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RESEARCH ARTICLE

FINANCING RURAL WATER UTILITIES: MITIGATING RISKS TO CLEAN WATER ACCESS

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ABSTRACT

Access to safe drinking water remains a pressing global issue, with over 2.2 billion people still lacking safely managed water services. In Indonesia, rural communities often face disparities in access, relying on decentralized systems with limited sustainability. This study investigates financing mechanisms for community-based rural water utilities (RWS) in Piyungan Subdistrict, Bantul Regency, to identify suitable models that support long-term service sustainability. By employing Analytical Hierarchy Process (AHP) method, this research analyzes social, economic, and environmental criteria and sub-criteria influencing financing preferences from the RWS. Primary data were collected through structured interviews and questionnaires with eight RWS entities meeting specific performance and operational criteria. The results show that social factors, particularly community-based management and participation, are the most influential in sustaining RWS. Among four financing alternatives, community financing emerged as the most preferred (62%), followed by private financing and grants, with debt financing receiving the lowest priority. These findings highlight the critical role of local engagement, institutional capacity, and adaptive financial strategies in ensuring service continuity. The study proposes a phased, blended financing approach, tailored to each stage of RWS development, emphasizing that long-term sustainability must be supported by institutional reforms, improved financial management, and environmental risk governance.

KEYWORDS

Rural Water Utility, Water, Financing Water Utility, Sustainable

1. INTRODUCTION

Access to safe water is a fundamental human right and a cornerstone of public health and well-being (Birawida et al., 2021; Utami et al., 2023). Inadequate access limits people's ability to maintain hygiene and exposes them to waterborne diseases such as diarrhea, typhoid, and urinary tract infections (Birawida et al., 2021). While the Sustainable Development Goal (SDG) 6.1 aims to ensure universal access to safe and affordable drinking water by 2030, WHO report in 2023 revealed that over 2.2 billion people are still lack of access to safe drinking water, with 115 million relying on unsafe surface water sources. In Indonesia, while 90% of the population had access to improved water as of 2021, only 11% had access that met the criteria for safely managed water. Safely managed water is indicated as water that is available on premises, when needed, and free from contamination.

Indonesia, like many developing countries, has adopted the global "water ladder" framework to measure water service levels. This framework categorizes water access into five tiers: no access, unimproved access, limited access, basic access, and safely managed access (Bappenas, 2020). Safely managed water—predominantly piped water—is prioritized in national planning, including the Medium-Term National Development Plan (RPJMN), which targets 100% basic access and 15% safely managed access. Piped systems offer quality control, ease of access, and environmental protection through regulated withdrawal and distribution of water. These systems are monitored periodically for water quality and encourage efficient water use through tariff-based pricing.

Despite of these efforts, rural areas in Indonesia often remain underserved. Urban utilities like PDAM typically manage piped services but focus on densely populated urban centers where investment costs yield better returns. In contrast, rural areas face geographical challenges and dispersed populations, making infrastructure investments costly and less feasible (Putirama, 2021). Consequently, rural residents rely on decentralized sources, such as protected wells or unprotected surface water, which the WHO classifies as unsafe (Aikowe & Mazancová, 2021). Unregulated groundwater extraction in rural areas risks aquifer depletion and water quality deterioration from pollution and saltwater intrusion (Carrard et al., 2019; Lo et al., 2021).

Recognizing these disparities, Indonesia launched several community-led rural water utility providers for rural areas. These systems empower local communities to manage, operate, and maintain water services, aligning with global trends that highlight community-based water supply as a viable solution for rural access (Dhoba, 2020; Freire Machete and Marques, 2023; Kleemeier, 2000). This community-led rural water utility providers are called the Rural Water System (RWS), which operations are handled by the community of the rural residents. While water points and non-piped systems are prevalent in regions like sub-Saharan Africa, piped networks are increasingly recognized for their ability to provide safer, more sustainable services (Armstrong et al., 2022; Mwagomba and Tilley, 2021; Wescoat et al., 2022).

