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Article

Risk assessment of public-private partnership water projects in Indonesia

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Abstract: Public-private partnerships (PPPs) are vital for infrastructure development in developing countries, integrating private efficiency with public oversight. However, PPP models often face risks, particularly in Indonesia's water sector, due to its unique geographical and regulatory challenges. This study aims to identify and evaluate risk factors specific to drinking water PPP projects in Indonesia. Using a quantitative approach, structured questionnaires were distributed to experts in the sector, and the data was analyzed using a fuzzy evaluation method. Risks were categorized into location, design and construction, financial, operational, revenue, and political. The study emphasizes that effective risk management, including identification, analysis, and mitigation, is essential for project success. It highlights the importance of stakeholder involvement and flexible risk management strategies. Comprehensive and proactive risk management is key to the success of drinking water infrastructure projects. The research suggests that an integrated and collaborative approach among stakeholders can enhance risk management effectiveness. These findings provide valuable insights for policymakers, project managers, investors, and other stakeholders, underscoring the necessity for adaptable regulatory frameworks and robust policy guidelines to improve the sustainability and efficacy of future water-related PPPs.

Keywords: water; public private partnership; infrastructure; risks

1. Introduction

Public-private partnerships (PPP) have emerged as an increasingly popular model for infrastructure development particularly for developing countries, integrating private sector efficiency with public sector oversight to provide critical services (Yescombe, 2007). For instance, PPP models in India leverage private capital for infrastructure services, focusing on incentivizing sustainable development rather than merely financial returns (Patil et al., 2016). Similarly, in Brazil, the model encourages initial investments and greater private sector responsibility in managing infrastructure. However, the outcomes can deviate from expectations, with costs potentially exceeding initial forecasts (Marques, 2016). While PPP investments in developing countries have been shown to significantly reduce investment cash flows and improve the operating performance of private sector firms in the long run (Chauhan and Marisetty, 2019), the integration of environmental and social considerations remains inadequate. This is due to the absence of appropriate instruments or processes, and conflicting political and economic interests (Malvestio et al., 2018) and many other factors. These examples illustrate how PPP models vary worldwide in terms of contractual structures, payment mechanisms, infrastructure needs, investment sectors, and legal contexts.

In developing economies like Indonesia, where the need for infrastructure is substantial, PPPs play a crucial role, especially in the water supply and sanitation sector (Rahman et al., 2022). Indonesia's unique archipelagic geography presents specific logistical challenges, such as the need for decentralized solutions and the high costs associated with infrastructure distribution across numerous islands. This is markedly different from challenges faced in continental settings (Carbonara et al., 2016), where infrastructure projects often benefit from economies of scale and easier material transport. Additionally, Indonesia's regulatory and political frameworks are uniquely suited for a detailed analysis of PPP setups aimed at addressing local issues. For instance, the government allows for varied approaches to PPP contracts, which can differ significantly from other models in countries like India or Brazil.

Despite the potential benefits of PPPs, projects often experience varying levels of success, primarily due to the range and complexity of associated risks (Ameyaw and Chan, 2013). The risk factors can vary significantly between sectors, such as water projects and building construction projects. These differences are shaped by the nature of the services provided, the infrastructure requirements, and the regulatory environments involved. Some common risks found in both water and building projects including financial, contractual, and project management risks (Ameyaw and Chan, 2015a; Moradi Shahdadi et al., 2023), while some other risk factors are unique to particular sector. One of the primary concerns is environmental risks, as these projects are highly sensitive to environmental conditions. This includes issues related to water availability and quality, as well as potential impacts on local ecosystems (Lima et al., 2023).

This study offers a focused examination of the risk factors that influence public-private partnerships (PPPs) in the water sector of Indonesia, a critical area that has been largely overlooked in the existing literature. The research provides specific insights that can directly influence policy formulation and project management by incorporating factors tailored to the study context and water project into a comprehensive risk analysis model.

The study's results will underscore the necessity of regulatory frameworks that are adaptable and can accommodate the environmental variabilities and infrastructural challenges that often found by policymakers in developing countries. This could result in more robust policy guidelines that improve the sustainability and efficacy of future water-related PPPs. A greater comprehension of the risk landscape will be helpful to project managers and investors, enabling them to make more informed investment decisions and risk mitigation strategies. The study identifies specific risks, thereby establishing a foundation for the development of more effective risk assessment methodologies and project management practices. In addition, the research introduces a risk assessment approach that considers the inherent uncertainties in PPP initiatives through the use of synthetic fuzzy evaluation methods. This methodological argued can be a valuable resource for stakeholders, as it can enhance the strategic planning of PPPs and improve the precision of risk evaluations.

