Journal of Applied Data Sciences
Vol. 5, No. 4, December 2024, pp. 1963-1976

Fuzzy SAW Based Decision Model for Determining the Priority Scale of ICT Handling in Public Sector Organizations

Rissa Yulanda[1,*], Ditdit Nugeraha Utama[2]

[1,2]*Computer Science Department-BINUS Graduate Program-Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480*

(Received: July 20, 2024; Revised: August 24, 2024; Accepted: September 13, 2024; Available online: November 7, 2024)

Abstract

Determining the priority of handling information and communication technology (ICT) infrastructure in public sector organizations can help them take the right actions in maximizing limited budgets, to handle technical maintenance, improve human resource (HR) capabilities and governance of ICT infrastructure. The purpose of this research is to develop a decision-making model that is able to determine the priority of handling ICT, especially in public sector organizations. Decision support modeling (DSM) with Fuzzy Simple Additive Weighting (Fuzzy SAW) method is used to build a computer model that supports decision making in this case. The study consists of four stages, which are an integral part of the Fuzzy SAW-based DSM process. These stages include analyzing the case, determining parameters, collecting data and building the model. This study produces a Fuzzy SAW-based DSM consisting of 14 parameters, namely governance, number of internet users, number of ICT managers, work experience of ICT managers, bandwidth service capacity, router device age, educational background of ICT managers, network firewalls, network maintenance, server room availability, Network Attached Storage (NAS) storage devices, neatly organized cable devices, adequate electrical resources and internet connection backup networks, to determine the priority ranking of 34 existing alternatives. The final result of this research is a Fuzzy SAW-based DSM that is able to provide a priority score for handling ICT infrastructure in Public Sector Organizations. The findings in this model show that the parameter weights affect the final score of the model. Thus, the conclusion of this research is that the model has been successfully implemented, making a significant contribution in providing guidance on determining accurate ICT infrastructure handling for public sector organizations.

Keywords: Decision Support Model, Fuzzy Simple Additive Weighting, Public Sector Organizations; Priority Scale, Information and Communication Technology

1. Introduction

The effectiveness of Information and Communication Technology (ICT) is often hampered by many non-technical factors that are not prepared by government organizations [1]. Starting from the maturity level of managers, ICT hardware, and even maintenance techniques [2]. Currently, public sector organizations have made a number of technology integration efforts to improve efficiency, transparency and quality of public services [3]. A robust ICT infrastructure is one of the pillars of successful implementation of e-Government and other digital services offered by the government [4]. Central level government organizations in carrying out their duties throughout the province are represented by the existence of branch offices in each province. This representation is to support the implementation of tasks and functions carried out by the Organization. There are 34 branch offices spread throughout the province. The implementation of digital transformation is highly dependent on the utilization of ICT. A very vital role to support the implementation of the tasks and functions of the organization [5]. The effectiveness of ICT implementation in government organizations needs more attention, given its central role in the process of making managerial or other decisions. To increase the use of ICT, which will clearly affect the effectiveness of achieving business processes carried out by government organizations. The factors that affect effectiveness mention other potential factors that can affect the priority of handling ICT, one of which is the effort to maintain the stability and connectivity of the internet network is through continuous maintenance of ICT Infrastructure updates [6]. Proper maintenance not only ensures smooth service, but also prevents vulnerability to cyber-attacks and other security risks [7]. The implementation of tasks and

***Corresponding author: Rissa Yulanda (rissa.yulanda@binus.ac.id)**
DOI: https://doi.org/10.47738/jads.v5i4.419

ISSN 2723-6471

functions requires adequate handling of ICT infrastructure. But of course, it requires a lot of budgets. Head office leaders need comprehensive data-based insights to decide which branch offices are prioritized first for ICT infrastructure handling. With such a limited budget, it is necessary to find a method that can determine which branch offices need priority for ICT Infrastructure Handling in technical maintenance, improving Human Resources (HR) capabilities and governance.

To overcome this challenge, the use of a decision support model (DSM) can be an effective solution [8]. DSM is a method that uses data analysis principles and algorithms to assist decision making. By utilizing DSM, it can process fuzzy and non-fuzzy parameters that become decision-making factors into data that has weights and values so that decision makers in the Organization can gain a better analytical understanding of which branch office ICT Infrastructure handling requires more attention, so that they can allocate budgets, resources and time effectively and efficiently. The main objective of this research is to provide priority options for handling ICT infrastructure to branch offices. Fuzzy SAW method was chosen because of its ability to handle qualitative and quantitative data. When the assessment of criteria cannot be expressed with certainty, fuzzy methods can overcome uncertainty and the method is simpler so that the calculation process is faster than using the AHP and TOPSIS methods [9], [10]. Furthermore, SAW is used to produce a final judgment by summing up the predetermined weights for each criterion. [11]. After that the results of the calculation are ranked with the aim of getting the highest priority. So that the data generated by this model can be a reference for the head of the head office in allocating the budget effectively and efficiently and on target.

Then the selection of parameters in the model is based on empirical research and practical considerations. The level of governance maturity is one of the important factors [12], as it reflects the extent to which the organization is able to manage resources effectively and anticipate challenges that may arise. In addition, network maintenance is another important factor because it is directly related to the sustainability and reliability of the system. Research [13] shows that poor maintenance causes frequent disruptions, longer downtime, and potentially significant financial losses for organizations due to decreased productivity.

Several studies have been conducted in decision making with different topics. In research [14] developed Fuzzy SAW-based DSM to design a decision support system to determine the best employee. Where the decision results are taken from the best score value. While the difference with this study, the priority of handling ICT infrastructure actually prioritizes the worst value of the existing condition of ICT. So that support is given so that it can increase to an adequate condition. Furthermore, in the second study [15] the research used a fuzzy multi-criteria method (MCDM) for optimizing asset maintenance priorities. This model also uses type-2 fuzzy AHP which is based on pairwise comparisons used to measure criteria weights and shows a 10% tolerance for inconsistent assessments. Then research [16], Decision Making Model combines TOPSIS and SAW methods to Secure IoT devices in Smart Industries. Simulation results show that the proposed model achieves an increased success rate of 85%. Furthermore, in research [17], Decision support system in determining the priority of disaster mitigation infrastructure development at the village level using SAW method. Based on the results of the analysis using the SAW method, it shows that the priority of infrastructure development is the village of Inderapura Selatan with a priority value of 10. The results showed that the SAW method has simple and few calculations. Therefore, the SAW method is suitable for use in the decision-making process, especially with predetermined criteria weights and rating scales, and ease of application is its main advantage.

