

RISK MANAGEMENT IN A REGIONAL DRINKING WATER COMPANY IN OGAN KOMERING ILIR REGENCY USING THE HOUSE OF RISK (HOR) METHOD

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Abstract

Water is an important factor in human life. Fulfilling the need for clean water is very important for the government to achieve prosperity in society. PDAM (Regional Drinking Water Company) is an agency created as a government effort to fulfill the community's need for clean water. PDAM Tirta Agung plays a role in providing clean, healthy drinking water that meets health requirements in the Ogan Komering Ilir Regency. In order for this role to be realized, actions are needed to prevent risks in the company's supply chain from getting worse which results in a decrease in product quality. This study aims to identify risks and risk sources to determine priority risk sources and also propose a mitigation plan to reduce the impact of risks. The method used in this study is the Supply Chain Operations Reference (SCOR) to identify risks in the company's business processes and also the House of Risk (HOR) to find priority risk sources and then create appropriate mitigation strategies. In the process of identifying the company's business processes, 17 risk events and 37 risk sources were found in PDAM Tirta Agung, Ogan Komering Ilir Regency. Based on the results of the House of Risk stage 1 calculation, from 37 risk sources (Risk Agents) in the company's supply chain identification process, 5 priority risk sources (Risk Agents) were obtained. The selection of priority risk sources (Risk Agents) was based on the largest to smallest Aggregate Risk Potential (ARP) value. The selected priority risk sources (Risk Agents) were non-compliance with SOP (A22), damaged production machines (A27), lack of maintenance (A23), poor maintenance by second parties (A4), late payment by customers (A2).

Keywords: Risk Management, House of Risk, Supply Chain Operations Reference, PDAM

1. INTRODUCTION

Water is one of the most essential resources for human survival, as daily activities and healthy living depend on the availability of clean and high-quality water (Tiri et al., 2018; Ahamed et al., 2015). However, the provision of potable water in developing countries has been declining rapidly due to increasing demand and limited resources (Ezugwu et al., 2019). Public drinking water services play a critical role in converting raw water sources into safe and consumable water supplies through conventional treatment processes (Vorstius et al., 2019).

In Indonesia, Regional Drinking Water Utilities (**Perusahaan Daerah Air Minum**—PDAM) are mandated to ensure access to safe drinking water, as regulated by the Decree of the Minister of Home Affairs No. 690/7027/SJ (1991), which targets 75% coverage in urban areas and 60% in rural areas (Maser et al., 2017). Nevertheless, empirical evidence shows that PDAM performance remains uneven. Lagu et al. (2016) reported that only 50% of PDAMs are classified as healthy, while the remainder exhibit varying degrees of operational inefficiency. This condition indicates that the performance of PDAMs as providers of Drinking Water Supply Systems (**Sistem Penyediaan Air Minum**—SPAM) has not yet reached an optimal level.

Rapid changes in both internal and external environments—such as globalization, technological advancement, increasing service quality requirements, regulatory changes, socio-political dynamics, and pandemic conditions—have significantly increased business risk complexity. Consequently, the implementation of a formal, structured, and integrated risk management system is essential to enhance

organizational resilience and support Good Corporate Governance. Risk identification, covering both internal and external sources, is a critical initial step (Durst et al., 2019). Previous studies have demonstrated that the House of Risk (HOR) method is effective in identifying risk events and risk agents through systematic risk mapping in HOR Phase 1 and Phase 2 (Cahyani et al., 2016; Magdalena & Vannie, 2019).

Risk refers to uncertainty regarding the occurrence of an event within a certain period, where such an event may result in losses, ranging from minor and insignificant losses to major losses that can affect the sustainability of a company (Ennouri W., 2013).

Risk management is a system of risk control and protection of assets, property rights, and profits of organizations or individuals against potential losses arising from risk exposure. Risk management is not a static process; rather, it is a dynamic process that evolves in response to changing conditions to address risks that may affect the achievement of organizational objectives (Merna & Al-Thani, 2005).

The objectives and targets of risk management must be aligned with the overall objectives of the company (Ward, 2001). The main objectives of risk management include identifying potential losses, evaluating potential losses through appropriate assessment, and selecting suitable strategies to mitigate such losses (Ennouri W., 2013).

