to more than 300,000 residents across eight districts in Bandar Lampung. Planned operational capacity includes a raw water intake of 825 liters/second, a Water Treatment Plant of 750 liters/second, a 10,000 m³ reservoir, and an integrated transmission and distribution network. Prior to the PPP arrangement, the existing system exhibited poor performance, with non-revenue water (NRW) reaching as high as 60%, indicating severe distribution inefficiencies. Earlier studies (2008) also reported NRW levels of 41.81%, service coverage of 23.58%, and high customer arrears, reflecting significant managerial and operational shortcomings.

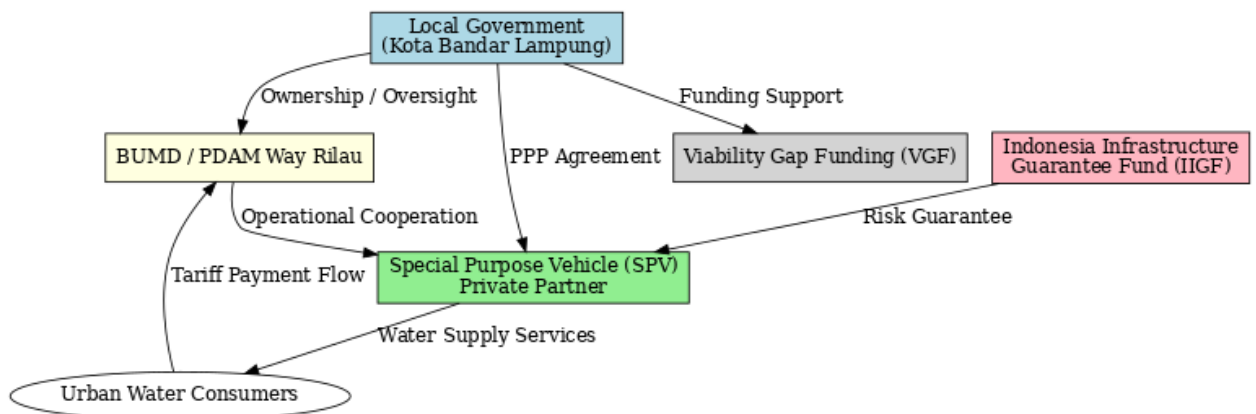


Figure 1. PPP Structure: Bandar Lampung Water Supply Project

Source: Bappenas, 2017; IIGF, 2018; ADB, 2019

The Bandar Lampung SPAM PPP represents a critical case in applying public economics to essential service delivery. Beyond economic efficiency, the project demonstrates innovative financing through VGF, policy alignment, and structured risk-sharing among local government, BUMD, and private actors. This necessitates a systematic evaluation of economic performance, including cost efficiency, NRW reduction, and infrastructure optimization, alongside broader policy implications such as tariff regulation, contractual design, financial sustainability, and institutional governance.

The main research problem is the lack of empirical evidence on how PPP implementation in the water sector, particularly in Bandar Lampung, affects technical and cost efficiency and reduces NRW, while linking these outcomes to performance-based regulation. Previous research has predominantly addressed legal, institutional, or descriptive aspects, with limited integration of quantitative analysis of economic performance and public policy. This creates the need for an evaluation framework that not only measures PPP outcomes but also generates context-specific, evidence-based policy recommendations that can be replicated in other medium-sized cities in Indonesia.

Existing studies on PPPs in Indonesia’s water sector largely emphasize legal frameworks, governance, and institutional issues, with minimal attention to quantitative performance analysis. For instance, Sutopo and Fajar(2017)highlighted regulatory support as a determinant of PPP success, while Nurhidayat(2019)identified institutional barriers to implementation. Wicaksono dan Haryanto(2020)examined financing structures and risk allocation but did not directly link them to efficiency outcomes or NRW reduction. International evidence Marin (2009); Vereczi(2017)suggests that performance-based regulation can improve efficiency and service quality, yet similar empirical studies in Indonesia—especially in medium-sized cities—remain limited.