Finally, there is research with a similar topic, conducted by researchers [18], by adopting Fuzzy AHP to evaluate the performance of ICT centers. This study concluded that the important criteria for Telecenter evaluation in this study are based on several factors, such as general training, specialized training, cultural services, social services, government services, and other services. Based on Fuzzy AHP analysis, it was found that general training and cultural services are the most significant criteria in evaluating Telecenter performance.

In contrast to previous studies, this research combines two different aspects, namely the evaluation of HR capabilities and the hardware asset aspect of ICT devices, so it is not only reviewed from one side. In addition, there is no research that discusses the priority of handling ICT infrastructure in government agencies, so this is a new step that contributes to enriching the literature.

ISSN 2723-6471

2. The Proposed Method

2.1. DSM

From the literature study conducted [19], DSM is a method designed to support the decision-making process that can be modified by providing relevant information, assessments, or recommendations. DSM can help a modeler make the right decision in situations that have many choices. As stated by [20], defining DSM as a system designed to guide decision makers in situations that are not fully structured by integrating data, model structures, and human thinking logic. According to [21] the model in DSM is a replica of reality presented with the number of parameters and the values and rules attached to it. Then from research [22] explains that DSM applies a series of techniques and tools, including data mining, knowledge-based systems, and artificial intelligence, to provide the best alternatives or suggestions in a variety of business or organizational contexts. Thus, designing and implementing decision support models is essential to help entities or individuals overcome challenges and uncertainties when making decisions. Although it can provide decision alternatives, DSM itself is not intended to take over the decision-making process to be automated. Instead, it provides the decision maker with an interactive model that can generate a variety of decision analyses.

2.2. SAW

The SAW method is an approach to decision making that is used to evaluate and select the most optimal alternative from a number of predetermined criteria. In this method, each criterion has a certain weight that reflects its level of importance. Each alternative is rated on each criterion, multiplied by its weight, and the results are summed to get a total value that reflects the relative performance of each alternative. The alternative with the highest total value is considered the best alternative [23]. Described in research [24] the SAW method is also known as the weighted sum method. The basic concept of the SAW method is to find the weighted sum of the performance ratings on each alternative from all attributes with the steps of the SAW method as follows: For the first step, a decision matrix Z of size $m \times n$ is created, where m are alternatives, and n are criteria. Then given the x value of each alternative (i) on each criterion (j) that has been determined, where, i = 1,2, ... m and j = 1,2, ... n in the Z decision matrix. Where Z = decision matrix xij = alternative value against criteria, i = alternative, j = criteria as in (1) The next step is given the value of the preference weight (W) on each criterion that has been determined, by the decision maker where: j = criteria as in (2)

$$\boldsymbol{Z} = \begin{bmatrix} x_{11} & x_{12} & x_{1j} \\ \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & x_{ij} \end{bmatrix} \tag{1}$$

$$W = [W1\ W2\ W3\ldots\ Wj] \tag{2}$$

After that, normalize the decision matrix (Z) by calculating rij (normalised performance rating value) of Ai (alternative) on the attribute. The SAW method recognises the existence of 2 (two) attributes, namely benefit criteria and cost criteria. Which if benefit means the largest value is the best and cost means if the smallest value is the best. Can be seen with (3), with rij referring to the normalized performance rating. Here, 'i' represents alternatives while 'j' represents attributes. '*Xij*' signifies the specific value of the *i-th* alternative on the *j-th* attribute. In such data sets, '*Max Xij*' is the highest value that can be found for *Xij*, while '*Min Xij*' is the lowest value. After getting the normalized performance rating or rij, the normalized performance rating result value (rij) forms a normalized matrix (N) as in (4).

$$r_{ij} = \left\{ \begin{matrix} \frac{X_{ij}}{Max_i X_{ij}} \\ \frac{Min_i X_{ij}}{X_{ij}} \end{matrix} \right\} \begin{matrix} \text{if j is cost} \\ \text{if j is benefit} \end{matrix} \tag{3}$$

$$\boldsymbol{N} = \begin{bmatrix} r_{11} & r_{12} & r_{1j} \\ \vdots & \ddots & \vdots \\ r_{i1} & r_{i2} & r_{ij} \end{bmatrix} \tag{4}$$

Furthermore, the assessment process is carried out by multiplying the normalised matrix (N) by the preference weight value (W). Then, a preference value is given for each alternative (Vi) by summing the product of the normalised matrix

(N) with the preference weight value (W). where Vi = preference value for each alternative, Wj = preference weight rij = normalised matrix performance rating. A greater Vi value indicates that alternative Ai is the best alternative (5).

$$\mathrm{v_i} = \sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{w_i r_{ij}} \tag{5}$$

2.3. Fuzzy SAW

Fuzzy set is a set whose members have certain degrees of membership determined by a certain membership function or also called a characteristic function. This model is based on the generalization of the concept of a classic set and its characteristic function, namely by only taking the value 0 or 1 [24]. The combined fuzzy SAW method was developed from a combination of SAW and fuzzy logic as an analytical method. The difference is the application to the value of the comparison matrix, represented by the 3 alphabets a, b, c called triangular fuzzy numbers (TFNs).

In applications, it is often easier to work with (TFNs) due to their computational simplicity, and are useful in representing and processing information in fuzzy environments [25]. TFNs can be defined as a triplet (a, b, c) where a ≤ b ≤ c, with variable a being the bottom (lowest) value, variable b being the middle value and variable c being the top. TFNs in the SAW method is a series of patterned actions used to minimize uncertainty in the SAW scale in the form of crisp values, by fuzzing the SAW scale so that a new scale is obtained, namely the F-SAW scale. The steps for completing the Fuzzy SAW method are as follows [26], In the evaluation process, the experts gave an assessment rating of the criteria in the form of linguistic variables as in table 1.

