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Evaluation and Ranking of Urban Drainage Systems Using SAW, TOPSIS, and VIKOR Methods: A Case Study in Bantul Regency

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ABSTRACT

Background: Urban flooding and waterlogging in Bantul Regency stem from inadequate drainage systems, exacerbated by rapid urbanization, land use changes, poor infrastructure planning, and intensified rainfall due to climate change. Therefore, an integrated risk management approach compassing both structural and non-structural solutions—is crucial for improving urban drainage resilience. Conversely, the comprehensive evaluation of drainage system performance continues to pose considerable challenges. Assessments that concentrate solely on hydraulic or technical parameters while neglecting environmental, social, and economic factors—often result in suboptimal or misdirected decisions. As such, adopting a more integrative approach through multi-criteria decision-making methods, such as Multi-Attribute Decision Making (MADM), emerges as a pertinent alternative.
Aims and Methods: The methods employed for MADM analysis in this study include the Simple Additive Weighting (SAW), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the Vlse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Each of these approaches is designed to accommodate different data characteristics, levels of analytical complexity required, degrees of uncertainty involved, computational load, and the decision maker's experience or expertise in applying the respective method.
Results: The analysis results indicate that, based on the SAW method, location A11 obtained the highest score (0.8637), signifying the poorest drainage system performance and thus requiring top-priority intervention, whereas location A77 achieved the lowest score (0.3132), indicating a well-functioning drainage condition. Using TOPSIS, location A9 ranked first with a preference value (Vi) of 0.7498, reflecting significant proximity to the ideal solution, while A6 recorded the lowest score (0.2152). Meanwhile, the VIKOR method identified location A99 as the top-ranked alternative with a VIKOR index of 16.5321, while A1 emerged as the lowest-ranked alternative with a VIKOR index of 0.0188.

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1. Introduction

Urban flooding and waterlogging have become pressing concerns in many parts of Indonesia, including Bantul Regency. One of the key contributing factors is the inadequate performance of existing drainage systems, which fail to effectively manage water accumulation in several critical urban areas. The challenges are further intensified by rapid urban expansion, shifts in land use, and insufficient planning and maintenance of drainage infrastructure (Hamdany & Saputra, 2024). As a result, these systems are unable to cope with the growing volume of stormwater runoff. The combined effects of climate change and accelerating urbanization present significant obstacles to achieving sustainable urban planning and management (Rahma *et al.,* 2024).

In recent years, the occurrence of extreme rainfall events has significantly impacted numerous urban areas, leading to severe economic losses, injuries, and fatalities. To effectively mitigate the adverse effects of flooding in the context of urban drainage management, it is essential to adopt a comprehensive risk management approach. This approach should incorporate both structural and non-structural measures aimed at prevention, mitigation, preparedness, response, and recovery from flood events (Arya & Kumar, 2023).

Conversely, the comprehensive evaluation of drainage system performance continues to pose considerable challenges (Ahmad *et al.,* 2025). Assessments that concentrate solely on hydraulic or technical parameters while neglecting environmental, social, and economic factors—often result in suboptimal or misdirected decisions. As such, adopting a more integrative approach through multi-criteria decision-making methods, such as Multi-Attribute Decision Making (MADM), emerges as a pertinent alternative. This method facilitates the incorporation of diverse performance indicators, enabling more precise and evidence-based policy formulation in the management of urban drainage systems (Yang & Zhang, 2021).

This study is intended to conduct a comprehensive assessment of the urban drainage system performance in Bantul Regency by employing the Multi-Attribute Decision Making (MADM) method. This approach facilitates the identification of the current condition of the drainage infrastructure, enabling an objective evaluation of its performance and the determination of priority levels based on data-driven analysis. The findings of this evaluation are expected to serve as a strategic basis for more effective decision-making in the planning and management of urban drainage infrastructure.

Several studies on drainage systems have primarily focused on technical aspects. Although some research has addressed both technical and non-technical factors, it is generally limited to resilience in the context of disaster mitigation. This study aims to evaluate and rank drainage infrastructure based on various factors related to condition and function, in order to identify poorly performing systems that require immediate intervention.

2. Methods

2.1 Research Location

This research was conducted within the urban area of Bantul Regency, which includes the districts of Bantul, Banguntapan, Sewon, and Kasihan. To support a comprehensive analysis, 100 drainage channel locations distributed across these four districts were purposively selected as representative sampling points. The availability of sufficient sample data, along with accurate and well-distributed data across all locations, will enhance the accuracy and reliability of this research (Min & Tashiro, 2024).

