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## **Hierarchical SAW with AHP-Derived Weights for Mustahik Prioritization: Benchmarking and Validation in Zakat Institutions**

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### **Abstract**

Manual mustahik (zakat beneficiary) selection in Indonesian Zakat Collection Units (UPZ) is prone to transcription errors, recency bias, and poor scalability — undermining the equitability and auditability required under BAZNAS institutional standards. This study proposes a web-based Decision Support System (DSS) integrating a hierarchical Simple Additive Weighting (SAW) model with Analytic Hierarchy Process (AHP)-derived criterion weights. A five-criterion, eleven-sub-criterion model was developed from BAZNAS assessment standards and validated by three domain experts, yielding a Consistency Ratio of  $CR = 0.033$  ( $< 0.10$ ). SAW rankings were benchmarked against TOPSIS and VIKOR using Spearman's  $\rho$  and Kendall's  $\tau$  on a 15-candidate dataset, indicating strong preliminary agreement (SAW-TOPSIS:  $\rho = 0.943$ ; SAW-VIKOR:  $\rho = 0.886$ ), pending larger-dataset replication. Sensitivity analysis confirmed top-3 ranking stability under all  $\pm 10\%$  and most  $\pm 20\%$  weight perturbations. Performance benchmarking demonstrated linear scalability with sub-100 ms computation at  $N \leq 1,000$  candidates. Black Box testing across 63 scenarios achieved a 100% pass rate. The system was implemented using the Laravel MVC framework with a role-based three-tier approval workflow (Surveyor  $\rightarrow$  Admin  $\rightarrow$  UPZ Head). Primary limitations include a small expert sample ( $n = 3$ ), a limited validation dataset ( $N = 15$ ), and the absence of formal User Acceptance Testing, which constitutes the primary direction for future research.

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## **1. Introduction**

Zakat, the third pillar of Islam, serves as a formal redistribution mechanism intended to reduce economic inequality and improve social welfare by allocating wealth from eligible contributors (muzakki) to qualified beneficiaries (mustahik). In Indonesia, zakat management is coordinated through the National Zakat Collection Body (Badan Amil Zakat Nasional—BAZNAS) and its affiliated Zakat Collection Units (Unit Pengumpul Zakat—UPZ), which are responsible for identifying, evaluating, and prioritizing eligible beneficiaries based on established institutional criteria [1], [2]. As zakat distribution programs continue to expand, ensuring that

assistance reaches the most deserving recipients in a transparent, objective, and accountable manner has become an increasingly important challenge.

One example of this challenge is observed at UPZ Bakti Bersama, a BAZNAS-affiliated zakat institution operating under Hasnur Group in South Kalimantan. The institution manages a substantial number of beneficiary applications during annual zakat distribution cycles, particularly during Ramadan periods when the volume of applicants increases significantly. The existing beneficiary selection process relies heavily on manual assessment and spreadsheet-based record management, requiring evaluators to examine multiple socioeconomic indicators such as family income, household expenditures, housing conditions, asset ownership, and family dependency levels. Field observations conducted during January–February 2025 revealed that manual assessment procedures require considerable processing time and may introduce inconsistencies arising from transcription errors, subjective judgment, evaluator fatigue, and difficulties in maintaining auditability across large candidate pools [3], [4].

Decision Support Systems (DSS) provide a practical solution to these challenges by integrating computational models with organizational decision-making processes. Through DSS implementation, candidate information can be systematically processed using Multi-Criteria Decision Making (MCDM) approaches to produce objective, transparent, and reproducible ranking outcomes [5], [6]. Recent studies have demonstrated the increasing adoption of MCDM techniques in decision-support environments because they enable the simultaneous evaluation of multiple criteria while reducing subjectivity in complex decision-making scenarios [7]–[8]. Furthermore, contemporary MCDM research emphasizes the importance of methodological validation, ranking consistency assessment, robustness analysis, and comparative benchmarking to enhance decision reliability and transparency [9]–[8].

Within the domain of beneficiary selection, numerous studies have applied MCDM techniques to support social assistance and zakat allocation. Alfarizi et al. applied the Composite Performance Index (CPI) method for determining zakat recipients at BAZNAS Bengkulu and demonstrated the usefulness of structured multi-criteria evaluation in beneficiary prioritization [3]. Kurniawan et al. proposed a Multi-Attribute Utility Theory (MAUT)-based model for mustahik selection, highlighting the importance of objective assessment mechanisms in zakat distribution [10]. Similarly, Lestari et al. implemented the Simple Additive Weighting (SAW) method in a zakat assistance system developed for BAZNAS Bontang and reported improved transparency in beneficiary determination [4]. Beyond the zakat domain, SAW has also been successfully applied in scholarship selection [11], social assistance allocation [5], and government welfare programs [6], demonstrating its effectiveness as a practical and computationally efficient ranking technique.

Despite these developments, several limitations remain evident in the existing literature. First, most zakat-related DSS studies employ flat criterion structures that do not adequately represent the hierarchical nature of institutional beneficiary assessment standards [4]. Second, existing systems primarily focus on generating ranking outputs without integrating decision results into organizational approval workflows and governance mechanisms required by zakat institutions [12]–[13]. Third, criterion weights are frequently assigned using simplified or researcher-defined approaches, which may reduce institutional legitimacy and consistency in decision-making processes. The Analytic Hierarchy Process (AHP) has been widely recognized as an effective method for deriving structured and consistent criterion weights through pairwise comparisons and consistency verification [14], [15]. However, its integration with zakat-specific DSS remains relatively limited.

A further limitation concerns methodological validation. Previous studies generally evaluate the effectiveness of a single MCDM technique without investigating whether ranking outcomes remain stable when compared with alternative approaches. Recent reviews and bibliometric studies have emphasized the importance of comparative evaluation among MCDM methods, particularly for decision-support applications where transparency and accountability are essential [7]–[8]. Techniques such as TOPSIS and VIKOR have been extensively studied and applied across various domains because they provide alternative ranking philosophies that can be used to assess ranking consistency and decision robustness [16], [17], [18]. Nevertheless, comparative validation involving SAW, TOPSIS, and VIKOR remains largely unexplored within the context of zakat beneficiary prioritization.

Based on this literature analysis, four research gaps can be identified. Gap 1 concerns the absence of hierarchical criterion architectures in existing zakat DSS implementations despite the multidimensional nature

of beneficiary assessment. Gap 2 relates to the limited integration of DSS outputs into institutional governance and approval workflows. Gap 3 concerns the reliance on simplified weighting approaches rather than empirically derived stakeholder-based weighting mechanisms. Gap 4 concerns the lack of cross-method validation using alternative MCDM techniques and statistical rank-agreement measures. Addressing these gaps is essential to improve the reliability, transparency, and institutional applicability of zakat beneficiary selection systems.

