Jurnal Dinamis (*Scientific Journal of Mechanical Engineering*)
Journal homepage: https://talenta.usu.ac.id/dinamis/

Risk Analysis of Potable Water Service Improvement in PDAM Malang City

Rona Rofida*[1], Fadhila Fadhila[2], Calysta Deli Ad'hani[1]
[1]*Department of Environmental Engineering, Faculty of Science and Technology, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, 65144, Indonesia*
[2]*Program Study of Environmental Engineering, Faculty of Engineering, University Sumatra Utara, Medan, Indonesia*

*Corresponding Author: ronarofida@uin-malang.ac.id

ARTICLE INFO
Article history:
Received April 14th 2026
Revised May 21th 2026
Accepted June 30th 2026
Available online June 30th 2026

E-ISSN: 2809-3410

How to cite:
Rona Rofida, Fadhila Fadhila, Calysta Deli Ad'hani, "Risk Analysis of Potable Water Service Improvement in PDAM Malang City", *Junal Dinamis (Scientific Journal of Mechanical Engineering)*, Vol. 14, No. 1, pp. 71-79, June 2026.

http://doi.org/10.32734/dinamis/v14i1.25208

ABSTRACT
PDAM Malang has legally and technically provided potable drinking water through the Zona Air Minum Prima (ZAMP) program. Although most service areas have met ZAMP requirements, several areas still require improvements in service quality. The development of potable drinking water services requires substantial investment and faces technical, operational, and financial risks that may affect project performance and sustainability. This study analyzes the risks associated with improving potable drinking water services in PDAM Malang under a Public Private Partnership (PPP) scheme, focusing on risk allocation and mitigation strategies throughout the project lifecycle. A mixed-methods approach was employed, combining qualitative and quantitative techniques. Risks were identified through semi-structured interviews with five experts selected using purposive sampling. Risk assessment used the water sector risk matrix developed by PT Penjaminan Infrastruktur Indonesia, based on probability and impact scores ranging from 1 to 5. The results show that the dominant risks during the pre-construction stage were land acquisition delays and design errors, each with a risk score of 12. During construction, the highest risk was unclear output specifications, with a risk score of 20. In the operational stage, inaccurate life-cycle cost estimation and low initial service uptake were identified as the most critical risks, each scoring 25. The operational stage exhibited the highest overall risk level and was predominantly allocated to the private sector partner. These findings highlight the importance of appropriate risk allocation and effective mitigation strategies to ensure the sustainable delivery of potable drinking water services under a PPP framework.

Keywords: *Mitigation, Potable Drinking Water, Public Private Partnership, Risk, ZAMP.*

ABSTRAK
PDAM Kota Malang secara legal dan teknis telah menyediakan air siap minum melalui pelaksanaaan program Zona Air Minum Prima (ZAMP). Meskipun sebagian besar wilayah pelayanan telah memenuhi persyaratan ZAMP, masih terdapat beberapa kawasan yang memerlukan peningkatan kualitas layanan. Pengembangan sistem air siap minum memerlukan investasi besar serta menghadapi berbagai risiko teknis, operasional, dan finansial yang dapat memengaruhi keberhasilan proyek. Penelitian ini bertujuan untuk menganalisis risiko pada peningkatan pelayanan air siap minum di PDAM Kota Malang berbasis skema Kerja Sama Pemerintah dan Badan Usaha (KPBU), dengan fokus pada aspek operasional, keandalan sistem, alokasi risiko, dan strategi mitigasi pada setiap tahapan proyek. Kajian ini menggunakan metode campuran (*mixed methods*) dengan pendekatan kualitatif dan kuantitatif. Identifikasi risiko dilakukan melalui wawancara semi terstruktur kepada responden ahli yang dipilih menggunakan *purposive sampling*. Penilaian risiko dilakukan menggunakan

