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Implementation of a hybrid SWOT–Fuzzy BWM approach for prioritization of information technology strategies: A case study at Semarang university

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Abstract

For higher education institutions dealing with resource limitations and the needs of digital transformation, strategic IT planning is essential. In order to systematically prioritize and rank IT strategies, alternatives at Semarang University, Indonesia. this paper presents a novel hybrid framework that combines the Fuzzy Best-Worst Method with Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. In order to create a TOWS matrix with 24 strategic initiatives, we use this mixed-methods approach to collect data via expert interviews and questionnaires. The FBWM was use to quantify expert linguistic judgements and calculate the weights under uncertainty. Based on the analysis, strategic alignment is the most important evaluation criterion with 56.5% of the overall weight. Moreover, the prioritization result highlight that Enhanced Security Organization, Service-Based Disaster Recovery Plan, and Fill Critical Positions as the top three strategic priorities. A consistency ratio of 0.000 and sensitivity analysis that was part of the FBWM verified the rankings' strong resilience. Additionally, the findings show crucial institutional preference for enhancing operational resilience and security governance over merely technical advancements. Finally, this paper proposes a replicable, quantitative framework for universities to objectively align IT investments with long-term strategic objectives.

Keywords: Information Technology Strategy; Fuzzy Best-Worst Method; SWOT Analysis; Multi-Criteria Decision Making; Higher Education; Strategic Prioritization

1. Introduction

Strategic IT planning is crucial for organizations seeking adaptability and a competitive edge amid pervasive digital transformation.[1]. Multi-criteria decision-making (MCDM) methods are a well-known area that is widely used in IT strategies, where many different criteria, including cost, performance, security, and stakeholder preference, are systematically evaluated. There are different MCDM methods, such as AHP, TOPSIS, BWM, and FBWM, which are useful in providing a framework for examining important parameters for further optimization and prioritization [2]. However, in many different situations, expert judgments are sometimes wrong, which encourages MCDM methods to handle uncertainty more effectively. Fuzzy logic helps increase the probability of biased decisions by replacing words such as “moderately important” or “very important” with ambiguous numbers [3]. MCDM methods provide a structured framework that combines quantitative and qualitative factors, enabling organizations to accurately assess and prioritize IT projects [4].

Semarang University is just one of many universities facing limited funding and a growing focus on technology [5]. As a result, IT strategy planning often relies on quantitative or individualized decision-making approaches [6]. This lack of a structured methodology can hinder a university's ability to align its IT investments with its broader business and academic objectives [5]. Moreover, although many standard multi-criteria decision-making tools, such as the Analysis

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Hierarchy Process (AHP) and Topic Selection and Optimal Solutions (TOPSIS), are commonly used in higher education, especially university IT management, their reliance on precise statistics often fails to capture the uncertainty in expert opinions [7]. This knowledge gap highlights the need for a unified methodology that integrates qualitative approaches into the IT strategy selection process. To overcome these challenges, our study proposes the implementation of a novel hybrid framework that combines Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis [8] with the Fuzzy Best-Worst Method (Fuzzy BWM) to prioritize IT sub-strategies at Semarang University [9].

The first objective of this study is to identify relevant IT strategies for Semarang University via literature review, the university's strategic goals, and expert validation. The second step involves identifying the IT sub-strategies through a comprehensive SWOT analysis and TOWS matrix. Third, prioritize these sub-strategies using the fuzzy best-worst method. Lastly, to provide a replicable strategic framework for IT strategy selection that can be used in other universities.

The following are the predetermined research questions that direct this thesis. First, how can Semarang University use a hybrid SWOT–Fuzzy BWM approach to systematically identify and prioritize key IT strategies that address internal factors (strengths/weaknesses) and external ones (opportunities/threats)? Second, what is the most critical IT sub-strategies identified through SWOT analysis and evaluated using Fuzzy BWM? Third, how can SWOT–Fuzzy BWM transform subjective expert judgments about IT strategy importance into quantified and reliable priority weights? Lastly, which IT sub-strategies, ranked by the SWOT–Fuzzy BWM method, should Semarang University implement first to achieve optimal impact? To answer these research questions and gets the expected result a several interviews and online questionnaire will be conducted with 10 experts and IT leaders and staff form the Information Technology Unit (SaKTI) at Semarang University, alongside with colleting and review institutional documents. Additionally, experts will answer to these quotations using Best→Others and Others→Worst pairwise comparisons after determine the main criterion, and measure the performance of each sub-strategies (will be determine after reviewing the relative institutional documents) using the linguistic scales.