Risk refers to factors that hinder company operations within the supply chain and may occur at the supplier, manufacturing, distribution, and consumer levels. These risks are commonly associated with uncertain events that may occur within a specific period of time (Immawahyu & Oktiarso, 2022; Jüttner et al., 2003). Risks can be avoided, minimized, or even eliminated through appropriate risk management practices (Pujawan & Geraldin, 2009), which primarily aim to identify and evaluate potential losses (Sofyan, 2005). The House of Risk (HOR) method is applied to systematically identify risks and develop mitigation plans through two sequential phases. HOR Phase 1 focuses on identifying risk agents and potential risks, followed by the assessment of risk severity, occurrence probability, and the correlation between risks and risk agents, while HOR Phase 2 determines and selects appropriate risk mitigation strategies based on the prioritized risk agents (Oktiarsol et al., 2022).

The House of Risk (HOR) method is used to identify and analyze potential risks affecting companies and the surrounding environment within supply chain activities. Developed by Pujawan and Geraldin (2009), HOR consists of two phases: Phase 1 focuses on identifying risk causes and formulating mitigation strategies, while Phase 2 prioritizes the implementation of appropriate mitigation actions to address the identified risk sources (Kusmantini et al., 2015; Purwaningsih et al., 2021).

2. METHODOLOGY

Data were processed using the House of Risk (HOR) method, a supply chain risk management approach that combines the House of Quality and Failure Modes and Effects Analysis (FMEA) to manage supply chain risks. FMEA was used because it provides a systematic way to identify and evaluate potential failure modes.

The data processing consisted of three main stages: risk event identification, HOR Phase 1, and HOR Phase 2. Risk events were identified and evaluated using FMEA to determine their severity and occurrence levels. HOR Phase 1 was applied to analyze the relationship between risk agents and risk events and to prioritize risk agents based on their Aggregate Risk Potential (ARP) values. The prioritized risk agents were then used in HOR Phase 2 to determine priority preventive actions. Further analysis and discussion were conducted for the selected risk agents and preventive actions (Ratnasari et al., 2018).

The House of Risk (HOR) method proposed by Pujawan and Geraldin (2009) comprises two stages: HOR 1 and HOR 2. HOR 1 prioritizes risk agents based on their Aggregate Risk Potential (ARP), while HOR 2 supports management in prioritizing risk mitigation actions derived from HOR 1 results. Although the HOR framework is computationally straightforward, its application involves subjective judgment; therefore, cross-functional expert involvement is necessary to enhance assessment reliability (Pujawan & Geraldin, 2009). The steps in the House of Risk method are as follows:

2.1. House of Risk (HOR) phase I

In the first stage of the HOR method, the HOR 1 model is applied, and its framework is presented in Table 1.

Table 1. House of Risk Phase I

Business Proseses	Risk Event (E _i)	Risk Agents (A _i)							Severity Risk Event (S _i)
		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	

Plan	E ₁							S ₁
	E ₂							S ₂
Source	E ₃							S ₃
	E ₄							S ₄
Make	E ₅							S ₅
	E ₆							S ₆
Deliver	E ₇							S ₇
	E ₈							S ₈
Return	E ₉							S ₉
Occurance of Agent j		O ₁	O ₂	O ₃	O ₄	O ₅	O ₆	O ₇
Aggregate Risk Potential j		AR P ₁	AR P ₂	AR P ₃	AR P ₄	ARP 5	ARP 6	ARP 7
Priority rank of agent j								

Source: (Pujawan & Geraldin, 2009).

The HOR 1 framework is applied to determine which risk agents should be prioritized for subsequent risk prevention. By adopting the House of Quality (HOQ) concept, HOR 1 is conducted through the following steps:

1. Identification of business process activities, followed by the identification of risk events occurring within these processes. In the HOR 1 framework shown in Table 1., risk events are listed in the leftmost column and denoted as E_i .
2. Assessment of risk event severity if the risk occurs. The assessment uses a scale ranging from 1 to 10, where a value of 10 represents an extreme or catastrophic impact. In the HOR 1 framework shown in Table 1, the severity score for each risk event is placed in the rightmost column and denoted as S_i .
3. Identification of risk agents and assessment of the probability (occurrence) of each identified risk agent. The assessment scale ranges from 1 to 10, where a value of 1 indicates that the risk agent rarely occurs and a value of 10 indicates frequent occurrence. In the HOR 1 framework shown in Table 1, risk agents are denoted as A_j and listed in the top row, while the occurrence values are placed in the bottom row and denoted as O_j .
4. Assessment of the correlation between risk agents and risk events, denoted as R_{ij} in Table 1., using values of 0, 1, 3, and 9. A value of 0 indicates no correlation, 1 indicates low correlation, 3 indicates moderate correlation, and 9 indicates high correlation.
5. Calculation of the Aggregate Risk Potential (ARP_j) for each risk agent.
6. Ranking of risk agents based on their ARP values from highest to lowest.

