# Evaluating Smart Agricultural Production Efficiency using Fuzzy MARCOS method

**Abedallah Zaid Abualkishik** [*1], **Rasha Almajed** [2], **William Thompson**[3]

[1,2]American University in the Emirates, Dubai, UAE
[3]Towson University, Towson University, Maryland's University, USA

Emails: abedallah.abualkishik@aue.ae, rasha.almajed@aue.ae, wvthompson@towson.edu

**Abstract**

Agricultural production efficiency can be improved, the environment can be improved, and sustainable agricultural development can be achieved with smart agriculture. Several nations and businesses are devoted to developing or introducing innovative agricultural practices and technologies. As long as conventional agricultural management systems are in place, it's going to be tough for businesses to choose and apply smart agriculture solutions without running into stiff competition. As a result, businesses must weigh their options and choose a workable solution ahead of time. There is a novel fuzzy multi-criteria decision model presented in this research that may be used to evaluate the agriculture solution. We created fuzzy MARCOS, which uses the COmpromise Solution's Measurement Alternatives and Ranking Method (fuzzy MARCOS). Triangular fuzzy numbers (TFNs) linguistic dimension was also developed. According to this technique, the criteria weights used to evaluate the road network parts were calculated. Consequently, it is clear that a certain part of agriculture is affected by the study results.

**Keywords:** Fuzzy; MARCOS; MCDM; agriculture;

## 1. Introduction

Smart agriculture has emerged as a result of the widespread use of the Internet of Things, big data, and smart technology in the sector of agriculture. [1], [2]smart agriculture combines current technology, such as smartphones, IT platform, cloud services, big data, Internet of Things, 3S technologies, and the wisdom and expertise of experts,[3], [4] to intelligently create and manage agriculture. Precision agriculture, smart water management, agricultural tracking, agronomical systems, and traceability of the quality and safety of agricultural products are just a few of the ways that smart agriculture, as a whole, contributes to better and more efficient farming and, ultimately, a more sustainable food supply chain[5].

The conversion and improvement of the agricultural sector are supported by many nations' laws or administrative regulations, which help to promote agriculture's long-term growth. It is critical to encourage agricultural businesses that already have smart agricultural solutions in place to use them to construct a new model of smart agricultural growth. It has been difficult for farmers to apply agricultural smart solutions because of the limits imposed by the conventional agricultural management software and the lack of technological capability of the agricultural firms that employ them. [6] Because of the glut of smart agricultural solutions on the market today, which vary widely in terms of technical quality, advantages, and management methods, it is difficult for agribusinesses to make an informed decision. To make matters more complicated, successful implementation of the smart agricultural solution would need a significant outlay of resources, both in cash and in human capital. [7]The company's decision to go with smart agricultural solutions must thus be supported by a fair assessment of the available alternatives. Agricultural solutions are evaluated and selected

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using a variety of variables, many of which are hard to measure using objective data[8] such as technical complexity and predicted advantages. As a result, these signals are hard to evaluate by specialists in the shape of accurate values because of environmental uncertainty,[9] intricacy, and the personal tastes of decision-makers.

Researchers in the agricultural area are using the fuzzy set (FS) concept to overcome uncertainty and personal preferences in the assessment process. To maximize crop yields in numerous seasons, Biswas and Pal developed a fuzzy goal programming approach to optimize land utilization. Then, Hernandez and Uddameri [10] introduced an algorithm based on intuitionistic fuzzy set (IFS) theory for sorting and choosing agricultural management practice solutions. An analytic hierarchy process (AHP) and VIKOR model were used to evaluate 7 sustainable energy conversion solutions for addressing agricultural admixtures, according to Wang and colleagues [11]. Contaminants in agricultural soils may be assessed and ranked using a fuzzy comprehensive assessment model developed by Zhao et al.[12] A new optimization stochastic fuzzy programming approach, introduced by Ray[13], was developed to figure out the best irrigation and plant strategy for agricultural purposes. [14]Numerous new FS concept research and decision support algorithm is proposed for crop water transport and allocation systems,[15] hospital performance evaluation[16] the dynamic top-notch index for agrarian soils[17] beef cattle ranching sustainability[18] agricultural drought disaster[19] and land suitability assessment have also been developed by other authors[20].