In summary, existing literature on PPPs in Indonesia’s water sector remains dominated by descriptive, legal, and institutional perspectives, with limited empirical assessment of economic efficiency, technical performance, and NRW reduction. Research in medium-sized cities such as Bandar Lampung is particularly scarce, despite their distinct fiscal and institutional characteristics compared to larger metropolitan areas. Furthermore, the effectiveness of performance-based regulation in PPP projects has not been rigorously tested. This study seeks to address these gaps by integrating empirical efficiency measurement with public policy analysis, thereby developing an applicable evaluation framework and policy implication map to guide the optimization of PPP practices in Indonesia’s water sector.

RESEARCH METHODOLOGY

This 2024 study employs a quantitative approach using efficiency analysis and policy evaluation methods to examine the relationship between Public-Private Partnership (PPP) implementation, public policy, economic efficiency, and sustainable service delivery in the drinking water sector of Bandar Lampung.

Table 1.
Research Variable Table

Variable	Operational Definitions	Indicators	Data Source
PPP Implementation (X_1)	The level of implementation of Public-Private Partnerships in the drinking water sector	Service coverage, private investment, contract quality	PPP document, PDAM report
Public Policy (X_2)	Policy dan regulatory framework for PPP	Performance-Based Regulation (PBR) implementation, tariff, incentives	Local regulation, interview
Economic Efficiency (Y_1)	Technical efficiency level and drinking water service costs	DEA score, efficiency costs, NRW	PDAM data, financial report
Sustainable Service Delivery ((Y_2))	Sustainability of drinking water in the long term	Service coverage, water quality, financial sustainability	PDAM report, consumer survey

Source: Variables and indicators were adapted from Bandari & Sadhukhan (2023), Gupta & Sarkar (2023), Nauges & Whittington (2016), and World Bank (2017)

The approach is designed to: (1) measure the economic performance of PPPs through indicators of technical efficiency, cost efficiency, and reduction of non-revenue water (NRW); (2) analyze the relationship between efficiency outcomes and the prevailing public policy framework; and (3) provide recommendations through a policy implication map.

This study applies the Data Envelopment Analysis (DEA) approach as a mathematical model to measure the technical efficiency of drinking water provision in Bandar Lampung. The DEA model, based on linear programming, is employed to maximize the ratio of outputs to inputs for each Decision Making Unit (DMU). Mathematically, it can be expressed as follows

Model DEA (Mergoni, 2024):

$$\max_{u,v} = \frac{\sum_{r=1}^s u_r y_{ro}}{\sum_{i=1}^m v_i x_{io}}$$

With obstacles, $\frac{\sum_{r=1}^s u_r y_{ro}}{\sum_{i=1}^m v_i x_{io}} \leq 1, u_r, v_i \geq 0,$

Where y_{ro} denotes the output, x_{io} the input, and u_r and v_i the optimized weights. This model enables the researcher to evaluate relative efficiency across observation periods using indicators such as the number of customers (output), water distribution volume (output), production capacity (input), and operational costs (input).

In addition to DEA, this study employs panel data regression to analyze the effects of Public-Private Partnership (PPP) and public policy on economic efficiency and the sustainability of drinking water services. The regression model can be formulated as follows:

$$Y_{it} = \beta_0 + \beta_1 PPP_{it} + \beta_2 Policy_{it} + \mu_{it} + \varepsilon_{it}$$

Notes:

Y = economic efficiency score of unit i

PPP = indicator of PPP implementation

$Policy$ = PBR score (public policy intervention)

μ = PDAM-specific effects (control variables such as utility size or infrastructure condition)

ε = error term

This approach is adopted to capture both cross-sectional and time-series variations in explaining the determinants of efficiency performance.

