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Risk Analysis of Water Distribution in PDAM City of Makassar Using the House of Risk (HOR) Method

Ahmad Padhil, Eriskah M., Lamatinulu, Muhammad Fachry Hafid, A. Dwi Wahyuni P.

Industrial Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia

Email address:

ahmad.padhil@umi.ac.id (Ahmad Padhil), eriskahm24@gmail.com (Eriskah M.), Lamatinulu.ahmad@umi.ac.id (Lamatinulu)

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Abstract: Humans cannot survive without water. Cooking, bathing, washing, and other daily activities all require water. Water that is sometimes cloudy and yellowish becomes a problem for the community, leaks and pipe repairs also have an impact on the Makassar City PDAM water distribution process. This research aims to measure the risk of water distribution in Makassar City PDAM and get a proposed mitigation strategy to minimize the risk of water distribution in Makassar City PDAM. This study uses the House Of Risk (HOR) method to analyze the risk of water distribution in Makassar City PDAM. The result of this study are 15 risk events and 31 risk agent in the distribution of water in PDAM Makassar City. In the House Of Risk (HOR) phase I, there are 9 risk agents areatment with different levels of risk including 5 risk agents categorized as having a critical risk level (high risk) and 4 risk agents being categorized as having a moderate risk level (medium risk) and based on the House Of Risk (HOR) phase II, it is determined that the recommended mitigation proposal to reduce risk in water distribution must use a preventive maintenance strategy.

Keywords: Water Distribution, Risk, Risk Mitigation, House of Risk (HOR)

1. Introduction

Water is very important for human survival. Water is needed for cooking, bathing, washing, and other daily activities. Good quality water that has been carefully managed is beneficial to human health and is safe to drink.

With the growth of water consumption, the local government formed a Regional Drinking Water Company (PDAM) [1]. PDAM is a regional business entity that is responsible for the administration of drinking water to meet the community's need for safe drinking water [2].

In terms of physical criteria, good water is water that has no taste, smell, or color and does not damage health [3]. A pH of 6.5-8.5 is recommended for clean water. Physical, chemical, and biological quality tests are carried out on water to ensure it does not have a negative impact on health when consumed [4].

Of the 199 household heads who use the Makassar City PDAM, the highest physical quality of clean water is 20% or as many as 40 families who say the water is colored, 10.1 percent or as many as 20 household heads say it tastes good, and 12.6 percent or as many as 25 the head of the family who said it stinks [5].

Poor water quality has a negative impact on body health. Disease experienced include itchy skin and fever [6].

The piping network system is one of the most important components of the clean water distribution system, especially with regard to water use in metropolitan [7].

Some of the community's difficulties include cloudy and yellowish water, especially in low-pressure areas in Makassar City. Water quality becomes unstable. The water distribution process carried out by the Makassar City PDAM is also influenced by regional conditions that are far from water treatment equipment, leaks, and pipe repairs.

To mitigate these problems, it is necessary to analyze the risk of water distribution as an effort to reduce the risk of water distribution in PDAM Makassar City. One of the methods used in risk management is the House Of Risk (HOR) method.

The House of Risk (HOR) method is used to assess potential risks and determine their probabilities and impacts [8] Research on risk analysis using the House of Risk method was conducted by [9-12].

The House of Risk (HOR) method is used to assess potential risks and determine their probabilities and impacts [8] Research on risk analysis using the House Of Risk method was conducted by [9-12].

HOR is a modification of FMEA (Failure Modes and Effect of Analysis) and the quality house model (HOQ) to prioritize which risk sources are first selected to take the most effective action in order to reduce the potential risk from risk sources. House of Risk is a model based on the need for risk management that focuses on preventive measures to determine which risk causes are a priority which will then be given risk mitigation or countermeasures. It is hoped that the handling of risks that arise can minimize the possibility of the impact of losses [13].