2. Material and methods

The following section describes the data collection process and the methodology, with a particular emphasis on the SWOT-Fuzzy BWM approach. The identification of the main and sub-criteria was conducted through a combination of semi-structured interviews, a structured questionnaire, a review of institutional documents, relevant academic literature, and the application of the fuzzy Best-Worst Method (BWM). From this input, SWOT factors representing the university's internal and external IT context were extracted. A 6 × 6 TOWS matrix has been synthesized from the SWOT factors. As illustrated in Figure 1, it summarizes the study model.

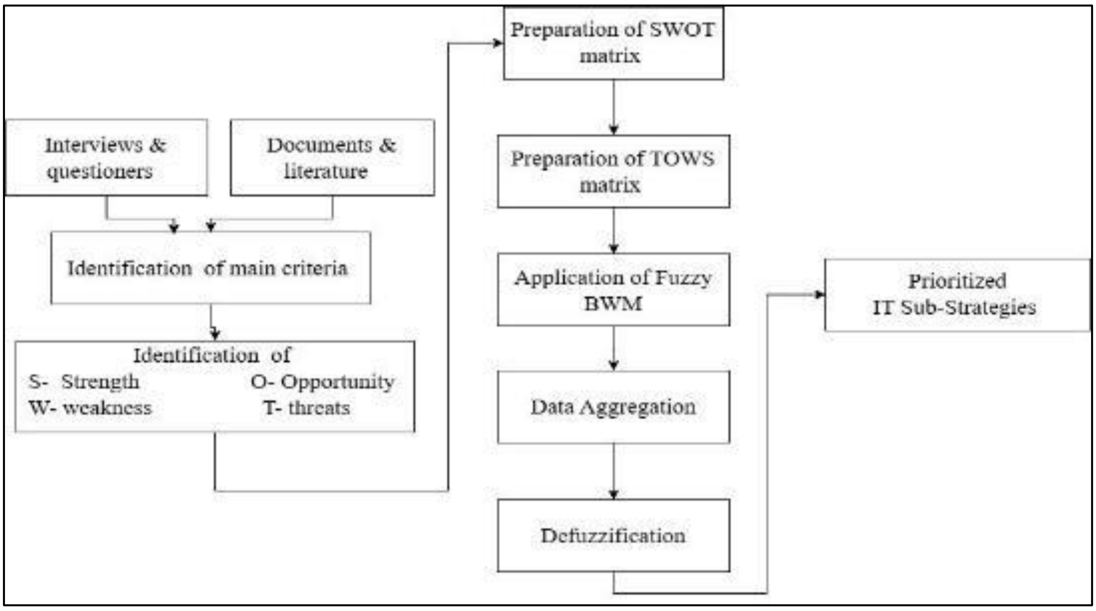

Figure 1 Research Model

2.1. Data collection process

In this study, data collection was conducted in two stages. First, semi-structured interviews and a review of institutional documents were used to identify internal and external IT conditions, resulting in a SWOT matrix that was further transformed into candidate sub-strategies using the TOWS approach. Second, a structured questionnaire was designed based on the implementation of FBWM and distributed to a panel of ten IT experts from Semarang University (including the Head of the IT Department, the Head of Data and Information Services, and staffs of the Information Technology Unit) to validate the criteria and evaluate the sub-strategies. Experts provided pairwise comparisons for the Fuzzy BWM and linguistic performance ratings, which were later transformed into triangular fuzzy numbers for analysis. Table 1 provides further information about the expert's panel.