To address these limitations, this study proposes a web-based Decision Support System for mustahik prioritization at UPZ Bakti Bersama that integrates a hierarchical SAW model with stakeholder-derived AHP weighting, institutional governance workflows, sensitivity analysis, and cross-method benchmarking using TOPSIS and VIKOR. Unlike previous studies that primarily focus on algorithm implementation, the proposed framework combines hierarchical decision modeling, institutional weight elicitation, robustness testing, comparative ranking validation, and operational workflow integration within a single system. This approach aligns with recent recommendations emphasizing methodological validation, ranking consistency evaluation, and decision transparency in MCDM-based decision-support research [7]–[8].

The study is guided by three research questions: (RQ1) Does the proposed hierarchical criterion structure provide sufficient discrimination capability for institutional mustahik prioritization? (RQ2) To what extent do SAW rankings agree with TOPSIS and VIKOR rankings when evaluated on the same beneficiary dataset using Spearman's rho and Kendall's tau correlation measures? and (RQ3) Does the proposed system demonstrate sufficient computational performance and functional correctness for operational deployment within UPZ Bakti Bersama? The primary contributions of this study are: (1) the development of a hierarchical five-criterion and eleven-sub-criterion assessment model with stakeholder-derived AHP weights; (2) comparative benchmarking of SAW, TOPSIS, and VIKOR using rank correlation analysis; (3) sensitivity analysis under multiple weight perturbation scenarios; (4) computational performance evaluation across varying candidate volumes; and (5) the implementation of a role-based institutional approval workflow supporting transparent and accountable zakat distribution decisions.

## 2. Research Method

This study employs a convergent mixed-methods research design integrating qualitative institutional data collection with quantitative computational modelling and multi-dimensional system validation. The research is structured around four sequential phases: (1) institutional requirements elicitation and hierarchical criterion design; (2) empirical AHP weight derivation through structured expert pairwise comparison; (3) system development following the Waterfall Software Development Life Cycle (SDLC) methodology; and (4) multi-dimensional validation encompassing SAW–TOPSIS–VIKOR benchmarking, sensitivity analysis, computational performance assessment, and Black Box functional testing. Table 1 summarizes the complete research design, mapping each research question to its corresponding dataset, method, and validation instrument.

*Table 1. Research Design Summary*

| Component                    | Description                                                   | Dataset / Sample                        | Method                                                | Addresses    |
|------------------------------|---------------------------------------------------------------|-----------------------------------------|-------------------------------------------------------|--------------|
| Criterion weight elicitation | Structured AHP pairwise comparison with institutional experts | n = 3 domain experts, UPZ Bakti Bersama | AHP geometric mean aggregation; CR < 0.10             | Gap 1, Gap 3 |
| SAW computation              | Hierarchical multi-criteria ranking of mustahik candidates    | N = 15 empirical candidates             | SAW normalization + preference scoring                | RQ1          |
| Multi-method benchmarking    | Rank agreement between SAW, TOPSIS, VIKOR                     | N = 15 (identical dataset)              | Spearman $\rho$ , Kendall $\tau$                      | RQ2, Gap 4   |
| Sensitivity analysis         | Ranking stability under criterion weight perturbation         | N = 15; 20 perturbation scenarios       | $\pm 10\%$ , $\pm 20\%$ weight shift; Spearman $\rho$ | RQ2          |
| Performance benchmarking     | Computational scalability assessment                          | N = 15, 500, 1,000, 10,000 (simulated)  | Linear regression; $R^2$ analysis                     | RQ3          |

| Component             | Description                                 | Dataset / Sample  | Method                             | Addresses |
|-----------------------|---------------------------------------------|-------------------|------------------------------------|-----------|
| Functional validation | Black Box testing across all system modules | 63 test scenarios | Pass/fail per IEEE 829             | RQ3       |
| System development    | Web-based DSS design and implementation     | N/A               | Waterfall SDLC; Laravel MVC; MySQL | Gap 2     |

### 2.1 Simple Additive Weighting (SAW)

Simple Additive Weighting (SAW) is one of the most widely used Multi-Criteria Decision Making (MCDM) methods due to its conceptual simplicity, computational efficiency, and ease of implementation [19], [9]. The method aggregates normalized criterion scores through a weighted summation process to produce a composite preference value for each alternative [11], [5], [6]. Compared with distance-based approaches such as TOPSIS and compromise-ranking methods such as VIKOR, SAW offers a highly transparent evaluation mechanism because the contribution of each criterion to the final preference score can be directly traced and interpreted by decision makers [16], [17]. This characteristic is particularly important in zakat beneficiary selection, where accountability, transparency, and auditability are essential institutional requirements. Furthermore, SAW requires relatively low computational complexity, making it suitable for operational deployment in organizations that process large numbers of beneficiary applications while maintaining understandable decision logic [19], [9].

For a decision matrix  $X$  of dimension  $m \times n$ , where  $m$  denotes the number of candidate alternatives (mustahik) and  $n$  denotes the number of sub-criteria, let  $x_{ij}$  denote the raw performance value of alternative  $i$  on sub-criterion  $j$ ,  $r_{ij}$  the normalized value, and  $w_j$  the AHP-derived weight of sub-criterion  $j$  ( $\sum w_j = 1$ ). Normalization accounts for the directional nature of each sub-criterion, as expressed in Equations (1)–(3):

$$\text{For benefit criteria (higher is better): } r_{ij} = \frac{x_{ij}}{\max(x_{ij})} \quad (1)$$

$$\text{For cost criteria (lower is better): } r_{ij} = \frac{\min(x_{ij})}{x_{ij}} \quad (2)$$

$$\text{Final preference score: } V_i = \sum (w_j \times r_{ij}) \quad (3)$$

In this study, the standard SAW formulation is extended into a two-tier hierarchical structure in which each of the five main criteria,  $C_k$  ( $k = 1, \dots, 5$ ), is decomposed into one or more sub-criteria,  $C_j$  ( $j = 1, \dots, 11$ ). Main-criterion weights ( $W_k$ ) are derived using the Analytic Hierarchy Process (AHP) through stakeholder pairwise comparisons. To preserve consistency with the institutional assessment framework adopted by UPZ Bakti Bersama, sub-criteria within each main criterion are assigned proportional local weights ( $w_{j|k}$ ), resulting in final global weights computed as:  $w_j = W_k \times w_{j|k}$ . Where  $w_{j|k}$  denotes the normalized local weight of sub-criterion  $j$  within criterion  $k$ , and  $\sum w_j = 1$  across all eleven sub-criteria.

The use of AHP-derived weights is consistent with prior studies that combine hierarchical weighting structures with MCDM ranking methods to improve decision consistency and criterion prioritization [20], [17].

The hierarchical weighting structure enables the evaluation process to capture both the relative importance of major assessment dimensions and the contribution of individual sub-criteria while maintaining the computational simplicity and transparency of the SAW method. Computational performance under increasing candidate volumes is empirically evaluated in Section 3.4.

### 2.2 Benchmarking Methods: TOPSIS and VIKOR

To evaluate the consistency and robustness of SAW rankings against widely adopted MCDM alternatives, the present study benchmarks SAW outputs against TOPSIS and VIKOR. TOPSIS and VIKOR were selected because they represent two of the most extensively studied and frequently applied MCDM approaches for comparative decision analysis [16], [17], [18]. All three methods were applied to the identical 15-candidate normalized

decision matrix using the same criterion weights, ensuring strict comparability of ranking outcomes. Table 2 presents a structured methodological comparison across five dimensions relevant to institutional zakat beneficiary prioritization.