Fuzzy theory[21]–[23] in combination with MCDM approaches [24]–[27] is a strong and effective tool for generating trustworthy decisions in a variety of decision-making domains. According to Stoji et al. [28], previous definitions and fulfillment of specific elements are necessary for the decision-making process, particularly when dealing with complicated situations. Multi-criteria decision-making occupies a specific role in science, according to Zavadskas et al [29].

Sections of intelligent agriculture may be evaluated using a novel fuzzy measurement alternative and ranking system (Fuzzy MARCOS) that was created in this article. The key contributions of this study are the invention of a new fuzzy MARCOS approach and the definition of a linguistic structure scale based on TFNs. The following are some of the benefits of using Fuzzy MARCOS: Model development should take into account the fuzzy ideal and anti-ideal solutions as early as possible, as well as the possibility of considering many different options, as demonstrated through the use of a realistic example. This will allow for a more accurate assessment of how useful each solution is, and will allow for the development of new utility functions.

The rest of this article consists of the following sections: Section 2 lays forth a four-tiered evaluation index methodology for smart farming technologies. A new concept, fuzzy MARCOS, is introduced in Section 3 and its operating principles are explained. In Section 4, the results and application. Section 5 concludes the paper.

## 2. Created using an index of smart agricultural solutions

Businesses or agencies can't select a smart agriculture solution because of the wide range of options, each with its own set of pros and cons in terms of input costs and performance, output advantages, and service levels. Distinct information systems reflect the preferences of decision-makers throughout the selection process, and this influences the final selection outcomes. 62 To do this, an appropriate assessment index system must be built to create the groundwork for assessing and choosing smart agricultural solutions Smart agricultural solutions may be evaluated in four ways: resource input, performance, expected benefits, and standard of support. Accordingly[30], the first-level indexes are refined based on this information, and the particular indexes are examined as follows:

I. Measuring the discrepancy between present user resources and those needed by smart agriculture solutions in the form of materials, human capital, and financial resources. Using four different indices, including contribution trying to match at the hardware/software level, input trying to match at the connectivity software level, skill early version and farming ability, and input corresponding at the daily service & maintenance level, this feature reflects the most believable dilemma variables and their contribution to the development of sustainable farming in real-time.

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II. The function and benefits of smart agriculture solutions may be measured using this solution. To determine which features of the remedy are urgently needed by businesses and which are beneficial to the development of smart agriculture mode, it is used to measure four dimensions: consistency of operation, security of operating condition, systems design, ideal combination, and extensibility.

III. The anticipated advantages of the solution, assess the production of businesses once they use smart agriculture solutions. Using four different metrics, this component determines whether the answer is worth implementing by businesses, including the company's bottom line, the supply chain's efficiency, its reputation, and the environment's health.

IV. To gauge the popularity of a product or service, a company's quality of customer service is used as an indicator. Implementing intelligent government agricultural methods for agricultural businesses is made easier when the service standard is high enough to give a firm assurance for their installation and operation. Personalization and installation, staff training, hardware, and software failure support, as well as customer service responsiveness and thoroughness, are all factors that are used to gauge this aspect's effectiveness.

## 3. Fuzzy MARCOS Method

Even though the criteria and choices are extensive, MARCOS remains stable. An ideal and an anti-ideal solution are considered early on and utility levels for both options are determined using this method. Even if the variety of criteria or options grows exponentially, the method remains simple. Proposing a compromise option, the MARCOS approach offers the most realistic alternative. Furthermore, it is able to analyse the preferences of experts without regard to the scale they use.

Despite its relative youth, the MARCOS approach has already been extensively used for a variety of objectives across a broad range of sectors, thanks to its many benefits and adaptability to a variety of MCDM methodologies. Fuzzy sets and their expansions may also be used.