Table 1 Expert profiles

NO	Expert	Profession	Experience (Year)	Self-Rated Expertise (1-10)
1	EX-1	Head of IT Department	10	9
2	EX-2	Head of Data and Information Services	11	8
3	EX-3	Communication and Information Technology Unit	10	8
4	EX-4	Programmer / SakTi (Information Technology Unit)	5	8
5	EX-5	Staff SaKTI (Information Technology Unit)	7	5
6	EX-6	Staf Manager SaKTI (Information Technology Unit)	6	9
7	EX-7	Staff SaKTI (Information Technology Unit)	8	8
8	EX-8	Staff SaKTI (Information Technology Unit)	12	8
9	EX-9	Staff SaKTI (Information Technology Unit)	10	8
10	EX-10	Staff SaKTI (Information Technology Unit)	2	8

Source: Primary data (expert questionnaire and interviews), 2025

2.2. SWOT analysis

SWOT analysis is a popular strategies planning tool that stand for strengths, weaknesses, opportunities and threats, it used to evaluate these factors with a particular organization or decision-making context [10, 11]. SWOT analysis is valuable tool; it is import for structuring discussion, ensuring strategies fit and offering a basic review for the organizations or companies [10]. Moreover, based on the internal and external factors we can develop and adopt good strategies. The TOWS matrix is an extremely effective tool and can be prepared based on SO (Strengths-Opportunities), ST (Strengths-Threats), WO (Weakness-Opportunity), and WT (Weakness-Threat) strategies [12, 13]. SO (Strengths-Opportunities) Strategies for leveraging strengths to maximize opportunities; ST (Strengths-Threats) Strategies that leverage strengths to mitigate threats; WO (Weakness-Opportunity) strategies that minimize weaknesses by taking advantage of opportunities; and WT (Weakness-Threat) Strategies for minimizing weaknesses and avoiding threats. [12, 14]

2.3. Fuzzy Best-worth Method

FBWM is a multi-criteria decision-making method initially proposed by Guo and Zhao that extends the traditional "best and worst" method to a fuzzy environment [15]. Additionally, it uses triangular fuzzy numbers and linguistic terms such as "equally important" and "moderately important" to describe the decision-maker's preferences in order to address the uncertainty in the input data. The decision-maker begins by defining two criteria: "best" and "worst." In a structured way, these two criteria are compared to each other and to other criteria. This structured comparison helps determine the fuzzy weights of the criteria and alternatives, thus solving the problem of maximizing the minimum. A crucial feature of FBWM is its built-in consistency analysis, which validates the reliability of the experts' judgments [16]. Ultimately, the method calculates the fuzzy scores of the alternatives by multiplying the criteria values and the fuzzy weights concerning the considered criteria, which makes it a useful tool for complex evaluations, such as prioritizing strategic planning models. Furthermore, including a consistency ratio is an important feature for verifying the reliability of the fuzzy preferences. Studies have shown that the fuzzy BWM provides reliable decision results and achieves higher comparison consistency than the original BWM [17].

In this paper, we will explain by details the steps of Fuzzy Best-worth methods for determining the fuzzy weights of criteria. It's important to note that these steps can also use for calculating the fuzzy weights of alternatives or sup-strategies.

Step 1. Determine the main criteria and identify the best and worth criteria from the set. Suppose there are n decision criteria {c 1, c 2… c n}. In this research the decision makers select four criteria as follows: C1: Strategic Alignment (Best); C2: Expected Impact; C3: Feasibility (Worth); and C4: Cost. These criteria were chosen for the following reasons. Because they represent the expected benefit of each action, they define the university's goals and policies, and they assess performance in light of local constraints. And because they define the impact on resources and capabilities.

Step 2. Calculate the fuzzy pair-wise comparisons for the best criterion. This step is very important for FBWM. In this the decision makers will ask to express the preference of the best criterion over all the other criteria using linguistic terms, which will then be translated into triangular fuzzy numbers. The obtained fuzzy Best-to-Others vector is:

$$\tilde{A}_B = (\tilde{a}_{B_1}, \tilde{a}_{B_2}, \dots, \tilde{a}_{B_n}) \quad (1)$$

where $\tilde{A}_B$ represents the fuzzy Best-to-Others vector; $\tilde{a}_{B_j}$ represents the fuzzy preference of the best criterion C_B over criterion j, j = 1, 2, ⋯, n. It can be known that $\tilde{a}_{BB}$ = (1, 1, 1).

In this paper we used TFNs scale (1 to 9) as presented in table 3.