However, the sustainability of rural piped water systems provided by the RWS depends on multiple interlinked factors namely economic, social, and environmental. Studies identify institutional, financial, environmental,

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technical, and social (FIETS) components as critical to long-term success (Carrard and Willetts, 2017; Valcourt et al., 2020). Improvements in one domain such as financial capacity, can positively influence others, particularly institutional strength (Daniel, Djohan, et al., 2021). Community-based water systems with robust governance, cost-recovering tariffs, accurate financial records, and access to external financing have demonstrated greater functionality and sustainability (Beresford et al., 2023; Machado et al., 2023; Rajput and Sharma, 2023). Economic constraints are often cited as the greatest challenge to the sustainability of community-based water systems to provide water access to its customers. Limited funding for operations and maintenance hampers service continuity, especially in low-income areas (Andreah et al., 2023; Espinoza et al., 2022). Access to suitable financial services, such as credit, grants, or community savings, enables systems to expand, maintain infrastructure, and improve service quality (Mvongo et al., 2021; Nelson-Nuñez et al., 2019). Financial resilience, in turn, supports stronger institutions and broader service coverage (Smith et al., 2023; Toan et al., 2023). Further, sustainability of an RWS also strongly related to social and environmental factors in addition to economic factors (Ankon et al., 2022).

Using Analytical Hierarchy Process (AHP) method, this study explores how the economic, environment, and social dimensions interact to influence rural water utilities in determining the priority of suitable financing mechanism that supports the sustainability of rural piped water services in Indonesia. It aims to identify priority criteria and alternatives for developing context-appropriate financial systems that support long-term service delivery of the rural water utility providers. This research aims to contribute to the ongoing discourse on achieving equitable and sustainable water access in rural settings.

2. Material And Methods

The Analytical Hierarchy Process (AHP) method is used in this study to analyse the appropriate financial systems based on the ranking of specified criteria. Developed by Professor Thomas L. Saaty in the 1970s, AHP serves as a decision-making methodology aimed at resolving complex problems by systematically organizing them within a multi-tiered hierarchical framework (Ho, 2008; Saaty, 1987). This methodology simplifies the decision-making process by disaggregating complex issues into more digestible components across various analytical levels (Saaty, 1987; Vosoughi et al., 2017; Yin et al., 2023). AHP has been extensively applied across diverse domains, including scholarly research pertaining to water resources management (Ho, 2008; Yin et al., 2023).

The AHP process involves three integral components: hierarchy organization, priority evaluation, and consistency assessment (Ho, 2008). In the first step, a hierarchical structure is developed to decompose the complex problem into multiple levels. In this research, the financing scheme for RWS challenge was categorized into three main criteria, social, economic, and environmental. Each of these principal criteria was further specified into sub-criteria informed by a comprehensive literature review, thereby constituting the subsequent tiers of the hierarchy. The criteria and sub-criteria selected were derived from academic literature sources. The alternative options was also determined based on the academic literature sources, which then completes the hierarchy structure.

2.1 Criteria And Sub-Criteria Selection

The sustainability of RWS is shaped by the interplay of social, economic, and environmental factors, each embedded with specific indicators that collectively influence the functionality, resilience, and financing of these systems. Drawing from the FIETS (Financial, Institutional, Environmental, Technical, Social) sustainability framework (Daniel, Prawira, et al., 2021), the present analysis affirms that improvements in one domain can catalyze positive changes in others, highlighting the systemic nature of sustainability in rural water service provision.

From the social dimension, four critical indicators emerged: community participation, institutional governance, stakeholder support, and cultural compatibility. Systems with active community involvement in decision-making and a sense of ownership tend to be more sustainable, as demonstrated by studies linking timely tariff payment and communal infrastructure upkeep with improved functionality (Al Djono and Daniel, 2022; Machado et al., 2022; Murray et al., 2024). Institutional effectiveness, particularly in the form of accountable and capable local management, is essential to ensure service continuity (Daniel et al., 2023; Love et al., 2023; Smith et al., 2023). Moreover, sustained engagement from external stakeholder, such as local governments, NGOs, and private, has proven valuable in providing technical support and policy alignment (Ajith et al., 2022; Walters et al., 2022). The role of local beliefs and cultural norms also warrants attention; cultural alignment in water management enhances community adherence to system rules and maintenance practices (Avidar, 2024; Toan et al., 2023).