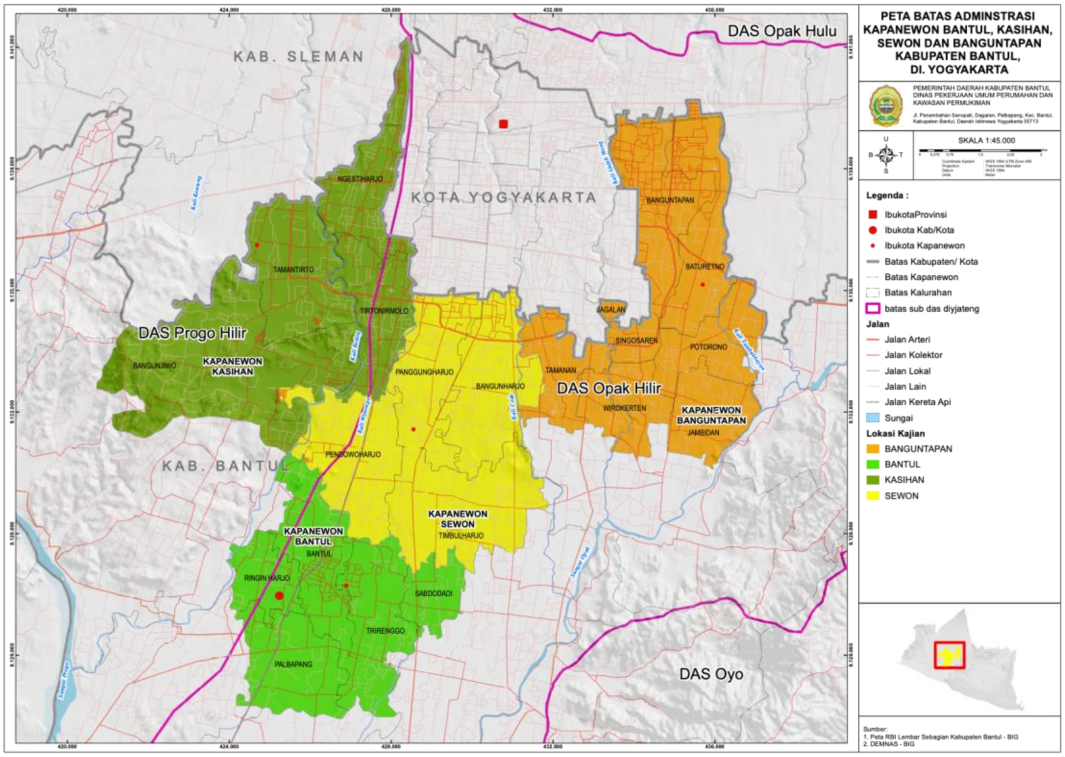

Figure 1. Research Location

2.2 Material and Tools

The materials and tools used in this study included digital survey forms, measuring tapes, GPS devices, smartphones, and digital cameras. Data processing was carried out using data processing software such as Microsoft Excel, while modeling was conducted using SWMM (Storm Water Management Models) software.

2.3 Research Method

The research employs a quantitative descriptive evaluative approach using the Multi-Attribute Decision Making (MADM) method to assess the performance of urban drainage systems in Bantul Regency. This approach enables a comprehensive analysis of various technical and non-technical criteria within the drainage system. Multi-Attribute Decision Making (MADM) plays a crucial role in supporting complex decision-making processes, particularly for policymakers. This method enables them to systematically visualize various influencing factors, conduct objective measurements of each relevant criterion, and enhance accountability and transparency throughout every stage of the decision-making process. Furthermore, MADM assists in identifying and comparing multiple available decision alternatives, resulting in more targeted, data-driven policies that comprehensively consider multiple aspects (Axelsson *et al.,* 2021).

2.3.1 Data Collection Technique

The data collection technique in this study was conducted systematically through two main sources of data: primary and secondary data, in order to obtain comprehensive and in-depth information regarding the performance of urban drainage systems within the study area. Primary data were collected directly in the field using survey forms by observing the physical conditions of the drainage channels, such as the shape and dimensions of the channels, the presence of sediment or blockages, the extent of infrastructure damage, and the connectivity of the drainage network. In addition, primary data were also obtained through interviews with relevant authorities, such as the Department of Public

Works, Spatial Planning, Housing, and Settlement Areas (PUPKP) Bantul Regency, the Regional Disaster Management Agency (BPBD) Bantul Regency, and local community leaders, in order to gather information regarding policies on drainage system management and maintenance. Furthermore, questionnaires were distributed to residents living in flood-prone areas to understand their perceptions, experiences, and levels of participation concerning the existing drainage system.