2.2. House of Risk (HOR) Phase II

After obtaining the ARP ranking of risk agents from highest to lowest in HOR Phase I, the second stage, namely HOR Phase II, is conducted. The HOR Phase II framework is presented in Table 2. HOR Phase II aims to support management or the company in prioritizing effective risk mitigation actions.

Tabel 2. *House of Risk* Fase II

To be Treated Risk Agent (A _j)	Preventive Action (PA _j)					Aggregate Risk Potential (ARP _j)
	PA ₁	PA ₂	PA ₃	PA ₄	PA ₅	
A ₁						ARP ₁
A ₂						ARP ₂
A ₃						ARP ₃
A ₄						ARP ₄
Total Effectiveness of action k	TE ₁	TE ₂	TE ₃	TE ₄	TE ₅	
Degree of difficulty performing action k	D ₁	D ₂	D ₃	D ₄	D ₅	
Effectiveness to difficulty ratio	ETD ₁	ETD ₂	ETD ₃	ETD ₄	ETD ₅	
Rank of Priority	R ₁	R ₂	R ₃	R ₄	R ₅	

Source: (Pujawan & Geraldin, 2009).

The working steps applied in the HOR Phase II framework are as follows:

1. Selection of risk agents (sources or causes of risk) with the highest Aggregate Risk Potential (ARP) values, which may also be identified through Pareto analysis. In Table 2, these values are presented in the rightmost column and denoted as ARP_j .
2. Identification of preventive actions considered effective in controlling and preventing the selected risk agents. It should be noted that a single risk agent may be addressed by one or more preventive actions, and a single preventive action may simultaneously reduce the probability of multiple risk agents. In

Table 2, preventive actions are listed in the top rows as responses to the question “How” in the HOR framework.

3. Assessment of the correlation between preventive actions and risk agents, using correlation scores of 0, 1, 3, and 9, which have the same interpretation as in HOR Phase I. In Table 2., the correlation between preventive action k and risk agent j is denoted as E_{jk} .
4. Calculation of the total effectiveness (TE_k) of each preventive action using the following formula:

$$TE_k = \sum_j ARP_j E_{jk}$$
5. Assessment of the level of difficulty in implementing each preventive action, denoted as D_k . The difficulty scale may follow a Likert scale (1–5) or other appropriate scoring systems. This assessment considers the availability of resources and the costs required to implement the preventive actions.
6. Calculation of the effectiveness-to-difficulty ratio (ETD_k) using the following formula:

$$ETD_k = TE_k/D_k$$
7. Prioritization and ranking of preventive actions (R_k) based on the ETD_k values. The highest ETD_k value indicates the highest priority action. Preventive actions ranked at the top represent those that should be implemented first, as they provide high effectiveness with relatively manageable resource and cost requirements.

3. RESULT

The first step in the HOR Phase 1 model is to identify risks occurring in the business activities of PDAM Tirta Agung. This risk identification is conducted through interviews and direct field observations. After the identification process, the severity value is determined to represent the level of impact caused by each identified risk. Table 3 presents the assigned severity ratings. The next step is to assess the occurrence of the identified risk agents. This assessment is conducted using a scale of 1–10. Table 4 presents the assigned occurrence ratings.