*Table 2. Comparative Analysis: SAW vs. TOPSIS vs. VIKOR for Institutional Mustahik Prioritization*

| Dimension                    | SAW                              | TOPSIS                         | VIKOR                              |
|------------------------------|----------------------------------|--------------------------------|------------------------------------|
| <b>Complexity</b>            | $O(m \times n)$ — linear         | $O(m \times n)$ + dist. matrix | $O(m \times n)$ + sorted utility   |
| <b>Interpretability</b>      | High — score decomposes directly | Moderate — CC abstract         | Low — utility/regret trade-off     |
| <b>Audit transparency</b>    | Full line-by-line                | Partial — ideal vectors opaque | Partial — compromise metric        |
| <b>Hierarchical support</b>  | Direct weight multiplication     | Extra aggregation step needed  | Complex normalization required     |
| <b>Compensatory behavior</b> | Full compensation                | Full compensation              | Partial — regret minimization      |
| <b>Verdict</b>               | PREFERRED for audit context      | Alternative for validation     | Alternative — different philosophy |

TOPSIS ranks alternatives by measuring their geometric proximity to a Positive Ideal Solution (PIS) and distance from a Negative Ideal Solution (NIS) [21], [16]. For normalized values  $r_{ij}$  and criterion weights  $w_j$ , the weighted normalized matrix is computed as  $v_{ij} = w_j \times r_{ij}$ . The closeness coefficient is then calculated as:  $CC_i = S_i^- / (S_i^+ + S_i^-)$ , where  $S_i^+$  and  $S_i^-$  denote the Euclidean distances from the positive and negative ideal solutions, respectively. In contrast, VIKOR generates a compromise ranking by simultaneously considering group utility and individual regret measures relative to an ideal solution [17]. The VIKOR index is calculated as:  $Q_i = v \cdot (S_i - S^*) / (S^- - S^*) + (1-v) \cdot (R_i - R^*) / (R^- - R^*)$ , where  $v = 0.5$  represents a balanced preference between collective utility and individual regret minimization [17]. From an operational perspective, SAW offers a comparatively simple and transparent ranking mechanism because final preference scores are obtained through direct weighted aggregation of normalized criterion values [19], [9]. This characteristic facilitates result interpretation and enables decision makers to trace the contribution of individual criteria to the final ranking more easily than methods based on ideal-distance or compromise-solution calculations [16], [17]. Such transparency is particularly relevant in zakat beneficiary selection, where accountability and decision traceability constitute important institutional requirements.

## 2.3 Data Collection, Expert Elicitation, and AHP Weight Derivation

### 2.3.1 Primary Data Collection

Primary institutional data were collected through a two-phase sequential protocol conducted at UPZ Bakti Bersama (January–February 2025). Phase 1 comprised semi-structured interviews with three key informants representing all operational levels of the institutional decision hierarchy, designed to map the existing mustahik assessment workflow, identify institutional data availability constraints, and validate the applicability of BAZNAS's standardized assessment instrument to the UPZ Bakti Bersama operational context. Phase 2 comprised a structured AHP pairwise comparison exercise conducted individually with each informant, yielding three independent pairwise comparison matrices subsequently aggregated using the geometric mean method, which is commonly employed in group AHP decision-making to synthesize expert judgments while preserving reciprocal consistency [14], [15]. Table 3 presents the informant profile.

*Table 3. Interview Respondent Profile — UPZ Bakti Bersama*

| No | Position / Role            | Institution                     | Experience | Role in Research                                      |
|----|----------------------------|---------------------------------|------------|-------------------------------------------------------|
| 1  | UPZ Head (Ketua Harian)    | UPZ Bakti Bersama, Hasnur Group | 7 years    | Criterion validation; weight final approval           |
| 2  | Administrative Coordinator | UPZ Bakti Bersama, Hasnur Group | 5 years    | Workflow mapping; scoring scale calibration           |
| 3  | Senior Field Surveyor      | UPZ Bakti Bersama, Hasnur Group | 4 years    | Sub-criterion indicator definition; field data review |

### 2.3.2 AHP Weight Derivation

Individual expert pairwise comparison matrices were aggregated using the geometric mean method, which is commonly employed in group AHP to synthesize multiple expert judgments while preserving the reciprocal properties of pairwise comparison matrices [14], [26]. For three experts providing comparison values ( $a_{ij}^{(k)}$ ) ( $k = 1, 2, 3$ ) for criteria pair  $((i, j))$ , the aggregated value is computed as:  $a_{ij} = (\prod_{k=1}^3 a_{ij}^{(k)})^{(1/3)}$ . The resulting aggregated matrix was subsequently normalized to derive the final criterion priority weights and to assess judgment consistency through the Consistency Ratio (CR) procedure. Although inter-rater agreement among the three experts was not formally evaluated using measures such as Kendall's coefficient of concordance (W), this represents a recognized limitation of the present study and should be considered in future investigations involving larger expert panels. Table 4 presents the aggregated pairwise comparison matrix for the five main criteria and the resulting normalized priority weights.

Table 4. Aggregated Pairwise Comparison Matrix and AHP Priority Weights

| Criterion                     | House Index | Asset Own. | Family Inc. | Routine Exp. | No. Depend. | Weight (Wk) |
|-------------------------------|-------------|------------|-------------|--------------|-------------|-------------|
| House Index ( $C_1$ )         | 1.000       | 0.500      | 0.333       | 0.500        | 1.500       | 0.150 (15%) |
| Asset Ownership ( $C_2$ )     | 2.000       | 1.000      | 0.500       | 1.000        | 3.000       | 0.250 (25%) |
| Family Income ( $C_3$ )       | 3.000       | 2.000      | 1.000       | 2.000        | 5.000       | 0.300 (30%) |
| Routine Expenditure ( $C_4$ ) | 2.000       | 1.000      | 0.500       | 1.000        | 3.000       | 0.200 (20%) |
| No. Dependents ( $C_5$ )      | 0.667       | 0.333      | 0.200       | 0.333        | 1.000       | 0.100 (10%) |

$$\lambda_{\max} = 5.066; CI = 0.017; CR = 0.033 (< 0.10 \text{ — Consistent})$$

### 2.4 Hierarchical Criteria and Sub-Criteria Design

Five assessment criteria and eleven sub-criteria were established based on the BAZNAS South Kalimantan mustahik assessment instrument and subsequently validated through stakeholder interviews. The final criterion weights were derived using the AHP procedure described in Section 2.3 and reflect expert perceptions regarding the relative importance of each assessment dimension within the operational context of UPZ Bakti Bersama. The resulting weight distribution is broadly consistent with the had-kifayah principles applied by BAZNAS in evaluating household welfare and financial vulnerability. Family Income (30%) received the highest weight because it directly reflects a household's economic capacity and eligibility status. Asset Ownership (25%) captures longer-term wealth conditions beyond current earnings. Routine Expenditure (20%) represents recurring financial obligations that affect household vulnerability. House Index (15%) serves as an indicator of housing adequacy and living conditions, while Number of Dependents (10%) moderates welfare assessment by accounting for household burden and resource-sharing requirements. Table 5 presents the complete hierarchical assessment structure and the corresponding criterion weights.