Secondary data were obtained from various official documents and written sources, including existing drainage network maps, historical rainfall data from the Regional Public Works, Housing and Energy and Mineral Resources Office (PUPESDM) of the Special Region of Yogyakarta Province, flood and inundation incident records from the Regional Disaster Management Agency (BPBD), as well as technical planning documents such as the Master Plan for the Drainage System and the Regional Spatial Planning (RTRW) documents. The collection of both primary and secondary data serves as a critical foundation for the analysis process using the Multi-Attribute Decision Making (MADM) method, as it enables more accurate weighting and assessment of each factor influencing the performance of the urban drainage system.

2.3.2 Data Analysis Technique

The methods employed for MADM (Multi-Attribute Decision Making) analysis in this study include the Simple Additive Weighting (SAW), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the Vlse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Each of these approaches is designed to accommodate different data characteristics, levels of analytical complexity required, degrees of uncertainty involved, computational load, and the decision maker's experience or expertise in applying the respective method (Axelsson *et al.,* 2021).

The Simple Additive Weighting (SAW) method is employed due to its simplicity in calculating aggregate scores across multiple criteria. This method facilitates policymakers in understanding and interpreting the performance evaluation results of the drainage system. SAW is particularly effective in situations where the criteria have clearly defined weights and do not conflict with one another (Chen, 2021). In the Simple Additive Weighting (SAW) method, the decision-making process involves summing the values of each alternative after they have been normalized and multiplied by the respective weights of each criterion. The general formula to calculate the final score (preference score) using the SAW method is as follows:

$$V_i = \sum_{j=1}^{n} w_j \, . \, r_{ij}$$

With V_i is total score or final value of alternative i, W_j is the weight of criterion j, r_{ij} is the normalized value of alternative i with respect to criterion j, and n is the total number of criteria.

Considering that each criterion can be classified as either a benefit (where higher values are more desirable) or a cost (where lower values are more desirable), a normalization process must be conducted beforehand. This ensures that all criterion values are converted to a uniform scale and can be compared fairly. The normalization formulas for both benefit and cost criteria are as follows.

Normalization formula for benefit criteria:

$$r_{ij} = \frac{X_{ij}}{Max_{(Xj)}}$$

Normalization formula for cost criteria:

$$r_{ij} = \frac{\min(X_j)}{X_{ij}}$$

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method is employed in this study as a multi-criteria decision-making approach to evaluate and rank the performance of drainage channels. This method was selected due to its intuitive logic, clarity of interpretation, and high computational efficiency (Bakhshipour *et al.,* 2021). The calculation in the TOPSIS method requires the performance value of each alternative A_i for each criterion C_j to be normalized first, using the following formula.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

In the implementation of the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, the determination of the positive ideal solution (A^+) and the negative ideal solution (A^-) is based on the normalized weighted rating values (denoted as y_{ij}). These values result from the normalization and weighting processes applied to the initial decision matrix, ensuring a fair comparison among alternatives across all criteria. The positive ideal solution (A^+) represents the most optimal condition, which corresponds to the maximum value for benefit-type criteria and the minimum value for cost-type criteria. In contrast, the negative ideal solution (A^-) reflects the least desirable condition-defined by the minimum value for benefit-type criteria and the maximum value for cost-type criteria. The formulas used to determine A^+ and A^- are as follows.

$$y_{ij} = w_j r_{ij}$$

$$A^+ = (y_1^+, y_2^+, \cdots, y_m^+);$$

$$A^- = (y_1^-, y_2^-, \cdots, y_m^-);$$

Where :

$$y_j^+ = \begin{cases} \max\limits_i y_{ij}; & if\ j\ is\ a\ benefit\ attribute \\ \min\limits_i y_{ij}; & \text{if j is a cost attribute} \end{cases}$$

$$y_j^- = \begin{cases} \min\limits_i y_{ij}; & \text{if j is a benefit attributet} \\ \max\limits_i y_{ij}; & \text{if j is a cost attribute} \end{cases}$$

The distance between alternative A_i and the positive ideal solution is formulated as follows:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(y_j^+ - y_{ij}\right)^2};$$

The distance between alternative A_i and the negative ideal solution is formulated as follows:

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(y_{ij} - y_j^-\right)^2};$$

The preference value for each alternative (V_i) is determined as follows:

$$V_i = \frac{D_i^-}{D_i^- + D_i^+};$$

The final result of this method indicates that a higher V_i value reflects a more preferred alternative A_i.