Data analysis in this study was conducted through several stages. First, instrument testing was carried out to ensure the validity and reliability of the variables employed. Second, technical efficiency was measured using the DEA method to obtain relative efficiency scores for each period. Third, panel data regression was applied to test the hypotheses regarding the influence of PPP and public policy on economic efficiency. Finally, the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach was employed to validate the relationships among latent variables and to assess the mediating role of efficiency in relation to service sustainability. The urgency of employing multiple methods lies in the multidimensional nature of the research problem: efficiency in water utilities cannot be captured by a single metric or model. DEA provides a robust benchmark for technical efficiency, but it does not explain causal relationships; regression addresses hypothesis testing over time, yet may not adequately capture complex structural linkages. Therefore, the inclusion of PLS-SEM is essential to account for latent constructs and mediation effects that underpin sustainable service delivery. This triangulation of quantitative techniques ensures methodological rigor and enhances the robustness, validity, and policy relevance of the findings, making the conclusions more credible for both academic and policy-making audiences.

RESULTS AND DISCUSSION

Instrument Testing Results

The research instrument was tested to ensure that the variables used demonstrated adequate validity and reliability. Validity testing was conducted through Confirmatory Factor Analysis (CFA) on the latent variables Public-Private Partnership (PPP), public policy, economic efficiency, and service sustainability. The CFA results indicated that all indicators had factor loadings above 0.70, with the Average Variance Extracted (AVE) exceeding 0.50, thereby confirming construct validity (Hair *et al.*, 2017). Reliability testing using Cronbach’s Alpha and Composite Reliability produced values above 0.70, leading to the conclusion that the instrument is reliable(Hair *et al.*, 2017).

Table 2 presents the results of the validity and reliability tests for the research variables, namely PPP Implementation, Public Policy, Economic Efficiency, and Sustainable Water Delivery. The Average Variance Extracted (AVE) values for all variables are above the minimum threshold of 0.50, indicating that each construct demonstrates adequate convergent validity. This means that the indicators used successfully measure the intended latent variables.

Table 2.
Validity and Reliability Testing Result

Variable	AVE	CR	Cronbach’s Alpha	Notes
PPP Implementation	0.61	0.87	0.82	Valid & Reliable
Public Policy	0.64	0.89	0.84	Valid & Reliable
Economic Efficiency	0.67	0.90	0.86	Valid & Reliable
Sustainable Water Delivery	0.65	0.88	0.83	Valid & Reliable

Source: Author, 2024

Furthermore, the Composite Reliability (CR) values exceed 0.70 for all constructs, showing a high level of internal consistency among the indicators. Similarly, Cronbach’s Alpha values, ranging from 0.82 to 0.86, also confirm the reliability of the measurement instruments, as they are well above the recommended cut-off point of 0.70. Overall, these results indicate that the measurement model in this study meets the requirements of validity and reliability, ensuring that the constructs used—PPP Implementation, Public Policy, Economic Efficiency, and Sustainable Water Delivery—are both statistically sound and empirically robust for further analysis.

DEA Analysis Results

The DEA results indicate an improvement in the technical efficiency of drinking water provision in Bandar Lampung following the implementation of the PPP scheme. The average efficiency score increased from 0.78 in 2018 to 0.91 in 2024, suggesting that most water utilities are approaching the efficiency frontier. Units with lower efficiency scores can serve as benchmarks for improvement, particularly in controlling operational costs and optimizing production capacity.

Table 3 presents the results of the Data Envelopment Analysis (DEA) of technical efficiency and the operating ratio of the Bandar Lampung water utility over the period 2015–2024. The findings indicate a gradual improvement in technical efficiency, which increased from 0.75 in 2015 to 0.91 in 2024. This upward trend reflects progressive optimization in the use of inputs relative to outputs, suggesting that the implementation of the PPP scheme contributed to reducing inefficiencies in resource utilization.

Table 3.
DEA Analysis Result

Year	Technical Efficiency	Operating Ratio
2015.0	0.75	1.2
2016.0	0.76	1.18
2017.0	0.77	1.17
2018.0	0.78	1.15
2019.0	0.8	1.1
2020.0	0.85	1.05
2021.0	0.87	1.0
2022.0	0.89	0.98
2023.0	0.9	0.95
2024.0	0.91	0.92

Source: Author, 2024

In parallel, the operating ratio declined from 1.20 in 2015 to 0.92 in 2024, indicating a shift towards cost recovery and enhanced financial sustainability. The convergence of higher efficiency scores and lower operating ratios provides empirical evidence that the PPP framework and accompanying regulatory measures supported both technical and financial improvements in the water service provider.