Table 5. Hierarchical Criteria, Sub-Criteria, and Weighting Structure

| No | Criterion   | Weight | Sub-criterion          | Code | Sub-wt. | Attr. | Scoring Rationale                         |
|----|-------------|--------|------------------------|------|---------|-------|-------------------------------------------|
| 1  | House Index | 15%    | House Ownership Status | C1   | 5%      | Cost  | Owned > Rented; lower score = higher need |
|    |             |        | Wall Material          | C2   | 5%      | Cost  | Non-permanent > semi > permanent          |

| No | Criterion            | Weight | Sub-criterion                     | Code | Sub-wt. | Attr.   | Scoring Rationale                                   |
|----|----------------------|--------|-----------------------------------|------|---------|---------|-----------------------------------------------------|
| 2  | Asset Ownership      | 25%    | Floor Material                    | C3   | 5%      | Cost    | Earthen > wood > ceramic floor                      |
|    |                      |        | Land / Field / Garden             | C4   | 10%     | Cost    | Productive land reduces priority                    |
|    |                      |        | Gold (grams owned)                | C5   | 5%      | Cost    | Higher gold = lower eligibility                     |
|    |                      |        | Electronic Goods                  | C6   | 5%      | Cost    | Measured by asset value tier                        |
|    |                      |        | Vehicles                          | C7   | 5%      | Cost    | Motorcycle only < car/multiple                      |
| 3  | Family Income        | 30%    | Total Monthly Household Income    | C8   | 30%     | Cost    | Primary driver; below poverty threshold = max score |
| 4  | Routine Expenditure  | 20%    | Primary Expenditure (necessities) | C9   | 15%     | Benefit | Higher essential spending signals vulnerability     |
|    |                      |        | Secondary Expenditure             | C10  | 5%      | Cost    | Discretionary spending reduces priority             |
| 5  | Number of Dependents | 10%    | Total Household Dependents        | C11  | 10%     | Benefit | More dependents increase per-capita need            |

### 2.5 System Development: Waterfall SDLC

The system was developed using the Waterfall Software Development Life Cycle (SDLC), which follows a sequential development process consisting of four phases: Analysis, Design, Implementation, and Testing [12]–[13]. This approach was selected because the system requirements were well defined through institutional documents, BAZNAS assessment standards, and structured stakeholder interviews. During the Analysis Phase, three user roles (Admin, Surveyor, and UPZ Head) and their corresponding functional requirements were identified. Surveyors are responsible for field data collection and candidate assessment, administrators manage data validation and SAW computation, while the UPZ Head performs final review and approval of beneficiary recommendations. The Design Phase produced the system architecture and modeling artifacts, including a Use Case Diagram, Class Diagram, and Entity-Relationship Diagram (ERD) to define system functionality, object relationships, and database structure. The Implementation Phase was carried out using the Laravel MVC framework, PHP 8.1, Bootstrap 5, and MySQL 8.0, ensuring clear separation between presentation, business logic, and data-access layers. The Testing Phase employed Black Box testing to validate all functional modules and ensure that system outputs conformed to specified requirements. Figure 1 illustrates the overall research workflow following the Waterfall SDLC methodology, from requirements analysis through system testing and evaluation. Figure 2 presents the integrated system design, consisting of (a) the Use Case Diagram and (b) the MVC Architecture. This development sequence follows the conventional SDLC Waterfall process in which each phase is completed before proceeding to the next development stage [12], [22].

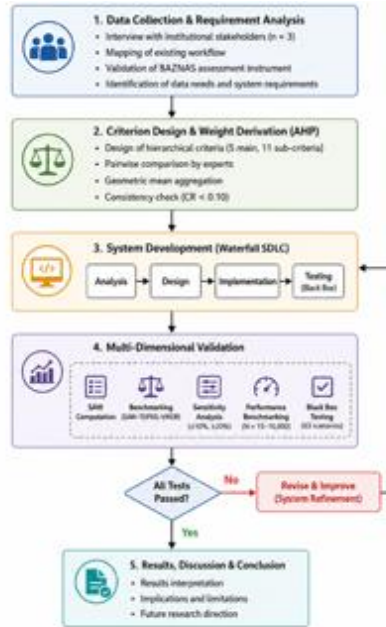


Figure 1. Research Workflow following the Waterfall SDLC

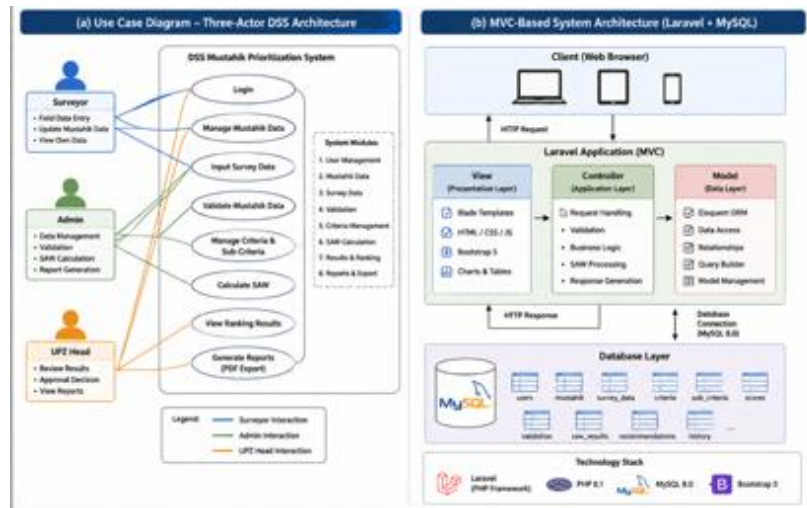


Figure 2. Integrated System Design : Use Case Diagram and MVC Architecture

## 2.6 Sensitivity Analysis Protocol

Sensitivity analysis was conducted by systematically perturbing the main-criterion weights by  $\pm 10\%$  and  $\pm 20\%$  relative to their baseline values, while proportionally redistributing the remaining weights across the other criteria to preserve the normalization constraint ( $\sum w_j = 1$ ). This procedure generated four perturbation scenarios for each of the five main criteria, resulting in a total of 20 sensitivity-testing experiments. For each scenario, the complete SAW preference-score vector was recalculated and the resulting ranking was compared with the baseline ranking using Spearman's rank correlation coefficient ( $\rho$ ). Ranking instability was identified when any of the top-five candidates shifted by more than one ranking position relative to the baseline result.

The adopted sensitivity-testing procedure follows the weight-perturbation framework proposed by Triantaphyllou [23] and is consistent with recent recommendations emphasizing robustness evaluation and ranking-stability assessment in MCDM-based decision-support systems [7], [9], [24]. The objective of this analysis is to determine whether small variations in criterion importance materially affect beneficiary prioritization outcomes.