The Vlse Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method is employed to identify the optimal alternative by emphasizing a compromise solution that is closest to the ideal solution. This method is particularly useful when no single alternative excels across all criteria simultaneously. VIKOR focuses on balancing group utility and individual regret, thereby facilitating the selection of the most suitable option in situations involving trade-offs among criteria. This approach is highly relevant for decision-makers who must consider such trade-offs when formulating optimal urban drainage policies (Zhu *et al.,* 2023). The first step in implementing the VIKOR method is to construct a decision matrix that represents the relationship between the selected alternatives and criteria. In this matrix, the element X_{ij} denotes the performance rating of alternative A_i with respect to criterion C_j, derived from field measurements or expert assessments.

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix}$$

The normalization process is carried out by applying the following equation.

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} \left(x_{ij}\right)^2}}$$

Identify the positive ideal point (fj*) and the negative ideal point (fj−) for each criterion using the following calculation:

$$\text{For benefit criteria:} \begin{cases} f_j^* = max\left(f_{ij}\right) \\ f_j^- = min\left(f_{ij}\right) \end{cases}$$

$$\text{For cost criteria:} \begin{cases} f_j^* = min(f_{ij}) \\ f_j^- = max(f_{ij}) \end{cases}$$

The next step is to calculate the values of profitability (S) and regret (R). The value of S reflects the cumulative relative distance of alternative A_i from the positive ideal point, while the value of R represents the maximum individual regret of alternative A_i in relation to the positive ideal point.

$$S_i = \sum_{j=1}^{m} w_j \left(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right)$$

$$R_i = max \left(w_j \left(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right) \right)$$

Calculate the VIKOR index (Q) for each alternative based on the predetermined formula as follows.

$$Q_i = v \left[\frac{S_i - S^*}{S^- - S^*} \right] + (1 - v) \left[\frac{R_i - R^*}{R^- - R^*} \right]$$

To determine the criteria that influence the performance of the urban drainage system, an analysis was conducted using the Consensus Method by involving respondents from various groups, including policymakers, water resources experts, and academics. The Consensus Method is highly suitable for this study because the respondents represent a diverse and hierarchical group of decision-makers (multi-stakeholders). There are ten criteria identified as influential to the performance of drainage channels, namely: (1) channel capacity, (2) type of drainage channel, (3) channel material, (4) catchment area size, (5) topographical conditions, (6) climate change, (7) regulations and planning, (8) cost, (9) rainfall intensity, and (10) channel condition (Arifin *et al.,* 2025).

3. Results and Discussions

3.1 Determination of Weight Values Using the Consensus Method

This study utilizes three Multi-Attribute Decision-Making (MADM) methods—Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)—to evaluate the performance of the urban drainage system in Bantul Regency. The analysis is conducted based on ten key criteria derived from a weighting process using the Consensus Method, which incorporates responses collected from stakeholders, including policymakers, technical experts, and academic professionals (Axelsson *et al.,* 2021).

Through the distribution of questionnaires to respondents, weights were obtained that reflect the relative importance of each criterion in evaluating the performance of the urban drainage system. The final results of this process indicate that the criterion “channel capacity” received the highest weight, followed by “type of channel” and “channel material,” highlighting the technical urgency in assessing the system’s effectiveness and efficiency. This approach not only enhances the validity of the analytical outcomes but also ensures that the decisions made are grounded in both scientific and practical consensus. The results of the normalized weight analysis using the Consensus Method are presented in the following table.