Table 1. Fuzzy Numbers and linguistic variables

Linguistic Variable	Code	Fuzzy Number
Very Low	VL	(0.0, 0.0, 0.1)
Low	L	(0.0, 0.1, 0.3)
Medium Low	ML	(0.1, 0.3, 0.5)
Medium	M	(0.3, 0.5, 0.7)
Medium High	MH	(0.5, 0.7, 0.9)
High	H	(0.7, 0.9, 1.0)
Very High	VH	(0.9, 1.0, 1.0)

Each criterion is rated using terms that describe the level of suitability, such as 'very poor', 'poor', 'fair', 'good', and 'excellent'. The next step is to convert the judgements in the suitability rating table into fuzzy numbers. This conversion process aims to convert linguistic variables into numerical values that can be used in further analysis. Then to determine the weight value (W), according to (2), calculate the average value of fuzzy numbers, defuzzification values, and normalized weights of each criterion. In determining the value of W is to calculate the average value of fuzzy numbers, using (6). where Ajk = average value of fuzzy numbers, f j k n = fuzzy numbers for each criterion in each alternative and n, m = number of numbers in TFNs. The next step is to calculate the defuzzification value a = smallest fuzzy number, b = middle fuzzy number, c = largest fuzzy number 3 = number of fuzzy numbers using (7). To calculate the normalised weight using the where Wi= weight for criterion i, ei = defuzzification value of criterion i as (8).

$$\mathrm{Ajk} = \frac{(\mathrm{f^k_{j1} f^k_{j2} \ldots f^k_{jn}})}{\mathrm{n}}\text{; j =1,2,..m; k=1,2..n;} \tag{6}$$

$$e = \frac{(a + b + c)}{3} \tag{7}$$

$$W_i = \frac{ei}{\sum_{i=1}^{n} ei} \tag{8}$$

ISSN 2723-6471

Furthermore, the preference value for each alternative (Vi) is determined by summing up the product of the normalised matrix (N) with the preference weight value (W) according to (5). Then, the final value becomes the rank order to be chosen as the best alternative decision.

3. Methodology

3.1. Algoritm Model

The model algorithm illustrates each important step in the evaluation and calculation process, from parameter and weight inputs, data transformation, to SAW calculations that result in the final evaluation. This diagram provides a clear visual guide on how the Fuzzy SAW-based DSM method is applied in the research context to assess alternatives based on certain parameters [27]. Furthermore, collecting data from experts through questionnaires to obtain an assessment of the weight of each parameter [28]. The experts were selected based on their positions as Head of Data Division and Information System Development and ICT Experts of the company. The assessment obtained from the expert questionnaire is then used to calculate the parameter weights using the Fuzzy SAW method. The results of the parameter weight calculation are stored for use in the next stage. Data collection was carried out by questionnaire method to each ICT manager in 34 branch offices. with 100% response from ICT managers in each branch. The questionnaire has been tested for reliability using the data validation method with results that reflect the condition of the entire organization in accordance with field conditions.

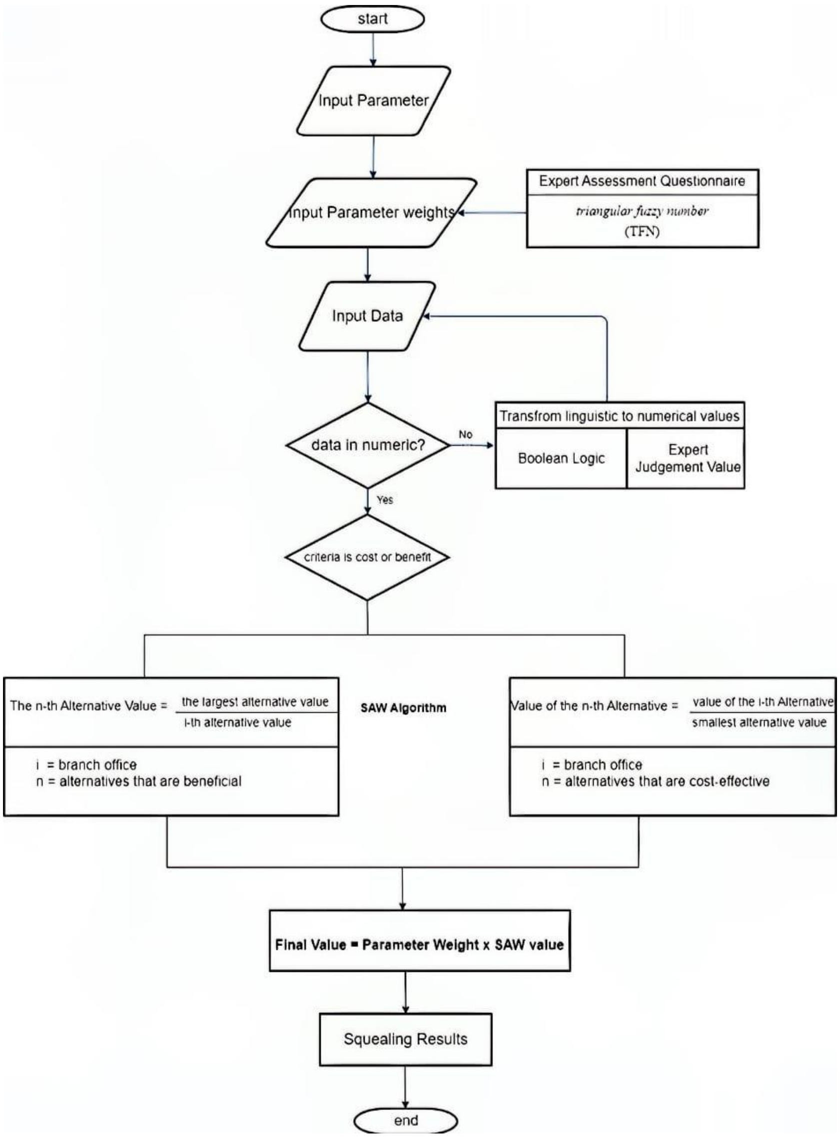

Figure 1. Algorithm Model

MOThe SAW method recognizes the existence of 2 (two) properties, namely benefit and cost. Which if benefit means the largest value is selected and cost means if the smallest value is selected to be prioritized. The filled data is further processed by classifying the nature of each data, whether as “Cost” or “Benefit” and also checking whether the input data is numeric or linguistic. If the data is not numerical, then a transformation from linguistic data to numerical values is performed using Boolean logic and expert judgment values. Linguistic data is converted into numerical values based on Boolean logic and expert judgment. As in example P8, in the parameter data, there is a choice of data worth There is a Firewall and There is No Firewall. The Boolean Value assignment on the data There is a Firewall is given a numerical value of 1, and otherwise it is given a numerical value of 0. After the data is in numerical form, the system will check whether the parameter is cost or benefit. If the parameter is cost, the parameter value is calculated by the formula: *Nth Parameter* Value = i-th Parameter Value/Lowest Parameter Value, where *i* is the branch office and *n* is the cost parameter. If the parameter is a benefit, the parameter value is calculated by the formula*: Nth Parameter Value = Largest Parameter Value / Ith Parameter Value*, where *i* is the branch office and *n* is the benefit parameter. Then the next step, from the SAW calculation results, each parameter is multiplied by the parameter weight. The results of this final calculation are then used to determine the ranking of each branch office. The calculation process is complete and the final result in the form of a ranking of each branch office can be used for decision making. The model algorithm is presented in figure 1.

