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Water Allocation Based on Source Capacity, Non-Revenue Water (NRW), and Customer Priority at PT Air Minum Giri Menang Perseroda Mataram."

Nurul Hidayati*, I Wayan Yasa, Hartana
Universitas Mataram, Indonesia
Email: nh562915@gmail.com*

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Abstract

The increasing demand for clean water services and inefficiencies in distribution systems have become major challenges in sustainable water resource management. High levels of Non-Revenue Water (NRW) reduce the effective capacity of water supply systems and contribute to inequitable water distribution, particularly in areas with limited water availability. This study aimed to evaluate water source capacity conditions, analyze NRW distribution and customer characteristics, determine service zone priorities, and develop an effective water allocation model using a hybrid decision-support approach. The research was conducted in the West Lombok Regional Government Housing Area served by PT Air Minum Giri Menang Perseroda. A quantitative approach was applied using water balance analysis based on International Water Association (IWA) standards, followed by the integration of the Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW) methods. The results showed that groundwater source capacity remained within sustainable limits, with an Ecological Exploitation Index of 41.89%. However, the distribution system experienced a high NRW level of 44.72%, which significantly reduced the effective water supply capacity. The AHP analysis identified NRW as the most important criterion, with a weight of 52.63%, followed by average consumption, connection density, and the social customer ratio. The SAW ranking determined Zone 1 as the highest priority (Vi = 0.946), followed by Zone 2 (Vi = 0.941) and Zone 3 (Vi = 0.924). The allocation simulation revealed that the available effective capacity could meet the water demand of Zones 1 and 2 but resulted in a supply deficit in Zone 3. This study concluded that integrating NRW evaluation, customer priority assessment, and multicriteria decision-making provides an effective framework for improving equitable and sustainable water allocation management.

INTRODUCTION

The operational reliability of the pipeline network in the West Lombok Regional Government Housing Area has faced technical challenges in maintaining continuous water flow to downstream consumers. Based on preliminary studies and a global water balance analysis using official annual volume data from agencies for the 2024 period, the level of network leakage, represented by Non-Revenue Water (NRW), in the residential cluster was calculated to exceed 40%. This significant water loss value was determined from the quantitative difference between the total upstream production volume and the accumulated volume of water recorded through customer meters during the year (Frauendorfer & Liemberger, 2010). According to Hidayaty et al. (2017), improving clean water service capacity at PT Air Minum Giri Menang Perseroda requires consideration of water source availability, production capacity, and fluctuations in customer demand across service areas. The study identified that limited production capacity and high NRW levels were the main factors contributing to suboptimal services, making the determination of distribution priority scales crucial.

The limited availability of clean water due to high water losses potentially disrupts service continuity and creates unequal distribution among service areas. Under these conditions, the effective capacity of the system may not be sufficient to simultaneously fulfill the demands of all zones, requiring more targeted and scalable water distribution management strategies (Bello et al. 2019; Bouramdane 2023; Giudicianni et al. 2020; Leigh et al. 2019; Poff et al. 2016).

In line with these findings, Rahman et al. (2024) analyzed the factors contributing to water losses in the distribution system of PT Air Minum Giri Menang Perseroda. The study found that NRW was influenced by both technical and non-technical factors, which directly reduced distribution effectiveness and limited the volume of clean water available for allocation.

Currently, water distribution management in residential areas still relies on conventional service patterns without the support of data-driven prioritization tools. Consequently, areas with higher water loss levels or different customer characteristics may experience unequal service quality (Coleman et al. 2020; Furlong et al. 2017; Gowela et al. 2017; Hendricks et al. 2021; Tangaja et al. 2021).

Furthermore, Fitriyani (2020) demonstrated that the implementation of priority scales in clean water allocation could maintain supply stability for public sector facilities and healthcare facilities compared with other sectors, particularly during periods of supply shortages.

Therefore, water allocation based on actual raw water source capacity and production system conditions can minimize distribution disparities among service areas. A quantitative allocation approach that integrates supply and demand relationships has been proven effective in improving water resource utilization efficiency and supporting technical decision-making in drinking water supply system management (Loucks & van Beek, 2017; Alegre et al., 2016).

In Indonesia, drinking water management challenges are also associated with limited source capacity, increasing customer demand, and inefficiencies in distribution networks. The performance of regional drinking water companies (Perusahaan Daerah Air Minum [PDAM]) is strongly influenced by their ability to effectively manage water resources, production systems, and distribution networks. PT Air Minum Giri Menang Perseroda, which serves the Mataram and West Lombok regions, faces similar challenges in maintaining reliable water distribution services. Previous research by Hidayati et al. (2017) identified that limited production capacity and high water losses were among the main factors affecting the improvement of clean water services at PT Air Minum Giri Menang Perseroda. Furthermore, Rahman et al. (2024) found that water losses within the distribution system of PT Air Minum Giri Menang Perseroda were influenced by technical and non-technical factors, including network conditions, operational management, and customer-related factors. These findings indicate that improving water services requires a comprehensive approach that considers both technical efficiency and managerial decision-making.