matriks risiko sektor air minum PT Penjaminan Infrastruktur Indonesia berdasarkan parameter probabilitas dan dampak dengan skala 1–5. Hasil penelitian menunjukkan bahwa risiko dominan pada tahap pra-konstruksi adalah keterlambatan pembebasan lahan dan kesalahan desain (nilai risiko 12), pada tahap konstruksi adalah ketidakjelasan spesifikasi output (nilai risiko 20), sedangkan pada tahap operasional adalah kesalahan estimasi biaya siklus hidup dan rendahnya serapan layanan pada awal operasi (nilai risiko 25). Tahap operasional merupakan tahap dengan tingkat risiko tertinggi dan didominasi oleh risiko yang dialokasikan kepada Badan Usaha. Hasil penelitian menunjukkan bahwa keberhasilan peningkatan pelayanan air siap minum sangat dipengaruhi oleh ketepatan alokasi risiko, keandalan sistem distribusi, serta penerapan strategi mitigasi yang efektif dan berkelanjutan.

Kata kunci: Air Siap Minum, KPBU, Mitigasi, Risiko, ZAMP

1. Introduction

The Malang City Water Utility (PDAM) has legally and technically provided potable water through the implementation of the Premium Drinking Water Zone (ZAMP) program. Based on the results of a mapping study [1], the service area of the Malang City Water Utility generally meets ZAMP requirements. However, there are still several areas that do not meet ZAMP requirements. This creates an urgent need to improve water quality across the entire scope of the PDAM's potable water service. With a service coverage of 90.03% and approximately 169,571 household connections across an area of approximately 110 km², PDAM Kota Malang plays a strategic role in supporting economic growth and improving the quality of life for the community. The drivers of economic growth and improvements in the standard of living are heavily dependent on the ability to provide drinking water. There are several service areas within PDAM Kota Malang that can be categorized as regions capable of paying a premium for improved drinking water service quality, namely in upscale residential areas. Improvements and developments aimed at enhancing drinking water services carry various risks. Investments in drinking water infrastructure and services require significant initial capital and involve relatively high levels of risk, thus necessitating the implementation of sound risk management [2]. Drinking water infrastructure is characterized as a long-term investment with a large initial capital requirement and a long payback period, making it highly vulnerable to various financial and operational uncertainties [3], [4]. These conditions result in a relatively high level of risk in the drinking water sector, so the success of its management depends heavily on the implementation of effective and integrated risk management [5].

Furthermore, improving the quality of drinking water inevitably carries certain impacts or risks. Risk is a condition arising from uncertainty that can be measured both qualitatively and quantitatively and has the potential to cause losses to the system under study. In the context of infrastructure management, risks can be identified, analyzed, and controlled through a systematic risk management approach to minimize their impact [6][7]. Previous studies have generally focused on financial and policy aspects and have not specifically examined risks associated with improving drinking water services. Furthermore, few studies have integrated risk analysis with project phases (pre-construction, construction, and operations) and the allocation of risks among stakeholders in the context of ZAMP implementation at the PDAM level. However, from a technical perspective, system reliability, operational efficiency, and distribution network performance are critical factors influencing the success of drinking water services.

Therefore, this study is urgently needed to address this gap by conducting a comprehensive risk analysis—not only from a financial perspective but also from technical and operational system perspectives. This approach is expected to contribute to improving system reliability and the effectiveness of risk management in potable water services. The objective of this study is to analyze the risks associated with improving the potable water service at PDAM Kota Malang under a PPP scheme by examining operational aspects, system reliability, and risk allocation and mitigation at each project stage. It is hoped that this service improvement will yield maximum financial benefits from the development and enhancement of drinking water quality through the risk management process.

2. Metode

Risk analysis is conducted by identifying potential risks at each stage. This risk analysis also determines risk allocation and strategies based on the ranking of the greatest impacts identified through the assessment. This study employs a mixed-methods approach, combining qualitative and quantitative methods to analyze the risks in the potable water supply system at PDAM Kota Malang. The qualitative approach is used to identify risks through expert interviews, while the quantitative approach is used for risk assessment and prioritization.

