Exploring Simple Addictive Weighting (SAW) for Decision-Making

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Abstract – The Simple Additive Weighting (SAW) method is a well-known and widely utilized approach for decision-making in various disciplines. The SAW method involves a step-by-step process that enables decision-makers to evaluate and rank alternatives based on their respective attribute values and assigned weights. Within this context, this paper aims to provide a comprehensive exploration of SAW for decision-making. This study demonstrates the utilization of the SAW method in supplier selection, which aims to streamline and optimize the supply chain management process for organizational business. The results derived from the study have revealed its practicality, effectiveness, and adaptability in handling multi-criteria decision problems, by examining its principles, advantages, limitations, and application based on real situations. It's important to note that the method's reliance on accurate weight assignment to criteria poses a challenge. This process can be subjective and intricate, especially when faced with conflicting objectives. However, SAW stands as a valuable addition to the decision-maker's toolkit, providing a structured and transparent framework for making well-informed choices amidst complexity.

Keywords - decision-making, decision support system, SAW

I. INTRODUCTION

Decision-making plays a vital role in numerous industries, including business, management, engineering, finance, and healthcare. Organizations face constant challenges that demand a systematic and informed process, in order to select the most favorable option from a wide range of possibilities [1]. The decision-making process involves evaluating and comparing multiple criteria or factors that influence the final choice. Throughout this process, there is always some level of uncertainty surrounding the outcome. To make informed decisions, accurate information is required regarding current and potential future conditions to minimize uncertainty. Once this information is gathered, it can be utilized to generate various alternative solutions that serve as a solid foundation for reaching a final decision. Accordingly, the development of a decision-making process that enables efficient information processing for problem-solving becomes crucial [2]. This system aids decision-makers in navigating complexities and making well-informed choices, hence enhancing overall decision-making effectiveness.

Researchers have developed and utilized various methodologies and techniques known used for decision-making, such as Multi-Criteria Decision Making (MCDM) approach. A various MCDM techniques have emerged as effective solutions to a variety of decision-making problems. MCDM method is characterized by a decision matrix, which includes a group of alternatives denoted as A_i (i=1, …, m), a set of criteria represented by c_j (j=1,…, n), the relative importance of the criteria (or weights) w_j, and r_{ij} corresponding the ranking of alternative i with respect to criterion j [3]. TOPSIS, SAW, MOORA, ELECTREE, COPRAS, and VIKOR have been proven to be successful in resolving numerous decision-making problems [4]–[9] . Significantly, SAW has received considerable attention method and stands as one of the most extensively utilized MCDM techniques [10]. SAW is a technique for multi-criteria decision-making that simplifies complex decision-making processes by employing weights and scores. This approach offers a structured framework for evaluating and ranking alternatives based on their performance. The SAW method, in particular, is gaining popularity due to its user-friendliness and simple computational process [11], [12].

The SAW method, also known as weighted linear combination or scoring methods [13]–[16]. It employs a weighted average approach, in which each alternative is assigned a score by multiplying its scaled value for each attribute by the assigned weights, these weighted scores are then summed up across all criteria [17]. The SAW method has the benefit of maintaining the relative order of magnitude of the standardized scores due to its utilization of a proportional linear transformation of the raw data. As a result, the SAW method has found widespread use in a wide range of studies. Researchers and decision-makers value its effectiveness and practicality, making it a popular choice. The SAW technique has been shown to be very adaptive and versatile, making it appropriate for a wide range of decision-making settings [18]–[22]. It enables decision-makers to combine both qualitative and quantitative aspects into the assessment process, allowing for a thorough examination of the available alternatives. SAW helps to handle the inherent subjectivity and ambiguity associated with decision-making by assessing numerous variables at the same time.

The purpose of this paper is to explore Simple Additive Weighting (SAW) as a decision-making tool. It aims to give a through overview of the SAW method, its underlying principles, and its application in real situations. The steps involved in implementing SAW will be discussed in this paper, including criteria selection, weight assignment, and score aggregation. Furthermore, it will also explore the approach's strengths and limitations.