The specific issue examined in this research was the imbalance between available effective water capacity and water demand distribution among service zones in the West Lombok Regional Government Housing Area. Based on operational data from PT Air Minum Giri Menang Perseroda, the distribution network experienced a high level of water loss, with NRW exceeding 40% during the operational period. This condition significantly reduced the amount of water that could be effectively allocated to customers. Although the upstream water source capacity remained within sustainable limits, the available effective capacity after considering NRW reduction was insufficient to simultaneously fulfill the water requirements of all service areas. Therefore, determining service zones requiring higher allocation priorities became an important managerial challenge. Conventional distribution mechanisms that allocate water equally among zones may not accurately represent actual system conditions because each zone has different network characteristics, customer densities, consumption patterns, and social priorities.

Several previous studies have addressed water allocation and prioritization problems using various approaches. Fitriyani (2020) developed a water allocation optimization model by considering customer priorities in PDAM service systems and demonstrated that priority-based allocation could improve supply stability under limited water availability conditions. Ismarmiaty and Rizky (2020) applied the Simple Additive Weighting (SAW) method to determine priority areas experiencing water crises and showed that multicriteria decision-making could support objective decision processes. Meanwhile, Alegre et al. (2016) emphasized the importance of performance indicators in evaluating water supply systems, particularly through NRW measurement and operational efficiency indicators. Loucks and van Beek (2017) also highlighted that integrated water resource management requires analytical models capable of balancing supply availability, demand requirements, and sustainability considerations. These studies demonstrated that decision-support approaches could improve water management effectiveness; however, most previous studies focused separately on NRW reduction, water allocation optimization, or priority determination without integrating these aspects into a comprehensive allocation framework.

Despite previous contributions, several research gaps remain. First, existing studies generally evaluate water distribution performance without directly integrating source capacity, NRW conditions, customer characteristics, and allocation priorities into a single decision-making model. Second, limited research has explored the application of hybrid multicriteria decision-making models combining the Analytic Hierarchy Process (AHP) and SAW methods for water allocation under conditions of limited effective capacity. Third, previous approaches often determine priority areas based primarily on technical indicators, while social dimensions, such as customer characteristics and service equity, receive limited attention. Therefore, an integrated model is required to support water utilities in determining allocation priorities based on measurable criteria representing technical efficiency, resource availability, and social responsibility.

The urgency of this research was related to the increasing need for sustainable and equitable water management strategies. Without an appropriate allocation mechanism, downstream areas or areas with higher dependency on water services may experience supply deficits due to unequal distribution impacts and accumulated losses within the network. The implementation of a data-driven decision-support system is therefore essential to assist water utilities in making transparent, objective, and adaptive allocation decisions. By identifying priority service zones based on actual system conditions, utilities can optimize limited water resources while improving service reliability. This approach is particularly important for regional water companies that must maintain public services while operating under infrastructure limitations and increasing demand pressures.

The novelty of this research lies in the development of a hybrid AHP–SAW-based water allocation framework that integrates four important dimensions: source capacity reliability, NRW performance, network characteristics, and customer priority aspects. Unlike previous studies that analyzed these components separately, this research combines them into a unified decision-support model to determine service zone priorities and simulate tiered water allocation based on effective capacity availability. The AHP method was used to determine the relative importance of each criterion based on expert judgment, while the SAW method was applied to objectively rank service zones. Furthermore, this research extended the decision model by incorporating allocation simulations to evaluate whether available effective capacity could satisfy water demand across prioritized zones.

The contribution of this research is both theoretical and practical. From a theoretical perspective, this study contributes to water resource management literature by introducing an integrated multicriteria decision-making approach for allocation problems under limited supply conditions. From a practical perspective, the proposed model provides PT Air Minum Giri Menang Perseroda and other water utilities with an analytical instrument to support strategic decision-making regarding distribution priorities, NRW management, and service improvement planning. The model can assist utilities in identifying critical zones, optimizing existing capacity utilization, and improving fairness in water distribution by considering both technical and social factors.

Based on these considerations, this research aimed to analyze existing water source capacity conditions, evaluate NRW distribution and customer characteristics across service zones, develop a priority ranking model using the AHP–SAW hybrid method, and simulate effective capacity allocation based on the resulting priority order. The expected benefit of this research is to provide an evidence-based framework for improving water allocation efficiency, reducing distribution inequality, and supporting sustainable drinking water management. Furthermore, the findings are expected to serve as a reference for future studies and practical applications involving decision-support systems, water resource optimization, and integrated management of urban drinking water supply networks.

METHOD

Research Location

This research was conducted in the distribution network area of the West Lombok Regional Government Housing Area, located in Dasan Tapen Village, Gerung District, West Lombok Regency. The study area's piping system served 528 Home Connections (HCs), predominantly consisting of domestic household customers.

Data Collection

The data collection used in this study is classified into two main groups, namely primary data and secondary data. Secondary data was obtained from PT Air Minum Giri Menang

(Perseroda), in 2026 which includes.

1. Spatial data: data on the results of spatial processing in the form of service zones, pipeline lengths, distribution distances, number of customers, consumption, and the number of customers of social tariff and RT 2B for each service zone.
2. Non-spatial data: *Safe Yield*, and pump-installed capacity, as well as global production and consumption capacity (*Biiled Authorized Consumption* (BAC) and annual time range from January 2025 to December 2025.
3. Complementary operational data is in the form of the age classification of the customer's meter.