Table.1 Results of ranking and weighting of criteria using the Consensus Method

No.	Attribute	Criteria Name	Normalized Weight (w)	Category
1	C1	Channel Capacity (Dimension)	0.341	Cost
2	C2	Type of Channel	0.171	Benefit
3	C3	Channel Material	0.114	Benefit
4	C4	Catchment Area	0.085	Benefit
5	C5	Topographical Condition Factor	0.068	Cost
6	C6	Climate Change	0.057	Benefit
7	C7	Planning and Regulation	0.049	Benefit
8	C8	Required Cost	0.043	Cost
9	C9	Rainfall	0.038	Benefit
10	C10	Channel Quality/Condition	0.034	Benefit

3.2 Simple Additive Weighting (SAW) Method

The Simple Additive Weighting (SAW) method is employed to assign an aggregate score to each alternative by summing the normalized and weighted values of all criteria. Each drainage location alternative is evaluated based on its performance across ten criteria. The results of the SAW method applied to 100 sample locations indicate that location A11 obtained the highest score of 0.864, signifying that this site has the poorest drainage system performance and thus requires the most immediate intervention based on all criteria. Conversely, location A77 recorded the lowest score of 0.313, suggesting that no improvements are necessary due to its satisfactory condition and performance. The top 10 priority rankings based on the SAW method are presented in the following table.

Table 2. Results of priority analysis using the SAW method

Rank	Alternative	Location	Preference Score
1	A11	Drainage Dsn. Gatak, Rt.03 (Jln. Rukeman), Tamantirto, Kasihan, Bantul	0.8637
2	A9	Drainage Dsn. Sonosewu, Rt.03, Ngestiharjo, Kasihan, Bantul	0.8584
3	A79	Drainage Dsn. Karasan RT.05 - 06	0.7570

4	A68	Drainage Dsn. Wiyoro (Jl. Ngipik) dari arah Barat	0.7232
5	A85	Drainage Dsn. Priyan	0.6734
6	A12	Drainage Dsn. Jadan, Rt.02, Tamantirto, Kasihan	0.6396
7	A22	Drainage Jl. Sonopakis, Sonopakis Lor, Ngestiharjo, Kasihan	0.6360
8	A55	Drainage Dsn. Kragilan	0.6182
9	A27	Drainage Dsn. Wojo, Rt.04 (Utara Pengadilan Tinggi Samping Ringroad Selatan)	0.6157
10	A32	Drainage Dsn. Ngireng-ngireng, Rt.07 (Jln. Sewon Indah)	0.6089

3.3 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is utilized to assess the relative closeness of each alternative to the ideal positive solution while simultaneously distancing from the ideal negative solution. The TOPSIS analysis results indicate that alternative A9 ranks first with a preference value (Vi) of 0.75, reflecting a significant proximity to the ideal solution. Meanwhile, location A6 recorded the minimum score of 0.215. The top 10 priority rankings based on the TOPSIS method are presented in the following table.

Table 3. Results of priority analysis using the TOPSIS method

Rank	**Alternative**	**Location**	**Preference Score**
1	A9	Sistem drainase Dsn. Sonosewu, Rt.03, Ngestiharjo, Kasihan, Bantul	0.7498
2	A12	Sistem drainase Dsn. Jadan, Rt.02, Tamantirto, Kasihan	0.7327
3	A13	Sistem drainase Dsn. Sengotan, Rt.09 (jln. Ring Road Selatan), Tirtonirmolo, Kasihan	0.7167
4	A11	Sistem drainase Dsn. Gatak, Rt.03 (Jln. Rukeman), Tamantirto, Kasihan, Bantul	0.7059
5	A4	Sistem drainase Dongkelan Kauman (Jln prapanca), Tirtonirmolo, Kasihan, Bantul	0.7012
6	A3	Sistem drainase Ngebel, Jl. Puntadewa, Tamantirto, Kasihan, Bantul	0.7007
7	A40	Sistem Drainase Jl. Yudhistira	0.6861
8	A27	Sistem Drainase Dsn. Wojo, Rt.04 (Utara Pengadilan Tinggi Samping Ringroad Selatan)	0.6851

9	A22	Sistem drainase Jl. Sonopakis, Sonopakis Lor, Ngestiharjo, Kasihan	0.6739
10	A21	Sistem drainase Jl. Soragan (Rel kereta), Ngestiharjo, Kasihan	0.6623

3.4 VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

The VIKOR method is applied to evaluate alternatives using a compromise-based approach. The aggregate utility value, maximum regret, and compromise index are calculated based on the positive and negative ideal values for each criterion. With v = 0.5 as the compromise weighting factor, the analysis results indicate that location A100 represents the best condition with a Q value of 0.0188, whereas A12 obtained the highest Q value of 16.53, indicating the poorest performance. The top 10 priority rankings based on the VIKOR method are presented in the following table.