According to Pujawan and Geraldin (2009), there are two phases for HOR, namely the first phase I HOR is used to prioritize which risk agent will receive corrective action. HOR stage 1 is the initial stage of the House Of Risk method, where HOR stage 1 is the risk identification stage used to determine risk agents that must be prioritized for preventive action. The two phase II HORs are used to prioritize a number of actions based on financial viability and resource availability. HOR stage 2 is the second stage of the House Of Risk approach. Several treatment strategy options that have been found in HOR phase 2 will be selected to limit the possible impact of risk agents [14].

2. Research Methods

2.1. Research Time and Place

The time of this research was carried out for one month starting from January 10 to February 10, 2022, while the place of research was carried out at PDAM Makassar City, located on Jalan Dr. Ratulangi No. 3, Mangkura, Ujung Pandang District, Makassar City, South Sulawesi.

2.2. Data Collection

2.2.1. Primary Data

Primary data in the form of interviews and questionnaires were obtained from respondents, namely the head of the DKA section, the head of the Engineering Planning section, the Head of the Maintenance Section and the Head of the Engineering Planning Section. Where the determination of respondents using purposive sampling.

2.2.2. Secondary Data

The secondary data in this study is the distribution pipe damage data.

2.3. Data Processing

The data processing used in this study uses the House Of Risk (HOR) method, namely:

1) Identification and assessment of risks and risk agents

The method for determining the risk of House Of Risk is based on two variables of possible risk (occurance) and risk impact (severity) [15].

2) Risk calculation

a. HOR phase I serves to determine the source of priority risk based on the Aggregate Risk Potential (ARP) value.

$$ARPj = Oj \cdot \sum Si \cdot Rij$$

b. HOR phase II functions to determine mitigation proposals by calculating the total effectiveness of mitigation to minimize the impact of these risk agents [16].

$$TEk = \sum(ARPj \cdot Ejk$$

3. Results and Discussion

3.1. Risk Identification and Assessment (Risk Event)

Risk events that occur in water distribution have been determined based on questionnaires and interviews. There are 15 risk events that occur in the distribution of water and then an assessment of the level of impact caused by the risk (severity) is carried out. The scale used for severity assessment is a Likert scale, which is a scale of 1-10.

Table 1. *Risk Event List and Assessment.*

No	Code	*Risk Event*	*Severity*
1	E1	There is a broken pipe	10
2	E2	There is corrosion on the distribution pipe	9
3	E3	There is a blockage in the distribution pipe	9
4	E4	The occurrence of water loss in the distribution process	6
5	E5	There is damage to the water distribution pipe that flows into customers' homes	6
6	E6	Water distribution to customers is not optimal	7
7	E7	There is equipment damage in the distribution section (distribution pump)	8
8	E8	There is a pipe installed underground that is dented and difficult to identify	7
9	E9	Micro-cracks that are difficult to identify in the distribution pipeline	6
10	E10	There is thinning of the distribution pipe wall	8
11	E11	Low raw water debit	9
12	E12	There is a water meter malfunction	8
13	E13	Clean water theft has occurred	9
14	E14	There is damage to equipment in the production section	9
15	E15	There is a leak in the distribution pipe	8

3.2. Identification and Assessment of Risk Agents (Risk Agents)

Identification of risk agents for each risk event that exists, there are 31 risk agents that have been identified. and then an assessment of the likelihood that the risk will occur (occurance) is carried out. The scale used for the assessment of occurrence is a Likert scale, namely a scale of 1-10.

Table 2. *List and Assessment of Risk Agents.*

No	Kode	*Risk Agent*	*Occurrance*
1	A1	Drainage excavation	4
2	A2	The presence of high pressure from outside the pipe	2
3	A3	Lack of automatic pipeline monitoring system	8
4	A4	The water meter is old	9
5	A5	Pipe wall scraping	7
6	A6	Reduced pipe diameter	7
7	A7	Unsystematic checking	6
8	A8	Vibration of the load from outside	2
9	A9	A lot of material is carried away by the current when the water flow is heavy	3
10	A10	There is project work	5
11	A11	Installation error on the water meter	2
12	A12	Pipe life past the usage limit	8
13	A13	Hit an external object	6
14	A14	Missing pipe connection	6
15	A15	Many pipes are not embedded	1
16	A16	There was damage to the water treatment plant	2
17	A17	Seepage at pipe joints	5
18	A18	Soil that is carried away when repairing a leaky pipe	6
19	A19	There is a pipeline installed out of control	1
20	A20	Undetected leaks	8
21	A21	Incorrect pipe connection position	5
22	A22	The glue used is not up to standard	1
23	A23	Lack of supervision from the company's internal parties	6
24	A24	Too expensive water payment	3
25	A25	Irregular maintenance schedule	3
26	A26	Excavation of cabling from an external company	3
27	A27	Submerged in sewer water	6
28	A28	Inability to pay for water	4
29	A29	Lack of maintenance on equipment	5
30	A30	Natural conditions	1
31	A31	The life of the pump has passed the service limit	8