Meanwhile, the primary data in this study is sourced from the results of a paired comparison matrix assessment by a panel of experts totaling 6 (six) respondents, who occupy strategic positions, namely Distribution Section Manager, *Non-Revenue Water Section Manager*, and Engineering Director or Engineering Manager.

Delineation of Service Zones

The service area is designed to be divided into three imaginary service zones, namely Zone 1 (Upstream), Zone 2 (Central), and Zone 3 (Downstream) to support the spatial analysis of clean water distribution.

Given the agency's internal regulations that limit the dissemination of raw spatial files (*shapefile* / .shp), the process of delineating the zone boundaries is executed by the agency based on the concept proposed by the researcher. The geospatial data output obtained is in the form of schematic maps resulting from deliniation. The schematic map of the results of the delineation of the service zone is shown in Figure 1.

Figure 1. Schematic Map of the West Lombok Regional Government Housing Service Zone

(Source: PT Air Minum Giri Menang Perseroda, 2026)

The results of the deliniation produce different characteristics in each service zone. These characteristics include the number of house connections, the length of the pipeline, the volume of water consumption, and the distribution of subsidized tariff customers (Social and Household Tariff 2B) as the basis used in the next stage of analysis. A recapitulation of the characteristics of each service zone is presented in Table 1.

Table 1. Characteristics of Delination Result Service Zones

Zone Services	Quantity Connection Home (SR)	Pipe Length (km)	Water Consumption (m^3/Year)	Quantity Customers Social Tariff and RT 2B
Zone 2	76	1,778	10.197	71
Zone 2	165	3,657	23.551	164
Zone 3	287	5,247	39.272	272
Total	528	10,681	73.020	507

(Source PT Air Minum Giri Menang Perseroda, 2026)

Analysis of the Existing Conditions of Upstream Water Supply Reliability

Ratio analysis was derived to extract upstream performance indicators by adopting three standard mathematical formulations (Kodoatie & Sjarief, 2010; Tchobanoglous et al., 2014). This quantitative procedure is carried out by the researcher independently by converting all upstream data parameters from the agency's extraction into an annual accumulated volume (m^3/year) based on 365-day operations. The three indicators are calculated with the following parameters:

1. Pump Utilization Rate: Is a comparison of the actual production capacity to the mechanical installed capacity of the pump to measure the efficiency of the utilization of operational assets.
2. Design Planning Ratio: A comparison between the installed capacity of the pump and the hydrological safe limit (*safe yield*) of the legal document to assess the alignment of the capacity of the machinery infrastructure with the carrying capacity of nature.
3. Ecological Exploitation Index: It is the ratio between the actual production capacity to the *safe yield value* to evaluate the level of sustainability of groundwater utilization.

Audit Neraca Air Global

The processing of raw production volume data and annual billing transaction databases throughout 2025 is carried out using Microsoft Excel *spreadsheets* based on the *International Water Association*'s (IWA) water balancing *standardization*. The analysis was carried out by utilizing *System Input Volume* (SIV), *Billed Authorized Consumption* (BAC) data, and other supporting data obtained directly from the database of PT Air Minum Giri Menang Perseroda's agency.

The quantity *of Unbilled Authorized Consumption* (UAC) is set at a constant of 0.5% of the global *System Input Volume* (SIV) based on the *International Water Association* (IWA) water balance standards by considering the operational conditions of PT Air Minum Giri Menang Perseroda through consultation with the company's stakeholders. Meanwhile, the estimated loss of commercial water due to unofficial consumption (theft) and administrative errors was set at 0.35% of the total official water sales volume (*Billed Authorized Consumption*) taking into account the operational conditions of PT Air Minum Giri Menang Perseroda. Another component of commercial loss, namely the inaccuracy of customer meters (*apparent losses*), is calculated based on the classification of the meter service life error index which refers to the standards of the Directorate General of Cipta Karya of the Ministry of PUPR

(2016). The results of the audit are then used as the basis for the process of decentralizing NRW to each service zone.

Decentralized Water Balance Audit

The quantity *of Unbilled Authorized Consumption* (UAC) is distributed proportionally based on the ratio of the number of existing Home Connections (SRs). Apparent losses are proportionally reduced based on the distribution of the number of customers or active home connection points, while the burden of physical losses (*real losses*) is decentralized proportionally based on the pipeline length ratio (Alegre et al., 2016).

The quantity of *System Input Volume* (SIV) of each service zone is calculated from the Billed *Authorized Consumption* (BAC) value of the zone plus the NRW volume of the relevant zone. The internal water loss rate (%NRW) of each zone is obtained from the comparison between the volume quantity of the NRW zone to the volume quantity of the SIV of the corresponding zone. This water loss rate (%NRW) will be used as the *C1* criterion in the priority analysis using the SAW method.

Water Demand Analysis

The analysis of water needs was carried out referring to the Minister of Public Works and Public Works Regulation Number 27 of 2016 concerning the implementation of the drinking water supply system. The calculation is carried out based on the number of customers in each service zone calculated based on the standard of domestic water needs so that the annual water needs of each service zone are obtained. The value of water needs is used as a comparison in the evaluation of the results of the tiered water allocation simulation.