3.2. Parameterizing

The Fuzzy SAW method in its process requires parameters that will be used as calculations for the process of determining the priority scale for handling ICT Infrastructure. Each parameter is given a certain code to make it easier to identify and process. In this study, there are fourteen parameters that need to be described as shown in table 2.

Table 2. Parameters

Parameters	Code	Parameters	Code
Information security maturity score	P1	Network Firewall	P8
Number of Internet Users	P2	Network Maintenance	P9
Number of ICT Managers	P3	Server Room Availability	P10
ICT Manager Work Experience	P4	NAS Storage Device	P11
Bandwidth Service Capacity	P5	Well-organised Cable Device	P12
Age of Router Device	P6	Adequate Electrical Power Source	P13
Educational Background of ICT Manager	P7	Backup Network Internet Connection	P14

3.3. Data Sets

The dataset used in this study was collected by distributing online questionnaires using the Google Forms platform to obtain the results of identifying the condition of the ICT infrastructure of each branch office. The data collected was filled in by all branch office ICT managers. A total of 34 branch offices each have diverse conditions of 14 parameters. The collected data is presented in table 3 (here mentioned 6 six branch office examples of 34).

Table 3. Alternatives and parameters dataset

Alter.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
A1	27	180	1	4	250	8	3	0	1	1	1	5	2	0
A2	44	150	2	3	600	8	5	0	3	1	1	5	4	1
A3	29	100	1	5	520	5	5	0	2	1	0	3	5	1
…	…	…	…	…	…	…	…	…	...	…	…	…	…	…
A32	58	178	1	13	50	3	5	0	3	1	1	5	4	0
A33	53	186	2	4	250	2	5	0	3	1	1	5	2	0

A34	49	275	1	2	150	2	5	1	3	1	0	5	3	1

3.4. Fuzzy Saw-based DSM Construction

Based on the stages of the model algorithm, the first step is done first by giving the weight of the level of importance to each parameter calculated using the Likert scale expert judgment method. This process involves the judgment of five experts who assign importance values to each parameter that has been determined. The experts used a linguistic variable scale consisting of seven levels: Very Low (VL) with range (0.0.0.1), Low (L) with range (0.0.1.0.3), Medium Low (ML) with range (0.1.0.3.0.5), Medium (M) with range (0.3. 0.5.0.7), Medium High (MH) with range (0.5.0.7.0.9), High (H) with range (0.7.0.9.1), and Very High (VH) with range (0.9.1.1). Membership Function (MF) of TFN parameter importance ranges from 0.0 to 1. On the graph, each line is triangular or trapezoidal, which shows how a particular input value has a degree of membership in a category as presented in figure 2.

Then based on the results of interviews conducted with five experts using a Likert scale, the parameter ratings are shown in table 4. The interview process involved assessments from experts who have in-depth expertise and experience in fields relevant to this research. It aims to evaluate various important aspects of these parameters. Each parameter, ranging from P1 to P14, reflects important aspects of the ICT infrastructure. Based on expert judgment, these parameters were prioritized for analysis in further research. For example, for parameter P1 possibly related to infrastructure accessibility, all experts gave it a rating of VH (very important), indicating collective agreement on its priority.

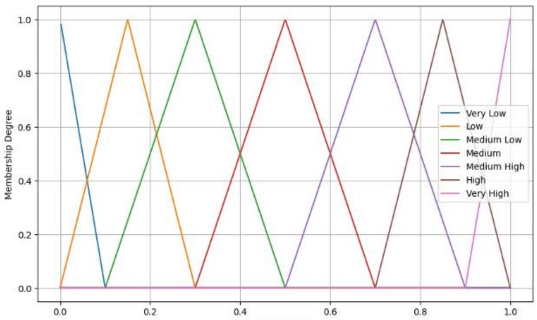

Figure 2. Membership function TFN parameter importance

After obtaining the parameter weight value, the next step is to process the parameter data based on the conditions at 34 branch offices. To facilitate the presentation of data, it is necessary to code each alternative at the branch office. This also helps in avoiding errors and confusion that might occur if only using regional names. The following provides the codification of branch offices across all provinces in Indonesia (ranging from A1 to A34). The specific names of the branch offices are withheld for confidentiality reasons.

Table 4. Rating parameters with linguistic variables

Parameters	Experts					Parameters	Experts				
	E1	E2	E3	E4	E5		E1	E2	E3	E4	E5
P1	VH	VH	VH	VH	VH	P8	VH	M	VH	VH	H
P2	H	ML	VH	MH	MH	P9	H	MH	VH	VH	VH
P3	MH	H	VH	VH	VH	P10	VH	M	VH	H	H
P4	H	H	VH	MH	H	P11	VH	M	H	H	MH
P5	H	MH	MH	H	H	P12	H	H	VH	VH	H
P6	H	M	VH	H	H	P13	H	MH	VH	VH	VH
P7	VH	M	H	VH	VH	P14	VH	ML	VH	VH	H

4. Results and Discussion

4.1. Fuzzy Saw-based DSM Construction Result

The first stage carried out in the Fuzzy Saw-based DSM calculation process is to calculate the weight of each parameter. With reference to table 2, parameter weights are obtained from the results of a Likert scale questionnaire to experts. Then the linguistic data is translated into TFNs as shown in Table 6. This conversion is important to convert qualitative data into quantitative data that can be further processed in mathematical analysis. The parameter weights are obtained through a systematic process starting with the determination of the initial weights based on expert judgment which then calculates the average fuzzy score of the assessment results represented by TFN. After that, a defuzzification process is carried out to convert the fuzzy numbers into crisp or firm values, which represent the concrete weights of each parameter. The last stage is normalization, where the calculated weights are converted into a certain scale (usually between 0 to 1) to make the results more measurable and relevant. With the parameter weights that have been obtained through this process, the results are more stable and ready to be used in statistical analysis or decision-making. This process ensures that each parameter under consideration is properly weighted based on its relative contribution, resulting in more accurate and data-driven conclusions or decisions.