The economic sustainability of SPAM hinges on five interrelated indicators: financial management, economic community involvement, incentives, external investment, and cost-recovery tariffs. Effective financial management, including transparent budgeting and accounting, underpins a system's ability to operate and maintain infrastructure over time (Beresford et al., 2023; Rajput and Sharma, 2023). Regular financial contributions from users, particularly through monthly water fees, have been linked with higher system functionality and service coverage (Al Djono and Daniel, 2022; Mwagomba and Tilley, 2021). Additionally, the presence of economic incentives and access to external funding can stimulate both initial system development and long-term viability. However, reliance on grants should be accompanied by structured plans to transition toward locally sustainable financing models (Dang Mvongo et al., 2021; Machado et al., 2023). Importantly, cost-recovery mechanisms must strike a balance between affordability and the actual cost of service delivery to prevent service degradation or financial collapse (Andreah et al., 2023; Truslove et al., 2020).

Environmental factors present both a challenge and a framework for long-term planning. Key indicators of environmental sustainability include the protection of ecosystem services, the availability of water resources, climate resilience, prevention of environmental degradation, and water resource management. Overreliance on untreated groundwater, as is common in many rural communities in Indonesia and other developing countries, risks environmental degradation (Carrard et al., 2019; Lo et al., 2021). Sustainable RWS operations therefore require sound resource management strategies that account for seasonal variability, source protection, and environmental stewardship. Climate change further compounds these issues, making adaptive infrastructure and long-term planning indispensable (Grison et al., 2023; Nugroho et al., 2022). Moreover, unchecked land-use changes and pollution have the potential to reduce both water quality and availability, necessitating comprehensive catchment and land management approaches (Schlattmann et al., 2022; Wan Rosely and Voulvoulis, 2023).

Collectively, the interaction between social cohesion, financial viability, and ecological resilience not only determines the long-term sustainability of SPAM systems but also directly informs the type of financing mechanism that is most appropriate. For example, systems that demonstrate strong community ownership, stable institutional structures, and transparent financial records are better positioned to attract blended financing mechanisms, such as concessional loans, social impact investments, or results-based grants (Mvongo et al., 2021; Nelson-Nuñez et al., 2019). Conversely, systems with weak institutional capacity or unstable environmental conditions may require adaptive subsidies and technical support until foundational capacities are strengthened.

Financing schemes must be carefully tailored to the local context and the performance of SPAM systems across social, economic, and environmental domains. A one-size-fits-all approach is unlikely to deliver sustainable outcomes. Instead, integrated, multisectoral assessments should guide financial planning, ensuring that investment decisions reinforce the long-term sustainability of rural drinking water services.

2.2 Alternative Options

Designing sustainable financing systems for rural water utilities must incorporate economic, social, and environmental considerations. These factors, which influence risk profiles and funding needs, should inform the choice and structure of financing mechanisms to ensure that rural SPAMs remain resilient and responsive to community needs (Heckel, 2023; Machete and Marques, 2021).

Indonesia's water sector demands significant investment to expand drinking water access, with the Ministry of Public Works and Public Housing estimating a need of IDR 128 trillion for 2020–2024 and IDR 170 trillion for 2025–2030 (Wardhana, 2024). Current financing mechanisms for piped water infrastructure include Conventional Government Procurement (CGP), Public–Private Partnerships (PPP), and philanthropic funding, primarily from Corporate Social Responsibility (CSR) programs (Adhitya Wardhana, 2020).

In rural areas, where community-based rural water utilities (SPAM Perdesaan) are more prevalent, initial infrastructure development is commonly funded through CGP in the form of government grants. These grants serve as seed capital to construct small-scale piped systems with limited household connections. After construction, the systems are transferred to the community for ongoing management, maintenance, and potential expansion. At this post-construction stage, financial sustainability heavily depends on community participation through tariff payments, an arrangement referred to as community financing.

A review of previous literature highlights the need for financing models that are context-specific and capable of supporting long-term service delivery in rural settings (Machete and Marques, 2021). Key financial instruments should ensure full cost recovery through tariffs to cover operational and maintenance expenses, which is essential not only for sustainability but also to improve the system's bankability (Heckel, 2023; Machete and Marques, 2021). However, Heckel (2023) underscores a persistent financing gap between urban and rural water systems. Urban water utility are increasingly able to access commercial debt and hybrid financing schemes, while RWS remain constrained by low financial credibility and limited managerial capacity. To bridge this gap, innovative financing approaches such as blended financing, which combines grants or philanthropic funds with commercial finance, are proposed as viable solutions. Based on recent findings, four post-construction financing alternatives are identified as suitable for RWS:

- Grants from government or philanthropic sources.
- Community financing through user tariff collection.
- Debt financing via loans from banks or financial institutions.
- Private financing through strategic partnerships with third-party businesses.