Table 2 Triangular fuzzy numbers (TFNs) scale used for main criterion

Linguistic Terms	**Abbreviation**	**Triangular Fuzzy Numbers**
Equally important	EI	(1, 1, 1)
Slightly more important	SLI	(1, 2, 3)
Moderately more important	MO	(2, 3, 4)
Strongly more important	ST	(4, 5, 6)
Very strongly more important	VST	(6, 7, 8)
Extremely more important	EX	(8, 9, 9)

Source: Compiled by the author based on Guo and Zhao, 2017

Step 3. Calculate the fuzzy pair-wise comparisons for the worth criterion. Same like step 2 but this time we obtain the fuzzy other-to-worth vector, by using the linguistic terms of the experts which is listed in table 2.

$$\tilde{A}_W = (\tilde{a}_{W_1}, \tilde{a}_{W_2}, \dots, \tilde{a}_{W_n}) \quad (2)$$

where $\tilde{A}_W$ represents the fuzzy Others-to-worth vector; $\tilde{a}_{W_j}$ represents the fuzzy preference of the worth criterion C_W over criterion j, j = 1, 2, ⋯, n. It can be known that $\tilde{a}_{WW}$ = (1, 1, 1).

Step 4. Define the optimal fuzzy weights, the objective of this step is the calculate the fuzzy weight w*= $(w*_1, w*_2 \dots, w*_n)$. To achieve this, we optimize a nonlinear model as presented below, the model seeks to minimize the fuzzy consistency index ξ. subject to the constraints imposed by the "Best-to-Others" and "Others-to-Worst" preference vectors.

$$min\ \xi = \left\{ \left| \frac{\tilde{w}_B}{\tilde{w}_j} - \tilde{a}_{B_j} \right|, \left| \frac{\tilde{w}_j}{\tilde{w}_w} - \tilde{a}_{j_w} \right| \right\} \quad (3)$$

Subject to:

$$\text{s.t} \left| \frac{\tilde{w}_B}{\tilde{w}_j} - \tilde{a}_{B_j} \right| \leq \xi\ \forall_j = 1,2, \dots n$$
$$\left| \frac{\tilde{w}_j}{\tilde{w}_w} - \tilde{a}_{w_j} \right| \leq \xi\ \forall_j = 1,2, \dots n \quad (4)$$

$$\sum_{j=1}^{N} \widetilde{w}_j = 1, \qquad \widetilde{w}_j \geq = 0 \; \forall_j = 1,2, \dots n$$

Where $\widetilde{w}_B$ and $\widetilde{w}_{BW}$ represent the fuzzy weights of the best and worth criterion, $\widetilde{w}_j$ denote the fuzzy weight of any other criterion j, $\tilde{a}_{B_j}$ denote the expert's fuzzy preference of the Best over criterion j and $\tilde{a}_{j_w}$ denote the expert's fuzzy preference of criterion j over the Worst. By solving this model, the study will calculate the optimal fuzzy weights and o optimal value ξ which will be used later on to calculate the consistency ratio (CR).

Finally, the consistency ratio (CR) represents a very important aspect for the FBWM**,** it is use to check the consistence of the expert's pairwise comparisons. The CR is calculated as:

$$CR = \frac{\xi}{CI} \tag{5}$$

Where ξ is the optimal value resulting from the optimization model in step 4, and CI is a predefined consistency index. When the CR value is closer to 0, it indicates a perfect consistency in the expert's pairwise comparisons [18].

2.4. Performance Evaluation and Sensitivity Analysis

Following the calculation of the criteria weights derived from the FBWM, the final prioritizing of the strategic alternatives, which has been derived from the TOWS matrix, was carried out by creating a performance matrix. In order to calculate their global preference scores, the strategic alternatives were evaluated against the predetermined criteria. In addition, experts utilized linguistic terms (e.g., "high" and "very high") to assess alternative performance, as shown in table 3.

Table 3 Triangular fuzzy numbers (TFNs) for Performance evaluation of the alternatives

Linguistic Terms	**Abbreviation**	**Triangular Fuzzy Numbers**
Very Low	VL	(0, 0.1, 0.3)
Low	L	(0.1, 0.3, 0.5)
Medium	M	(0.3, 0.5, 0.7)
High	H	(0.5, 0.7, 0.9)
Very High	VH	(0.7, 0.9, 1)

Source: Compiled by the author based on Guo and Zhao, 2017

Furthermore, this evaluation is carried out in order to synthesize criteria weights with expert assessments, providing a systematic basis for prioritizing the strategic alternatives. Additionally, this process will help transforms subjective fuzzy inputs into a final ranking score. By utilizing equation 6.

$$Score\ i = \sum_{j=1}^{4} w_j \ \times r_{ij} \tag{6}$$

Where: i represents the final preference score.
w_j : is the weight of criterion.
r_{ij} : and is the performance rating of alternative.