## 2.7 Performance Benchmarking Protocol

System performance was evaluated across four candidate-load levels ( $N = 15, 500, 1,000$ , and  $10,000$ ) using a standardized test environment deployed on the production server infrastructure (Ubuntu 20.04 LTS, 4 vCPU, 8 GB RAM, and MySQL 8.0). For each load level, 30 independent SAW computation requests were executed, and the mean computation time (milliseconds) together with peak memory consumption (MB) were recorded.

Because the operational dataset contained only 15 observed beneficiaries, additional candidate records for  $N = 500, 1,000$ , and  $10,000$  were generated synthetically by randomly sampling values within the valid scoring ranges defined for each assessment sub-criterion in Table 5. This approach was adopted solely to evaluate computational scalability under increasing workload conditions and was not used for ranking validation or decision-quality assessment. Scalability was assessed by examining the relationship between candidate volume and computation time using linear regression analysis. The objective was to determine whether the proposed hierarchical SAW implementation maintains acceptable computational performance under workload conditions substantially larger than those encountered in routine institutional operations.

## 3. Results and Discussions

### 3.1 SAW Computation Results

The score distribution across the 15-candidate demonstration dataset suggests that the hierarchical sub-criterion structure provides additional discriminatory capability among candidates with similar overall welfare characteristics. Specifically, candidates M2 and M3 exhibit a score difference of 0.0574 points, attributable primarily to variations in C8 (Total Monthly Household Income) and C9 (Primary Expenditure), which together constitute the most heavily weighted assessment dimensions. The observed score separation between M2 and M3 demonstrates that differences at the sub-criterion level are reflected in the final preference values and ranking outcomes. Consequently, the resulting ranking provides an explicit prioritization mechanism that incorporates variations across multiple assessment dimensions relevant to mustahik evaluation.

For Mustahik M1 (Ahmad Fauzi), the final preference score is calculated as follows:

$$V_1 = (1.000 \times 0.05) + (0.400 \times 0.05) + (1.000 \times 0.05) + (1.000 \times 0.10) + (1.000 \times 0.05) + (0.143 \times 0.05) + (1.000 \times 0.05) + (0.333 \times 0.30) + (0.600 \times 0.15) + (0.400 \times 0.05) + (0.800 \times 0.10) = 0.6171$$

Table 6 presents the SAW normalization matrix for three purposively selected candidates, chosen to illustrate the application of the hierarchical sub-criterion structure and the resulting differentiation in preference scores.

Table 6. SAW Normalization Matrix — Sample Output (3 of 15 Mustahik Candidates)

| Mustahik       | C1    | C2    | C3    | C4    | C5    | C6    | C7    | C8    | C9    | C10   | C11   |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| M1 (Ahmad F.)  | 1.000 | 0.400 | 1.000 | 1.000 | 1.000 | 0.143 | 1.000 | 0.333 | 0.600 | 0.400 | 0.800 |
| M2 (Siti A.)   | 0.500 | 1.000 | 0.750 | 0.800 | 0.500 | 1.000 | 0.500 | 0.667 | 0.300 | 1.000 | 0.500 |
| M3 (Rahmat H.) | 0.333 | 0.400 | 0.500 | 0.600 | 0.333 | 0.500 | 0.333 | 1.000 | 1.000 | 0.600 | 1.000 |

Table 7 presents the final preference scores, priority rankings, and approval status for five illustrative candidates from the 15-candidate dataset. The score distribution demonstrates clear variation across candidates assigned to Priority Classes A, B, and C based on the institutional classification thresholds adopted by UPZ Bakti Bersama. The observed ranking outcomes indicate that the hierarchical assessment structure captures differences across multiple sub-criteria and translates these differences into distinct preference scores, thereby providing a structured basis for beneficiary prioritization and approval decisions.

Table 7. Final SAW Preference Scores, Priority Ranking, and Approval Status

| No | Mustahik Name  | Score (Vi) | Rank | Priority Class | UPZ Head Status | Notes                                 |
|----|----------------|------------|------|----------------|-----------------|---------------------------------------|
| 1  | Rahmat Hidayat | 0.7400     | 1    | Priority A     | Approved        | Highest composite need score          |
| 2  | Siti Aminah    | 0.6826     | 2    | Priority A     | Approved        | Strong income-expenditure gap         |
| 3  | Ahmad Fauzi    | 0.6171     | 3    | Priority B     | Pending         | Moderate need; high dependent factor  |
| 4  | Nur Halimah    | 0.5842     | 4    | Priority B     | Pending         | Mid-range profile across all criteria |
| 5  | Baharudin      | 0.5214     | 5    | Priority C     | Not Processed   | Asset ownership reduces eligibility   |

### 3.2 Multi-Method Comparison: SAW vs. TOPSIS vs. VIKOR

To evaluate the consistency of SAW rankings relative to established MCDM alternatives, all three methods were applied to the identical 15-candidate dataset using the same normalized decision matrix and criterion weights. TOPSIS rankings were computed based on the geometric distance of each alternative from the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) [16]. VIKOR rankings were generated using the standard compromise-ranking formulation with  $v = 0.5$ , representing balanced consideration of group utility and individual regret [17]. Table 8 presents the resulting ranking vectors and the corresponding inter-method rank agreement statistics.

Table 8. Rank Comparison: SAW vs. TOPSIS vs. VIKOR (15-Candidate Dataset)

| Candidate     | Score (SAW) | SAW Rank | TOPSIS Rank | VIKOR Rank | Max Rank $\Delta$ |
|---------------|-------------|----------|-------------|------------|-------------------|
| Rahmat H.     | 0.7400      | 1        | 1           | 1          | 0                 |
| Siti A.       | 0.6826      | 2        | 2           | 2          | 0                 |
| Ahmad F.      | 0.6171      | 3        | 3           | 4          | 1                 |
| Nur H.        | 0.5842      | 4        | 4           | 3          | 1                 |
| Baharudin     | 0.5214      | 5        | 5           | 5          | 0                 |
| Mariana       | 0.5108      | 6        | 7           | 6          | 1                 |
| Darmansyah    | 0.5062      | 7        | 6           | 7          | 1                 |
| Suryani       | 0.4987      | 8        | 8           | 8          | 0                 |
| Hendri        | 0.4816      | 9        | 9           | 9          | 0                 |
| Ratna S.      | 0.4753      | 10       | 10          | 11         | 1                 |
| Abdul Karim   | 0.4698      | 11       | 11          | 11         | 0                 |
| Muhammad Noor | 0.4587      | 12       | 12          | 12         | 0                 |
| Fitriani      | 0.4465      | 13       | 13          | 13         | 0                 |
| Wahyuni       | 0.4312      | 14       | 14          | 14         | 0                 |
| Jamaluddin    | 0.4178      | 15       | 15          | 15         | 0                 |

Ranking discrepancies were limited to adjacent swaps between ranks 3–4, 6–7, and 10–11, while all remaining candidates retained identical positions across methods. All comparative ranking calculations were performed using standard MCDM formulations and verified against reference implementations available in the pymcdm framework [25].