A fuzzy number D the membership function is F(x):

$$F(X) = \begin{cases} \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0 & otherwise \end{cases} \quad (1)$$

Let $D_1 = (a_1, b_1, c_1), D_2 = (a_2, b_2, c_2)$

$$D_1 \oplus D_2 = (a_1, b_1, c_1) + (a_2, b_2, c_2) = a_1 + a_2, b_1 + b_2, c_1 + c_2 \quad (2)$$

$$D_1 \otimes D_2 = (a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = a_1 \, x \, a_2, b_1 \, x \, b_2, c_1 \, x \, c_2 \quad (3)$$

$$D_1 - D_2 = (a_1, b_1, c_1) - (a_2, b_2, c_2) = a_1 - c_2, b_1 - b_2, c_1 - a_2 \quad (4)$$

$$\frac{D_1}{D_2} = (a_1, b_1, c_1) / (a_2, b_2, c_2) = a_1 / c_2, \frac{b_1}{b_2}, \frac{c_1}{a_2} \quad (5)$$

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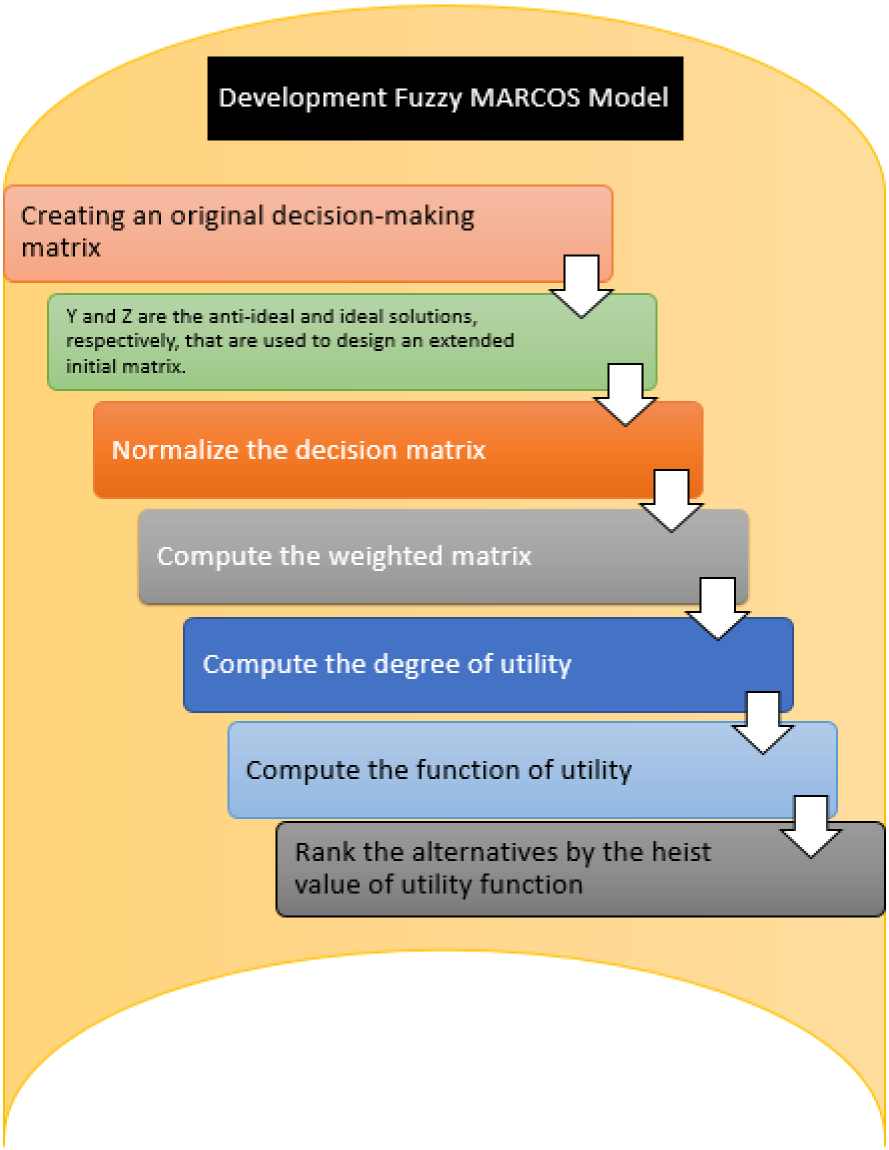


Figure 1: The steps of the MARCOS model.