This study investigates how the ranking of selected alternatives (sub-strategies) changes when the relative importance weights of the main criteria are modified; for this aim, we used a sensitivity analysis that follows the structure of FBWM. This analysis ensures the results are both robust and reliable for strategic implementation [19]. In this study, we use a -10% threshold for the weight of the most important criterion, C1 (Strategic Alignment).

All calculations, including fuzzy aggregation, defuzzification, weight computation, performance scoring, sensitivity analysis, and ranking, were implemented using Microsoft Excel with the Solver add-in.

3. Results and discussion

This section is organized into four primary subsections, the Identification of the TOWS alternative strategies, Analysis of Criteria Weights, Strategy Prioritization and Final Ranking and Robustness Verification (Sensitivity Analysis).

3.1. The Identification of the TOWS alternative strategies

Initially, in this study we used semi-structured interviews and a documents review of the Semarang University to identify SWOT factors, which were subsequently translated into Sub-strategies using the TOWS matrix. Moreover, this analytical study identified 24 IT sub-strategies, categorized into four distinct strategic axes: Strength-Opportunity, Weakness-Opportunity, Strength-Threat, and Weakness-Threat. Among these 24 alternatives it includes assertive digital expansions such as real-time financial integration, and also include defensive strategies for example filling important infrastructure positions which meant lower operational risks. The alternatives strategies are presented as TOWS matrix in Figure 2.

Figure 2 The alternative strategies presented in TOWS matrix

3.2. Analysis of Criteria Weights

To determine the weights of the main criteria, we used FBWM. Based on the aggregated expert inputs, Strategic Alignment C1 emerged as the best criteria (most significant), while Feasibility (C3) was selected as the worst criteria (least significant). Strategic Alignment received a weight of 0.565, meaning that the strategic priority aligned with the university's vision and long-term goals received more than half of the strategy weight. Expected Impact (C2) and Cost (C4) were considered equally important, each with a weight of 0.161. This finding indicates that the university must maintain a balance between expected benefits and financial resource requirements. Furthermore, Feasibility (C3) received the lowest priority with a weight of 0.113. Moreover, we test these findings by applying a consistency analysis to confirm their robustness; the model produces a Consistency Ratio (CR) of 0.000, indicating remarkable internal coherence in the experts' judgments. The weights for each criterion are presented in Table 4 and illustrated in Figure 3.

Table 4 Weights of the main criteria

Approach	Criteria Weights				CR
	C1	C2	C3	C4	
Proposed Fuzzy BWM	0.565	0.161	0.113	0.161	0.000