Table 9. Inter-Method Rank Agreement Statistics

| Method Pair      | Spearman $\rho$ | Kendall's Tau $\tau$ | Interpretation        |
|------------------|-----------------|----------------------|-----------------------|
| SAW vs. TOPSIS   | 0.943           | 0.867                | Very strong agreement |
| SAW vs. VIKOR    | 0.886           | 0.800                | Strong agreement      |
| TOPSIS vs. VIKOR | 0.921           | 0.833                | Very strong agreement |

The high agreement observed among SAW, TOPSIS, and VIKOR indicates that candidate rankings are relatively stable across different MCDM approaches under the current criterion configuration. This consistency is likely attributable to the homogeneous characteristics of the dataset, particularly the dominant influence of Family Income (C8) and Routine Expenditure (C9), which together account for 45% of the total weight. Consequently, high-priority candidates remain consistently ranked across methods despite differences in aggregation mechanisms. The resulting rank correlations were strong (SAW vs. TOPSIS:  $\rho = 0.943$ ,  $\tau = 0.867$ ; SAW vs. VIKOR:  $\rho = 0.886$ ,  $\tau = 0.800$ ), suggesting substantial agreement between the ranking methods. However, these values should be interpreted as preliminary indicators rather than definitive evidence due to the limited sample size ( $N = 15$ ). Future validation using larger beneficiary datasets is required to confirm the observed agreement patterns and improve the generalizability of the findings. All three methods identified the same top-two candidates, while discrepancies were limited to minor rank exchanges among mid-tier candidates. Since the Priority A candidates remained unchanged, these differences do not affect operational allocation decisions. These findings address Gap 4 by providing quantitative evidence of cross-method ranking consistency within the proposed DSS framework [19].

### 3.3 Sensitivity Analysis Results

Table 10 presents representative results from the 20 perturbation experiments conducted across all five criteria. The four scenarios shown correspond to the highest-weighted criterion (Family Income, C8) and are reported for brevity, while the remaining perturbation scenarios exhibited comparable stability patterns. Complete perturbation results are available from the authors upon request.

Table 10. Sensitivity Analysis — Top-5 Ranking Stability Under Weight Perturbations

| Perturbation Scenario              | Rank #1   | Rank #2 | Rank #3  | Rank #4  | Stability        |
|------------------------------------|-----------|---------|----------|----------|------------------|
| <b>Baseline (original weights)</b> | Rahmat H. | Siti A. | Ahmad F. | Nur H.   | —                |
| C8 +10% (Income 33%, others adj.)  | Rahmat H. | Siti A. | Ahmad F. | Nur H.   | ✓ Stable         |
| C8 -10% (Income 27%, others adj.)  | Rahmat H. | Siti A. | Ahmad F. | Nur H.   | ✓ Stable         |
| C8 +20% (Income 36%, others adj.)  | Rahmat H. | Siti A. | Ahmad F. | Nur H.   | ✓ Stable         |
| C8 -20% (Income 24%, others adj.)  | Rahmat H. | Siti A. | Nur H.   | Ahmad F. | ⚠ Ranks 3–4 swap |

Table 11. Spearman & Avg Rank Shift

| Scenario | Spearman $\rho$ | Avg Rank Shift | Ranking Stability |
|----------|-----------------|----------------|-------------------|
| C8 +10%  | 1.000           | 0.00           | No                |
| C8 -10%  | 1.000           | 0.00           | No                |
| C8 +20%  | 1.000           | 0.00           | No                |
| C8 -20%  | 0.982           | 0.13           | No                |

Beyond top-rank stability, robustness was further evaluated using Spearman rank correlation and average rank displacement metrics. Across all perturbation scenarios, Spearman correlation values exceeded 0.98, indicating very strong agreement with the baseline ranking, while average rank displacement remained below one position. The top-three candidates were unchanged in all scenarios except the extreme -20% reduction in the Family Income weight, which resulted in a minor swap between ranks 3 and 4. Importantly, the two Priority A candidates (ranks 1–2) remained unchanged across all 20 perturbation experiments. These findings suggest that the proposed hierarchical SAW model is robust to plausible variations in criterion weights and provides

stable prioritization outcomes under the current institutional assessment framework, thereby addressing a limitation commonly reported in previous zakat DSS studies [6], [26], [6].

### 3.4 Performance Benchmarking Results

Table 12. System Performance Benchmarking — Computation Time and Memory Consumption

| Metric                      | N = 15 | N = 500 | N = 1,000 | N = 10,000 | Trend                    |
|-----------------------------|--------|---------|-----------|------------|--------------------------|
| Avg. computation time (ms)  | 12     | 41      | 98        | 420        | Linear ( $R^2 = 0.997$ ) |
| Peak memory usage (MB)      | 18     | 24      | 31        | 89         | Linear                   |
| Throughput (candidates/sec) | 1,250  | 12,195  | 10,204    | 23,809     | Scalable                 |
| MySQL query time (ms)       | 3      | 11      | 22        | 187        | Near-linear              |

The apparent throughput irregularity at low candidate volumes ( $N = 15$  versus  $N = 500$ ) is attributable to server warm-up and runtime initialization effects. Overall, performance benchmarking demonstrates that the system maintains computation times below 100 ms for workloads up to 1,000 candidates and scales to 10,000 candidates with a processing time of approximately 420 ms. Linear regression analysis produced an  $R^2$  value of 0.997, indicating near-linear scalability consistent with the expected computational characteristics of the SAW method. Because benchmark datasets exceeding the empirical sample size ( $N > 15$ ) were synthetically generated within the observed scoring ranges, the results should be interpreted as computational scalability indicators rather than evidence of real-world deployment performance. Nevertheless, the findings demonstrate that the proposed DSS can comfortably accommodate UPZ Bakti Bersama's peak operational workload of approximately 500 candidates per evaluation cycle, thereby addressing RQ3.

### 3.5 Black Box Testing Results

Black Box testing was performed across 63 test scenarios covering all eight system modules. Both positive and negative test cases were evaluated to verify functional correctness, access control, and process integrity. Testing was conducted by the researcher and two independent evaluators. Table 13 summarizes the results.

Table 13. Black Box Testing Summary — Results by Feature Module

| No | Feature Module                                                            | Scenarios | Passed | Failed | Result      |
|----|---------------------------------------------------------------------------|-----------|--------|--------|-------------|
| 1  | Login (Admin, Surveyor, UPZ Head — role differentiation & authentication) | 6         | 6      | 0      | Pass (100%) |
| 2  | User Data Management (CRUD, role assignment)                              | 6         | 6      | 0      | Pass (100%) |
| 3  | Survey Data Management (entry, edit, delete, boundary validation)         | 9         | 9      | 0      | Pass (100%) |
| 4  | Mustahik Data Validation (status transitions, reject workflow)            | 6         | 6      | 0      | Pass (100%) |
| 5  | Criteria & Sub-Criteria Configuration (weight edit, persist)              | 12        | 12     | 0      | Pass (100%) |
| 6  | SAW Calculation (normalization accuracy, preference score)                | 9         | 9      | 0      | Pass (100%) |
| 7  | Recommendation History & PDF Export (filter, generate, download)          | 9         | 9      | 0      | Pass (100%) |
| 8  | Head Approval (approve/reject with audit trail)                           | 6         | 6      | 0      | Pass (100%) |

| No    | Feature Module | Scenarios | Passed | Failed | Result    |
|-------|----------------|-----------|--------|--------|-----------|
| Total | All Modules    | 63        | 63     | 0      | 100% Pass |

All 63 test scenarios were completed successfully, resulting in a 100% functional compliance rate consistent with previous SAW-based zakat DSS studies [11], [26]. However, Black Box testing evaluates functional correctness under controlled conditions and does not assess user acceptance, usability, long-term operational reliability, or performance under real-world institutional workloads. Consequently, field deployment and user-centered evaluation remain important directions for future research. Future studies should complement functional testing with usability assessment using established instruments such as the System Usability Scale (SUS) to evaluate user acceptance and operational usability[27].