2.3 Study Area

This study is taken place in Piyungan Subdistrict, Bantul Regency, in Yogyakarta Province, Indonesia. Bantul Regency is currently experiencing challenges pertaining to water resources because of various environmental determinants linked to anthropogenic activities, particularly with the escalation of population growth and urbanization (Harjanta, S., Ningrum, D. 2023). The increasing trend of urbanization is marked by the expansion of metropolitan areas and commercial establishments, including hospitality venues and retail outlets, both within Bantul and its adjacent regions, such as Sleman, thereby exacerbating the pressure of the crisis on local water resources. The developmental initiatives in urban areas, in conjunction with the increasing prevalence of such commercial establishments, have resulted in a heightened demand for water and intensified competition for its accessibility, which is becoming progressively arduous. Bantul Regency is confronted with the prospective challenge of groundwater depletion attributable to unregulated groundwater extraction, resulting in aquifer replenishment occurring at a rate insufficient to match its utilization (Harjanta, and Ningrum, 2023). Bantul Regency is further confronted with issues concerning the management of domestic and industrial waste that pose a risk of water contamination and degradation of groundwater quality. The ultimate waste disposal facility (landfill) located at Piyungan in produces leachate that permeates the regional water supply, thereby compromising the integrity of the water quality. In addition to refuse, the management of household fecal sludge does not completely conform to established safety standards, wherein there exists a potential for septic tank failures that could conceivably contaminate groundwater with pathogenic microorganisms.

Considering its diverse geographical conditions, Bantul Regency also faces challenges related to accessibility, particularly in rural areas. Rural communities often encounter significant challenges in securing access to water due to the unequal distribution of infrastructural resources. In these rural regions, residents typically rely on shallow wells, which are vulnerable to depletion during dry seasons, thereby necessitating dependence on expensive water delivery services. To address these challenges, RWS offers solution to accessibility and water resource management issues by engaging local communities in water governance practices. RWS enhance access to water through the establishment of infrastructure strengthened by community participation, thereby fostering a sense of shared responsibility and sustainability. This approach facilitates the decentralization of water distribution, reduces reliance on depleting groundwater reserves, and enhances resilience against water scarcity.

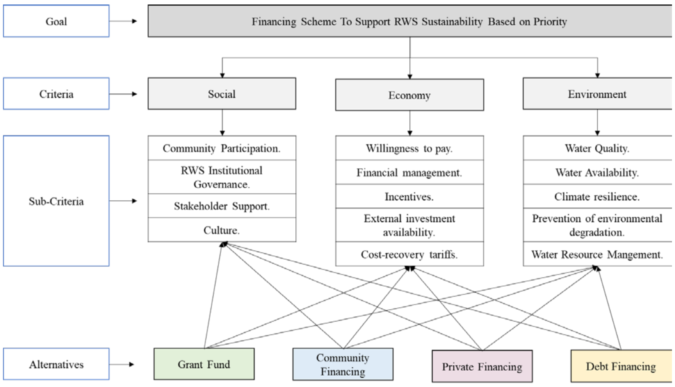
2.4 Interviews and Questionnaires

Purposive sampling approach will be used to determine the RWS to be interviewed. Samples are selected based on specific characteristics that are considered relevant to the aims of the study. Subjective parameters are used to identify individuals, collectives, or instances that are presumed to yield valuable data to address their investigative inquiries (Palinkas et al., 2015). In this analysis, the parameters established to identify RWS samples in Bantul Regency are as follows: RWS in Piyungan Subdistrict that has been established for at least 5 years and is actively functioning, water source from RWS constitutes the community's primary supply of potable water in the sampled region, maintains active household connections at least 50% of its capacity and still have potential network expansion, and have the experience with accessing alternative financial services. According to these parameters, there are eight RWS in Piyungan that adhere to the sample selection criteria.

2.5 Analysis Method

This research adopted the Analytic Hierarchy Process (AHP) to identify the most viable and sustainable funding mechanisms for RWS. The AHP model was constructed with three criteria; social, economic, and environmental, which were further categorized into corresponding sub-criteria. Based on the criteria and sub-criteria selected, the analytical hierarchy tree is constructed as shown in Picture 1.