2. Literature study

2.1. Public private partnership (PPP)

The public-private partnership (PPP) has become a key strategy worldwide for infrastructure development. By definition, PPP is a long-term agreement between government entities and private parties (Berawi et al., 2018). Private entities take on substantial financial, technical, and operational risks to provide public services or projects. This partnership offers various advantages, fostering an environment that supports efficiency, innovation, and enhanced resources for large-scale infrastructure projects (Sarmento and Renneboog, 2016). Historically, PPPs were pioneered in countries like the UK and Australia as a solution to public sector constraints, leveraging private sector efficiency and capital for public infrastructure needs (Li et al., 2005). This model has evolved to address broader socio-economic goals including sustainability and public service quality.

In both developed and developing contexts, PPPs serve similar fundamental purposes: to optimize resource use, enhance service delivery, and bridge infrastructure gaps. Nevertheless, the application shows substantial differences. In developed countries, public-private partnerships (PPPs) frequently prioritize innovation and the utilization of cutting-edge technology, while in developing nations such as Indonesia, the emphasis is frequently on the resolution of fundamental infrastructure requirements and the overcoming of investment deficits (Osei-Kyei and Chan, 2017a).

One key advantage of PPPs is the shared risk concept, which allows for more effective management of the inherent risks associated with massive infrastructure projects. By corresponding the objectives of the public and private sectors, each party can use its particular strengths to manage various types of risks, resulting in stronger project outcomes (Hodge, 2004). Furthermore, the mobilization of private investment is critical in complimenting governmental resources and bridging the funding gap commonly associated with infrastructure development (Marques and Berg, 2011).

Despite these benefits, PPPs face several challenges. The complexity of long-term contracts can lead to management difficulties and potential disputes. Balancing public service goals with private profit motives, especially in critical sectors like water and sanitation are required. As PPP often comes under scrutiny for issues of transparency and accountability, especially concerning the management of public resources, requires careful negotiation and transparent risk allocation (Shen and Wu, 2005).

Indonesia has recognized PPPs as a vital tool for its infrastructure development, particularly in sectors such as transportation, energy, and notably, water and sanitation. While PPPs in developed nations might prioritize technological innovations and cost efficiencies, Indonesia’s focus is on overcoming basic infrastructural deficits and ensuring access to essential services. Regulatory reforms and initiatives like the Indonesia Infrastructure Guarantee Fund (IIGF) have been crucial in mitigating risks and attracting private investment (Bappenas, 2020).

Yet, challenges persist. Regulatory uncertainties, issues surrounding land acquisition, and capacity constraints highlight the complex nature of implementing PPPs in Indonesia. The water sector, though less commonly associated with PPPs compared to transportation or energy, presents significant potential for enhancing service delivery and infrastructure development through PPP models.

2.2. Risk factors in PPP

Risk factors in public-private partnerships (PPPs) are important for infrastructure projects. Risks such as location primarily concern delays and the increased costs are significant to land acquisition as highlighted by Babatunde et al. (2017) and Rafaat et al. (2020). These issues underscore the challenges in securing suitable sites for infrastructure projects within expected timeframes and budgets. Other risks such as design, construction, financial, operational, revenue, and political risks are also frequently found in infrastructure project and often shared between public and private partners. While these risks apply to all PPP projects, some factors are tailored to water PPP project.

There are numerous reasons drinking water initiatives are significant for analysis. Unlike other infrastructure projects, drinking water systems need uninterrupted service delivery (Gunasekara et al., 2014; Hassanzadeh et al., 2016; Shrestha et al., 2018), which makes operational risks more significant. The provision of water is strictly regulated, as it is a fundamental human right. The effective management of regulatory risks is further restricted by the potential for severe public health crises and societal backlash in the event of service delivery failures. The impact of climate change on water resources—such as variability in supply and increasing scarcity (Shaheen and Chan, 2016; Shrestha et al., 2017; Sohail et al., 2022). These risks are more acute in the water sector than in other types of infrastructure due to the direct dependency on stable water cycles (Cheung and Chan, 2011; Shrestha et al., 2017). Additionally, the technical requirements for the purification and distribution of potable water are often complex and demand specialized infrastructure, which increases the risks during design, and construction stage.