With reference to table 5, the fuzzy decision matrix shown in table 6 can be calculated. This matrix presents the experts' assessments of various parameters using TFNs values. Each parameter is rated by five experts (E1, E2, E3, E4, and E5), and each rating is given in the form of triplets representing the minimum value, probable value, and maximum value (TFN). For example, for parameter P1, all experts gave consistent ratings with triplets (0.9, 1, 1). On the other hand, parameter P2 showed greater variation in the experts' ratings, with E1 and E3 giving high values (0.9, 1, 1), while E2 gave lower values (0.1, 0.3, 0.5). Other parameters such as P3 and P4 also show variations in expert judgment. For example, P3 had high scores from most experts, while P4 showed more varied assessments with scores ranging from (0.5, 0.7, 0.9) to (0.9, 1, 1). The process of converting the experts' judgments into TFN form allows the integration of multiple perspectives and accommodates the uncertainty in their judgments.

Table 5. Linguistic variables and fuzzy numbers

Linguistic Variable	Code	Fuzzy Number
Very Low	VL	(0.0, 0.0, 0.1)
Low	L	(0.0, 0.1, 0.3)
Medium Low	ML	(0.1, 0.3, 0.5)
Medium	M	(0.3, 0.5, 0.7)
Medium High	MH	(0.5, 0.7, 0.9)
High	H	(0.7, 0.9, 1.0)
Very High	VH	(0.9, 1.0, 1.0)

Table 6. TFNs parameter matrix

Par.	Experts														
		E1			E2			E3			E4			E5	
P1	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)
P2	(0.7	0.9	1.0)	(0.1	0.3	0.5)	(0.9	1.0	1.0)	(0.5	0.7	0.9)	(0.5	0.7	0.9)
P3	(0.5	0.7	0.9)	(0.7	0.9	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)
P4	(0.7	0.9	1.0)	(0.7	0.9	1.0)	(0.9	1.0	1.0)	(0.5	0.7	0.9)	(0.7	0.9	1.0)
P5	(0.7	0.9	1.0)	(0.5	0.7	0.9)	(0.5	0.7	0.9)	(0.7	0.9	1.0)	(0.7	0.9	1.0)
P6	(0.7	0.9	1.0)	(0.3	0.5	0.7)	(0.9	1.0	1.0)	(0.7	0.9	1.0)	(0.7	0.9	1.0)
P7	(0.9	1.0	1.0)	(0.3	0.5	0.7)	(0.7	0.9	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)

P8	(0.9	1.0	1.0)	(0.3	0.5	0.7)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.7	0.9	1.0)
P9	(0.7	0.9	1.0)	(0.5	0.7	0.9)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)
P10	(0.9	1.0	1.0)	(0.3	0.5	0.7)	(0.9	1.0	1.0)	(0.7	0.9	1.0)	(0.7	0.9	1.0)
P11	(0.9	1.0	1.0)	(0.3	0.5	0.7)	(0.7	0.9	1.0)	(0.7	0.9	1.0)	(0.5	0.7	0.9)
P12	(0.7	0.9	1.0)	(0.7	0.9	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.7	0.9	1.0)
P13	(0.7	0.9	1.0)	(0.5	0.7	0.9)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.9	1.0	1.0)
P14	(0.9	1.0	1.0)	(0.1	0.3	0.5)	(0.9	1.0	1.0)	(0.9	1.0	1.0)	(0.7	0.9	1.0)

From the results of the parameter matrix, it can be seen that the evaluation results from each expert have a range of fuzzification values ranging from 0.1 to 1. Then for each parameter, the average fuzzy score value is calculated according to equation (6). An example of the results of calculating the average value of the fuzzy score on P1 gives the results (0.9, 1 and 1). Similar calculations are applied to all other parameters, from P1 to P4. After obtaining the defuzzification value of each parameter, the next step is normalization on each parameter from P1 to P14 using equation (8). This normalization aims to convert various parameter values into the same scale, so that they can be compared directly and more easily analyzed. The results of the normalization calculation on P1 obtained a value of 0.082, namely by dividing the defuzzification value of each parameter by the total defuzzification value. for the weight results on each parameter can be seen in table 7.

Table 7. Parameter weight

Code	Average fuzzy Scores (Ajk)			Defuzzied value (e)	Normalized Weight (Wj)
P1	0.90	1.00	1.00	0.967	0.082
P2	0.54	0.72	0.86	0.707	0.060
P3	0.78	0.92	0.98	0.893	0.075
P4	0.70	0.88	0.98	0.853	0.072
P5	0.62	0.82	0.96	0.800	0.067
P6	0.66	0.84	0.94	0.813	0.069
P7	0.74	0.88	0.94	0.853	0.072
P8	0.74	0.88	0.94	0.853	0.072
P9	0.78	0.92	0.98	0.893	0.075
P10	0.70	0.86	0.94	0.833	0.070
P11	0.62	0.80	0.92	0.780	0.066
P12	0.78	0.94	1.00	0.907	0.076
P13	0.78	0.92	0.98	0.893	0.075
P14	0.70	0.84	0.90	0.813	0.069

Next, from the numerical values of the parameters, the SAW algorithm equation (3) is calculated. For example, A1 results in SAW value P1 of 0.111 P2 0.040 P3 0.5 and so on until P14. This calculation process is done for each alternative. The results of the SAW algorithm calculation on each alternative can be seen in table 8 (only 6 out of the 34 branch offices are mentioned here as examples).