Questionnaire inputs were carried out through AHP-OS, a web-based AHP system, in which respondents supplied pairwise comparisons to establish the prioritization of criteria and funding alternatives (Goepel, 2018). The AHP-OS then calculated priority vectors, consistency ratios (CR), and consensus rates to ensure statistical robustness and concord among participants. A CR value beneath 0.1 and a consensus rate exceeding 80% signified high coherence and collective concurrence.



Picture 1: Analytical Hierarchy Tree

3. Result And Discussion

Pairwise comparison matrices were carried out separately or criteria and alternatives of the hierarchy structure. The analysis revealed that the social criteria was deemed the most significant (45%), followed by economic (36%) and environmental (19%). Among sub-criteria, community-based management (25%) and financial management (14%) were ranked highest, reflecting the pivotal role of institutional capacity and local governance in preserving service sustainability. Other notable sub-criteria encompassed community participation (12%) and willingness to pay (11%), highlighting the significance of collective engagement and user trust.

Table 1: Geometric Mean of Criteria Pairwise Comparison

Criteria	Social	Economy	Environment
Social	1.000.000	1.320.759	2.304.173
Economy	0,757141	1.000.000	1.969.347
Environment	0,433995	0,507783	1.000.000
CR	0,001702		
AHP Consensus	0,857606		

Insights from interviews with the Association of Bantul RWS and the Village and Community Empowerment Office reveal that several RWS have ceased operations due to their inability to fund repairs for pumps and pipelines. A lack of long-term financial planning exacerbates vulnerability, especially during periods when raw water sources become limited. These financial risks are inherent to the community-based management model itself.

From a social perspective, the community's willingness to connect to piped water services is strong, with most respondents indicating customers' desire to maintain or acquire a new connection. However, in areas with access to alternative water sources such as wells, the preference for piped water drops, indicating a potential limitation for customer base expansion. While the participatory nature of RWS showcases strong social capital, institutional limitations such as the lack of legal status and low professional capacity, pose risks to long-term financial feasibility. On the economic side, current tariffs are not meeting full cost recovery (FCR), as rates are set through community consensus rather than cost analysis. This undermines long-term financial sustainability, particularly for asset maintenance and infrastructure expansion. Limited access to formal

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financial institutions further restricts growth.

Environmental risks also weigh heavily in financing sustainability. Seasonal variability in water availability, especially dependence on surface water and deep wells susceptible to drought, makes water supply unpredictable. Low climate resilience and the absence of watershed protection mechanisms heighten operational risks. Furthermore, water quality issues, often due to domestic and livestock waste pollution, reduce public trust and raise treatment costs. The absence of conservation initiatives and fragmented resource management among PABs weaken system-wide efficiency and increase long-term vulnerability.

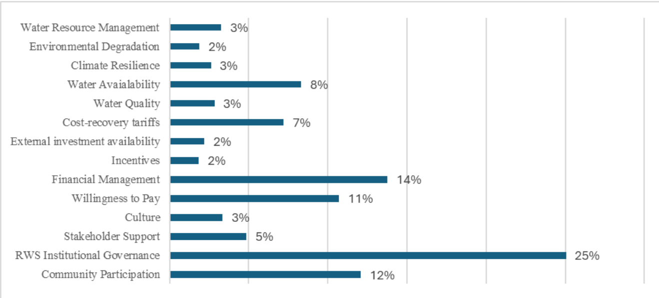


Figure 1: Sub-Criteria Priority

The four funding alternatives priority score evaluated were Community Financing, Private Financing, Grant Funding, and Debt Financing. As shown in Table 2, the result of alternative matrix clearly demonstrated a preference for Community Financing, as indicated by a leading priority score of 62%, supported by a commendably low consistency ratio (CR = 0.00482) and a high consensus rate of 81%. This decision illustrates the correlation between significant social engagement and sustainable financing, wherein community involvement nurtures ownership, trust, and operational continuity.

Grant Funding (12.5%) and Private Financing (13.7%) trailed considerably. While not ranked as the foremost choice, they are still regarded as pertinent complementary mechanisms, particularly advantageous within blended financing frameworks or for infrastructure development and technical support. These alternatives must, however, be sensitive to contextual nuances and participatory in nature to avert the erosion of community ownership.