Other notable risks include:

- Unclear project specifications and scope changes that can lead to disputes and cost overruns. Studies indicate that ambiguities in output specifications and subsequent increases in construction costs are common in PPP projects (Chan et al., 2015; Cheung and Chan, 2011; Yang et al., 2020).
- Challenges such as achieving financial closure, managing currency fluctuations, and dealing with variable interest rates are significant (Cheung and Chan, 2011; Pramudya and Wibowo, 2022; Shrestha et al., 2017). Additionally, revenue uncertainties from low initial demand or tariffs not meeting projections pose threats to economic sustainability (Valipour et al., 2019).
- The community's low ability to pay (Yang et al., 2020), and tariffs that do not meet projections (Valipour et al., 2019) challenge the economic sustainability of water projects. There are also errors in volume projection estimates (Cheung and Chan, 2011) that can also lead to financial discrepancies.

- Political risks such as government intervention, inadequacies in law, and regulatory changes further complicate the landscape, potentially altering the course of project execution (Cheung and Chan, 2011; Li et al., 2022; Yang et al., 2020).

The review explores how different risks specifically impact water projects, differentiating them from other infrastructure sectors. This focus helps in understanding strategies necessary to mitigate risks effectively in drinking water systems, especially within the dynamic and diverse regulatory landscape of developing countries like Indonesia.

2.3. Fuzzy synthetic evaluation

Fuzzy synthetic evaluation is an innovative approach in risk assessment that has gained attention due to its proficiency in handling the complexities of the real world. Originating from fuzzy set theory, which was introduced by Lotfi Zadeh in 1965, this method is specifically designed to manage ambiguity and complex relationships between various factors.

A distinctive strength of the fuzzy synthetic evaluation method is its ability to effectively handle uncertainty. Traditional risk assessment approaches often struggle with ambiguity, but fuzzy synthetic evaluation overcomes this by using linguistic terms instead of numeric values (Li and Zou, 2011). This allows for a more nuanced interpretation of complex decision-making scenarios. Additionally, fuzzy synthetic evaluation is extremely useful in the context of multi-criteria decision-making (Ammar et al., 2013). The method can accommodate various risk factors simultaneously, offering a more holistic view of the risk landscape. This technique is particularly relevant for Public-Private Partnership projects (PPP), where various types of risks—financial, technical, operational—need to be considered concurrently. Another strength is the inherent flexibility of the method (Nguyen et al., 2015). It can integrate various risk factors and adapt to different expert opinions, making it a versatile tool, especially when faced with the complex and evolving scenarios typical of PPP projects.

However, the fuzzy synthetic evaluation method is not without limitations. A significant concern is the subjectivity introduced by its reliance on expert opinions. While this allows for a deeper understanding of risks, it also has the potential to affect the accuracy and consistency of the results. Additionally, the method can involve complicated calculations, often requiring specialized software, which may pose a barrier to its application.

Nevertheless, the use of fuzzy logic may be restricted to individuals with specialized knowledge due to the complexity of its application and interpretation, which necessitates an in-depth understanding of its theoretical foundations. Ilbahar et al. (2018) examines the mathematical underpinnings of fuzzy logic, underscoring the necessity of rigorous training in its implementation. Furthermore, the fuzzy synthetic evaluation's efficacy is dependent on the precision and quality of the input data. The significance of detailed data collection and validation is underscored by the potential for misleading results resulting from inadequate or inaccurate data (Zadeh, 1965). The method's dependence on subjective assessments can also introduce biases, which must be meticulously managed to guarantee the reliability and validity of outcomes.

The use of fuzzy synthetic evaluation in the field of PPP has grown, particularly because of its ability to handle complex, uncertain, and ambiguous situations. For instance, a study by Osei-Kyei et al. (2017) successfully used this method to assess risks in PPP construction projects worldwide. They utilized fuzzy synthetic evaluation to determine the importance of various risk factors, providing valuable insights into risk prioritization. In another example, Kukah et al. (2023) developed a risk assessment model for PPP projects using this method. They incorporated various risk factors such as contract and payment risks, environmental risks, financial and cost risks, legal and guarantee risks, operation risks, and used fuzzy synthetic evaluation to produce a comprehensive risk assessment.

While these studies illustrate the potential utility of fuzzy synthetic evaluation for risk assessment in PPP, its specific application in the water sector, particularly in the context of developing countries like Indonesia, remains largely unexplored. Given the flexibility and comprehensive nature of this approach, it promises to assess risks effectively in water PPP projects. Further research could yield significant insights for this under-researched area.

3. Research methodology

The methodology of this study incorporates a quantitative approach, employing a blend of different data collection methods to ensure a comprehensive analysis. Benchmarking was used to compare current project practices against the industry standards or best practices from similar projects, helping to identify performance gaps and opportunities for improvement. Alongside this, secondary data was gathered from a wide range of sources, including academic journals, industry reports, and existing case studies, providing a broad perspective and a rich context for the analysis. From the benchmarking and secondary data, variables used for this study were identified as shown in **Table 1**.