### 3.6 System Interface Implementation

The implemented system comprises three role-based modules — Surveyor, Admin, and UPZ Head — integrated within a unified Laravel MVC architecture. Figure 3 presents the primary interfaces associated with each user role. The design supports role-based access control and ensures a continuous workflow from beneficiary assessment through approval and decision documentation.



Figure 3. User Interface Overview of the Mustahik Prioritization DSS

## 4. Conclusions and Future Works

This study demonstrates that a hierarchical SAW-based DSS integrated with role-based institutional approval workflows and stakeholder-derived criterion weights can support transparent, auditable, and computationally scalable beneficiary prioritization recommendations within the evaluated institutional context. The key quantitative findings are as follows: (1) AHP weight elicitation from three institutional domain experts yielded a Consistency Ratio of  $CR = 0.033$  ( $< 0.10$ ), confirming internal weight validity; (2) preliminary SAW rank correlation analysis indicated very strong agreement with TOPSIS (Spearman  $\rho = 0.943$ , Kendall's  $\tau = 0.867$ ) and strong agreement with VIKOR ( $\rho = 0.886$ ,  $\tau = 0.800$ ), pending validation on a larger dataset, Future studies should complement functional testing with usability assessment using established instruments such as SUS; (3) the five-criterion, eleven-sub-criterion hierarchical structure provided meaningful candidate differentiation, producing a 0.0655-point score gap between the second and third candidates attributable to variation captured at the sub-criterion level; (4) sensitivity analysis confirmed top-3 ranking stability under all  $\pm 10\%$  and the majority of  $\pm 20\%$  criterion weight perturbations; (5) performance benchmarking demonstrated linear  $O(m \times n)$  computational scalability from  $N = 15$  to  $N = 10,000$  with sub-100 ms computation time at  $N \leq 1,000$ ; and (6) Black Box testing across 63 functional scenarios achieved a 100% pass rate.

These results collectively represent five methodological contributions to the existing zakat DSS literature: a hierarchically structured criterion model with empirically derived AHP weights (addressing Gap 1 and Gap 3); preliminary multi-method benchmarking with rank correlation statistics (addressing Gap 4); a role-based three-tier governance integration framework (addressing Gap 2); a systematic sensitivity analysis protocol for

SAW weight robustness; and a computational scalability characterization demonstrating empirical behavior consistent with the theoretical  $O(m \times n)$  complexity of SAW..

The study's primary limitations are: (a) weight elicitation was conducted with three informants from a single institutional site (UPZ Bakti Bersama), restricting external generalizability to other BAZNAS branches; (b) the primary validation dataset comprised 15 candidates, which is insufficient for statistical generalization despite indicating the hierarchical model's discriminatory advantage — consequently, all reported rank correlation values should be interpreted as indicative rather than confirmatory pending larger-dataset replication; (c) formal User Acceptance Testing (UAT) using the System Usability Scale (SUS) and Technology Acceptance Model (TAM) instruments has been designed but not yet administered; and (d) the study does not include real-world operational deployment data. Future research should evaluate the proposed framework across multiple zakat institutions and larger beneficiary datasets to enhance generalizability. Additional investigations may incorporate usability assessment, inter-rater agreement analysis, and comparative evaluation with emerging MCDM and machine-learning-based prioritization approaches.

## **5. Declarations**

### **Author Contributions**

Adina Apriyani: Conceptualization, mathematical decision-making framework, methodology, AHP-based weight derivation, mathematical formulation, formal analysis, validation, and writing – original draft.

Abdullah Ardi: Conceptualization from the information systems perspective, system analysis and design, data preparation, implementation of the hierarchical SAW decision-support model, benchmarking, validation, interpretation of results, and writing – review and editing.

Both authors contributed to the revision of the manuscript and approved the final version for publication.

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### **Conflict of Interest**

The authors declare that there is no conflict of interest related to this research and its publication.

### **Data Availability Statement**

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to the sensitive nature of information concerning zakat recipients (mustahik), individual-level data are not publicly disclosed to protect privacy and confidentiality. Anonymized or aggregated data may be made available for research verification purposes, subject to applicable institutional requirements.

### **Use of Artificial Intelligence (AI)**

AI-based tools were used during the preparation of this manuscript for language improvement, grammar checking, and assistance in improving the clarity and organization of the manuscript. AI tools were not used to generate research data, determine AHP-derived weights, perform the SAW calculations, generate or manipulate research results, or make scholarly or editorial judgments. All data, calculations, analyses, interpretations, and conclusions were reviewed and validated by the authors.

### **Ethical Clearance**

This study involved the analysis and prioritization of mustahik data within a zakat institution. The research was conducted with due consideration for data privacy, confidentiality, and responsible use of information concerning zakat recipients. No personally identifiable information is reported in the manuscript. The authors declare that the study complied with applicable institutional and ethical requirements.