Sampling was conducted using purposive sampling, which involves selecting respondents based on their expertise and experience in the field of drinking water supply. The study included five respondents, comprising PDAM practitioners, academics, and relevant stakeholders with extensive experience in drinking water supply systems. This method involved interviewing several experts and practitioners familiar with the field. Based on the results of these discussions and interviews, risks were identified, along with their probability and impact values, which were subsequently analyzed. The method used to analyze these risks employs the drinking water sector matrix developed by PT. Penjaminan Infrastruktur Indonesia. Data collection was conducted through semi-structured interviews using a guided questionnaire that covered risk identification during the pre-construction, construction, and operational phases. The interview results were then validated through expert judgment to ensure the consistency and appropriateness of the risk assessments.

The framework for this risk analysis consists of risk identification, risk assessment, risk allocation, and risk management strategies. Risk is the effect of uncertainty on objectives, which can be measured by the likelihood of an event occurring and the magnitude of the resulting consequences [7]. The risk analysis refers to the drinking water sector risk matrix from PT. Penjaminan Infrastruktur Indonesia, which consists of four stages: risk identification, risk assessment, risk allocation, and risk mitigation.

Risk assessment is conducted using two main parameters: probability (P) and impact (I), which are rated on a scale of 1–5. The probability scale indicates the likelihood of an event occurring, ranging from very rare (1) to very frequent (5), while the impact scale indicates the severity of consequences, ranging from very mild (1) to very severe (5). The risk value is calculated using the following equation:

$$R = P \times I \quad (1)$$

R where R is the risk level, P is the probability, and$I$ is the impact. This method is a commonly used approach in semi-quantitative risk analysis because it is simple yet effective in determining risk management priorities [8]. Based on these values, risks are classified into several categories: low risk (R = 1–5), moderate risk (R = 6–12), and high risk (R = 15–25).

Next, risks are ranked to identify the dominant risks that require priority management. Risk allocation is carried out by determining which party is best equipped to manage the risk whether the PDAM as the public entity or the business entity as the operator. Risk mitigation strategies are formulated based on the risk level and the management capabilities of each party. Risk mitigation aims to provide the best approach to managing risks by considering both the capabilities of the party managing the risk and the impact of the risk [2][6]. The analysis stages are carried out systematically, from risk identification to mitigation, for each project phase, thereby providing an overview of the distribution and dominance of risks within the potable water supply system.