Analysis of Network Physical Characteristics and Customer Demographic Profiles

This stage is aimed at extracting secondary data on the physical parameters of the pipeline and consumer socio-economic variables into quantitative indicators of the field. These parameters were derived using three basic calculation formulations in each study area, namely:

1. Connection Density (*C2*): The network density value is obtained from the ratio between the number of housing connection units and the total length of the pipeline in kilometers (km).
2. Average Customer Consumption (*C3*): The volume of domestic consumption is calculated from the average monthly water consumption in each service zone per number of units of the relevant active home connection points.
3. Proportion of Priority Customers (C_4): The percentage value is obtained from the comparison between the number of special house connection points in the Social and Household (RT) 2B category to the total total number of registered home connection units in the same zone.

These three field characteristic variables are then locked as the value of the benefit criterion input which will be processed at the next stage of the decision support system.

Weighting of Criteria Using *the Analitycal Heerarchy Process* (AHP) Method

The initial stage of weighting criteria using the AHP method involves distributing a *pairwise comparison questionnaire* to 6 people of the company's internal managerial expert panel to extract the weight of relative importance between criteria. The steps of AHP computing are detailed as follows:

1. Combining individual questionnaire fill sheets from six experts into a single Synthetic Paired Comparison Matrix using the *geometric mean* function.

2. Calculate *the eigenvalue* and normalize the matrix to produce the final decimal weight for each criterion.
3. Controlling the validity of group assessments through the calculation *of Consistency Index* (CI) and *Consistency Ratio* (*CR)* refers to the Saaty standard (1980), where the CR value must meet the mathematical tolerance threshold, which is CR ≤ 0.10.

Allocation Priority Ranking Using the SAW Method

The hybrid decision support system modeling process is carried out through 2 stages of integrated computing:

1. Alternative Ranking (*Simple Additive Weighting* / SAW): The procedure is continued by compiling an orderly initial decision matrix (*X*) (3 x 4) representing 3 service zones as alternatives and 4 field parameters as criteria. All criteria—which include % NRW (*C1*), connection density (*C2*), average monthly consumption (*C3*), and percentage of social tariff and RT 2B (*C4*) customers—are uniformly classified as benefit *criteria*. The transformation of the decision matrix is carried out through a linear normalization process by dividing each element of the actual value by the maximum performance value recorded in the same criterion column.
2. Final Preference Score and Prioritization: The final stage of computation is performed by multiplying the matrix elements of the linear normalization results by the relative importance weight coefficient obtained from the AHP analysis. The accumulation of this weighted sum results in the final preference score value of SAW (*Vi*) for each alternative distribution area. The service zone with the highest value (*Vi*) is automatically determined as the area with the highest priority rating, where the hierarchical order of this final decision will be locked as an instrument to control the direction of the allocation of raw water supply quota at the next stage of water allocation simulation.

Tiered Water Allocation Simulation

The operational simulation was compiled using a Microsoft Excel spreadsheet to cascading the Effective Capacity quota (*QEeffative*) between service areas, which was guided linearly by the order of the highest preference score results from the SAW algorithm (Zone 1, Zone 2 and Zone 3). Effective Capacity Volume as the basis for balancing clean water quotas is calculated annually from the results of the reduction in *the value of the global System Input Volume* (SIV) by the accumulation of global *Non-Revenue Water* (NRW) volume in the residential network. The target volume of domestic water load at this stage is based on the Ministry of PUPR's Domestic Water Demand Standard of 120 liters/person/day, assuming the demographics of one Home Connection (SR) serves an average of 5 residents. The distribution of the flow of the essential water quota is carried out in stages, starting from the main priority zone. If the needs in the zone with the priority level above it have been fully met, the remaining quota of effective capacity of clean water will be continued (*cascading*) to flow to the zone at the next priority level until the total volume of effective capacity is exhausted. The results of the tiered volume availability analysis are then evaluated to assess the suitability of clean water allocation in each sub-region. The evaluation is measured through two qualitative performance indicators, namely:

1. Quantity adequacy of volume: Assess the ability of effective capacity to meet 100% of the target load of domestic clean water needs of government standards in the zone concerned.

2. Technical efficiency conditions (network NRW urgency): Justify the feasibility of the final status of the allocation by considering the resistance of the internal water loss rate (%NRW) in each service zone.

The integration of these two indicators gave birth to the classification of the final decision in the form of a status of Accordance with the Record for priority areas that meet their water needs but still leave a high leakage problem, as well as a 'Not Suitable' status for service areas that are experiencing a supply deficit crisis due to system reliability failures.

RESULT AND DISCUSSION

Existing Conditions of Upstream Water Supply Reliability

The analysis of existing conditions in upstream systems is focused on evaluating the alignment between the mechanical capacity of the pump infrastructure and the natural hydrological carrying capacity of the environment. This quantitative evaluation is measured through three main indicators, namely Design Planning Ratio, Pump Utilization Rate, and Ecological Exploitation Index (IEE) which are calculated cumulatively on an annual scale. A summary of the results of the calculation of technical and ecological performance at the upstream source of PT Air Minum Giri Menang (Perseroda) is presented in full in Table 2.