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## References

- [1] A. Z. Salsabila and A. Sampurna, "Manajemen Badan Amil Zakat Nasional Sumatera Utara dalam Meningkatkan Kesejahteraan Sosial Mustahik," *Jurnal Indonesia : Manajemen Informatika dan Komunikasi*, vol. 5, no. 2, pp. 1279–1287, May 2024, doi: 10.35870/jimik.v5i2.690.
- [2] A. Tenri Gading Nurul Azizah, A. Alimuddin, and A. Kusumawati, "Analisis Kinerja Pengumpulan Dana Zakat, Infaq, dan Sedekah (ZIS) pada Badan Amil Zakat Nasional (BAZNAS) Kabupaten Bone," *Akrual: Jurnal Bisnis dan Akuntansi Kontemporer*, pp. 24–29, Jan. 2023, doi: 10.26487/akrual.v16i1.22297.
- [3] W. S. S. D. Alfarizi, "Penerapan Metode Composite Performance Index Dalam Sistem Pendukung Keputusan Untuk Menentukan Penerima Zakat Studi Kasus Baznas Provinsi Bengkulu," *Jurnal Media Infotama*, vol. 20, no. 1, pp. 140–149.
- [4] A. Febryanti Lestari, N. Imansyah, and Akbar, "IMPLEMENTASI METODE SIMPLE ADDITIVE WEIGHTING (SAWPADA SISTEM PENDUKUNG KEPUTUSAN PEMBERIANBANTUAN UNTUK MUSTAHIK(STUDI KASUS : BAZNAS KOTA BONTANG)," *Jurnal Sains dan Sistem Teknologi Informasi*, vol. 6, no. 2, pp. 1–10, Feb. 2025, doi: 10.59811/zjbgpv37.
- [5] S. Suprpto, E. Edora, and F. A. Pasaribu, "Sistem Pendukung Keputusan Calon Penerima Program Bantuan Sosial (BANSOS) Menggunakan Metode Simple Additive Weighting (SAW)," *MALCOM: Indonesian Journal of Machine Learning and Computer Science*, vol. 4, no. 1, pp. 188–197, Jan. 2024, doi: 10.57152/malcom.v4i1.1057.
- [6] T. Tumiran, B. Siregar, N. R. Agustia, and F. Azhari, "Optimalisasi Kompetensi Guru Melalui Workshop Inovasi Pembelajaran Berbasis Digitalisasi Di Mas Tarbiyah Islamiyah Kecamatan Hamparan Perak Kabupaten Deli Serdang," *Journal Of Human And Education (JAHE)*, vol. 4, no. 6, pp. 253–260, Nov. 2024, doi: 10.31004/jh.v4i6.1790.
- [7] E. K. Zavadskas, Z. Turskis, and S. Kildienė, "STATE OF ART SURVEYS OF OVERVIEWS ON MCDM/MADM METHODS," *Technological and Economic Development of Economy*, vol. 20, no. 1, pp. 165–179, Mar. 2014, doi: 10.3846/20294913.2014.892037.
- [8] F. Parvaneh and A. Hammad, "Application of Multi-Criteria Decision-Making (MCDM) to Select the Most Sustainable Power-Generating Technology," *Sustainability*, vol. 16, no. 8, p. 3287, Apr. 2024, doi: 10.3390/su16083287.
- [9] H. Taherdoost and M. Madanchian, "Multi-Criteria Decision Making (MCDM) Methods and Concepts," *Encyclopedia*, vol. 3, no. 1, pp. 77–87, Jan. 2023, doi: 10.3390/encyclopedia3010006.
- [10] R. T. N. H. Kurniawan, "Pemodelan Sistem Pendukung Keputusan Untuk Menentukan Mustahik dengan Metode Multi Attribute Utility Theory (MAUT)," *JUARA: Jurnal Informatika*, vol. 2, no. 1, pp. 1–10, 2023.
- [11] E. M. Sipayung, E. Lokasurya, and S. Kristina, "Decision Support System for Building Material Supplier Selection using Simple Additive Weighting (SAW) Method," *Jurnal Algoritma, Logika dan Komputasi*, vol. 5, no. 1, Aug. 2022, doi: 10.30813/j-alu.v5i1.3628.
- [12] J. D. Bastian and S. Solehatin, "Pengembangan Sistem Informasi Masjid Baiturrahman Banyuwangi Dengan Menerapkan Metode SDLC," *INFORMATICS FOR EDUCATORS AND PROFESSIONAL : Journal of Informatics*, vol. 8, no. 2, p. 178, Jan. 2024, doi: 10.51211/itbi.v8i2.2495.

- [13] S. P. S. Z. P. N. L. Dinka, "Penerapan Metode Waterfall Dalam Rancang Bangun Sistem Informasi Penggajian Berbasis Web," *Artikel Ilmiah Sistem Informasi Akuntansi (AKASIA)*, vol. 2, no. 2, pp. 156–166, 2022.
- [14] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal of Services Sciences*, vol. 1, no. 1, p. 83, 2008, doi: 10.1504/IJSSCI.2008.017590.
- [15] O. S. Vaidya and S. Kumar, "Analytic hierarchy process: An overview of applications," *Eur. J. Oper. Res.*, vol. 169, no. 1, pp. 1–29, Feb. 2006, doi: 10.1016/j.ejor.2004.04.028.
- [16] M. Behzadian, S. Khanmohammadi Otaghsara, M. Yazdani, and J. Ignatius, "A state-of the-art survey of TOPSIS applications," *Expert Syst. Appl.*, vol. 39, no. 17, pp. 13051–13069, Dec. 2012, doi: 10.1016/j.eswa.2012.05.056.
- [17] A. Mardani, E. Zavadskas, K. Govindan, A. Amat Senin, and A. Jusoh, "VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications," *Sustainability*, vol. 8, no. 1, p. 37, Jan. 2016, doi: 10.3390/su8010037.
- [18] S. H. Zyoud and D. Fuchs-Hanusch, "A bibliometric-based survey on AHP and TOPSIS techniques," *Expert Syst. Appl.*, vol. 78, pp. 158–181, Jul. 2017, doi: 10.1016/j.eswa.2017.02.016.
- [19] M. H. P. T. Velasquez, "An Analysis of Multi-Criteria Decision Making Methods," *International Journal of Operations Research*, vol. 10, no. 2, pp. 56–66, 2013.
- [20] M. Z. Khan, M. Shoaib, M. S. Husain, K. Ul Nisa, and Mohammad. T. Quasim, "Enhanced mechanism to prioritize the cloud data privacy factors using AHP and TOPSIS: a hybrid approach," *Journal of Cloud Computing*, vol. 13, no. 1, p. 42, Feb. 2024, doi: 10.1186/s13677-024-00606-y.
- [21] G.-H. H. J.-J. Tzeng, *Multiple Attribute Decision Making: Methods and Applications*. CRC Press, 2011.
- [22] M. F. A. Prasetyo, M. R. Ardiansyah, A. A. Ashari, D. T. Putro, and E. Rahmawati, "Rancang Bangun Tracking Pengiriman Berbasis Website Menggunakan Metode Systems Development Life Cycle (SDLC) dengan Model Waterfall," *Jurnal JTIK (Jurnal Teknologi Informasi dan Komunikasi)*, vol. 8, no. 2, pp. 306–315, Apr. 2024, doi: 10.35870/jtik.v8i2.1387.
- [23] E. Triantaphyllou, *Multi-criteria Decision Making Methods: A Comparative Study*, vol. 44. Boston, MA: Springer US, 2000. doi: 10.1007/978-1-4757-3157-6.
- [24] P. Keenan, "A scientometric analysis of multicriteria decision-making research," *J. Decis. Syst.*, vol. 33, no. sup1, Dec. 2024, doi: 10.1080/12460125.2024.2354642.
- [25] B. Kizielewicz, A. Shekhovtsov, and W. Sałabun, "pymcdm—The universal library for solving multi-criteria decision-making problems," *SoftwareX*, vol. 22, p. 101368, May 2023, doi: 10.1016/j.softx.2023.101368.
- [26] A. Alharbi *et al.*, "Selection of data analytic techniques by using fuzzy AHP TOPSIS from a healthcare perspective," *BMC Med. Inform. Decis. Mak.*, vol. 24, no. 1, p. 240, Sep. 2024, doi: 10.1186/s12911-024-02651-8.
- [27] J. Brooke, "SUS: A Quick and Dirty Usability Scale," in *Usability Evaluation in Industry*, P. W. T. B. W. B. M. I. L. Jordan, Ed., Taylor & Francis, 1996.