The MARCOS approach defined by Stevi et al. [31] is described in the next section: Figure 1 shows the steps of the proposed algorithm. We used the scale as

Step 1: Generating an original judgement-creation matrix is the first step in the process.

Step 2: Y and Z are the anti-ideal and ideal solutions, respectively, that are used to design an extended initial matrix.

$$Y = \min_{i} x_{ij} \ beneficial, \quad (6)$$

$$Y = \max_{i} x_{ij} \ non-beneficial, \quad (7)$$

$$z = \max_{i} x_{ij} \ beneficial, \quad (8)$$

$$z = \min_{i} x_{ij} \ non-beneficial, \quad (9)$$

Step 3: Normalize the decision matrix as:

$$r_{ij} = \frac{x_y}{x_{ij}} \ non-beneficail \quad (10)$$

$$r_{ij} = \frac{x_y}{x_{ij}} \ beneficial \quad (11)$$

Step 4: Compute the weighted matrix as

$$Wr_{ij} = r_{ij} \ x \ W_j \quad (12)$$

Step 5: Compute the degree of utility as:

$$L_i^- = \frac{S_i}{S_z} \quad (13)$$

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$$L_i^+ = \frac{S_i}{S_y} \tag{14}$$

$$S_i = \sum_{i=1}^{n} W r_{ij} \tag{15}$$

Step 6: Compute the function of utility

$$f(L_i) = \frac{L_i^+ + L_i^-}{1 + \frac{1 - f(L_i^+)}{f(L_i^+)} + \frac{1 - f(L_i^-)}{f(L_i^-)}} \tag{16}$$

$$f(L_i^-) = \frac{L_i^+}{L_i^+ + L_i^-} \tag{17}$$

$$f(L_i^+) = \frac{L_i^-}{L_i^+ + L_i^-} \tag{18}$$

Step 7: Rank the options by the heist assessment of the usefulness task.

## 4. Results

Agricultural businesses have a variety of criteria from which to pick when evaluating and selecting innovative solutions for agriculture. Criteria for evaluating the options were chosen based on the real elements, such as resource input, performance, anticipated benefits, and service level, and the optimal option for agricultural companies was selected based on the evaluation findings.. An expert panel was assembled to rate the evaluation indices, such as the degree of review and approval, throughout the review procedure.

Each farm will have a unique need for smart agricultural solutions, hence the assessment index will be weighted differently by the many farms included in the review process. The decision makers and experts evaluated criteria and survey from previous studies, surveys and questioneers.

In this study, we used four main criteria, sixteen sub-criteria, and four alternatives as below.

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| Main criteria | Sub criteria | Alternatives |
|---|---|---|
| Matching resource inputs required for the solution | Input matching at the hardware equipment level SAC1 | XAG SAA1 Chinasoft SAA2 JXIOT SAA3 Longsoft SAA4 |
| | Input matching at the network software level SAC2 | |
| | Talent introduction and cultivation ability SAC3 | |
| | Input matching at the daily operation and maintenance level SAC4 | |
| The performance of the solution | Stability of operation SAC5 | |
| | Security of operation SAC6 | |
| | System integration SAC7 | |
| | System compatibility and extensibility SAC8 | |
| The expected benefits created by the solution | Economic benefits of the enterprise SAC9 | |
| | Optimization benefits of supply chain cooperation SAC10 | |
| | Reputation benefits of the enterprise SAC11 | |
| | Ecological environment improvement benefits SAC12 | |
| The service level of the company to which the solution belongs | The personalized customization and installation service of the solution SAC13 | |
| | The operation training service of employees SAC14 | |
| | Failure support service of hardware and software SAC15 | |
| | The service response and thoroughness level SAC16 | |

Step 1: Table 1 shows the decision matrix. Then convert these numbers to crisp values in table 2.
Step 2: By using Eqs. (6-9) are used to compute the maximum and minimum values for beneficial and non-beneficial criteria
Step 3: Normalize the decision matrix by Eqs. (10-11) in table 3.
Step 4: Compute the weighted matrix by Eq. (12) in table 4.
Step 5: Compute the degree of utility by Eqs. (13-15):
Step 6: Compute the function of utility by Eqs. (16-18)
Step 7: Rank the alternatives by the heist value of utility function in figure 2.