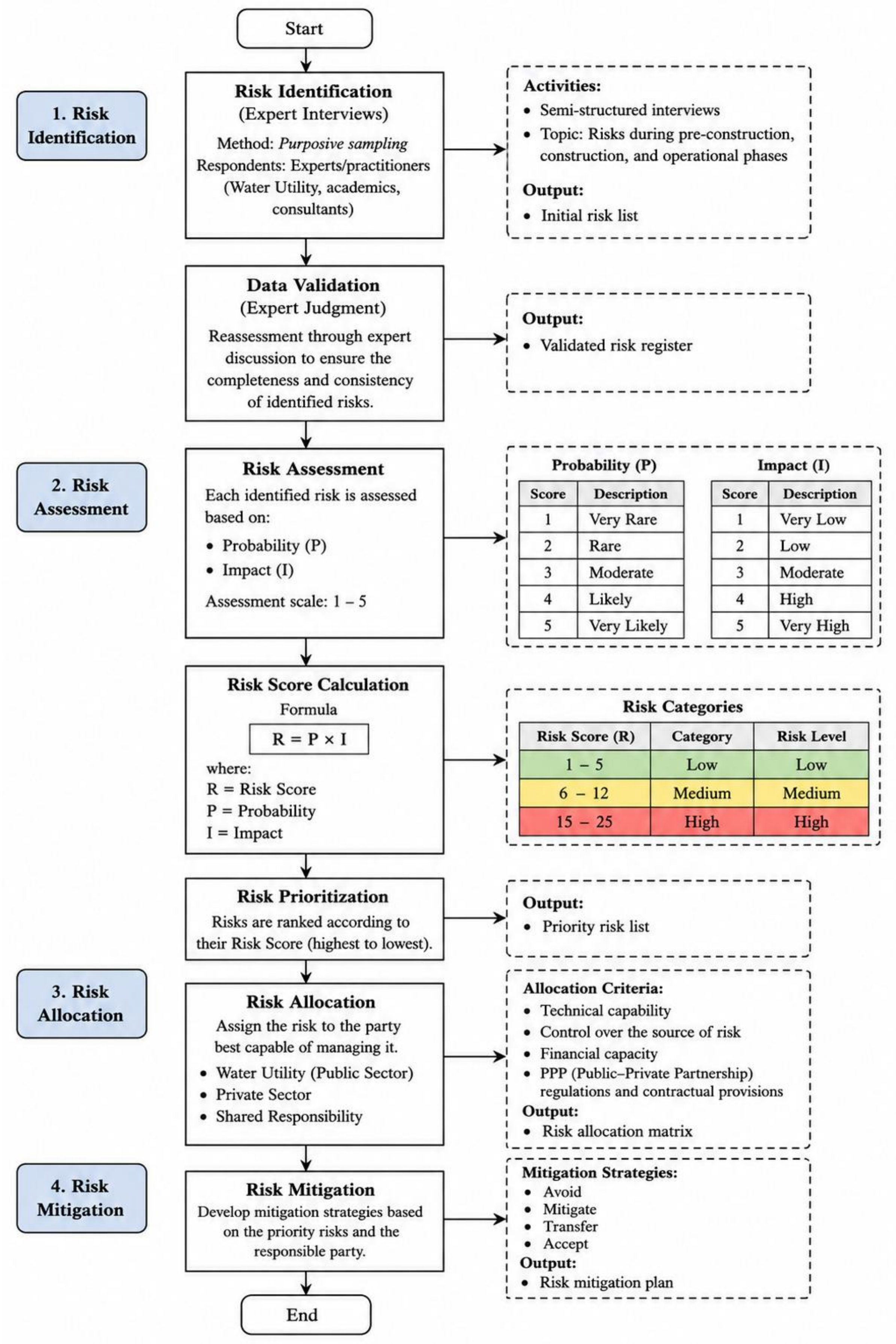

Figure 1. Flowchart of the Risk Analysis Method for Improving Drinking Water Services at PDAM Malang

3. Results and Discussion

Risk management, as described by Simamora and Kurniati [10], is a systematic process for identifying risks, analyzing their likelihood and consequences, and managing risk levels. The risk analysis process consists of risk identification, risk allocation, risk assessment, and risk mitigation. After conducting interviews with experts, the risks most likely to occur in the investment to improve drinking water services at PDAM Kota Malang were identified. Subsequently, risk allocation and strategies were analyzed based on the drinking water sector matrix of PT. Penjaminan Infrastruktur Indonesia, adjusted to field conditions and discussions with PDAM officials.

The results of the risk analysis show that the risks associated with improving drinking water services at PDAM Kota Malang are distributed across three main phases: pre-construction, construction, and operations. However, not all risks carry the same level of significance. Therefore, the discussion focuses on the risks with the highest scores to understand their root causes, impacts on the system, and technical implications.

3.1 Pre-Construction Phase Risk Analysis

During the pre-construction phase, the risk with the highest score is delays and cost overruns in land acquisition, as well as design errors (risk score = 12). This risk is high because it is directly related to uncertainties in planning aspects and initial technical readiness. Froman engineering perspective, design errors indicate that the planning process is not yet fully based on accurate technical data, such as topographic conditions, network pressure, and water flow requirements. This can lead to redesigns that result in project delays and increased costs. Additionally, delays in land acquisition disrupt the construction schedule, ultimately hindering the implementation of the water distribution system.