Table 1. Variables in the research study.

Type of risks	Sources	References
Location risks	Delays and increases in land acquisition costs	(Babatunde et al., 2017; Rafaat et al., 2020)
Design, construction and operation	Unclear output specification	(Chan et al., 2015; Rafaat et al., 2020)
	Increases in construction costs	(Chan et al., 2015; Cheung and Chan, 2011; Yang et al., 2020)
	Changes in the scope of work after signing the contract	(Rafaat et al., 2020; Yang et al., 2020)
Financial risks	Failure to achieve financial close	(Cheung and Chan, 2011; Yang et al., 2020)
	Land bailout refund	(Pramudya and Wibowo, 2022)
	Currency exchange rate	(Rafaat et al., 2020; Shrestha et al., 2017; Valipour et al., 2019)
	Delay in government support	(Cheung and Chan, 2011; Yang et al., 2020)
	Increase interest rates	(Li et al., 2022; Rafaat et al., 2020; Shrestha et al., 2017)
	Insurance risk	(Demirag et al., 2012; Pramudya and Wibowo, 2022)

Table 1. (*Continued*).

Type of risks	Sources	References
Operational risks	Irregular water availability	(Gunasekara et al., 2014; Hassanzadeh et al., 2016; Shrestha et al., 2017)
	Increase in O&M costs	(Li et al., 2022; Shrestha et al., 2017)
	Water loss and quality	(Shaheed et al., 2014; Shrestha et al., 2017; Sohail et al., 2022)
Revenue risks	Low demand in the beginning of project	(Cheung and Chan, 2011; Shrestha et al., 2017)
	Low ability to pay	(Yang et al., 2020)
	Tariff adjustments do not match expectations	(Valipour et al., 2019)
	Estimation error and change in volume projection	(Cheung and Chan, 2011)
Political risks	Government intervention	(Cheung and Chan, 2011; Li et al., 2022; Valipour et al., 2019; Yang et al., 2020)
	Imperfect law and supervision system	(Cheung and Chan, 2011; Li et al., 2022; Yang et al., 2020)
	Regulatory changes	(Li et al., 2022; Yang et al., 2020)

Additionally, a structured questionnaire survey was conducted, targeting industry professionals to gain direct insights into specific aspects of project management and performance. The combination of benchmarking, secondary data retrieval, and direct surveys enables the research to not only draw on existing knowledge but also to incorporate fresh, empirical data directly from the field, enhancing the robustness and relevance of the findings (Berawi et al., 2023). This multi-source data collection approach helps to overcome the limitations associated with single-method data collection by balancing the potential biases of questionnaires with the extensive scope of secondary data.

3.1. Data collection

Data was gathered via structured questionnaires distributed to selected experts. For studies involving expert panels, an optimal number of three to seven experts is recommended (Hora, 2004). Each respondent rated the impact of various risk events on one another using predefined linguistic terms in fuzzy set theory: "very high", "high", "medium", "low" and "very low" (see **Figure 1**).

Linguistic variables	Code	Triangular Fuzzy Number (d_{ij})
Very low	VL	(0.00; 0.10; 0.30)
Low	L	(0.10; 0.30; 0.50)
Medium	M	(0.30; 0.50; 0.70)
High	H	(0.50; 0.70; 0.90)
Very high	VH	(0.70; 0.90; 1.00)

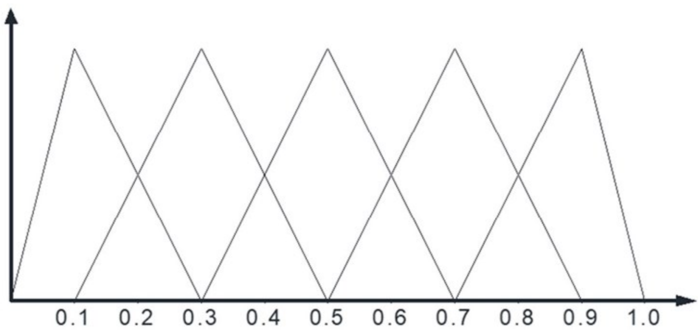

Figure 1. Linguistic terms in fuzzy theory.

In research contexts that are marked by ambiguity and uncertainty, The fuzzy set theory (FST) approach is particularly valued. This method's capacity to manage the imprecision that is inherent in human judgments is one of its primary advantages.