3.3. House of Risk (HOR) Phase I

In HOR phase I, the Aggregate Risk Potential (ARP) value is calculated to determine which risk agent should be prioritized for risk management.

Risk Event (Ei)	Risk Agent (Ai)																															Severity
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	
E1	9	3			1			1				9														3						10
E2												9					1										3					9
E3			3			3			3									1														9
E4	3		9											9			9		9	9			3									6
E5	3	1					1	1				9								1						3						6
E6										1										9										9		7
E7																									3				9		3	8
E8	9	3						1					3										3			9						7
E9	1	1	1		3			3				9	3							9						3						6
E10												9											1						1			8
E11																1														9		9
E12				9							9		3																9			8
E13															1									9				3				9
E14																							9		3				9			9
E15	9	3										9									3	1				9						8
Occurrence	4	2	8	9	7	7	6	2	3	5	2	8	6	6	1	2	5	6	1	8	5	1	6	3	3	3	6	4	5	1	8	
ARP	1068	174	696	648	196	189	36	82	81	35	144	3384	378	324	9	18	315	54	54	1416	120	8	768	243	153	603	162	108	1165	144	192	
Rank	4	16	6	7	13	15	27	23	24	28	19	1	9	10	30	29	11	25	25	2	21	31	5	12	18	8	17	22	3	19	14	

Figure 1. *Value of Aggregate Risk Potential (ARP).*

Based on the Aggregate Risk Potential (ARP) value, the highest value was 3384 at risk agent A12. Then use the Pareto diagram to find the dominant risk agent based on the ARP value obtained from the calculations in the table above.