These findings are consistent with previous studies stating that the early stages of infrastructure projects involve a high degree of uncertainty due to various risks related to planning, coordination, permitting, and land acquisition, which have the potential to cause implementation delays and increased project costs [3][6].

Table 1 below outlines the results of the risk identification process, including the highest-rated risks, their allocation, and risk mitigation strategies for the pre-construction phase. The pre-construction phase in this planning process pertains to site preparation and permitting.

Tabel 1. Pre-construction Phase Risk Analysis

Risk Identification	PDAM	BU	Joint	value	Mitigation*
Delays and increases in land acquisition costs	√			12	Provide project land before the procurement process of business entities by: • Conducting an analysis of the suitability of the project site layout with the RTRW where the project will be carried out • Set a project location and make sure all requirements are met before applying for a Location Assignment Permit • Ensuring the availability of land acquisition funds; • Ensuring that there are teams carrying out the land acquisition process; • Ensuring the land acquisition process can run in accordance with the provisions of the laws and regulations; and • The process of monitoring and evaluating the land acquisition process, especially for critical or priority lands.
Design errors that led to design revisions		√		12	• Conducting design consultations to experienced and reliable. • Making a mature agreement and commitment from various parties in determining the design of the project plan [11]
Land cannot be freed	√			10	• Ensure clear land legal status and procedures in project land acquisition

Risk Identification	PDAM	BU	Joint	value	Mitigation*
					• Indemnity Depository to the court so that the land acquisition process can be continued

* [9]

Risk allocation during the pre-construction phase, based on the identification that has been conducted, is borne primarily by PDAM. This is related to location and permitting, where the government is in a better position or has easier access to information compared to the private sector due to regulatory or legislative risks.

3.2 Construction Phase Risk Analysis

During the construction phase, the risks with the highest scores are unclear output specifications (risk score = 20) and delays in construction completion (risk score = 16). These risks are closely related to the technical aspects of project implementation. Unclear output specifications indicate a gap between planning and technical implementation, particularly regarding mechanical design standards and system operations. In drinking water supply systems, unclear specifications can lead to mismatches in pump capacity, network pressure, and water distribution efficiency. Network pressure, of course, also affects the quality of the water being distributed. In addition, construction delays can have a direct impact on system performance, such as delays in commissioning and increased operational costs due to system readjustments. This indicates that project management and construction quality control are key factors in the system's success.

The following is a description of the identified risks that may occur; the allocation, assessment, and mitigation strategies for risks during the construction phase can be seen in Table 2. The construction phase is the stage during which the project is underway or the physical construction is being carried out.

Tabel 2. Construction Phase Risk Analysis

Risk Identification	PDAM	BU	Joint	value	Mitigation*
Delays and cost increases due to unclear output specifications		√		20	• Clarification during the tender process • Good design capacity • Ensure auction documents are presented clearly and easily in order to increase competition and lower project costs
Late completion of construction		√		16	Choosing a reliable contractor and standard contractual clauses, including penalty clauses on Liquidity Damages
Time/cost estimation error in technical operation test		√		16	Coordinating contractors and operators well

* [9]

Based on the analysis that has been done and refers to the matrix of PT. Penjaminan Infrastruktur Indonesia, the risk allocation at the construction stage is more borne by business entities. This is because business entities have more ability to manage risks related to financing, design, construction, procurement, operation and maintenance.

3.3 Operational Phase Risk Analysis

The operational phase carries the highest level of risk compared to other phases, with some risks rated as high as 25. The risks identified in the analysis primarily relate to cost aspects, such as errors in estimating *life-cycle* costs and low water intake at the start of operations. From an asset management perspective, errors in estimating *life-cycle costs* are also linked to a lack of integration between technical planning and maintenance strategies. Many water infrastructure projects have not fully adopted a *life-cycle thinking* approach, so the costs of maintenance, rehabilitation, and asset replacement are not accurately accounted for from the outset [12][13]. As a result, the operational phase faces significant financial pressure and a decline in system performance. The risk of low water uptake at the start of operations also reflects a mismatch between production capacity and actual user demand, which often occurs due to inaccurate demand forecasting.