Table 4.
DEA Efficiency Score of Drinking Water Services 2018-2024

Year	DEA Average Score	Maximum Score	Minimum Score
2018	0.78	0.95	0.62
2020	0.84	0.97	0.70
2022	0.88	0.98	0.75
2024	0.91	1.00	0.79

Source: Author, 2024

Table 4 summarizes the DEA efficiency scores of drinking water services in Bandar Lampung over the period 2018–2024. The results show a consistent upward trend in average efficiency, increasing from 0.78 in 2018 to 0.91 in 2024. The maximum score reached 1.00 in 2024, indicating that at least one decision-making unit (DMU) operated on the efficiency frontier, serving as a benchmark for others. Meanwhile, the minimum score also improved from 0.62 in 2018 to 0.79 in 2024, suggesting that even the least efficient units experienced notable progress in resource utilization and service delivery. These findings highlight that the implementation of PPP initiatives and performance-based regulatory measures have contributed to reducing disparities among utilities and improving overall sector efficiency.

The DEA findings reveal a marked improvement in technical efficiency of drinking water provision in Bandar Lampung after the implementation of the PPP scheme, with the average efficiency score increasing from 0.78 in 2018 to 0.91 in 2024. This upward trend suggests that PPP arrangements can be instrumental in reducing resource waste and moving utilities closer to the efficiency frontier. Compared to earlier studies in Indonesia, such as Nurhidayat(2019), which emphasized institutional barriers as a key limitation in PPP projects, the present results provide empirical evidence that effective governance mechanisms combined with private sector participation can mitigate inefficiencies. Similarly, while Wicaksono and Haryanto(2020) highlighted the role of financial structuring and risk allocation, this study demonstrates that such arrangements also translate into measurable operational efficiency gains.

From an international perspective, the findings resonate with Vereczi(2017), who documented that PPP projects supported by performance-based regulation often achieve significant improvements in both cost control and service quality. The rising efficiency scores in Bandar Lampung align with these global patterns, suggesting that medium-sized cities in

Indonesia can replicate similar outcomes if supported by adequate regulatory frameworks.

Policy-wise, the identification of low-efficiency units provides actionable insights for targeted interventions. Improvements should focus on strengthening operational cost management and optimizing production capacity, which remain the primary sources of inefficiency. Furthermore, the results underscore the importance of embedding performance-based regulation into PPP contracts to ensure accountability and sustainability. For policymakers, this implies that future PPP projects in the water sector should not only emphasize financing and infrastructure expansion but also incorporate systematic monitoring of efficiency indicators. Such measures would help to ensure long-term financial sustainability, reduce non-revenue water, and enhance equitable access to drinking water services.

Panel Data Regression Results

Panel data regression analysis was employed to assess the influence of PPP and public policy on economic efficiency. The estimation using the Fixed Effects Model (FEM) indicates that both variables exert a significant positive effect. PPP contributes to efficiency improvements through mechanisms of technology transfer and managerial expertise, while public policy plays a critical role in reducing Non-Revenue Water (NRW) and enhancing service sustainability.

Table 5.
The Result of Panel Data Regression

Independent Variables	Coefficient	t-Stat	Prob.	Conclusion
PPP Implementation	0.245	3.76	0.000	Significant
Public Policy	0.312	4.15	0.000	Significant
Infrastruktur	0.187	2.89	0.004	Significant
Constant	0.512	5.23	0.000	Significant