This is particularly useful when evaluating subjective data, such as expert opinions in risk assessments. In this context, FST is utilized to transform linguistic assessments into triangular fuzzy numbers (TFNs), allowing for three-point estimations—minimum (*l*), most likely (*m*), and maximum (*r)* values—rather than definitive ones as in traditional models. This approach, exemplified in TFNs, simplifies handling and processing of fuzzy information environments effectively (Xu et al., 2010).

3.2. Data analysis

The responses were analyzed using triangular fuzzy relation matrices (TFRM) to evaluate the strength of relationships between risk events. The notation (~) placed above the symbol (*D*) indicates a fuzzy set. In fuzzy set, each element $\tilde{d}_{ij}^{k}$ is expressed as a fuzzy number $\tilde{d}_{ij}^{k} = \left(l_{ij}^{k}, m_{ij}^{k}, r_{ij}^{k}\right)$, representing the expert *k* assessment of the impact of event *i* on event *j*.

$$\tilde{D}^{k} = \begin{bmatrix} 0 & \tilde{d}_{12}^{k} & \cdots & \tilde{d}_{1n}^{k} \\ \tilde{d}_{21}^{k} & 0 & \cdots & \tilde{d}_{1n}^{k} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{d}_{n2}^{k} & \tilde{d}_{n2}^{k} & \cdots & 0 \end{bmatrix}$$

3.3. Defuzzification approach

Each assessment is then defuzzified using methods such as the centroid technique, although this study opts for a method that converts fuzzy data into crisp scores to address the limitations of traditional defuzzification (Opricovic and Tzeng, 2004). This conversion involves normalizing the fuzzy scores and calculating a crisp total score for each interaction, which informs the subsequent decision-making process. The procedure as follows:

1) Normalizing TFN

$$a_{ij}^{k} = \frac{(l_{ij}^{k} - \min l_{ij}^{k})}{\Delta_{\min}^{\max}}, b_{ij}^{k} = \frac{(m_{ij}^{k} - \min l_{ij}^{k})}{\Delta_{\min}^{\max}}, c_{ij}^{k} = \frac{(r_{ij}^{k} - \min l_{ij}^{k})}{\Delta_{\min}^{\max}}$$

$$\Delta_{\min}^{\max} = \max_{k \in \{1,2,\ldots,p\}} r_{ij}^{k} - \min_{k \in \{1,2,\ldots,p\}} l_{ij}^{k}$$

2) Calculating left and right limits from these normalized values

$$u_{ij}^{k} = \frac{b_{ij}^{k}}{(1 + b_{ij}^{k} - a_{ij}^{k})}$$

$$v_{ij}^{k} = \frac{\mathrm{c}_{\mathrm{ij}}^{\mathrm{k}}}{(1 + c_{ij}^{k} - b_{ij}^{k})}$$

3) Compute a total normalized crisp score

$$w_{ij}^{k} = \frac{u_{ij}^{k}(1 - u_{ij}^{k}) + (v_{ij}^{k})^{2}}{(1 + b_{ij}^{k} - a_{ij}^{k})}$$

4) Calculate total crisp score

$$d_{ij}^{k} = \min l_{ij}^{k} + w_{ij}^{k} \text{ x } \Delta_{\min}^{\max}$$

5) Integrate crisp score

$$d_{ij} = \frac{1}{p} \text{x} \sum_{k=1}^{p} d_{ij}^{k}$$

6) Determine direct fuzzy relationship matrices

$$D = \begin{bmatrix} 0 & d_{12} & \cdots & d_{1n} \\ d_{21} & 0 & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & 0 \end{bmatrix}$$

7) Transform into initial reachability matrices using an intercept coefficient (α)

The direct fuzzy relation matrix can be transformed into an initial reachability matrix [T] using an intercept coefficient (α). Elements equal to or greater than α will be replaced with the value 1; otherwise, they are reset to 0.

$$t_{ij} = \begin{cases} 1, \text{if } (d_{ij} \geq \alpha) \\ 0, \text{if } (d_{ij} < \alpha) \end{cases}$$

4. Analysis and results

4.1. Respondent demographics

The analysis of the respondents indicates a diversity in terms of occupation, experience in the drinking water infrastructure sector, and education levels (see **Table 2**). Generally, the respondents come from three main areas: education, government, and professional associations. From the education sector, there are four respondents who serve as lecturers or researchers. They possess high educational backgrounds, with two holding doctoral degrees and two others holding master's degrees. Their experience in the drinking water infrastructure field varies from 1 to 15 years, demonstrating a combination of deep theoretical and practical expertise.