Source: Processed primary data, 2026

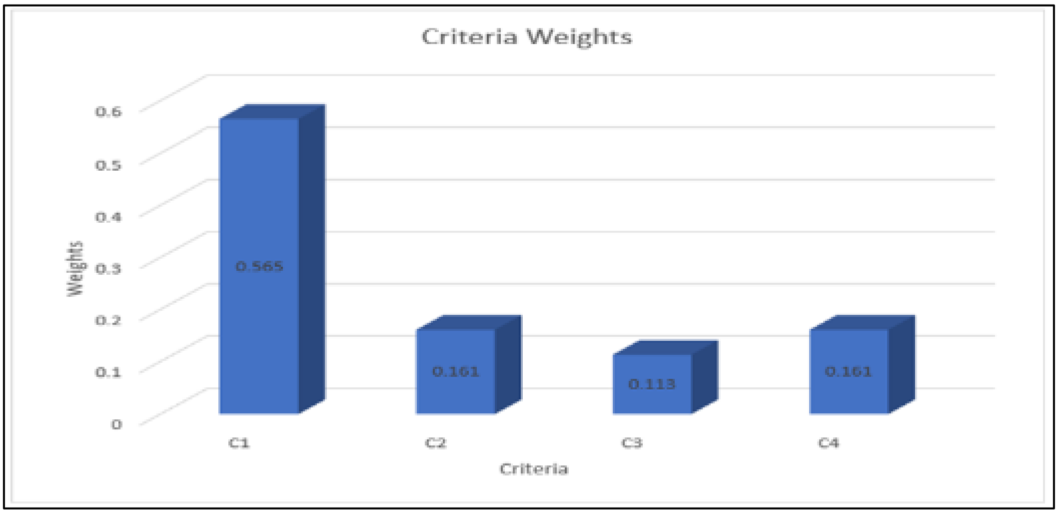

Figure 3 Comparative Analysis of criteria Weights

3.3. Strategy Prioritization and Final Ranking

In this section we combined the FBWM criteria weights with each normalized alternative's performance scores to generate a prioritized IT sub-strategies roadmap for Semarang University. With a score of 0.705, Enhanced Security Organization (ST6) took the highest ranking, this higher ranking points to the need for a security framework that can help span access control, patching, and monitoring to help safeguard Semarang University's integrated systems. Furthermore, Service-Based Disaster Recovery Plan (ST2) is placed second, with a score of 0.677, while Fill Critical Positions (WT1) comes in third at 0.674. this was followed closely by Peak Period Stabilization (WT2) (0.661), and Hardware & Access Fulfillment (WO5) (0.656). If we look to these top- tier result we can see clearly that these results indicate a clear institutional preference to help strengthening and enhancing the human resource stability and the operational resilience over the technical improvement. API Catalog & Versioning (WT3) comes last in the list by receiving the lowest score of 0.476, exhibiting the model's ability to prioritize critical structural requirements over less pressing optimization. The complete hierarchical ranking list of IT sub-strategic is presented in Table 5.

Table 5 Final aggregated scores & Ranking for all sub-strategies

Code	Strategy Name	Score	Ranking
SO1.	Real-Time Financial Integration.	0.639	9
SO2.	Automated Quality Evidence.	0.608	16
SO3.	Internal Public API.	0.6	17
SO4.	Two-Way Academic Validation.	0.61	15
SO5.	Self-Service Portal.	0.629	12
SO6.	High Availability/Disaster Recovery Across Data Centers.	0.589	18
WO1.	Core Integration Program – Wave 1.	0.646	7
WO2.	Web Content Governance.	0.577	20
WO3.	Technical Chapters & SOPs.	0.632	10

WO4.	IT Portfolio Accountability.	0.632	10
WO5.	Hardware & Access Fulfilment.	0.656	5
WO6.	Accreditation Automation.	0.612	14
ST1.	Layered Security Control	0.585	19
ST2.	Service-Based DRP (Disaster Recovery Plan).	0.677	2
ST3.	Centralized Compliance.	0.525	23
ST4.	Standardized Technology Stack.	0.643	8
ST5.	Load Surge Reduction.	0.549	22
ST6.	Enhanced Security Organization.	0.705	1
WT1.	Fill Critical Positions	0.674	3
WT2.	Peak Period Stabilization.	0.661	4
WT3.	API Catalog & Versioning.	0.476	24
WT4.	Access & Digital Literacy Equalization.	0.561	21
WT5.	Vendor & Cost Management.	0.652	6
WT6.	Data Growth Management	0.623	13

Source: Processed primary data, 2026

Figure 4 shows the rankings and the performance score of each sub-criterion.