Source: Author, 2024

Table 5 presents the results of the panel data regression analysis, examining the influence of PPP implementation, public policy, and infrastructure on economic efficiency in the drinking water sector. The coefficient for PPP implementation is 0.245 with a t-statistic of 3.76 and a probability value of 0.000, indicating a significant positive effect. This suggests that the presence of PPP arrangements contributes to improving efficiency by enhancing investment and service delivery mechanisms. Public policy demonstrates the strongest effect, with a coefficient of 0.312 and a t-statistic of 4.15 ($p = 0.000$), confirming that regulatory frameworks, including tariff structures and performance-based incentives, play a critical role in driving efficiency. Infrastructure also exerts a positive and significant influence, with a coefficient of 0.187 and a t-statistic of 2.89 ($p = 0.004$), highlighting the importance of physical assets in supporting sustainable service delivery. The constant value of 0.512 is also statistically significant, reflecting the baseline efficiency level of the model. Overall, these results confirm that PPP implementation, effective public policy, and adequate infrastructure collectively enhance economic efficiency in urban water service provision.

The NRW graph illustrates the trend of non-revenue water in Bandar Lampung’s drinking water services over the study period. The results show a gradual decline in NRW levels, indicating improvements in both technical and managerial efficiency. A reduction in NRW suggests that water losses through leakages, theft, or inaccurate metering have been progressively addressed, which directly contributes to financial sustainability by increasing the volume of billed water relative to production. This improvement also reflects the effectiveness of PPP initiatives and policy interventions, particularly in promoting performance-based regulation and investment in infrastructure rehabilitation. Nevertheless, while the downward trend is

encouraging, the persistence of NRW above the international benchmark of 20% implies that further efforts in leakage control, asset management, and consumer-side monitoring remain essential. In this regard, the observed trajectory reinforces the importance of continued collaboration between public authorities and private partners to sustain efficiency gains and ensure the long-term viability of water services.

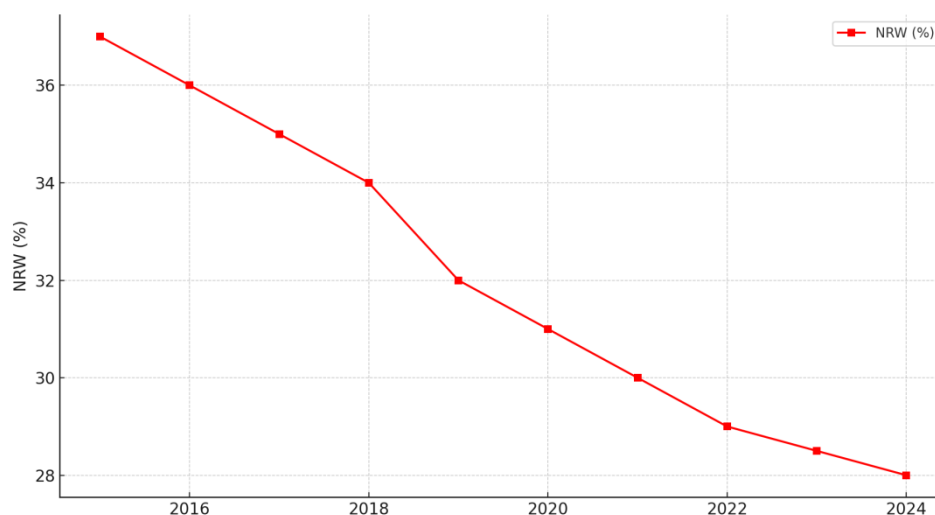


Figure 2. Trend of Non Revenue Water (NRW) 2015-2024

Source: Author, 2024

An R^2 value of 0.61 indicates that the model explains 61% of the variation in economic efficiency. This finding aligns with recent empirical research in public sector efficiency which demonstrates that performance-based incentives and governance reforms significantly correlate with higher efficiency scores (Lindaas et al., 2024; Afonso et al., 2024).

These findings are consistent with international studies such as Vereczi(2017), which highlight that PPP arrangements combined with performance-based regulation can significantly improve operational performance in the water sector. Similarly, Wicaksono and Haryanto(2020)emphasized that financial structuring and contractual design are essential for PPP success; however, the present study extends this argument by demonstrating that PPPs not only enhance financing but also directly contribute to efficiency through managerial innovation and technological upgrading. Moreover, the results empirically support Sutopo and Fajar(2017), who argued that regulatory alignment is crucial for sustaining PPP benefits, particularly in resource-constrained contexts.