II. STUDY SIGNIFICANCE

A. *Literature Study*

The SAW method has been used in a variety of domains, as evidenced by studies; the problem of the selection of thermoplastic polymers has been explored through the application of the SAW method [18]. In this study, SAW is used to solve the problem of selecting thermoplastic polymers for use as bipolar plates in direct methanol fuel cell applications. To evaluate thermoplastic polymers, the criteria used in this study consisted of mechanical properties such as surface change, thickness change, flexural strength, degradation rate, density solution absorption, and cost. This research demonstrates the effectiveness of the SAW method for the material selection process, which is crucial for improving the performance and efficiency of methanol fuel cells. Four MCDM methods namely, AHP, CORPAS, TOPSIS, and SAW are implemented to address material selection issues. Despite SAW being considered the method with the simplest calculations, its ranking results are closely aligned with the outcomes obtained from other methods.

The efficacy of the SAW method in delineating groundwater potential (GWP) was showcased in a study [19]. In this case, SAW is used for delineating GWP in the northern United Arab Emirates and Oman. This study integrates geospatial technology with SAW, AHP, and PFR methods to assess groundwater potential zones. Some of the criteria used, such as geology, land use, topography, and soil characteristics, are used to evaluate the suitability of various regions for groundwater extraction. The study results show how SAW can effectively handle spatial data and support the management of groundwater data sources.

Pipyros et al, demonstrated the SAW method to enhance the evaluation of cyber attacks in the context of the Tallinn Manual [20]. The Tallinn Manual provides guidelines for international law applicable to cyber warfare and cyber operations. Researchers use SAW to evaluate various cyber-attack scenarios based on criteria such as attack severity, damage potential, and mitigation effectiveness. By applying the SAW technique, this study illustrates how SAW can contribute to the development of cybersecurity strategies and risk assessment protocols.

In the healthcare sector, the SAW method was demonstrated to facilitate supplier selection in the hospital field [21]. In this case the criteria used included product quality, price, delivery speed, supplier reputation, and supplier compatibility with hospital requirements. This study shows how SAW can help streamline supplier selection processes and support decision-making in healthcare procurement. Moreover, the capacity of the SAW method to analyze various oxygen production techniques was explored [22]. By using criteria such as efficiency, cost, environmental impact, and scalability, this study has demonstrated the effectiveness of the SAW approach to facilitate comprehensive decision-making in the field of oxygen production.

As seen from the various studies, the SAW method's adaptability and effectiveness underscore its potential for application in different sectors. Furthermore, Figure 1. represents the primary subject areas obtained from a search conducted on the "ScienceDirect" database on June 2, 2022, using the search term "*simple additive weighting*" [23].

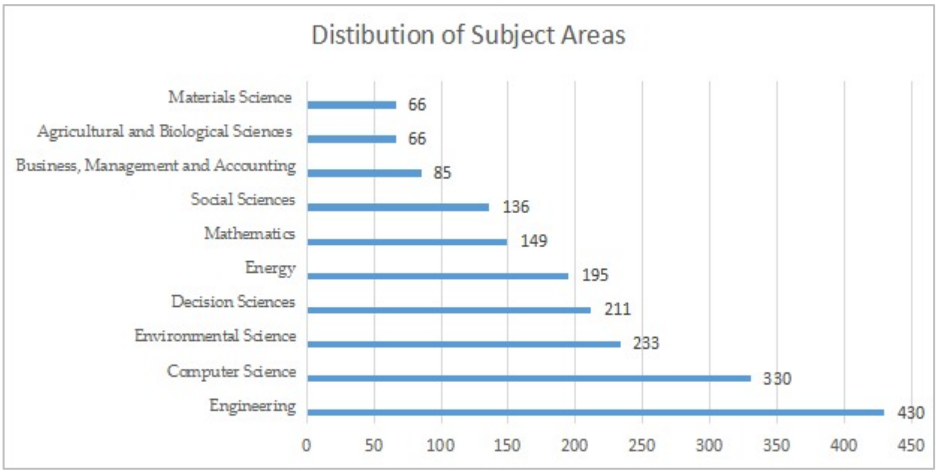

Figure 1. Subject areas' distribution utilizing the SAW method.