Table 2. Respondents demographic.

Occupation	**Frequency**	**Percentage (%)**	**Years of experience in construction**	**Frequency**	**Percentage (%)**
Technical staff	5	38.46	1–5	2	15.38
Practitioner	4	30.77	6–10	5	38.46
Government institution	2	15.39	11–15	4	30.78
Consultant	1	7.69	16–20	2	15.38
Researcher	1	7.69			
Total	13	100.00	Total	13	100.00
Level of education	**Frequency**	**Percentage (%)**			
Undergraduate	5	38.46			
Master	5	38.46			
PhD	3	23.08			
Total	13	100.00			

In the government sector, there are three respondents with roles as civil servants and one as a technical staff member. All civil servants hold bachelor's degrees and have work experience ranging from 1 to 15 years, indicating their involvement in the implementation of policies and management of drinking water infrastructure projects. The technical staff, with a bachelor's degree and 6–10 years of experience, demonstrates technical skills that may be more focused on operational aspects.

From professional associations, there are four respondents serving as observers or consultants/advisors. They have a diverse educational background, from bachelor's to doctoral degrees, and extensive work experience (6–20 years). This suggests that they may have a broader and more in-depth perspective on industry issues, as well as the capability to provide strategic and technical advice.

Overall, this analysis shows that the respondents possess a diverse combination of theoretical and practical expertise, which is extremely valuable in the discussion and development of drinking water infrastructure. The mix of field experience and academic knowledge among these respondents offers rich and varied insights, which are crucial for understanding and addressing complex challenges in this sector. Despite the small sample size of thirteen completed responses, this range is considered adequate as shown by previous literature (Bakhtari et al., 2021; Balaji and Arshinder, 2016; Kumar et al., 2013).

4.2. Level 1 risks

First-level risk events include "delays and cost increases in land acquisition" (L1A1), "scope of work changes after contract signing" (L1A2), and "failure to achieve financial close" (L1A3), "irregular water availability" (L1A4), "low initial project demand" (L1A5), and "government intervention" (L1A6). Risk event A2 is influenced by several causes including the cost of land acquisition, unclear external specifications, and other risk events such as construction costs and time (Permatasari et al., 2020; Walker and Jacobsson, 2014).

Several studies have confirmed the significance of risks associated with land acquisition (Babatunde et al., 2017). Asian Development Bank (2015) states that land acquisition and permitting are major issues in various infrastructure projects such as toll roads, sanitation, clean water, and bridges, which can cause delays and recommend that at least 80% of the needed land is acquired before tendering. Bhatt and Sarkar (2020) indicate that the risk of land acquisition is also critical in India. Indonesia is in a similar situation, with several projects delayed due to prolonged land acquisition processes (Meckelburg and Wardana, 2024).

On the other hand, irregular water availability (A4) and low initial demand (A5) in public-private partnership projects for drinking water are crucial issues that need to be seriously addressed. Access to clean water is a fundamental human right and essential for public welfare. Instability in clean water supply can directly impact the health and daily lives of the community. Additionally, low demand at the beginning of a project indicates a mismatch between the services provided and the community needs, which can be caused by various factors such as high tariffs or inadequate water quality. This situation not only hampers cost recovery and the financial sustainability of the project but also negatively impacts the local and national economy.

Furthermore, this issue can reduce public and investor trust in the project, resulting in difficulties in obtaining funding or support for similar future projects. It can also lead to public dissatisfaction, affecting social and political issues, especially if the community feels that their basic needs are not being met. Failure to address this issue also risks non-compliance with applicable standards and regulations and can result in legal sanctions and reputational damage for the government and businesses involved. Moreover, it also hinders the achievement of sustainable development goals (SDGs), particularly regarding access to clean water and sanitation.

Therefore, it is crucial for governments and businesses involved in public-private partnership projects to strategically and effectively address the issues of irregular water supply and low initial demand to ensure project success and community welfare.

4.3. Level 2 risks

The second tier of risk events includes “site selection” (L2A1), “work output specifications” (L2A2), and “delays in government support” (L2A3), “increases in operation and maintenance costs” (L2A4), “low public payment ability” (L2A5), and “an imperfect legal and regulatory system” (L2A6). This research reinforces findings by Javed et al. (2013) and Yescombe (2007), which highlight the importance of establishing strong output specifications. Failure to define expected output specifications accurately can impact subsequent phases (Indonesia Ministry of National Development Planning, 2023). Strong output specifications should clearly outline the needs of the public sector (Yescombe, 2007). They serve as guidelines for project implementation as they set the minimum requirements during the project planning phase. Output specifications need to be well-defined early in project development (Javed et al., 2013) and are an integral part of the project documentation for procurement and performance monitoring of public-private partnerships throughout the project lifecycle (Lam and Javed, 2013).