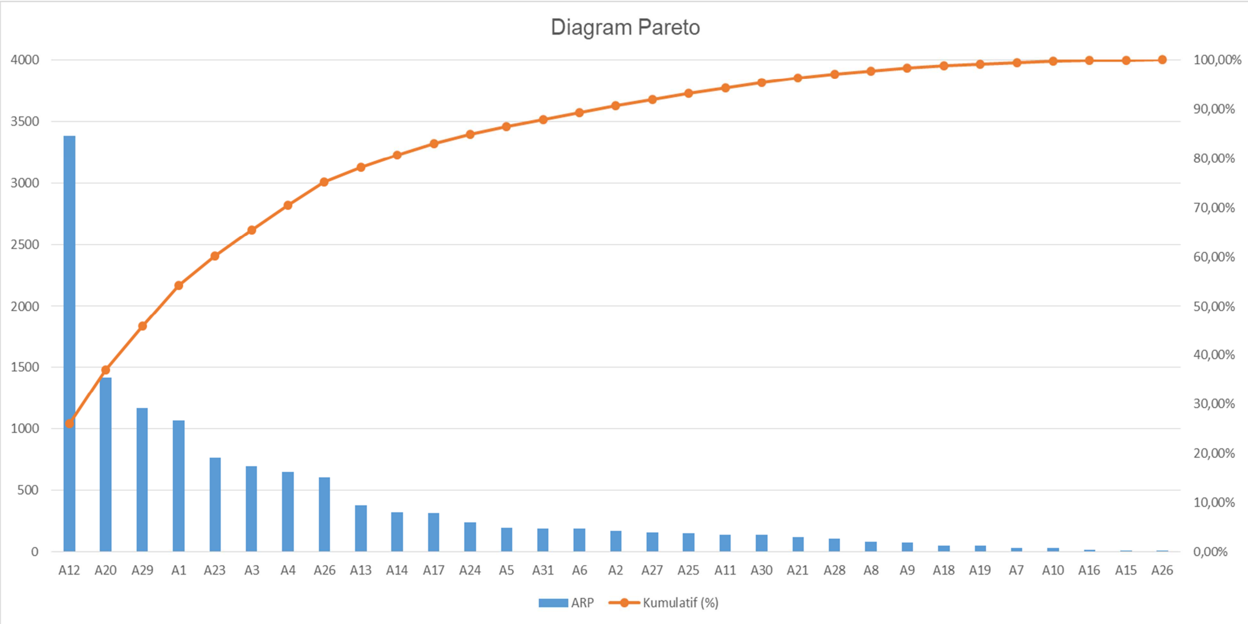

Figure 2. *Pareto Risk Agent Chart.*

The results of the Pareto diagram on the Aggregate Risk Potential (ARP) of risk sources are used to determine the priority of risk sources for risk mitigation actions. According to the 80/20 Pareto principle, 80 percent of risk agents are used to build a treatment approach that will affect the other 20 percent of risk agents. In Makassar City PDAM water distribution activities, there are 9 risk agents that dominate out of 31 risk agents.

Table 3. *Dominant Risk Agent Before Handling.*

Code	*Risk Agent*	ARP	*Severity*	*Occurrance*
A12	Pipe life past the wear limit	3384	6	8
A20	Undetected leaks	1416	7	8
A29	Lack of maintenance on equipment	1165	6	5
A1	Drainage excavation	1068	8	4
A23	Lack of supervision from the company's internal parties	768	7	6
A3	Lack of automatic pipeline monitoring system	696	6	8
A4	The water meter is old	648	8	9
A26	Excavation of cabling from an external company	603	8	3
A13	Hit an external object	378	6	6

After the list of priority risk sources is known, the dominant risk mapping is then carried out. This mapping aims to see the condition of the risk before handling it.

Table 4. *Risk Map Before Risk Mitigation Strategy Design.*

Occurrance	**Severity**				
	Very low	**Low**	**Medium**	**High**	**Very High**
Very High				A4	
High			A12, A3	A20	
Medium			A13	A23	
Low			A29		
Very Low				A1, A26	

Information:
Green = Low risk position;
Yellow = Medium risk position;
Red = Critical risk position.

3.4. House of Risk (HOR) Phase II

The results of the HOR phase 1 will be used to mitigate the most significant risks. The next stage of the risk agent mitigation process is determining preventive actions. The results of the discussion with the expert resulted in a risk mitigation strategy, which is detailed in the following table.

Table 5. *List of Mitigation Strategies.*

No	Kode	*Risk Agent*	Code strategy	Strategy *Preventive Maintenance*
1	A12	Pipe life past the wear limit	PA1	Planning to create a pipeline age database for early warning
2	A20	Undetected leaks	PA2	Planning for valve installation at each branch to detect leaks
3	A29	Lack of maintenance on equipment	PA3	Regular equipment maintenance scheduling
4	A1	Drainage excavation	PA4	Planning a direct review and coordination with the implementer of drainage improvement
5	A23	Lack of supervision from the company's internal parties	PA5	Scheduling regular employee evaluations
6	A3	Lack of automatic pipeline monitoring system	PA6	Planning for the installation of Leak Noise Correlator (LNC) an active leak search technology tool
7	A4	The water meter is old	PA7	Planning to check periodically to detect an old meter to be replaced
8	A26	Excavation of cabling from an external company	PA8	External parties must coordinate with PDAM before carrying out operations in the piping area
9	A13	Hit an external object	PA9	Planning for periodic inspections of pipelines

After determining the treatment approach, the expert re-evaluates the relationship between the risk agent and the mitigation strategy. Correlation values are given to determine the total effectiveness and degree of difficulty of the specified treatment. For the selection of priority management strategies, the calculation of the highest to lowest Effectiveness to Difficulty Ratio is carried out. to select a ranking of treatment strategies in order to reduce the probability of occurrence of risk sources which will be carried out first.