Debt Financing was allocated the lowest priority (11.4%), reflecting considerable apprehensions among community groups regarding financial risks, repayment capabilities, and limited access to formal credit. Interactions with stakeholders demonstrated that despite some factions obtaining loans from cooperatives or banks (secured by personal guarantees), debt persists as the least preferred and most limited alternative. Notwithstanding, it still possesses potential for future diversification if adapted to the legal and operational realities of rural water collectives.

Table 2: Priority Financing Scheme Result

Alternative Result	Debt Financing	Grant Fund	Community Financing	Private Financing	CR max
Priority Financing Scheme Result	11%	13%	62%	14%	0,00482
CR	0%				
AHP Consensus	81%				

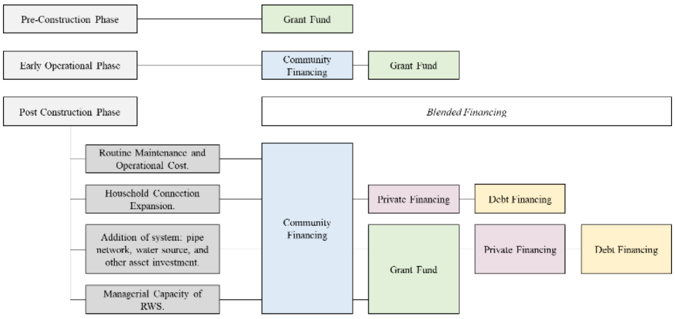
Based on the AHP analysis, community financing was identified as the most preferred scheme, followed by private financing, grants, and debt financing. An effective financial strategy must be adaptive to each operational phase of the rural water utility lifecycle. Accordingly, this study proposes a phased financing approach tailored to pre-construction, early operational, and post-construction stages (Picture 2).

During the pre-construction phase, funding is primarily grant-based that are typically sourced from government or donor contributions, which supports infrastructure and raw water development. This phase exhibits high dependency on grants, as RWS at this stage lack both a customer base, legal status, and financial standing to pursue alternative financing. While this approach helps establish initial access, its one-time nature poses challenges for operational continuity.

In the early operational phase, financing gradually transitions toward community contributions, derived from connection fees and regular billing. Nonetheless, actual tariffs that are fall short of cost-recovery and financial records that are still at rudimentary stage, omitting critical aspects such as asset depreciation. These gaps expose RWS to medium-term financial risk, especially as operating costs (e.g., electricity and maintenance) increase. Selective use of grants remains necessary for institutional strengthening and capacity building but should not serve as the primary funding source.

In the post-construction phase, financial needs become more complex, covering system expansion, network rehabilitation, and technology upgrades. While community contributions can support daily operations, they are insufficient for capital-intensive investments. Therefore, a multi-source financing strategy is essential, combining private and debt financing. Private financing may be mobilized through partnerships with local businesses or social enterprises for investments in reservoirs, water treatment, and monitoring systems. Debt financing from microfinance institutions, cooperatives, or regional development banks could also support long-term network expansion projects.

However, the feasibility of external financing is still limited by several key risks: the lack of legal status for most RWS's and their weak financial governance capabilities. These constraints prevent access to formal credit and discourage commercial investment. Additionally, environmental uncertainties, particularly around water source reliability, introduce further risks that must be addressed in financial planning. Therefore, any future financing scheme must be complemented by institutional development, including improvements in legal recognition, financial management, and environmental risk governance.



Picture 2: Recommended Financing Scheme Based on Priority

4. Conclusion

RWS in Piyungan Sub-district of Bantul Regency, play a vital role in delivering piped water services to rural communities. High community trust and demand for piped water are evidenced by the population's willingness to connect to the service and consistently pay for both new service connections and monthly usage. RWS managers fulfil multiple operational roles to meet service standards, yet sustaining these services remains challenging. particularly due to financial constraints.

The AHP analysis underscores that Community Financing is the most suitable and trusted model for sustaining rural water utilities in Indonesia, primarily due to its alignment with local social dynamics and the existing management capacity of community groups. While grant and private financing approaches can complement this foundation, they must be designed to reinforce, not replace, community-led efforts. Debt financing, though least favoured, may be developed cautiously as an alternative pathway to financial inclusion in the sector.

A layered and phase-responsive financial strategy is crucial for sustaining rural piped water services. A hybrid approach, blending initial grants, community-based contributions, and external financing, offers a realistic path forward. However, it must be supported by institutional reforms and risk-based planning to improve the financial viability and resilience of rural water supply systems.

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