Unclear output specifications can hinder the entire process, including land acquisition and the scope of work, which are crucial early parts of development implementation. However, developing good output specifications requires significant time and effort from all parties involved in monitoring until the concession period is complete (Javed et al., 2013). Rates can only increase if the requirements are satisfactorily met. To this extent, risks associated with unclear output specifications appear to be well-managed. However, empirical evidence also reveals that actual construction costs for some projects can deviate significantly from initial estimates due to changes in work scope. Rough estimates indicate that the risk of changes in work scope occurs in one out of every two projects, resulting in an average cost increase of about 5%–10% from initial contract (Serag et al., 2010). If the contract causes these changes, private operators must be compensated with an extension of the concession period or a rate adjustment to maintain the project’s expected return at an acceptable level. From a public perspective, the value for money of these projects can be questioned.

In Indonesia, Presidential Regulation No. 102/2016 provides a basis for the National Asset Management Agency (LMAN) to cover land acquisition costs directly or indirectly as a result of the risk of land bridge fund reimbursement. The risks associated with land acquisition are borne by the Government of Indonesia for public infrastructure development through regulation (Indonesia Ministry of National Development Planning, 2023). Given the limitations of public budgets, the private sector, in some cases, is permitted to bear the costs of land first to expedite its release and will obtain reimbursement. However, delays in land cost reimbursement by LMAN can pose challenges for the private sector in managing its cash flow.

Currency exchange rates in developed countries are relatively stable, but this is not the case in developing countries (Osei-Kyei and Chan, 2017b). The significance of this risk has also been affirmed by Ameyaw and Chan (2015b). Infrastructure investments such as toll roads are often marked by significant asset-liability mismatches where revenue is in local currency, but debt is in foreign currency. Therefore, exchange rate volatility can adversely affect the financial sustainability of the project. The 1999 Asian crisis, which hit Indonesia the hardest, provides a compelling example of how private investors must manage risk appropriately, as the Indonesian Rupiah plummeted from 2400 to 15,000 against the US dollar, increasing the value of US dollar-denominated debt sixfold in local currency (Wibowo and Kochendörfer, 2005).

The risk of "government support delays" in public-private partnership projects, particularly in the drinking water sector, is often a major challenge that can hinder project progress. These delays can take the form of delays in ratifying regulations, disbursing funds, or obtaining necessary administrative approvals (Ye and Tiong, 2000). This not only creates uncertainty in workflow and financial planning but can also affect investor confidence and business partners.

On the other hand, an "imperfect legal and regulatory system" also adds to the complexity of risk. Legal ambiguities and weak oversight can lead to legal uncertainty, potentially causing disputes and hampering project implementation (Wang et al., 2020). If these two risks are not managed well, they can lead to increased costs, project completion delays, and ultimately, affect the efficient and effective provision of drinking water services to the public. Therefore, it is important for the government and business entities to cooperate in creating a clear and efficient framework and strengthening the legal and regulatory system to mitigate these risks.

4.4. Level 3 risks

Third-tier risk events include "location permitting" (L3A1), "increases in construction costs" (L3A2), and "increases in interest rates" (L2A3), "quantity and quality of drinking water" (L3A4), "tariff adjustments not meeting expectations" (L3A5), and "regulatory changes" (L3A6).

Location permitting risk often becomes an early barrier in infrastructure projects. The lengthy and complicated permitting process not only hampers project progress but can also lead to construction cost increases (Ke et al., 2013). These cost increases can occur due to delays that extend construction time, increasing labor and raw material costs. Both of these risks are interrelated and often become the primary cause of overall project cost increases.

The risk of interest rate increases also plays a crucial role. In the context of project financing, rising interest rates can increase borrowing costs and affect the financial viability of the project (Manamgoda et al., 2018). This becomes crucial, especially in projects that rely on external financing. Rising interest rates can reduce profit margins and increase the risk of financial failure (Comeig et al., 2014). Subsequently, risks related to the quantity and quality of drinking water are equally important. Inadequate water availability or poor water quality can disrupt project operations and reduce public trust (Nizkorodov, 2021). These risks not only impact the technical aspects but also the social and sustainability aspects of the project.