Table 3. Risk Events and Severity Weights

Risk Event	Code	Severity
Errors in demand and sales data calculation	E1	2
Errors in maintenance scheduling for machinery and pumps	E2	3
Errors in production planning	E3	5
Errors in chemical procurement calculations	E4	4
Delays in chemical orders	E5	1
Insufficient chemical supply	E6	8
Poor raw water quality	E7	4
Raw water depletion	E8	7
Delays in raw water distribution	E9	6
Insufficient availability of machinery and pumps	E10	8
Delays in machinery and pump orders	E11	4
Production process errors	E12	8
Machinery failure	E13	9
Turbid drinking water	E14	8
Interruption of drinking water supply to customers	E15	7
Water losses in the distribution network (non-revenue water)	E16	8
Customer complaints	E17	4

Table 4. Risk Agents and Occurrence Ratings

Risk Agent	Code	Occurrence
Customer demand cannot be accurately forecasted	A1	2
Delays in customer bill payments	A2	8
Inaccurate determination of maintenance schedules	A3	3
Poor quality of maintenance services provided by third-party contractors	A4	6
Errors in production data calculation	A5	2
Inaccurate estimation of chemical and material requirements	A6	2
Supplier-related errors	A7	4
Unavailability of chemicals at suppliers	A8	2
Poor quality of chemicals supplied	A9	2
Damage during storage and warehousing	A10	2

Risk Agent	Code	Occurrence
High rainfall at raw water intake sources	A11	5
Raw water contamination	A12	9
Low rainfall at raw water intake sources	A13	2
Raw water distribution pump failure	A14	9
Leakage in raw water transmission pipelines	A15	9
Scarcity of required machinery and pumps	A16	1
Delays in the delivery of machinery and pumps	A17	1
Human error by treatment plant operators	A18	7
Failure of measuring and monitoring instruments	A19	8
Errors in chemical dosing operations	A20	6
Failure to use personal protective equipment (PPE)	A21	2
Non-compliance with standard operating procedures (SOPs)	A22	2
Insufficient preventive maintenance	A23	6
Excessive equipment usage (overloading)	A24	7
Errors in water quality measurement	A25	6
Backwashing process not performed	A26	4
Production equipment malfunction	A27	6
Absence of distribution pipelines to customer locations	A28	3
Errors during new service connection installation	A29	4
Leakage in distribution pipelines	A30	9
Water tanker units unavailable or non-operational	A31	2
Failure of raw water intake/distribution pumps	A32	8
Power outages	A33	7
Errors in water meter recording by operators	A34	5
Changes in customer tariff rates	A35	2
Long lead time for new service installation	A36	4
Poor drinking water quality	A37	8

Next, the correlation between risks and risk agents is assessed. The correlation assessment uses a scale of 0, 1, 3, and 9. A high correlation between a risk and a risk agent is indicated by a correlation value of 9, while a value of 0 indicates no correlation. The correlation assessment was conducted by the Director of CV. Ladang Management. After obtaining the severity, occurrence, and correlation values for each risk and risk agent, the next step is to calculate the Aggregate Risk Potential (ARP). The resulting ARP values help indicate the level of potential threat posed by each risk agent. Tables 5 present the calculations for the HOR Phase 1 model.

In the risk evaluation stage, the priority risk sources to be addressed first are identified. The prioritization process is conducted by referring to the ARP values obtained from the previous House of Risk Phase 1. Risk agents with the highest ARP values are given the highest priority for risk treatment, and vice versa. Table X presents the priority levels of the risk sources (risk agents). After obtaining the ARP values, the next step is to group the priority risk agents using a Pareto diagram. In this risk evaluation, the 30:70 Pareto principle is applied, indicating that addressing the top 30% of priority risk agents is expected to contribute to approximately 70% of the overall improvement in managing other risk sources. The Pareto diagram illustrating the prioritized risk agents for risk mitigation is presented below.