B. Methodology

1. System Design

In this study, the SAW application is illustrated for the selection of suppliers, which aims to streamline and optimize the supply chain management process for organizational business. The supplier selection process in this study, is depicted in Figure 1:

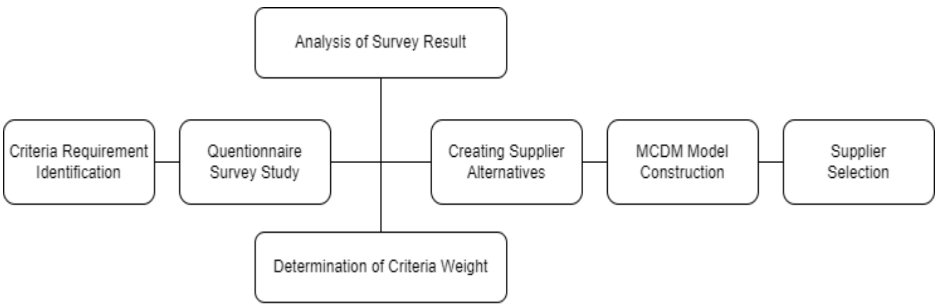

Figure 1. Supplier selection steps

Selecting a supplier involves considering a number of factors to determine whether a supplier is appropriate for a company. The goal is to identify the most suitable and reliable suppliers for procuring materials, ensuring high-quality products, price competitiveness, time deliveries, best services, and technical capability. Each criterion has a different level of importance depending on the company's needs and goals. Criteria and alternatives illustrated in Figure 2.

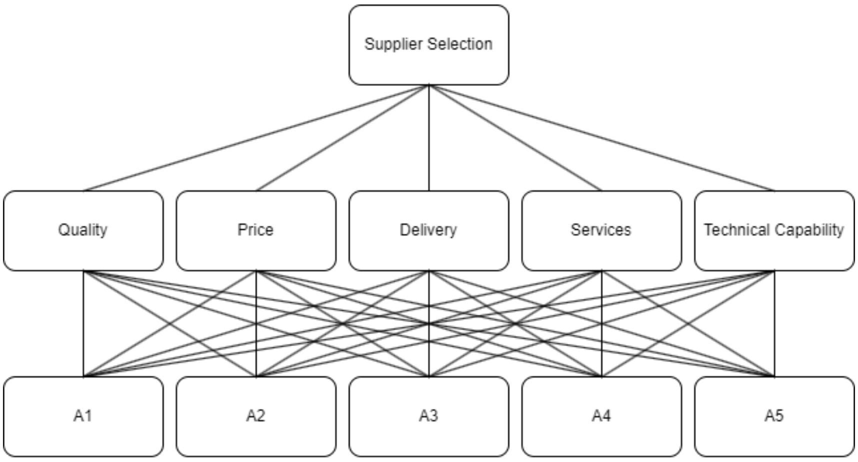

Figure 2. Supplier Selection Hierarchy

2. Simple Additive Weighting (SAW) method

The SAW method stands as one of the most extensively utilized Multiple Criteria Decision Making (MCDM) techniques. Decision-makers find numerous benefits in employing this method, while its drawbacks are relatively insignificant. The SAW approach is based on calculating a weighted total of performance ratings for each alternative while considering all attributes. To achieve this, a normalized decision matrix is prepared, which will be used to provide a scale to compare all alternative ratings. The SAW method involves the following steps in its process, shown in Figure 4. [24]:

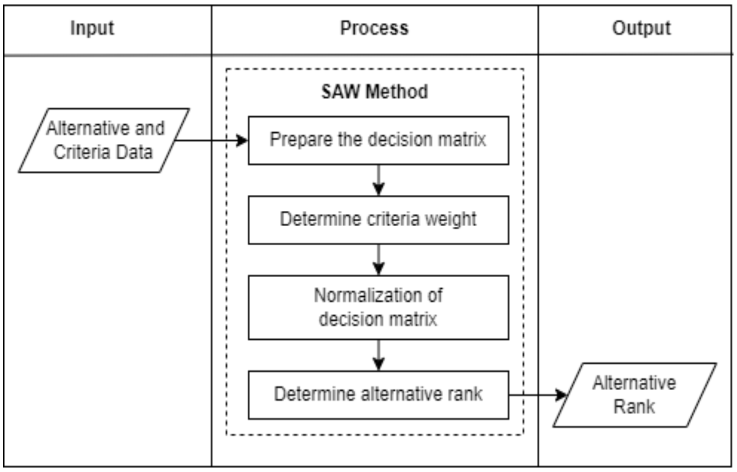

Figure 4. Steps of the SAW method

Step 1. Prepare the decision matrix (x_{ij})

The initial step of the SAW method involves creating a paired comparison matrix of each criterion in each alternative:

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Let $\boldsymbol{x_{ij}}$ represent the comparison matrix response of alternative *j* to criterion *i*, $\boldsymbol{n}$ are the criterion and $\boldsymbol{m}$ are the alternatives.

Step 2. Determine the criteria weight ($\boldsymbol{w_i}$)

These weights can be thought of as numbers ranging from 0 to 1 (or as percentages)) and considering:

$$\sum_{i=1}^{n} \boldsymbol{w_i} = \mathbf{1} \tag{2}$$

Where $\boldsymbol{w_i}$ is the criteria weight and must equivalent to 1

Step 3. Normalizing the value of $\boldsymbol{i}$ th criterion for the $\boldsymbol{j}$ th alternative ($\boldsymbol{r_{ij}}$)

The r_{ij} is the term used to represent the normalized value of the i-th criterion for the j-th alternative or object. The calculation of this value depends on whether the problem is a cost or benefit type. In cost problems, the objective is to minimize the value, whereas in benefit problems, the objective is to maximize the value. These differences are reflected in the calculation of r_{ij} as follows:

$$\boldsymbol{r_{ij}} = \frac{\min_{j} x_{ij}}{x_{ij}} \text{; if } \boldsymbol{j} \text{ is a cost attribute} \tag{3}$$

$$\boldsymbol{r_{ij}} = \frac{x_{ij}}{\max_{j} r_{ij}} \text{; if } \boldsymbol{j} \text{ is a benefit attribute} \tag{4}$$

Where $\boldsymbol{r_{ij}}$ is normalized matrix, min $\boldsymbol{r_{ij}}$ is the minimum value of each row and column of the $\boldsymbol{x}$ matrix, max $\boldsymbol{r_{ij}}$ is the maximum value of each row and column of the $\boldsymbol{x}$ matrix and rij

Step 4. Determine the alternative rank

$$\boldsymbol{V_i} = \sum_{j=1}^{n} \boldsymbol{w_j r_{ij}} \tag{5}$$

Where V_i is the final value of the alternative. A larger value of V_i indicates that alternative is more preferred

III. RESULT AND DISCUSSION

This section describes the outcomes of the supplier selection process based on the SAW decision support system application. The selection of suppliers needs to be done in several stages. In developing this system, a questionnaire is needed as a reference for evaluating criteria and alternatives in selecting suppliers. This questionnaire will be filled in by expert respondents from company. This questionnaire consists of two parts, the first questionnaire is to assess the weight of each criterion. While the second questionnaire is an alternative weight assessment for each criterion using a five-point likert scale. The five likert scale points are converted into numbers: 1 to 5 points, where 5 is the best.