Table 3 below outlines the results of the identification, allocation, assessment, and mitigation strategies for operational-phase risks.

Tabel 3. Operational Phase Risk Analysis

Risk Identification	PDAM	BU	Joint	value	Mitigation *
Error estimating *life cycle* cost		√		25	Make a deal / contract with the supplier as early as possible
Risk of absorption rate at the beginning of the period below the planning target	√			25	Creation of a "take or pay" clause in the water sale agreement
O&M fee increases		√		20	Choosing a reliable operator, escalation factor in the contract
Rising energy costs due to inefficient operating performance		√		20	Good unit quality and specifications
Failure in initial pricing	√			20	Eligibility support (VGF), regulations that support
Decrease in project output request volume	√			20	• Socializing potable water programs to the community that can be done by regularly checking the water quality of the area and reporting it to residents, • Conducting NRW downgrade program, • Managing PDAM's finances
Uncertainty of output continuity		√		20	Choosing a reliable operator and implementing a penalty mechanism
Decreased quantity and quality of output		√		20	Choosing a reliable operator and implementing a penalty mechanism
Water loss and quality in the pipeline network (leakage or contamination)		√		20	• Perform good standards of operating and supervisory performance • Things to note to achieve the success target of water loss reduction strategy in the distribution network are pressure management, active leak control measures, pipeline management, and rapid and high-quality repairs [14] • Inventory or estimate the condition and life of the pipe so that there is no leakage or rupture of pipes on the network. • Efforts made by PDAM Malang to overcome and minimize the risk to quality aspects include: ▪ Installation of inlet strainers in the pump tub and routinely cleaned once every two days ▪ Water level monitoring, garbage cleaning, and early warning systems for flood monitoring; ▪ Fencing of land boundaries and environmental preservation; and ▪ Make SOP or emergency response plan in the procedure of securing water quality handling. So that if there is a problem of water quality both in the customer and distribution will be resolved immediately. ▪ Water quality handling strategies can also be done physically by flushing.

* [9]

Based on the analysis, during the operational phase which encompasses usage and maintenance, the risk allocation is primarily borne by the business entity (65%) and by the PDAM (35%). Additionally, there are shared risks arising from extraordinary circumstances, such as natural disasters.

Operational risk is a dominant factor in drinking water infrastructure projects, primarily because this phase directly determines the system's long-term performance [12][15]. Furthermore, modern drinking water systems are complex infrastructures influenced by dynamic technical, operational, and environmental factors [12]. However, this study makes an additional contribution by demonstrating that, in the case of PDAM Kota Malang, operational risks are influenced not only by management factors but also by the technical performance of the distribution system. Although the risk analysis refers to the matrix developed by PT. Penjaminan Infrastruktur Indonesia, this study develops a more specific approach by integrating the local conditions of PDAM Kota Malang into the risk assessment process.

4. Conclusion

Based on the results of the risk analysis regarding the improvement of potable water services at PDAM Kota Malang, it can be concluded that the main risks are spread across three stages pre-construction, construction, and operations each with distinct characteristics and risk levels.

In the pre-construction phase, the dominant risks involve technical and cost aspects, namely delays and cost overruns in land acquisition, as well as design errors, with a risk value of 12. Risks in this phase are largely allocated to PDAM because they relate to regulatory, permitting, and land acquisition aspects. During the construction phase, the highest risk is delays and cost overruns resulting from unclear output specifications, with a risk score of 20, followed by delays in construction completion and errors in time/cost estimates, with a risk score of 16. Risks at this stage are primarily allocated to the Business Entity, as it possesses the technical and managerial capacity to execute the construction project. Meanwhile, in the operational phase, the risk with the highest level 25 is errors in life-cycle cost estimation and low initial uptake of service output. In addition, several other risks such as increases in operating and maintenance costs, uncertainty regarding service continuity, and water loss in the network carry high risk values (20). Risks at this stage are pre dominantly borne by the Business Entity (65%) and partly by the PDAM (35%), depending on their capacity for managing and controlling the operational system.