Table 1:The initial decision matrix

| | $SAA_1$ | | | $SAA_2$ | | | $SAA_3$ | | | $SAA_4$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SAC_1$ | 1 | 3 | 3 | 7 | 9 | 9 | 5 | 7 | 7 | 5 | 7 | 7 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SAC_2$ | 1 | 1 | 3 | 5 | 5 | 7 | 5 | 7 | 7 | 5 | 7 | 7 |
| $SAC_3$ | 5 | 7 | 7 | 1 | 3 | 3 | 5 | 5 | 7 | 5 | 5 | 7 |
| $SAC_4$ | 7 | 7 | 9 | 1 | 3 | 3 | 3 | 3 | 5 | 7 | 7 | 9 |
| $SAC_5$ | 5 | 7 | 7 | 3 | 3 | 5 | 3 | 3 | 5 | 5 | 7 | 7 |
| $SAC_6$ | 7 | 7 | 9 | 1 | 3 | 3 | 5 | 5 | 7 | 1 | 1 | 3 |
| $SAC_7$ | 1 | 3 | 3 | 1 | 1 | 1 | 5 | 5 | 7 | 5 | 7 | 7 |
| $SAC_8$ | 5 | 7 | 7 | 5 | 7 | 7 | 5 | 7 | 7 | 7 | 7 | 9 |
| $SAC_9$ | 5 | 7 | 7 | 1 | 3 | 3 | 7 | 7 | 9 | 5 | 7 | 7 |
| $SAC_{10}$ | 5 | 7 | 7 | 1 | 1 | 3 | 5 | 5 | 7 | 5 | 7 | 7 |
| $SAC_{11}$ | 7 | 9 | 9 | 5 | 7 | 7 | 5 | 7 | 7 | 5 | 7 | 7 |
| $SAC_{12}$ | 1 | 1 | 1 | 7 | 7 | 9 | 5 | 7 | 7 | 7 | 9 | 9 |
| $SAC_{13}$ | 5 | 7 | 7 | 3 | 3 | 5 | 5 | 7 | 7 | 5 | 5 | 7 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SAC_{14}$ | 5 | 7 | 7 | 5 | 5 | 7 | 3 | 3 | 5 | 1 | 3 | 3 |
| $SAC_{15}$ | 5 | 7 | 7 | 5 | 7 | 7 | 7 | 9 | 9 | 1 | 1 | 3 |
| $SAC_{16}$ | 7 | 9 | 9 | 5 | 7 | 7 | 5 | 7 | 7 | 3 | 3 | 5 |

Table 2: The crisp value of decision matrix.

| | $SAA_1$ | $SAA_2$ | $SAA_3$ | $SAA_4$ |
|---|---|---|---|---|
| $SAC_1$ | 2.666667 | 8.666667 | 6.666667 | 6.666667 |
| $SAC_2$ | 1.333333 | 5.333333 | 6.666667 | 6.666667 |
| $SAC_3$ | 6.666667 | 2.666667 | 5.333333 | 5.333333 |
| $SAC_4$ | 7.333333 | 2.666667 | 3.333333 | 7.333333 |
| $SAC_5$ | 6.666667 | 3.333333 | 3.333333 | 6.666667 |
| $SAC_6$ | 7.333333 | 2.666667 | 5.333333 | 1.333333 |
| $SAC_7$ | 2.666667 | 1 | 5.333333 | 6.666667 |
| $SAC_8$ | 6.666667 | 6.666667 | 6.666667 | 7.333333 |
| $SAC_9$ | 6.666667 | 2.666667 | 7.333333 | 6.666667 |
| $SAC_{10}$ | 6.666667 | 1.333333 | 5.333333 | 6.666667 |
| $SAC_{11}$ | 8.666667 | 6.666667 | 6.666667 | 6.666667 |
| $SAC_{12}$ | 1 | 7.333333 | 6.666667 | 8.666667 |
| $SAC_{13}$ | 6.666667 | 3.333333 | 6.666667 | 5.333333 |
| $SAC_{14}$ | 6.666667 | 5.333333 | 3.333333 | 2.666667 |
| $SAC_{15}$ | 6.666667 | 6.666667 | 8.666667 | 1.333333 |
| $SAC_{16}$ | 8.666667 | 6.666667 | 6.666667 | 3.333333 |