Table 2. Technical performance indicators of existing water source capacity and utilization

Quantity Parameters Upstream Source	The Real Value of the Network (m^3/year)	Evaluation Results Technical & Ecological	Remarks Standard
Safe Yield Limit	315.360,000	-	Environmental Conservation Thresholds
Installed Capacity (Pump Design)	157.680,000	-	Limits of the mechanical capabilities of the infrastructure
Real Production Volume (Actual)	132.095,000	-	The volume of water entering the master meter
Pump Utilization Rate		83,774%	Efficient (Close to optimal capacity)
Ecological Exploitation Index		41,887%	Sustainable and Sustainable
Design Planning Ratio		50,000%	Safe (Under natural bearing capacity)

Table 2. The above shows that the safe *yield* limit of groundwater is set at 315,360,000 m^3/year. Meanwhile, the design capacity or installed capacity of the pump infrastructure was recorded at 157,680,000 m^3/year or 50,000% of *the safe yield.* This ratio confirms that the mechanical capacity of the built infrastructure is still within the safe threshold of the potential for natural aquifer recharge. Upstream real production reached 132,095,000 m^3/year or equivalent to 83,774% of installed capacity, indicating that the pump unit has been operating efficiently close to its optimal capacity. Meanwhile, the controlled Ecological Exploitation Index (IEE) value of 41.887% confirms that groundwater utilization in the upstream system is still in the safe and sustainable category.

Global Water Balance Audit Results

The global water balance audit is carried out by utilizing *System Input Volume* (SIV), *Billed Authorized Consumption* (BAC) data, historical meter age data, and other parameters. This audit resulted in the total *non-revenue Water* (NRW) component with its constituent components, namely *global Unbilled Authorized Consumption* (UAC), global *apparent losses*, and global *real losses*, as presented in Table 3.

Table 3. Recapitulation of Input Data and Water Balance Recapitulation Results

Water Balance Components	Value
System Input Volume (SIV)	132,095 m³/year
Billed Authorized Consumption	73,020 m³/year
Total *Non-Revenue Water* (NRW)	59,075 m³/year
Unbilled Authorized Consumption	660,475 m³/year
Apparent Losses akibat Meter Error	5,991,722m³/year
Apparent Losses due to Theft and Administration	255,570 m³/year
Total *Apparent Losses*	6,247,292 m³/year
Real Losses	5.2167,233 m³/year
Global NRW Percentage of SIV	44,722%

Based on Table 3, the global water loss rate (NRW) of the West Lombok Regional Government's housing system reached 44.722%. The largest contributor to NRW was *real losses* of 5,2167,233 m³/year. *Apparent losses* caused by *meter errors* are the largest physical losses compared to *apparent losses* due to theft and administrative errors.

The components of the audited water balance, consisting of UAC, *apparent losses*, and *real losses* , will then be decentralized to each service zone proportionally according to the characteristics of the network and customers in the research area.

Decentralized Water Audit and Balance Results

The process of decentralization of the standard water balance *of the International Water Association* (IWA (Lambert et al., 1999) is carried out to detect the location and concentration of specific water loss volumes. Based on the results of the IWA standard *global water balancing audit* throughout 2025, a critical network performance visualization of the West Lombok Regional Government's housing distribution system was obtained. Of the total upstream supply (*System Input Volume* / SIV) of 132,095,000 m³/year, the volume of global non-revenue water (NRW) that was successfully extracted exceeded 59,075,000 m³/year or reached 44.722%. This high global leakage rate drastically cuts the quota of clean water flowed and leaves only the official water sales volume (*Billed Authorized Consumption* / BAC) or effective capacity of 73,020,000 m³/year.

A breakdown of the calculation of commercial and physical limiting parameters on the global water balance shows that *the locked Unbilled Authorized Consumption* (UAC) quantity of 0.5% accounts for a constant loss of 660,475 m³/year. Meanwhile, components of commercial loss due to unofficial consumption (theft) and adjusted administrative errors of 0.35% of the total *System Input Volume* (SIV) absorbed a volume of 255,570 m³/year. The largest commercial loss component was contributed by the apparent *losses* due to the accumulated life of the meter, which was 5,991,722 m³/year. The volume of NRW after deducting all commercial components is *real losses.* This physical loss rate was the largest contributor dominating the total global NRW rate of 44.722% at the study site. A summary of the results of the reconstruction of the global and interzonal water volume balance in the West Lombok Regional Government Housing network is presented in full in Table 4.

Table 4. Global and Decentralized Water Equilibrium Integration Matrix per Zone

Zone Services	Number of Customers (SR)	SIV Zone (m3/ Year)	Konsumsi/ *Billed* (m3/ Year)	Volume NRW (m3/ Year)	NRW Against SIV Global (%)	Internal NRW Level/ Criterion *C1* (%)
Zone 1	76	19.873,216	10.197,000	9.676,216	7,325	48,690
Zone 2	165	43.568,675	23.551,000	20.017,675	15,154	45,945
Zone 3	287	68.653,109	39.272,000	29.381,109	22,242	42,796
Total global	528	132.095,000	73.020,000	59.075,000	44,722	-
Average	-	-	-	-	-	44,722

Based on the table above, zone 2 produces an NRW of 29,381,109 m3/year which is equivalent to 22,242% of the total *global System Input Volume* (SIV). Zone 2 contributed NRW of 20,017,675 m3/year or 15.154% to the SIV of the residential system, while Zone 1 recorded the lowest NRW volume of 9676,216 m3/year or 7.325% of the SIV system. The volume of water loss (NRW) in each of these zones is the result of the cumulative reconstruction of the *Unbilled Authorized Consumption* (UAC) component, *apparent losses* due to metrological degradation factors of meter age, and proportionally decentralized real losses. Based on the calculation results, the physical loss component is the largest contributor to the three service zones.