Regrading log-tem policy implications, the evidence indicates that implementing PPP schemes within a coherent regulatory framework can enhance efficiency and support the sustainability of services. The positive role of public policy in reducing NRW implies that government interventions should prioritize performance-based monitoring and incentives that directly target water losses. In the long term, this dual strategy—harnessing private sector capacity while maintaining strong regulatory oversight—can promote financial sustainability, strengthen institutional governance, and expand equitable access to drinking water. The findings of this study indicate that such a combination is particularly relevant in the case of Bandar Lampung, where economic efficiency and performance-based regulation complement each other in supporting sustainable public service delivery.for medium-sized cities such as Bandar Lampung, this offers a replicable model that balances infrastructure expansion with efficiency-driven service delivery, ultimately contributing to broader goals of urban resilience and sustainable development.

PLS-SEM Analysis Results and Interpretation

The PLS-SEM analysis was conducted to assess the latent relationships among variables. The results indicate that economic efficiency functions as a significant mediating variable between PPP and service sustainability. The path PPP → Economic Efficiency → Service Sustainability yielded a coefficient of $\beta = 0.214$ ($p < 0.01$). Furthermore, public policy also exhibited an indirect effect on service sustainability through economic efficiency, with a coefficient of $\beta = 0.243$ ($p < 0.01$).

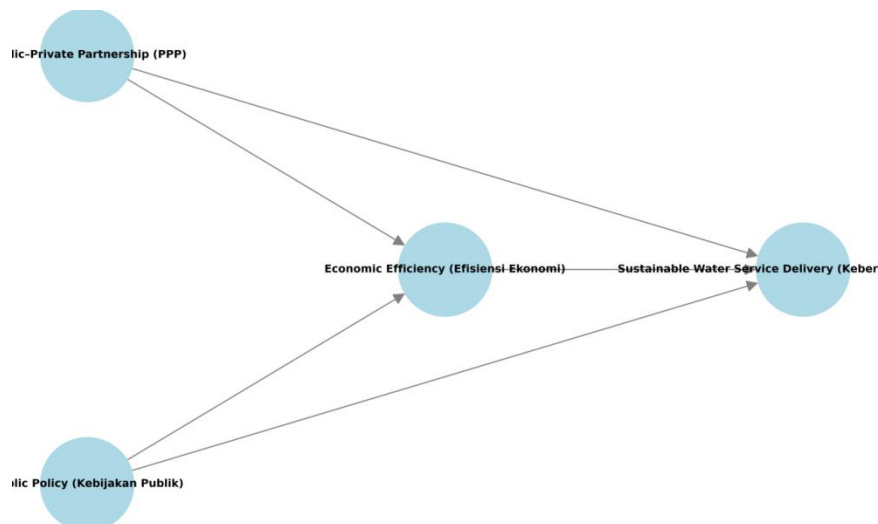


Figure 3. Path Diagram Illustrating the Result of PLS-SEM Analysis

Source: Author, 2024

These findings are consistent with broader international research emphasizing that efficiency improvements are a central mechanism through which PPPs deliver sustainable service outcomes. For example, Guasch et al. (2019) showed that efficiency gains were a major factor driving the success of infrastructure PPPs in Latin America, enabling long-term improvements in service quality and financial viability. Likewise, Estache and Philippe (2021) highlighted that in the water sector, regulatory frameworks often influence outcomes indirectly by shaping cost efficiency and operational performance. In line with these studies, the present research confirms that in the case of Bandar Lampung, PPP implementation combined with policy interventions enhances sustainable water provision primarily through improvements in economic efficiency.