A. Prepare The Decision Matrix

The first step in the SAW method is to establish the decision matrix, which contains evaluations of different alternatives concerning various criteria. This process was carried out using Eq. 1, and the outcomes are presented in Table I.

TABLE I
DECISION MATRIX

Code	QL	PR	DL	SV	TC
A1	5	4	4	5	4
A2	4	5	5	3	5
A3	5	4	5	4	4
A4	3	3	5	4	3
A5	4	3	3	5	4

B. Determination of the criteria weights

The decision-makers play a critical role in determine the supplier data. In other words, decision-makers must determine the weight preference for each criterion. In this study, the weighting criteria are divided into five (5) options criteria. The following steps were derived using Eq. 2 and the result shown in Table II.

TABLE II
SUPPLIER CRITERIA

Criteria Name	Code	Type	Weight
Quality	QL	Benefit	0.30
Price	PR	Cost	0.25
Delivery	DL	Benefit	0.20
Services	SV	Benefit	0.15
Technical Capability	TC	Benefit	0.10

C. Normalizing the decision matrix

The subsequent step involves calculating the normalized decision matrix using Eq. 3-4. For example, the calculation for alternative 1 (A1) is calculated as follows:

$$r_{11} = \frac{5}{\max\,(5; 4; 5; 3; 4)} = \frac{5}{5} = 1$$

$$r_{12} = \frac{min\{4; 5; 4; 3; 3)}{4} = \frac{3}{4} = 0.75$$

$$r_{13} = \frac{4}{max\{4; 5; 5; 5; 3)} = \frac{4}{5} = 0.8$$

$$r_{13} = \frac{5}{max\{5; 3; 4; 4; 5)} = \frac{5}{5} = 1$$

$$r_{14} = \frac{4}{max\{4; 5; 4; 3; 4)} = \frac{4}{5} = 0.8$$

This process is continued up to the 5th alternative. The final result of normalized decision matrix shown in Table III.

TABLE III
NORMALIZED DECISION MATRIX

Code	**QL**	**PR**	**DL**	**SV**	**ES**
A1	1.0	0.75	0.8	1.0	0.8
A2	0.8	0.6	1.0	0.6	1.0
A3	1.0	0.75	1.0	0.8	0.8
A4	0.6	1.0	1.0	0.8	0.6
A5	0.8	1.0	0.6	1.0	0.8

D. Perform alternative rankings

Finally, the weighted normalized decision matrix is formed by applying Eq. 5, where each element of the normalized decision matrix is multiplied by the corresponding criteria weights provided in Table II, and then sum it all to get V_i. Table IV. shows the weighted normalized decision matrix.

TABLE IV
WEIGHTED NORMALIZED DECISION MATRIX

Code	QL	PR	DL	SV	ES
A1	0.3	0.188	0.16	0.15	0.08
A2	0.24	0.15	0.2	0.09	0.1
A3	0.3	0.188	0.2	0.12	0.08
A4	0.18	0.25	0.2	0.12	0.06
A5	0.24	0.25	0.12	0.15	0.08

The step obtained to get the value of V_i are as follows:

$V_1 = \{(0.30\ x\ 1) + (0.25\ x\ 0.75) + (0.20\ x\ 0.8) + (0.15\ x\ 1) + (0.10\ x\ 0.8)\} = 0.878$
$V_2 = \{(0.30\ x\ 0.8) + (0.25\ x\ 0.6) + (0.20\ x\ 1) + (0.15\ x\ 0.6) + (0.10\ x\ 1)\} = 0.780$
$V_3 = \{(0.30\ x\ 1) + (0.25\ x\ 0.75) + (0.20\ x\ 1) + (0.15\ x\ 0.8) + (0.10\ x\ 0.8)\} = 0.888$
$V_4 = \{(0.30\ x\ 0.6) + (0.25\ x\ 1) + (0.20\ x\ 1) + (0.15\ x\ 0.8) + (0.10\ x\ 0.6)\} = 0.810$
$V_5 = \{(0.30\ x\ 0.8) + (0.25\ x\ 1) + (0.20\ x\ 0.6) + (0.15\ x\ 1) + (0.10\ x\ 0.8)\} = 0.840$

The higher the value obtained, identifying the alternative is the best choice. The results of the alternative ranking for supplier selection can be observed in Table 5 and Figure 5.