Tabel 5. House of Risk Phase I

Risk Event	Risk Agent (A _j)																		Severity
(E _i)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	(S _i)
E1	9	0	0	0	9	0	3	0	0	0	0	0	0	0	3	0	0	3	2
E2	0	9	9	3	3	0	3	0	0	0	0	3	0	9	0	9	3	3	3
E3	3	9	1	3	1	3	3	0	0	1	0	0	0	1	0	0	0	3	5
E4	0	0	0	0	9	9	3	0	3	0	0	3	0	0	0	0	0	3	4
E5	0	3	0	0	1	9	3	9	1	0	0	0	0	0	0	0	0	3	1
E6	0	9	0	0	3	9	3	9	3	9	3	9	0	0	0	0	0	0	8
E7	0	9	0	0	0	0	0	0	9	9	9	9	1	0	0	0	0	0	4
E8	0	0	0	0	0	0	0	0	1	1	0	0	9	0	3	0	0	0	7
E9	3	0	3	3	0	3	9	0	1	1	0	0	9	9	9	9	9	3	6
E10	3	9	9	9	1	0	3	0	0	0	1	0	0	9	1	9	9	1	8
E11	0	9	9	1	0	0	3	0	0	0	0	0	0	1	0	9	9	1	4
E12	3	0	0	3	9	9	9	9	9	3	1	9	3	0	0	0	0	9	8
E13	1	0	9	9	1	1	3	0	0	0	1	3	0	9	0	9	9	3	9
E14	0	3	0	0	0	9	9	9	9	9	9	9	9	0	0	0	0	9	8
E15	0	9	3	9	3	0	9	0	0	0	0	0	0	9	9	9	9	3	7
E16	3	0	9	9	3	0	9	0	0	0	0	0	0	9	1	1	3	8	8
E17	9	3	3	9	3	3	9	9	9	9	3	9	9	9	9	9	9	3	4
Occurrence (O _j)	3	9	4	9	4	4	7	2	1	2	7	9	2	9	9	1	1	7	
ARP _j	504	3510	1376	3546	956	1260	3507	522	266	516	1183	3024	506	3078	2340	377	359	2121	
Ranking _j	29	5	18	4	23	19	6	26	33	27	21	9	28	8	14	31	32	15	

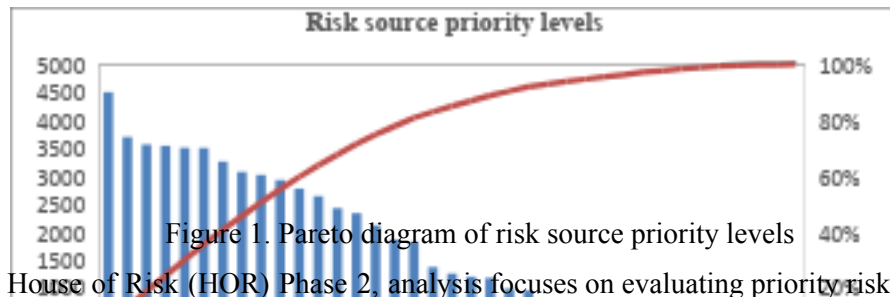


Figure 1. Pareto diagram of risk source priority levels

The House of Risk (HOR) Phase 2, analysis focuses on evaluating priority risk agents in order to determine appropriate mitigation actions to minimize their impacts. The first step involves designing mitigation strategies to achieve an ideal condition for addressing the main risk agents. Next, the correlation between risk agents and mitigation strategies is assessed to determine the effectiveness of each preventive action. Subsequently, the level of difficulty of each mitigation strategy is evaluated using the Degree of Difficulty (Dk) assessment, which aims to measure how challenging a mitigation strategy is to implement. Table 6 presents the Degree of Difficulty ratings for each planned mitigation strategy.

Table 6. Degree of Difficulty (Dk)

Risk Agent	Mitigation Strategy	Code	Dk
Non-compliance with standard operating procedures (SOPs)	• Enforcement of disciplinary sanctions	PA1	4
	• Review and revision of SOPs	PA2	4
	• Enhancement of SOP dissemination and operator training programs	PA3	3
	• Periodic monitoring and internal audits	PA4	5
Production equipment malfunction	• Temporary shutdown of affected equipment	PA5	3
	• Routine inspection and condition assessment	PA6	5
	• Development of SOPs for equipment operation and emergency handling	PA7	4
Insufficient preventive maintenance	• Establishment of a structured maintenance management system	PA8	5
	• Implementation of monitoring and evaluation systems	PA9	5
	• Scheduling of routine preventive maintenance	PA10	5
Poor quality of maintenance services by third-party contractors	• Performance evaluation of maintenance vendor	PA11	4
	• Review and enforcement of contracts and service level agreements (SLAs)	PA12	5
	• Development of internal backup maintenance capabilities	PA13	4
Delays in customer bill payments	• Professional and systematic customer communication	PA14	4
	• Issuance of formal billing and reminder notices	PA15	4
	• Enforcement of penalty or sanction clauses	PA16	5

The final results in the House of Risk Phase 2 table are used to determine the priority of mitigation strategies based on the ranking of the Effectiveness-to-Difficulty Ratio (ETDk). Mitigation

strategies with the highest ETDk values are assigned the highest priority for implementation. The results of the House of Risk Phase 2 table 7 are presented below.