Table 8. SAW Algorithm calculation results

Alter.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
A1	0.111	0.604	1.000	0.500	0.040	1.000	1.000	1.000	1.000	0.000	0.000	0.200	0.500	1.000
A2	0.068	0.503	0.500	0.667	0.017	0.027	0.600	1.000	0.333	0.000	0.000	0.200	0.250	0.000
A3	0.103	0.336	1.000	0.400	0.019	0.017	0.600	1.000	0.500	0.000	1.000	0.333	0.200	0.000
…	…	…	…	…	…	…	…	…	…	…	…	…	…	….
A32	0.052	0.597	1.000	0.154	0.200	0.010	0.600	1.000	0.333	0.000	0.000	0.200	0.250	1.000

A33	0.057	0.624	0.500	0.500	0.040	0.007	0.600	1.000	0.333	0.000	0.000	0.200	0.500	1.000
A34	0.061	0.923	1.000	1.000	0.067	0.007	0.600	0.000	0.333	0.000	1.000	0.200	0.333	0.000

Then the next step, from the SAW calculation results, each parameter is multiplied by the parameter weight according to equation (5). This calculation process begins by multiplying the value of each parameter of the alternative by the parameter weight. For example, for alternative A1, the value of parameter P1 is 0.111, which is then multiplied by the weight of P1 of 0.082, resulting in a value of 0.009102. This process is repeated for each parameter and alternative. After all parameter values are multiplied by their weights, the next step is to add up all the multiplied values to get a total value for each alternative. This total value is an aggregate that reflects the overall score of each alternative based on all parameters that have been taken into account. For example, the total value for alternative A1 is 0.591 which shows the cumulative score of the alternative. The final score results for A1 to A34 are shown in table 9 (here mentioned only six examples).

Table 9. Weight multiplication result with SAW algorithm

Alter.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**Total Score**
Weight	0.082	0.060	0.075	0.072	0.072	0.069	0.072	0.072	0.075	0.070	0.066	0.076	0.075	0.069	1.000
A1	0.111	0.385	1.000	1.000	0.040	1.000	1.000	1.000	1.000	0.000	0.000	0.200	0.500	1.000	0.591
A2	0.068	0.923	0.500	0.500	0.017	0.027	0.600	1.000	0.333	0.000	0.000	0.200	0.250	0.000	0.312
A3	0.103	0.800	1.000	1.000	0.019	0.017	0.600	1.000	0.500	0.000	1.000	0.333	0.200	0.000	0.465
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
A32	0.052	0.077	1.000	1.000	0.200	0.010	0.600	1.000	0.333	0.000	0.000	0.200	0.250	1.000	0.414
A33	0.057	0.385	0.500	0.500	0.040	0.007	0.600	1.000	0.333	0.000	0.000	0.200	0.500	1.000	0.366
A34	0.061	0.231	1.000	1.000	0.067	0.007	0.600	0.000	0.333	0.000	1.000	0.200	0.333	0.000	0.346

Furthermore, the final value for each alternative that has been calculated is sorted to determine the priority ranking for handling ICT infrastructure at branch offices. Thus, it allows decision makers to identify which branch offices need more attention for resource allocation, training planning, HR coaching, maintenance and development of strategies to improve the quality of ICT services at each branch office. The final score ranking of each branch office can be seen in table 10.

Table 10. Priority ranking score results

Alternative Code	**Score**	**Rank**	**Alternative Code**	**Score**	**Rank**
A1	0.591	1	A25	0.402	18
A18	0.534	2	A17	0.395	19
A9	0.531	3	A33	0.366	20
A23	0.507	4	A16	0.359	21
A24	0.479	5	A34	0.346	22
A5	0.476	6	A7	0.344	23
A6	0.474	7	A21	0.340	24
A3	0.465	8	A11	0.314	25
A30	0.460	9	A2	0.312	26
A27	0.442	10	A4	0.302	27
A14	0.431	11	A10	0.296	28
A22	0.426	12	A28	0.280	29
A15	0.424	13	A12	0.245	30

A32	0.414	14	A26	0.233	31
A29	0.410	15	A8	0.220	32
A31	0.409	16	A19	0.219	33
A13	0.405	17	A20	0.218	34

From table 10 it can be seen that the first priority in handling ICT infrastructure is the A1 with a priority score of 0.591. This shows that the A1 is considered the most urgent area for handling ICT infrastructure, according to the parameter assessment that has been done. Then the second priority is the A18 with a priority score of 0.534 and the third priority is the A9 with a priority score of 0.531 So then the handling of ICT infrastructure is carried out at each priority order of each branch office.

4.1.1. Sensitivity Analysis

This sensitivity analysis aims to explore how changes in the values of the parameters in the model can affect the ranking results. The model consists of several parameters whose weights are assigned according to their respective importance levels as explained in chapter 3.4. In this analysis, we tested changing the cost/benefit values and weights of parameters P8 and P11 that have an impact on the ranking. In parameters P8 and P11, the cost value was changed to benefit, and the weight of P8 of 0.075 was replaced with the weight of P11 of 0.66. The end result shows a change in ranking, where the first rank originally occupied by A1 changed to A5 with a score of 0.617, while the second rank originally A18 changed to A1 with a score of 0.594. This confirms that input changes can affect the rise and fall of rankings in the Fuzzy SAW-based DSM model.

4.1.2. Model Validation

Model validation is carried out by comparing the model with field conditions (real) using equation (9) There are two aspects of concern in the validation stage. First, comparing the number of parameters used in the model with those applicable in the field and their values. Second, comparing the final results produced by the model with the field conditions. Then, the same scoring system as the verification process will be applied, where if the two results match, it is worth 1. Whereas if they do not match, it is worth 0. For the validation result of each parameter from P1 to P14, it is displayed with a column indicating whether the parameter matches the model and real data. All parameters (P1 to P14) received a check mark in the Model and Real columns, indicating that each parameter in the model matches the real data. The verification value (VaTi) for each parameter is 1.0, indicating a full fit between the model and the real data. The average verification value (Va) of all parameters is 1.0, indicating that the developed model is highly accurate and fully matches the real data. As presented in table 11.

$$\mathrm{Va} = \frac{\sum_{1}^{n} \mathrm{VaTi}}{\mathrm{n}} \tag{9}$$

Table 5. Model validation

Parameter	Model	Real	VaTi
P1	✓	✓	1.0
P2	✓	✓	1.0
P3	✓	✓	1.0
P4	✓	✓	1.0
P5	✓	✓	1.0
P6	✓	✓	1.0
P7	✓	✓	1.0
P8	✓	✓	1.0
P9	✓	✓	1.0
P10	✓	✓	1.0
P11	✓	✓	1.0
P12	✓	✓	1.0

P13	✓	✓	1.0
P14	✓	✓	1.0
	Va		**1.0**

4.2. Discussion of Results

The results of this study make an academic contribution by offering a method that can be applied by government agencies in determining the priority scale for handling ICT infrastructure based on an evaluation of the condition of ICT devices and also the condition of existing ICT human resources. This aims to assist organizational leaders in making the right, fair, effective, and efficient decisions in determining which branch offices are more deserving of support from the head office. The handling includes maintenance/replacement of ICT devices, ICT HR training, addition of ICT management personnel, improvement of governance and others related to handling ICT infrastructure.