However, when viewed from the zone's internal SIV parameters, the highest NRW was recorded in Zone 1 with a water loss percentage of 48.690%. This figure means that almost half of the volume of water specially channeled into the Zone 1 network is wasted into lost water. Zone 2 is in second place with the percentage of NRW to SIV in its own zone recorded at 45.945%. Zone 3 ranks third with NRW against the SIV of the zone itself recorded at 42.796%.

The internal NRW percentage value of this zone (Zone 1 = 48.690% or in a decimal scale of 0.487; Zone 2 = 45.945% or decimal 0.459; Zone 3 = 42.796% or decimal 0.428) which is officially locked as the quantitative value for Criterion 1 (*C1*) in decision-making using *the Simple Additive Weighting* (SAW) method in the next stage of analysis.

Results of Water Demand Analysis

The water needs of each service zone are calculated based on the domestic water demand standard of the Ministry of PUPR of 120 liters/person/day, assuming one Home Connection (SR) serves 5 people. The results of the calculation of water needs are presented in Table 5.

Table 5. Water Needs per Service Zone

Service Zone	Number of Subscribers (SR)	Requirements (m³/year)
Zone 1	76	16.644,000

Zone 2	165	36.135,000
Zone 3	287	62.853,000
Total	528	115.632,000

The calculation results show that Zone 3 has the highest water needs, which is 62,853,000 m3/year. This is in line with the number of home connections in the zone which occupies the highest number (287 customers) compared to the other two zones. Furthermore, Zone 2 is in second place with a water requirement of 36,135,000 m3/year, and Zone 1 has the smallest water requirement, which is 16,644,000 m3/year. Thus, the total accumulated water demand for the housing system as a whole was recorded at 115,632,000 m3/year. This water demand value is used as a comparison in evaluating the level of water distribution fulfillment in the tiered water allocation simulation.

Results of Analysis of Physical Characteristics of the Network and Customer Demographic Profile

The integration of the physical parameters of the pipeline and consumer socio-economic variables is extracted into the criteria of Connection Density (*C2*), Average Consumption (*C3*), as well as Percentage of Social Tariff Customers and RT 2B (*C4*). This field characteristics matrix serves as the basis for standardizing basic operational data before entering the value transformation stage through the process of linear normalization and multiplication of the SAW preference weight, as presented in Table 6.

Table 6. Network Characteristics Value Matrix and Customer Criteria per Service Zone

Service Zone	Pipe Length (km)	Number of Subscribers (SR)	Connection Density (SR/km) [*C2*]	Total Consumption (m³/Year)	Average Consumption (m³/SR/Month) [*C3*]	Total Social Clients & RT 2B (SR)	Percentage of Social Tariff Customers & RT 2B (%) [*C4*]
Zone 1	1,778	76	42,754	10.197,000	11,181	71	93,421
Zone 2	3,657	165	45,124	23.551,000	11,894	162	98,182
Zone 3	5,247	287	54,699	39.272,000	11,403	272	94,774
Total	10,682	528	49,429	73.020,000	-	505	-
Rerata	-	-	-	-	11,525	-	95,644

The average consumption of customers in the study area ranged from 11,181 m3 to 11,894 m3 per SR/month. The range of values shows that customer consumption patterns are relatively uniform, but there are still variations that can be used as differentiators in the SAW analysis.

The percentage of social tariff and RT 2B customers in the study area was in the range of 93.421% to 98.182%. This high value indicates that most of the customers in each zone are subsidized tariff recipients. Therefore, zones with a larger proportion of RT 2B social customers are prioritized in water allocation as a form of fulfilling the aspect of service justice.

AHP-SAW Hybrid-Based Prioritization

The initial stage of decision model design is carried out by determining the relative importance weight of each criterion through *the Analytic Hierarchy Process* (AHP) method. The experts' assessment compiled from six internal managerial experts of PT Air Minum Giri Menang (Perseroda) is summarized in Table 7.

Table 7. Summary of the weighted value of the criteria based on the AHP method

Code	Criteria Rating	Quality Criteria	Bobot Criterion (Desimal)	Weight Criteria (%)	Status Consistency
C1	NRW	*benefit*	0,526	52,632	Consistent with a value CR= ,0689
C2	Connection Density	*benefit*	0,167	16,675	
C3	Average Consumption	*benefit*	0,231	23,139	
C4	Social rate customer ratio+2B	*benefit*	0,076	7,554	

Based on the results of group weighting that summarized questionnaires from six internal agency experts in Table 6, the criteria of Non-Revenue Water (NRW) or Water Loss Rate (*C1*) were agreed as the most critical parameter with the highest priority weight of 52.632% (0.526). The operational reason behind this weight dominance is the perspective of piping technical management that the rescue of residual energy supply and the suppression of leakage in the upstream area are absolute requirements that must be completed first. If the pipeline upstream has a severe leak, increasing supply capacity or regulating justice downstream will never be effective because the volume of clean water is already lost on the way.