On the other hand, the initial rate is the rate for the first year of operation. This rate is determined based on a willingness-to-pay survey and microeconomic forecasts (Lam and Tam, 1998). The rate level is usually set as a bidding parameter for infrastructure in Indonesia: private bidders offering the lowest rate win the contract. According to law, rates are adjusted every two years following inflation. In this capped price system, the private sector bears the demand risk. During the 1990s, the private sector faced significant tariff risks, as rates could not be adjusted according to the contract. However, since the enactment of Government Law No. 38/2004 in 2004, the private sector is relatively protected from these risks, as the Government of Indonesia will compensate the private sector for financial losses incurred due to rates lower than the agreed level. The private sector can also demand government guarantees that protect them from any contract breaches by the Government of Indonesia, such as failing to approve rate adjustments in a timely manner.

4.5. Level 4 risks

Fourth-tier risk events include "Limited household connections to drinking water pipes" (L4A1), "insurance risk" (L4A2), and "Miscalculation of household connection uptake" (L4A3), "Interface risk between the upstream and downstream sides" (L4A4).

Risk L4A1 relates to limitations in providing drinking water access to households. This can be caused by various factors, such as infrastructure limitations, geographical constraints, or financial resource limitations. These limitations not only affect customer satisfaction but also impact the project's revenue, which depends on the number of service users.

Insurance risk in drinking water infrastructure projects often relates to uncertainties in obtaining adequate insurance coverage or high premium costs. This risk can increase operational costs and reduce profit margins. These studies suggest that insurance can mitigate the economic impact of operational losses by replacing potential large losses with a predictable cost (the premium), but factors such as information risk can influence the insurer's costs, which may affect the overall operational investment costs (Chen et al., 2017).

On the other hand, miscalculations in estimating the number of households using the drinking water service can lead to inaccurate planning (Kumpel et al., 2017). This can affect infrastructure investment, resource management, and revenue projections. These miscalculations can lead to overinvestment or insufficient capacity, both of which negatively impact the sustainability of the project.

Risk L4A4 relates to the coordination and integration between water source provision (upstream) and distribution to end-users (downstream). Mismatches in management between these two sides can lead to inefficiencies, such as water loss, service disruptions, or water quality issues (González-Gómez et al., 2012). Previous research also showed that inefficient maintenance management in water distribution systems leads to water losses of up to 42.7 percent in northeast Brazil (Pereira et al., 2020). Managing these risks requires a comprehensive approach, involving meticulous planning, effective risk management, and good coordination among stakeholders. This is essential to ensure the success and sustainability of drinking water infrastructure projects.

5. Conclusion

this study has demonstrated that effective and comprehensive risk management is crucial for the success of infrastructure projects, particularly in the water sector involving public-private partnerships (PPPs). By employing the Fuzzy synthetic evaluation method, this research has provided risk classifications specific to water PPP projects. This methodology has proven instrumental in the identification and categorization of critical risks, such as ensuring proactive management of water availability and quality, careful handling of uncertainties in land acquisition, and defining clear output specifications. Such detailed risk assessment underscores the necessity for tailored risk management strategies that are informed through the fuzzy evaluation. These findings highlight the potential for improved risk management practices, ensuring more robust project outcomes in the sector.

The application of this method has not only confirmed known risks but also illuminated the interdependencies among them, providing a framework for anticipating and mitigating potential challenges. Although the findings are particularly relevant in the Indonesian context, where geographical and regulatory conditions present unique challenges, they can be used as a model for adaptation in other national contexts, indicating the universal applicability of comprehensive risk management principles.

Nevertheless, the study's limitations must be acknowledged. The respondent sample, primarily sourced from educational, governmental, and professional sectors within Indonesia, may not fully represent the global array of stakeholders in water infrastructure. This could limit the generalizability of research findings. Furthermore, while the Fuzzy synthetic evaluation method provides a detailed classification, it may not capture the evolving nature of risks throughout a project's lifecycle.

To build on the foundations laid by this study, future research should broaden the demographic and geographic scope of respondents to enhance the diversity and applicability of the risk assessments. Investigating the role of advanced technologies such as the Internet of Things (IoT), artificial intelligence, and machine learning could revolutionize risk management in infrastructure projects by providing real-time decision-making capabilities and predictive insights. Additionally, integrating perspectives from economics, sociology, and environmental science would help develop more resilient strategies that address broader concerns.

Further research should also explore the differential impacts of risks on various stakeholder groups, including local communities, investors, and government bodies, to tailor risk management strategies more effectively. Comparative studies across different cultural, economic, and environmental contexts are essential to uncover best practices and lessons learned, enhancing our understanding of how diverse factors influence risk management and project success in the water infrastructure sector.

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