This research has several limitations on the scope and dataset used. The scope of this research is on central government branch offices in the province with datasets using current year data. In the coming years, it is possible that the dataset will change, so it is necessary to update the dataset to utilize the results of this research in the coming years. Changes in government policy can also affect the results of this study, so it is necessary to update it regularly. In addition, this research also has the potential to be expanded in other fields, such as office building maintenance priorities, operational vehicle maintenance priorities, and other maintenance that has many decision options so that it requires the help of a DSM to help and facilitate top management in determining the best decision from existing alternatives.

5. Conclusion

In the research that has been conducted, conclusions are obtained based on the research objectives, namely identifying 14 parameters used to determine the priority of handling ICT infrastructure, namely governance scores, number of internet users, number of ICT managers, work experience of ICT managers, bandwidth service capacity, age of router devices, educational background of ICT managers, network firewalls, network maintenance, availability of server rooms, Network Attached Storage (NAS) storage devices, neatly arranged cable devices, adequate electrical resources, backup network internet connections. which were previously handled by conventional methods and have not covered the environmental aspects of the public sector in detail. There is a process of grouping parameter data on each aspect, where the SAW method recognizes the existence of 2 characteristics, namely benefit criteria and cost criteria. Where if benefit means the largest value is chosen and cost means if the smallest value is chosen.

This research successfully designed a decision support model that is useful for helping the head office of public sector organizations in determining the priority of handling ICT infrastructure at 34 branch offices using the Fuzzy SAW method. The results of the Fuzzy SAW calculation show the priority ranking of each branch office. Therefore, it is concluded that the Fuzzy SAW method can be used to produce calculations of ICT infrastructure handling priorities for public sector branch offices. The final result of the model is, alternative A1 is ranked 1 with a priority value of 0.591, so alternative A1 deserves the first priority in handling ICT infrastructure. Likewise, for the next priority ranking.

In addition, by using Fuzzy Saw-based DSM, organizations can gain actionable insights and enable them to make informed, effective and efficient decisions in optimizing limited budgets in providing support, maintenance and additional resources for branch offices as well as identifying areas that need improvement. Fuzzy Saw-based DSM serves as an invaluable tool to assist decision-making in improving the productivity and effectiveness of public sector organizations' ICT infrastructure handling priorities. In summary, this research provides a comprehensive guide to understanding the influential parameters in determining the prioritization scale.

While this research offers valuable insights for assessing as well as productivity and effectiveness of ICT infrastructure handling priorities of public sector organizations, there are limitations as it adapts to the conditions at the time of the research year. In the future, it is possible that there will be changes in government policies so that this research can be updated. This research can be continued for other fields such as: Priority Maintenance of Office Buildings, Priority Improvement of Disaster Emergency Response Capabilities, Priority Provision of Legal Service Assistance and others.

6. Declarations

6.1. Author Contributions

Conceptualization: R.Y. and D.N.U.; Methodology: D.N.U.; Software: R.Y.; Validation: R.Y. and D.N.U.; Formal Analysis: R.Y. and D.N.U.; Investigation: R.Y.; Resources: D.N.U.; Data Curation: D.N.U.; Writing Original Draft Preparation: R.Y. and D.N.U.; Writing Review and Editing: D.N.U. and R.Y.; Visualization: R.Y. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

The authors are grateful for the opportunities and support provided by Bina Nusantara University as well as the funding from the Ministry of Research, Technology, and Higher Education (Kemenristekdikti) of the Republic of Indonesia. The support ensured the research was conducted via the study program for the master thesis (Kemenristekdikti Budget 2024 with contract no: 105/E5/PG.02.00.PL/2024; 784/LL3/AL.04/2024; 092/VRRTT/VI/2024). Also, we would like to thank the Research Interest Group on Quantitative & Decision Sciences (RIG Q&DS) for their priceless support and facilitation in fostering collaboration and inspiring insightful discussions during this research work.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

Not applicable.

References

[1] L. Da Xu, E. L. Xu, and L. Li, "Industry 4.0: State of the art and future trends," *Int. J. Prod. Res.*, vol. 56, no. 8, pp. 2941–2962, 2018, doi: 10.1080/00207543.2018.1444806.

[2] J. T. D. Madronio, "Maintenance and Support System for Information and Communication Technology (ICT) Resources," *Am. J. Educ. Technol.*, vol. 2, no. 2, pp. 76–83, 2023, doi: 10.54536/ajet.v2i2.1619.

[3] J. W. Wairiuko, D. R. Nyonje, and D. E. O. Omulo, "Human Resource Capacity and Adoption of E-Government for Improved Service Delivery in Kajiado County, Kenya," *Int. J. Bus. Soc. Sci.*, vol. 9, no. 10, pp. 94-110, 2018, doi: 10.30845/ijbss.v9n10p10.

[4] S. N. Chami, D. Lagat, and B. Kimathi, "Factors Influencing Successful Implementation of Ict Systems for Enhancement of Regulatory Performance of the National Construction Authority," *Strateg. J. Bus. Chang. Manag.*, vol. 11, no. 1, pp. 435-444, 2024, doi: 10.61426/sjbcm.v11i1.2595.

[5] A. Cordella and N. Tempini, "E-government and organizational change: Reappraising the role of ICT and bureaucracy in public service delivery," *Gov. Inf. Q.*, vol. 32, no. 3, pp. 279–286, 2015, doi: 10.1016/j.giq.2015.03.005.

[6] A. Mottahedi, F. Sereshki, M. Ataei, A. N. Qarahasanlou, and A. Barabadi, *The resilience of critical infrastructure systems: , p.A systematic literature review*, vol. 14, no. 6, pp.1571-1602, 2021. doi: 10.3390/en14061571.

[7] L. Tawalbeh, F. Muheidat, M. Tawalbeh, M. Quwaider, and G. Saldamli, "Predicting and Preventing Cyber Attacks during COVID-19 Time Using Data Analysis and Proposed Secure IoT layered Model," *2020 4th Int. Conf. Multimed. Comput. Netw. Appl. MCNA 2020*, vol. 4 no. 1, pp. 113–118, 2020, doi: 10.1109/MCNA50957.2020.9264301.