Risk mitigation priorities can focus on improving the clarity of technical specifications and designs, selecting competent contractors and operators, strengthening financial planning, and implementing efficient, monitoring-based operational systems. Furthermore, technical strategies such as controlling water loss, improving the quality of the distribution network, and optimizing disinfection systems are critical aspects in reducing operational risks.

The results of this study indicate that the success of improving potable water services depends heavily on aligning risk allocation with each party's capacity, as well as implementing appropriate mitigation strategies from the planning stage through operations. Therefore, the integration of technical planning, construction management, and operational systems is key to sustainably improving the reliability of potable water services.

5. Acknowledgments

The author would like to thank the staff and employees of PDAM Malang and other relevant parties who took the time to assist and support the author in preparing this journal article.

References

[1] R. Rofida et al., "Water quality mapping of piped water supply in Malang City, Indonesia," Int. J. Integrated Engineering, vol. 11, no. 2, pp. 243–248, 2019.

[2] M. H. Pangeran, "Praktek manajemen risiko pada penyedia layanan air minum: Survey di beberapa tempat di Indonesia," Proc. Seminar Nasional ATPW, Surabaya, 2012.

[3] Indonesia Infrastructure Guarantee Fund, Acuan Alokasi Risiko KPBU di Indonesia. Jakarta: PT Penjaminan Infrastruktur Indonesia (Persero), 2020.

[4] World Water Council, "Water infrastructure and investment," 2025.

[5] K. Pietrucha-Urbanik and J. Rak, "Reliability, safety and risk modelling in water supply systems for climate-resilient infrastructure," *Water*, vol. 17, no. 24, p. 3554, 2025, doi: 10.3390/w17243554

[6] T. Aven and O. Renn, "Improving government policy on risk: Eight key principles," *Reliability Engineering & System Safety*, vol. 176, pp. 230–241, 2018.

[7] ISO, *ISO 31000:2018 Risk Management – Guidelines*, Geneva: International Organization for Standardization, 2018.

[8] E. Ilbahar, A. Karaşan, S. Cebi, and C. Kahraman, "A novel approach to risk assessment using fuzzy fine–Kinney method," Safety Science, vol. 103, pp. 124–136, 2018.

[9] Indonesia Infrastructure Guarantee Fund, Acuan Alokasi Risiko KPBU di Indonesia. Jakarta: PT Penjaminan Infrastruktur Indonesia (Persero), 2020.

[10] Y. Simamora and N. Kurniati, Analisis Risiko pada Instalasi Pengolahan Air Limbah (IPAL) PT Ajinomoto. Surabaya: ITS, 2016.

[11] E. E. Ameyaw and A. P. C. Chan, "Critical success factors for public private partnership in water supply project," Facilities, vol. 34, no. 3–4, pp. 124–160, 2016.

[12] International Water Association (IWA), *Asset Management for Water and Wastewater Utilities*, London: IWA Publishing, 2022.

[13] A. S. Mohd Noor, M. Z. Yusof, and N. A. Ramli, "Life cycle cost analysis in water supply system: A review," *Journal of Cleaner Production*, vol. 320, 2021.

[14] M. R. Sya'bani, "Penerapan jaringan distribusi sistem district meter area (DMA) dalam optimalisasi penurunan kehilangan air fisik," Tesis, Institut Teknologi Bandung, Bandung, 2016.

[15] World Bank, *Reducing Non-Revenue Water in Developing Countries: Improving Efficiency in Water Supply Systems*, Washington, DC: World Bank, 2021.