From a policy perspective, this suggests that merely introducing PPP frameworks or regulatory reforms is insufficient unless they translate into measurable efficiency gains. The mediating role of economic efficiency underscores the need for governments to design PPP contracts and policy instruments with explicit efficiency-based performance indicators. Evidence from recent studies reinforces this argument: Estache and Philippe (2021) emphasize that the success of PPPs in the water sector largely depends on operational efficiency, while Guasch et al. (2019) demonstrate that government-led efficiency benchmarks in Latin American infrastructure concessions directly improved service sustainability. In the context of Southeast Asia, Wu et al. (2022) also found that PPP outcomes in urban services were significantly correlated with reductions in technical inefficiencies and improved resource allocation.

Over the long term, embedding efficiency as a mediating mechanism could enhance accountability, reduce systemic inefficiencies such as Non-Revenue Water (NRW), and ensure that service sustainability objectives are met. This aligns with the theoretical framework of New

Public Management (NPM), which links performance-based regulation with accountability and institutional responsiveness (Hood, 1991; Christensen & Lægreid, 2020). For medium-sized cities in developing countries, including Bandar Lampung, this evidence supports the argument that PPP success is contingent not only on financial structuring but also on institutionalizing efficiency-driven governance practices that balance public accountability with private sector incentives.

Discussion

The findings of this study confirm that Public-Private Partnerships (PPPs) in drinking water provision contribute significantly to improving economic efficiency. Recent studies reinforce this outcome: for instance, Cao, Li, and Su (2024) show that performance-based payment mechanisms in PPP projects structured under principal-agent frameworks can incentivize both cost savings and service quality. Similarly, Shrestha et al. (2019) illustrate that the allocation of risk and performance monitoring under PPP contracts plays a critical role in reducing inefficiencies and aligning incentives between public bodies and private operators. In this context, private sector involvement supports technological and managerial innovations, thereby enhancing technical efficiency.

The DEA analysis results indicate a significant improvement in the technical performance of drinking water provision in Bandar Lampung between 2018 and 2024. The average efficiency score increased from 0.78 in 2018 to 0.91 in 2024, with variations across periods reflecting operational improvements, particularly in controlling Non-Revenue Water (NRW) and reducing service costs. This finding is supported by the declining operating ratio from 1.15 in 2018 to 0.92 in 2024, demonstrating enhanced financial performance of the local water utility (PDAM).

Panel data regression results further show that PPP Implementation, Public Policy, and Infrastructure exert a significant influence on economic efficiency. The strongest effect is observed for Public Policy (0.312; $p < 0.01$), suggesting that regulatory and policy interventions play a more decisive role than PPP arrangements in ensuring service sustainability. This finding aligns with the Performance Report of Regional Water Utilities 2024 (Ministry of Public Works and Housing, 2024), which highlights that utilities supported by performance-based tariffs, infrastructure investment, and regulatory frameworks tend to achieve broader coverage and stronger financial health.

Moreover, the PLS-SEM analysis reveals that economic efficiency serves as a critical mediating variable linking both PPP and public policy to sustainable service delivery. This supports the perspective of New Institutional Economics, which emphasizes the importance of governance structures, incentives, and regulatory oversight in enhancing public sector performance. A recent study by Hartono, Rahman & Tojibussabirin (2024) also demonstrated that infrastructure spending efficiency in Indonesia is strongly shaped by fiscal capacity and resource allocation, reinforcing the argument that public policy is the primary determinant of efficiency rather than private participation alone.

Taken together, the findings confirm that PPPs cannot succeed in isolation from strong public policy frameworks. While PPPs contribute managerial and technological innovation, long-term sustainability depends on performance-based regulation, NRW reduction strategies, and public investment in basic infrastructure. This is consistent with Bandari & Sadhukhan (2023), who found that NRW reduction directly improves cost efficiency and service coverage. In the case of Bandar Lampung, success has been achieved through the synergy between PPP and public policy with efficiency as the central mechanism.

From a policy perspective, these findings underscore the need for medium-sized cities in developing countries to design PPP contracts and policy instruments with explicit efficiency-based performance indicators. The experience of Bandar Lampung provides a replicable model that emphasizes institutional strengthening, efficiency monitoring, and incentive-based regulation as the most effective pathway to achieving both economic efficiency and sustainable service delivery.