[8] M. Sztubecka, M. Skiba, M. Mrówczynska, and A. Bazan-Krzywoszanska, "An innovative decision support system to improve the energy efficiency of buildings in urban areas," *Remote Sens.*, vol. 12, no. 2, pp.259-277, 2020, doi: 10.3390/rs12020259.

[9] K. Kabassi, C. Karydis, and A. Botonis, "AHP, fuzzy SAW, and fuzzy WPM for the evaluation of cultural websites," *Multimodal Technol. Interact.*, vol.4, no.1, pp.5-19, 2020, doi: 10.3390/mti4010005.

[10] M. M. Chamchali and A. Ghazifard, “A comparison of fuzzy logic and TOPSIS methods for landfill site selection according to field visits, engineering geology approach and geotechnical experiments (case study: Rudbar County, Iran),” *Waste Manag. Res.*, vol. 39, no. 2, pp. 325–350, 2021, doi: 10.1177/0734242X20952839.

[11] A. Fallahpour, E. Udoncy Olugu, S. Nurmaya Musa, K. Yew Wong, and S. Noori, “A decision support model for sustainable supplier selection in sustainable supply chain management,” *Comput. Ind. Eng.*, vol. 105 no.1, pp. 391–410, 2017, doi: 10.1016/j.cie.2017.01.005.

[12] M. Simonsson, P. Johnson, and M. Ekstedt, “The effect of IT governance maturity on IT governance performance,” *Inf. Syst. Manag.*, vol. 27, no. 1, pp. 10–24, 2010, doi: 10.1080/10580530903455106.

[13] J. Zhao, L. Jin, D. Liu, and S. Cheng, “Research on Key Technologies of Performance Monitoring and Operation and Maintenance of Optical Fiber Transmission Network Driven by Big Data,” *J. Phys. Conf. Ser*., vol. 1578, no. 1, pp.12078-12084, 2020, doi: 10.1088/1742-6596/1578/1/012078.

[14] L. C. Chen and D. N. Utama, “Decision Support Model for Determining the Best Employee using Fuzzy Logic and Simple Additive Weighting,” *J. Comput. Sci.*, vol. 18, no. 6, pp. 530–539, 2022, doi: 10.3844/jcssp.2022.530.539.

[15] M. Mahmoodian, F. Shahrivar, and C. Li, “Maintenance Prioritisation of Irrigation Infrastructure Using a Multi-Criteria Decision-Making Methodology under a Fuzzy Environment,” *Sustain.*, vol. 14, no. 22, pp. 1-35, 2022, doi: 10.3390/su142214791.

[16] G. Rathee, S. Garg, and G. Kaddoum, “A Decision-Making Model for Securing IoT Devices in Smart Industries,” *IEEE Transactions on Industrial Informatics*, vol. 17 no. 6, pp. 4270-4278, 2020, doi: 10.1109/TII.2020.3005252.

[17] A. Rasadi, B. Hidayat, and T. Ophiyandri, “Decision support system in determining the priority of disaster mitigation infrastructure development in villages level using the Simple Additive Weight (SAW) method,” *IOP Conf. Ser. Earth Environ. Sci.*, vol. 708, no. 1, pp. 12065-12074, 2021, doi: 10.1088/1755-1315/708/1/012065.

[18] S. H. Zolfani, M. Sedaghat, and E. K. Zavadskas, “Performance evaluating of rural ICT centers (telecenters), applying fuzzy AHP, SAW-G and TOPSIS Grey, a case study in Iran,” *Technol. Econ. Dev. Econ.*, vol. 18, no. 2, pp. 364–387, 2012, doi: 10.3846/20294913.2012.685110.

[19] A. C. Karmperis, K. Aravossis, I. P. Tatsiopoulos, and A. Sotirchos, “Decision support models for solid waste management : Review and game-theoretic approaches,” *Waste Manag.*, vol. 33, no. 5, pp. 1290–1301, 2013, doi: 10.1016/j.wasman.2013.01.017.

[20] Luo, P. Liu, and L. Cao, “Coupling a Physical Replica with a Digital Twin: A Comparison of Participatory Decision-Making Methods in an Urban Park Environment,” *ISPRS Int. J. Geo-Information*, vol. 11, no. 8, pp.452-468, 2022, doi: 10.3390/ijgi11080452.

[21] K. Aliyeva, A. Aliyeva, R. Aliyev, and M. Özdeşer, “Application of Fuzzy Simple Additive Weighting Method in Group Decision-Making for Capital Investment,” *Axioms*, vol. 12, no. 8, pp. 1–13, 2023, doi: 10.3390/axioms12080797.

[22] M. Khan, A. Al, K. Haj, I. Ishaque, and I. Hussain, “New combination of simple additive and entropy weighting criteria for the selection of best substitution box”, *Journal of Intelligent & Fuzzy Systems*, vol. 41, no.1, pp. 2325-2338. doi: 10.3233/JIFS-211176.

[23] B. Davvaz, I. Mukhlash, and S. Soleha, “Himpunan Fuzzy dan Rough Sets,” *Limits J. Math. Its Appl*., vol. 18, no. 1, p. 79-94, 2021, doi: 10.12962/limits.v18i1.7705.

[24] B. Davvaz, I. Mukhlash, and S. Soleha, “Himpunan Fuzzy dan Rough Sets,” *Limits J. Math. Its Appl.*, vol. 18, no. 1, pp. 79-94, 2021, doi: 10.12962/limits.v18i1.7705

[25] J. Dong, S. Wan, and S. M. Chen, “Fuzzy best-worst method based on triangular fuzzy numbers for multi-criteria decision-making,” *Inf. Sci. (Ny).*, vol. 547 no.1, pp. 1080–1104, 2021, doi: 10.1016/j.ins.2020.09.014.

[26] M. Kumar, P. Jayaswal, and K. Kushwah, “Exploring Fuzzy SAW Method for Maintenance Strategy Selection Problem of Material Handling Equipment,” *Int. J. Curr. Eng. Technol.*, vol. 3, no. 2008, pp. 600–605, 2013.

[27] R. Venkateswari and N. Rajasekar, “Review on parameter estimation techniques of solar photovoltaic systems,” *Int. Trans. Electr. Energy Syst.*, vol. 31, no. 11, pp. 1–72, 2021, doi: 10.1002/2050-7038.13113.

[28] A. Aithal and P. S. Aithal, “Development and Validation of Survey Questionnaire and experimental data,” *Int. J. Manag. Technol. Soc. Sci*., vol. 5, no. 2, pp. 233–251, 2020.