The placement of the NRW criterion as the greatest weight provides an engineering justification that the physical efficiency of the pipeline must be structurally resolved before evaluating commercial and social parameters downstream. Through the *geometric mean* function, all polarization of individual assessment data from experts was compromised into a single group representative value. This approach proves that the group AHP method successfully eliminates individual subjectivity bias, resulting in a stable, objective, and representative criterion weight coefficient to measure the level of urgency in each service zone.

The second most important parameter is occupied by Average Customer Consumption (*C3*) with a weight of 23.139% (0.231), followed by Connection Density (C2) of 16.675% (0.167). This weight structure indicates that the aspect of daily usage quantity and pipeline density are important hydraulic considerations to anticipate the risk of pressure drop due to simultaneous peak hour usage in customer-congested areas.

Meanwhile, the criteria for Social Tariff + RT 2B (*C4) Customer Ratio* are in the last position with a weight of 7.554% (0.076). Despite being at the bottom of the rankings, this criterion is still maintained in the decision system as an instrument to maintain social functions and enforce the principle of justice for subsidized community groups.

Methodologically, the *pairwise comparison* results of these testers were declared valid, valid, and very reliable to control the direction of water allocation. This is evidenced by *the Consistency Ratio* (CR) value which is locked at 0.0689. Because the CR value is below the maximum tolerance threshold of 0.10 initiated by Saaty (1980), the resulting decision preferences are free from the contradiction bias of human reasoning.

Armed with the value of the weight coefficient of the AHP criteria that has been tested valid, the modeling stage is continued into the *Simple Additive Weighting* (SAW) algorithm to evaluate the performance of each service area. The results of the process of normalization of the initial decision matrix and the integration of the multiplication of the weight of the criteria into the SAW preference matrix are presented in full in Table 8**.**

Table 8. Normalization result matrix (*R*) and final preponderance score (*Vi*)

Alternative Service Zones	*C1* (*Benefit)*	*C2* (*Benefit)*	*C3* (*Benefit)*	*C4* (*Benefit)*	Value of Preference (*Vi)*	Peringkat Priorities
Zone 1	1,000	0,782	0,940	0,952	0,946	First priority
Zone 2	0,944	0,825	1,000	1,000	0,941	Second priority
Zone 3	0,879	1,000	0,959	0,965	0,924	Third priority

Based on the final preference value (*Vi*), the decision support model consistently establishes a hierarchy of handling clean water allocation in a linear order, namely placing Zone 1 (upstream) in the first place with a score *of Vi* = 0.946, followed by Zone 2 (middle) with a *score of V2* = 0.941, and Zone 3 (downstream) in the lowest position with a *score of V3* = 0.924.

Sensitivity analysis on the normalization matrix reveals a unique phenomenon in which there is a contrast of the advantages of the criteria between regions. Zone 2 (middle) actually pocketed a perfect normalization value (1,000) on the average consumption criteria (*C3*) and the proportion of social customers/RT 2B (*C4*). However, the strength of the social dimension in Zone 2 was narrowly outperformed by Zone 1 (upstream) with a very tight preference score difference of 0.005. The dominant determining factor that launched Zone 1 to the first rank was absolute superiority on the criterion of water loss rate (*C1*) with a maximum normalization value of 1,000. Given that criterion *C1* holds the highest importance weight of 52.632% of the AHP analysis results, this maximum value contribution mathematically compensates for the lack of value of the Zone 1 piping physical criterion value on the connection density variable (*C2* = 0.782).

Results of Tiered Water Allocation Simulation

The evaluation of the level of reliability of the distribution system was carried out by testing the available clean water supply quota from the Global Effective Capacity of 73,020,000 m^3/year against the accumulated target load of demand public feasibility standards. The calculation results show that Zone 3 (downstream) bears the burden of domestic water needs, which is 62,853,000 m^3/year. This phenomenon is in line with and directly proportional to its demographic characteristics which accommodate the densest concentration of Home Connections (SR), which is 287 customers when compared to the other two service areas.

Furthermore, Zone 2 (Central) is in second place with a load of water needs of 36,135,000 m^3/year, while Zone 1 (Upstream) has the smallest domestic water demand record, which is 16,644,000 m^3/year. Thus, the accumulated total ideal water requirement for the overall documented housing system reaches 115,632,000 m^3/year. The effective capacity of the network (73,020,000 m^3/year) is much lower than the country's minimum feasibility target (115,632,000 m^3/year). The *cascading allocation pattern of controlled clean water supply by the* order of Simple Additive Weighting *(SAW) preference ratings* is presented in full in Table 9.

Table 9. Results of Simulation of Tiered Allocation to the PU Standard Target of 120 L/person/day

Sequence Priorities	Name Area	Requirements (m3/year)	Volume Available	Allocation	Remaining Volume (m3/year)	Status
1	Zone 1	16644	73020	16644	56376	Correspond to the Record
2	Zone 2	36135	56376	36135	20241	Correspond to the Record
3	Zone 3	62853	20241	62853	-42612	Inappropriate

Based on the allocation simulation in Table 6, the real supply quantity availability test relies on the movement of the effective capacity volume of the network. The total availability of ready-to-consume clean water quotas is locked at 73,020,000 m³/year, which is extracted from *the annual global System Input Volume* (SIV) value of 132,095,000 m³/year after being reduced by the global *non-revenue water* (NRW) load of 59,075,000 m³/year.