Table 4. Results of priority analysis using the VIKOR method

Rank	Alternative	Location	VIKOR Index
1	A99	Sistem Drainase Dsn. Klodran	16.5321
2	A98	Sistem Drainase Dsn. Melikan Kidul	12.8502
3	A100	Sistem Drainase Dsn. Keyongan	12.7021
4	A96	Sistem Drainase Dsn. Mandingan	12.5084
5	A97	Sistem Drainase Dsn. Gandekan	10.4037
6	A78	Sistem Drainase Dsn. Babadan (Jl. Pemuda)	9.3242
7	A35	Sistem Drainase Dsn. Glugo (Jl. Ring Road Selatan/ sebelah Utara Ringroad)	8.8761
8	A89	Sistem Drainase Dsn. Code	8.2445
9	A95	Sistem Drainase Dsn. Mandingan	8.1037
10	A91	Sistem Drainase Dsn. Bogoran	7.9641

The analysis results using the three methods indicate that the SAW and TOPSIS methods exhibit similar trends, whereas the VIKOR method produces significantly different outcomes. This discrepancy arises from VIKOR's approach, which incorporates the concept of compromise and the imbalance among criteria, rather than relying solely on the aggregate scores or average distances. A comparison of the results from the three methods is presented in Figure 2.

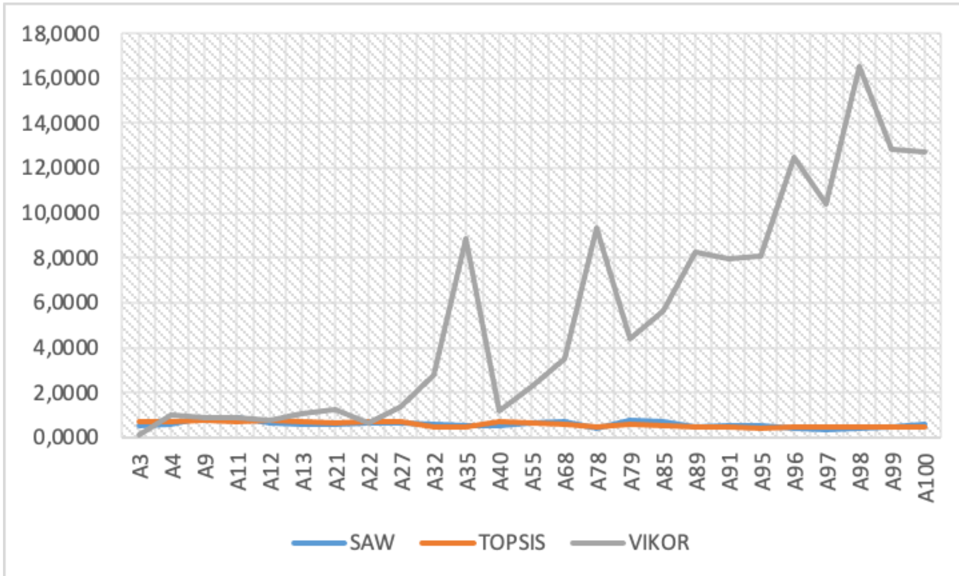

Figure 2. Comparison of Analysis Results Using the SAW, VIKOR, and TOPSIS Methods

4. Conclusions

This study reveals that the application of SAW, TOPSIS, and VIKOR methods yielded varying results in prioritizing urban drainage system improvements. Based on the SAW method, location A11 obtained the highest score (0.864), signifying the poorest drainage system performance and thus requiring top-priority intervention, whereas location A77 achieved the lowest score (0.313), indicating a well-functioning drainage condition. Using TOPSIS, location A9 ranked first with a preference value (Vi) of 0.75, reflecting significant proximity to the ideal solution, while A6 recorded the lowest score (0.215). Meanwhile, the VIKOR method identified location A99 as the top-ranked alternative with a VIKOR index of 16.532, while A1 emerged as the lowest-ranked alternative with a VIKOR index of 0.019. The SAW method identified A11, A9, and A79 as the most critical locations, whereas the TOPSIS method highlighted A9, A12, and A13. In contrast, the VIKOR method produced significantly different priorities, namely A99, A98, and A100. While SAW and TOPSIS showed relatively similar preference rankings, VIKOR demonstrated a distinct deviation. These discrepancies suggest the need for further investigation by disaggregating each criterion into more detailed sub-criteria to enhance the objectivity and robustness of the decision-making outcomes.

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6. Authors Note

The author declares that there are no conflicts of interest related to the publication of this article. Furthermore, the author affirms that the manuscript is an original work, has not been published elsewhere, and is free from any form of plagiarism.

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