Tabel 7. *House of Risk* Phase II

<i>Risk Event</i>	<i>Risk Agent (A_j)</i>																			<i>Saverity</i>
(E _j)	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	A34	A35	A36	A37	(S _i)
E1	9	0	0	3	0	9	0	0	0	9	3	3	0	0	0	9	9	0	0	2
E2	0	0	0	3	9	0	0	1	9	0	0	0	0	9	0	0	0	0	0	3
E3	3	3	0	3	1	9	0	9	9	3	3	0	0	0	0	1	0	0	0	5
E4	3	9	0	3	0	3	1	0	0	0	0	0	0	0	0	0	0	0	3	4
E5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1
E6	3	3	0	0	0	0	3	9	0	0	0	0	0	0	0	0	0	0	9	6
E7	0	0	0	9	0	0	9	0	9	0	0	0	0	0	0	0	0	0	9	5
E8	0	0	0	1	0	9	0	0	9	0	3	9	0	9	9	0	0	0	0	8
E9	3	0	0	9	9	9	0	0	9	9	3	9	1	9	9	0	0	0	0	6
E10	0	0	0	3	9	9	0	0	9	9	0	0	0	9	0	0	0	0	0	6
E11	0	0	0	1	3	3	0	9	3	3	0	0	0	3	0	0	0	0	0	2
E12	9	9	1	9	3	9	3	3	3	9	0	0	0	0	0	1	0	0	9	8
E13	3	0	0	9	9	3	0	9	9	9	0	0	0	9	1	0	0	0	0	9
E14	0	9	0	9	0	1	3	9	1	0	0	0	0	0	0	0	0	0	9	7
E15	0	0	0	9	9	0	0	3	9	9	0	9	0	9	9	0	0	0	0	7
E16	9	0	0	9	9	3	0	0	1	9	0	9	0	0	0	3	0	0	0	8
E17	3	3	0	9	9	3	3	3	9	9	9	9	1	9	3	3	9	9	9	4
<i>Occurrence</i> (O _j)	9	8	9	8	8	7	5	5	7	2	4	9	2	8	6	9	2	5	9	
ARP _j	2430	1872	72	4504	3568	2933	620	1830	3703	990	384	2646	20	3264	1206	603	108	180	2781	
Ranking _j	13	16	36	1	3	10	24	17	2	22	30	12	37	7	20	25	35	34	11	

House of Risk Phase 2 is a continuation of House of Risk Phase 1. In this phase, mitigation strategies (preventive actions) are formulated based on the priority risk agents identified in Phase 1. The mitigation strategies are developed through discussions with experts and by reviewing relevant references related to the previously identified priority risk agents. Each mitigation strategy is formulated for each priority risk agent identified in the previous phase.

From the five priority risk agents identified in Phase 1, a total of 16 mitigation strategies (preventive actions) were formulated in House of Risk Phase 2, including imposing sanctions (PA1), conducting routine inspections (PA6), enhancing socialization and training programs (PA3), scheduling routine maintenance (PA10), developing a structured maintenance system (PA8), implementing monitoring and evaluation systems (PA9), enforcing penalty and sanction clauses (PA16), establishing standard operating procedures for machine handling (PA7), maintaining professional communication (PA14), conducting periodic monitoring and audits (PA4), strengthening internal capabilities (PA13), increasing socialization and training activities (PA3), reviewing and enforcing contracts/service level agreements (PA12), issuing official billing letters (PA15), shutting down machine operations when necessary (PA5), and evaluating vendor performance (PA11).

4. CONCLUSION

This study concludes that supply chain risk management at PDAM Tirta Agung, Ogan Komering Ilir Regency, can be effectively analyzed using the House of Risk (HOR) framework. The identification process revealed 17 risk events and 37 risk agents. Based on HOR Phase 1, five priority risk agents were selected according to their Aggregate Risk Potential (ARP) values, including issues related to standard operating procedures, machine conditions, maintenance performance, third-party services, and customer payment delays.

In HOR Phase 2, 16 preventive actions were formulated and prioritized using the Effectiveness-to-Difficulty (ETD) ratio. Key mitigation strategies include strengthening enforcement mechanisms, improving inspection and training activities, implementing routine maintenance schedules, and establishing structured maintenance management systems. These strategies provide practical recommendations for enhancing operational reliability and risk resilience in public water utility supply chains.

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