The distribution mechanism is controlled linearly following the priority chain of SAW ratings. Because the initial supply quota (73,020,000 m³/year) exceeds the burden of domestic needs of Zone 1 as the upstream priority (16,644,000 m³/year), the zone has been successfully fulfilled in full (100%) by leaving a residual flow quota of 56,376,000 m³/year. The remaining volume of pure clean water supply is then *cascaded* to bear the ideal target load of Zone 2 (Central) of 36,135,000 m³/year. The success of Zone 2 in absorbing the supply in full leaves the final system quota of 20,241,000 m³/year to be channeled to the lowest priority level, namely Zone 3.

Based on the results of the final volume balancing, a technical justification was obtained regarding the determination of the allocation feasibility status in each operational sub-area. Zone 1 (Upstream) and Zone 2 (Central) successfully obtained the status of "Record Compliant". This assessment was given because in terms of the quantity of their essential water quota was fulfilled 100% of the ideal load target of the Ministry of PUPR (2016). However, the critical note inherent in both zones is the magnitude of the internal leak resistance factor (Zone 1 is 48.690% and Zone 2 is 45.945%).

The opposite condition occurs in Zone 3 (Downstream) which is locked in the status of "Non-Conform". This discrepancy is triggered by the system's failure to deliver a decent volume of clean water to the end of the pipeline, where the remaining final capacity sliding downstream is only 20,241,000 m³/year of the total water requirement of 62,853,000 m³/year. As a result, the downstream service area has to bear the cumulative impact of the water loss of the upstream and middle systems, thus triggering a supply deficit of 42,612,000 m³/year.

Managerial Implications

These managerial implications are structured based on the value of source capacity, *Non-Revenue Water* (NRW), and customer priorities

1. Implications based on source capacity: PT Air Minum Giri Menang Perseroda needs to optimize the utilization of water source capacity that is still within safe limits based on *safe yield* and make effective capacity as the basis for water distribution planning so that the supply is in accordance with the system's capabilities.
2. Implications based on NRW: Given that Zone 1 has the highest NRW rates, NRW reduction programs need to be prioritized in the zone through physical loss control, leak monitoring, and improved network operation efficiency.
3. Implications based on customer priorities: Under conditions of limited effective capacity, water distribution should not be carried out evenly, but consider the results of the customer's priority ranking using the AHP-SAW hybrid model so that water is available and allocated to a higher priority level objectively and transparently.

CONCLUSION

Based on the results of the spatial multicriteria hybrid analysis, International Water Association (IWA) standard water balance audit, and cascading allocation simulation in the distribution network of the West Lombok Regional Government Housing Area, several conclusions can be drawn. The water source capacity (safe yield) indicated that the installed pumping capacity remained within safe limits relative to the potential aquifer recharge capacity. Actual production reached 132,095,000 m³/year, equivalent to 83.77% of the installed capacity, indicating that the pumping system operated close to its optimal capacity. Meanwhile, the Ecological Exploitation Index of 41.89% indicated that groundwater utilization remained within safe and sustainable limits.

The existing Non-Revenue Water (NRW) conditions showed variations in water loss levels among service zones. Zone 1 had the highest estimated NRW value of 48.690%, followed by Zone 2 and Zone 3. The NRW value represented the accumulation of Unbilled Authorized Consumption (UAC), apparent losses, and physical losses (real losses), with physical losses identified as the largest contributing component. The analysis results showed that the priority hierarchy for clean water allocation sequentially placed Zone 1 (upstream) as the first priority, Zone 2 (middle) as the second priority, and Zone 3 (downstream) as the lowest priority.

The tiered allocation simulation was conducted using the effective system capacity of 73,020 m³/year after considering the global NRW value of 44.722%. The simulation results indicated that the available effective capacity was insufficient to simultaneously fulfill the water demands of all zones. Zone 1 obtained the status of “Record Compliant” because its required volume of 16,644,000 m³/year was fully met, although the zone still experienced a high NRW level. Zone 2 obtained the status of “Accordance with the Record” because the remaining effective capacity of 56,376,000 m³/year was sufficient to meet its domestic water demand despite the influence of high NRW levels. Zone 3 was classified as “Not Suitable” because the remaining effective capacity of 20,241,000 m³/year could not fulfill the zone’s water demand, resulting in a supply deficit of 42,612,000 m³/year.

PT Air Minum Giri Menang Perseroda is recommended to conduct field validation of the priority ranking results obtained in this study to ensure that the model implementation is aligned with operational conditions and the dynamic characteristics of the clean water distribution network. The company is also advised to improve the recording system for water production, distribution, and losses at the service zone level to enable more accurate NRW evaluations. Future studies are recommended to incorporate distribution network pressure data and leakage survey results to provide a more accurate estimation of physical losses (real losses) and better represent actual network conditions. Further research may also develop the water allocation model by incorporating additional criteria, such as network reliability, service quality, pressure conditions, and economic factors, to produce more comprehensive priority rankings. In addition, future studies are recommended to integrate the AHP–SAW model with Geographic Information System (GIS) and EPANET software to enable allocation priority determination based on spatial characteristics and hydraulic conditions of the distribution network, including pressure, flow velocity, and energy loss.

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