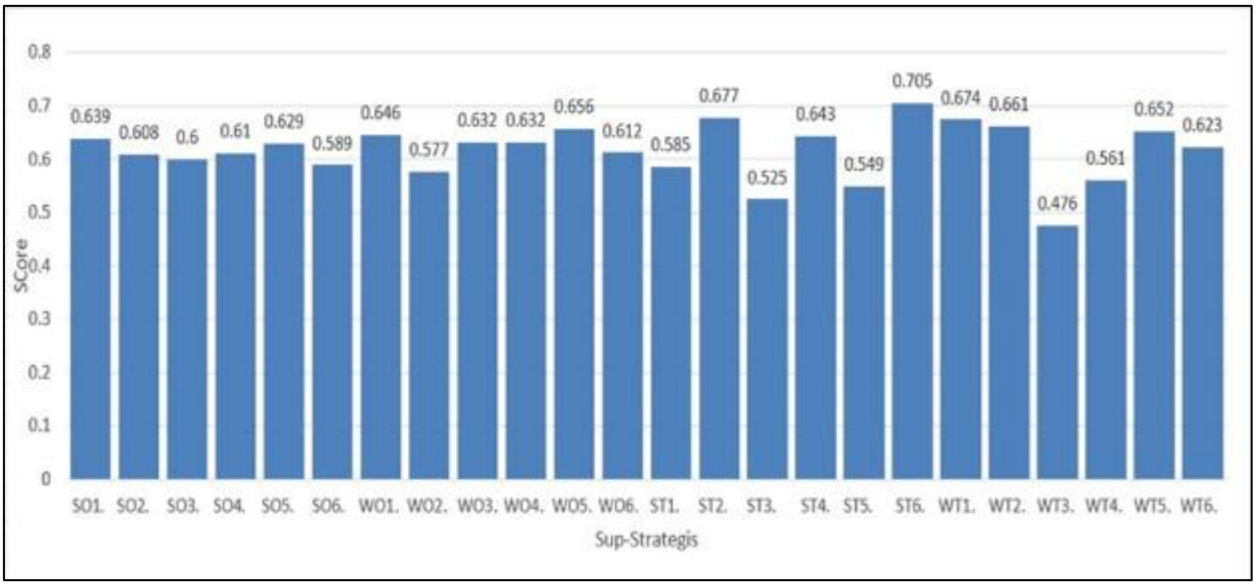

Figure 4 The rankings and the performance score of each sub-criterion

3.4. Robustness Verification (Sensitivity Analysis)

In order to evaluate the stability of the prioritization result, we conduct a sensitivity analysis by introducing a systematic perturbation of -10% to the main criteria weights. The analysis result demonstrated high robustness in the model's output. Although the performance scores saw slight variations due to the reduction in weight, the hierarchical ranking of the alternative remained mostly unchanged. The top sub-strategies priority (ST6, ST2, WT1, WT2, WO5) maintained their positions with "No change" statues. Furthermore, the analysis confirms that the strategy roadmap is robust against fluctuations in expert judgment and offers a dependable foundation for decision-making. Table 6 reports each sub-strategy's original score and rank, the score after a −10% perturbation.

Table 6 Sensitivity analysis of Sub-strategies (−10% perturbation)

Sup Strategy	Original Score	Ranking	Score After -10% decrease	New Ranking	Status
SO1.	0.639	9	0.633	9	(No Change)
SO2.	0.608	16	0.6	16	(No Change)
SO3.	0.6	17	0.596	17	(No Change)
SO4.	0.61	15	0.607	14	(Change)
SO5.	0.629	12	0.623	11	(No Change)
SO6.	0.589	18	0.585	18	(No Change)
WO1.	0.646	7	0.638	7	(No Change)
WO2.	0.577	20	0.572	20	(No Change)
WO3.	0.632	10	0.623	11	(No Change)
WO4.	0.632	10	0.624	10	(No Change)
WO5.	0.656	5	0.646	5	(No Change)
WO6.	0.612	14	0.604	15	(Change)
ST1.	0.585	19	0.58	19	(No Change)
ST2.	0.677	2	0.666	2	(No Change)
ST3.	0.525	23	0.523	23	(No Change)
ST4.	0.643	8	0.634	8	(No Change)
ST5.	0.549	22	0.543	22	(No Change)
ST6.	0.705	1	0.691	1	(No Change)
WT1.	0.674	3	0.663	3	(No Change)
WT2.	0.661	4	0.65	4	(No Change)
WT3.	0.476	24	0.478	24	(No Change)
WT4.	0.561	21	0.557	21	(No Change)
WT5.	0.652	6	0.642	6	(No Change)
WT6.	0.623	13	0.614	13	(No Change)

Source: Processed primary data, 2026

4. Conclusion

In conclusion, this study successfully employed a hybrid SWOT–Fuzzy BWM to prioritize information technology strategies at Semarang University, Indonesia. The methodology effectively transformed expert linguistic assessments into quantifiable data. The study yielded valuable insight; representing more than half of the sub-strategies' weights, strategic alignment is the most effective criterion. The main finding of the study can be summarized as follows: first, the optimal IT sub-strategies are enhanced security organization, a service-based disaster recovery plan, filling critical positions, peak period stabilization, and hardware & access fulfillment. Second, consistency ratio and sensitivity analyses confirm the robustness of the results. The proposed methodology can be used as a roadmap by other academic institutions looking to close the gap between complex environmental analysis and actionable IT governance.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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