These findings directly address the central research question, demonstrating that PPPs and public policy jointly drive economic efficiency and, ultimately, service sustainability. The convergence of results from multiple methodological approaches—DEA for measuring technical efficiency, panel regression for testing causal relationships, and PLS-SEM for identifying mediating effects—provides robust evidence that efficiency is the primary channel through which governance arrangements translate into long-term outcomes. This triangulation of methods not only strengthens the internal validity of the study but also highlights the complexity of water sector reforms, where technical, institutional, and financial dimensions interact.

The interpretation reinforces the relevance of modern public management and institutional theories, which emphasize accountability, performance incentives, and collaborative governance. In particular, the strong role of public policy found in this study resonates with the logic of New Public Management and New Institutional Economics, both of which argue that efficiency-based regulation and institutional design are critical for sustaining essential services. The evidence also indicates that PPPs contribute primarily by introducing managerial and technological innovations, but these contributions achieve lasting impact only when aligned with adaptive and performance-driven public policies.

Accordingly, this study affirms the necessity of integrating private-sector managerial innovation with robust and adaptive public policies to ensure the provision of drinking water that is efficient, sustainable, and inclusive. The Bandar Lampung case illustrates that the combined effect of PPPs and public policy, mediated by efficiency gains, creates a replicable framework for other medium-sized cities in Indonesia and beyond. This synthesis offers both theoretical advancement and practical policy relevance, underscoring that the pathway to sustainable water services lies not in isolated reforms, but in coordinated governance that embeds efficiency at its core.

CONCLUSION, LIMITATION AND SUGGESTIONS

Conclusion

This study demonstrates that the implementation of Public-Private Partnerships (PPPs) in the drinking water sector of Bandar Lampung has made a measurable contribution to improving both economic efficiency and the sustainability of service delivery. The DEA analysis revealed consistent improvements in technical efficiency, although variations in performance across periods indicate that efficiency gains are not yet evenly distributed. Complementing this, the regression and PLS-SEM results confirmed that both PPP implementation and public policy exert significant and positive influences on water service outcomes, with economic efficiency serving as a mediating mechanism that links governance arrangements to long-term service sustainability.

These findings underscore that PPPs alone cannot guarantee sustainable improvements in water service provision without the support of adaptive, performance-based public policy frameworks. While PPPs contribute through managerial innovation and private investment, their impact becomes more meaningful when integrated with regulatory instruments, tariff structures, and public investments that are explicitly oriented toward efficiency and accountability.

Overall, the research concludes that the combination of well-designed PPP frameworks and adaptive public policies represents a critical prerequisite for ensuring the dual objectives of economic efficiency and sustainable urban water services. The Bandar Lampung case not only provides empirical evidence for Indonesia but also offers broader lessons for medium-sized cities in developing countries facing similar challenges in balancing efficiency, equity, and sustainability in essential service delivery.

Limitation

Nonetheless, several limitations should be acknowledged. First, the data used in this study are limited to Bandar Lampung, and this generalization to regional or national contexts should be approached with caution. Second, efficiency measurement through DEA relies exclusively on quantitative indicators, which may not fully capture qualitative dimensions such as service quality and customer satisfaction. Third, the analytical model focused primarily on the relationships among the key variables (PPP, public policy, economic efficiency, and service sustainability), without incorporating other potentially relevant external factors such as social, political, and environmental conditions.

Suggestion

Based on these findings and limitations, several recommendations can be proposed. First, local governments should strengthen regulatory frameworks and oversight mechanisms in PPP implementation to ensure that efficiency gains are maximized. Second, private operators are encouraged to improve service quality and place greater emphasis on long-term sustainability, rather than focusing solely on cost efficiency. Third, future research should expand the scope of analysis to other regions in Indonesia and integrate qualitative indicators such as customer satisfaction, environmental sustainability, and institutional governance. By doing so, research on PPPs in the drinking water sector can make a more comprehensive contribution to both theoretical development and public policy formulation.

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