TABLE V
FINAL ALTERNATIVE RANKING

Code	Alternative	V_i	Rank
A1	0.3	0.878	2
A2	0.24	0.780	5
A3	0.3	0.888	1
A4	0.18	0.810	4
A5	0.24	0.840	3

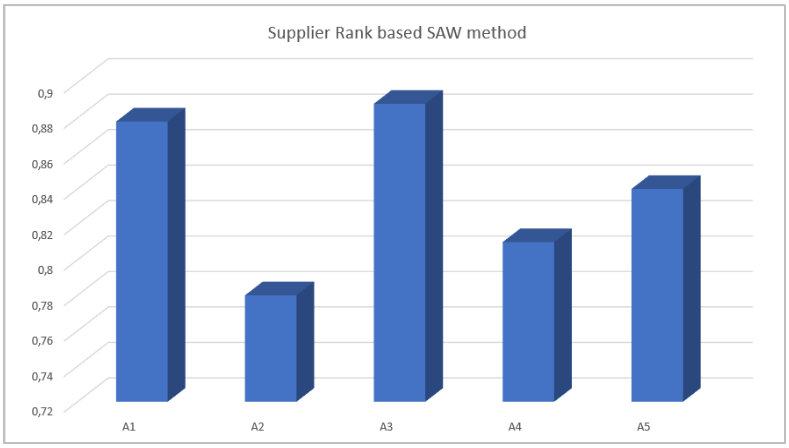

Figure 5. Final Alternative Ranking

Based on this study, the SAW approach has proven effective in yielding favorable ranking outcomes that align with the practical context of supplier selection in organizations. Despite the fact that this method is more often used in the engineering sector, as can be seen in Figure 1, it does not rule out the possibility that this SAW method can be used in various fields.

IV. CONCLUSION

Throughout this study, we delved into the foundational principles of SAW and its application. The exploration of Simple Additive Weighting (SAW) for decision-making has provided valuable insights into its applicability and effectiveness in handling complex multi-criteria decision problems. There are advantages and disadvantages associated with this approach, as indicated in the analysis presented in Table 6.

TABLE VI
ADVANTAGES AND DISADVANTAGES OF THE SAW

Advantages	Disadvantages
The capacity to adjust among criteria;	Transferring minimizing criteria to maximizing;
Simple calculation, no need complex programming;	Result gathered may not be logical;
This tool combines variable and weight values into a single magnitude;	Must provide the decision matrix with the attributes' weights;
Assisting in determining the differences between visually examined objects utilizing normalized values.	All of the variables' values should be positive. The calculation depends on by the type of transformation performed to convert to positive dimensions.

The straightforwardness and intuitive aspect of this method make it an attractive approach when faced with decision-making scenarios. By giving weight to the different criteria and aggregating them, SAW provides a transparent and systematic process, for assessing alternatives and reaching a final decision. The simplicity of SAW proved advantageous in situations where elaborate mathematical models or extensive data were not readily available or necessary. Despite its merits, there are notable limitations to consider. The method relies on the assumption of linear relationships between criteria and might not account for complex interactions among them. The method heavily relies on the accurate assignment of weights to criteria, and this process can be subjective and challenging, particularly when dealing with conflicting objectives. Additionally, SAW assumes independence among criteria, which may not always hold true in practical scenarios. It is highly recommended for further research to try the SAW hybridization method with other MCDM approaches such as the Analytical Hierarchy Process (AHP) method, where this technique provides an effective and systematic process of calculating the weight of criteria.

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