Table 6. *House of Risk (HOR) Phase II.*

Risk Agent (Ai)	Preventive Action (PAk)									ARP
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	
Pipe life past the wear limit	9									3384
Undetected leaks		3								1416
Lack of maintenance on equipment			9							1165
Drainage excavation				9						1068
Lack of supervision from the company's internal parties					3					768
Lack of automatic pipeline monitoring system						3				696
The water meter is old							9			648
Excavation of cabling from an external company								9		603
Hit an external object									3	378
Total Effectiveness of Action (TEk)	30456	4248	10485	9612	2304	2088	5832	5427	1134	
Degree of Difficulty preforming Action (Dk)	4	3	3	3	3	5	4	5	5	
Effeectiveness to Difficulty Ratio (ETD)	7614	1416	3495	3204	768	418	1458	1085	227	
Rank of Priority	1	5	2	3	7	8	4	6	9	

Based on the Effectiveness to Difficulty Ratio (ETD) value, the highest score was 7614 on preventive action PA1.

Table 7. *Order of Priority for Handling.*

No	*Preventive Action*	Kode	ETD
1	Planning to create a pipeline age database for early warning	PA1	7614
2	Regular equipment maintenance scheduling	PA3	1416
3	Planning a direct review and coordination with the implementer of drainage improvement	PA4	3495
4	Planning to check periodically to detect an old meter to be replaced	PA7	3204
5	External parties must coordinate with PDAM before carrying out operations in the piping area	PA8	768
6	Planning for valve installation at each branch for leak detection	PA2	418
7	Scheduling regular employee evaluations	PA5	1458
8	Planning for the installation of Leak Noise Correlator (LNC) an active leak search technology tool	PA6	1085
9	Planning for periodic checks on the pipeline network	P9	227

After determining the level of efficacy of the treatment strategy, a re-evaluation of the severity and incidence is carried out to determine the status of the risk agent in accordance with the priority design of the treatment strategy. Based on the results of discussions with the experts, the severity and occurrence risk agents were assessed after the design of the handling strategy was carried out.

Table 8. *Dominant Risk Agent After Priority Management Strategy Design.*

No	Kode	*Risk Agent*	*Severity*	*Occurrance*
1	A12	Pipe life past the wear limit	3	4
2	A20	Undetected leaks	5	5
3	A29	Lack of maintenance on equipment	5	4
4	A1	Drainage excavation	6	3
5	A23	Lack of supervision from the company's internal parties	4	4
6	A3	Lack of automatic pipeline monitoring system	3	5
7	A4	The water meter is old	6	5
8	A26	Excavation of cabling from an external company	6	2
9	A13	Hit an external object	4	4

Severity and occurrence values are obtained from expert predictions. It is hoped that after the design of this priority strategy for handling the risk agent is not in the critical category.

Table 9. *Risk Map After Priority Management Strategy Design.*

Occurrance	Severity				
	Very low	Low	Medium	High	Very High
Very High					
High					
Medium					
Low	A3	A20	A4		
Very Low	A12, A23, A13	A29	A1, A26		

Dari pemetaan risiko, dapat dilihat perbedaan sebelum dan setelah adanya perancangan prioritas strategi penanganan level risiko mengalami penurunan dapat dilihat di tabel 5 dan tabel 10.

4. Conclusions and Recommendations

4.1. Conclusion

Based on research that has been carried out at PDAM Makassar City regarding risks in water distribution and mitigation strategies for water distribution, it can be concluded as follows:

1) There are 15 risk events and 31 risk agents in the distribution of water in PDAM Makassar City. In the House of Risk (HOR) phase I, 9 risk agents became priority handling with different risk levels including 5 risk agents categorized as having a critical risk level (high risk) and 4 risk agents being categorized as having a medium risk level (medium risk).

2) Based on the results of the House of Risk (HOR) phase II, a proposed mitigation strategy to minimize risks in water distribution should use a preventive maintenance strategy by planning a treatment to overcome the risk agents that occur.

4.2. Recommendations

Suggestions that can be given to PDAM Makassar the author hopes that the company can accept the handling strategy that has been proposed to reduce the impact of risk on water distribution.

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