Table 3:The normalized decision matrix.

| | $SAA_1$ | $SAA_2$ | $SAA_3$ | $SAA_4$ |
|---|---|---|---|---|
| $SAC_1$ | 0.307692 | 1 | 0.769231 | 0.769231 |
| $SAC_2$ | 0.2 | 0.8 | 1 | 1 |
| $SAC_3$ | 1 | 0.4 | 0.8 | 0.8 |
| $SAC_4$ | 1 | 0.363636 | 0.454545 | 1 |
| $SAC_5$ | 1 | 0.5 | 0.5 | 1 |
| $SAC_6$ | 1 | 0.363636 | 0.727273 | 0.181818 |
| $SAC_7$ | 0.4 | 0.15 | 0.8 | 1 |
| $SAC_8$ | 0.909091 | 0.909091 | 0.909091 | 1 |
| $SAC_9$ | 0.909091 | 0.363636 | 1 | 0.909091 |
| $SAC_{10}$ | 1 | 0.2 | 0.8 | 1 |
| $SAC_{11}$ | 1 | 0.769231 | 0.769231 | 0.769231 |
| $SAC_{12}$ | 0.115385 | 0.846154 | 0.769231 | 1 |
| $SAC_{13}$ | 1 | 0.5 | 1 | 0.8 |
| $SAC_{14}$ | 1 | 0.8 | 0.5 | 0.4 |
| $SAC_{15}$ | 0.769231 | 0.769231 | 1 | 0.153846 |
| $SAC_{16}$ | 1 | 0.769231 | 0.769231 | 0.384615 |

Table 4. The weighted normalized decision matrix.

| | $SAA_1$ | $SAA_2$ | $SAA_3$ | $SAA_4$ |
|---|---|---|---|---|
| $SAC_1$ | 0.021726 | 0.070611 | 0.054316 | 0.054316 |
| $SAC_2$ | 0.01145 | 0.045802 | 0.057252 | 0.057252 |
| $SAC_3$ | 0.057252 | 0.022901 | 0.045802 | 0.045802 |

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| | | | | |
|---|---|---|---|---|
| $SAC_4$ | 0.05916 | 0.021513 | 0.026891 | 0.05916 |
| $SAC_5$ | 0.057252 | 0.028626 | 0.028626 | 0.057252 |
| $SAC_6$ | 0.04771 | 0.017349 | 0.034698 | 0.008675 |
| $SAC_7$ | 0.017939 | 0.006727 | 0.035878 | 0.044847 |
| $SAC_8$ | 0.071131 | 0.071131 | 0.071131 | 0.078244 |
| $SAC_9$ | 0.060722 | 0.024289 | 0.066794 | 0.060722 |
| $SAC_{10}$ | 0.057252 | 0.01145 | 0.045802 | 0.057252 |
| $SAC_{11}$ | 0.082061 | 0.063124 | 0.063124 | 0.063124 |
| $SAC_{12}$ | 0.007817 | 0.057325 | 0.052114 | 0.067748 |
| $SAC_{13}$ | 0.062977 | 0.031489 | 0.062977 | 0.050382 |
| $SAC_{14}$ | 0.051527 | 0.041221 | 0.025763 | 0.020611 |
| $SAC_{15}$ | 0.05138 | 0.05138 | 0.066794 | 0.010276 |
| $SAC_{16}$ | 0.072519 | 0.055784 | 0.055784 | 0.027892 |

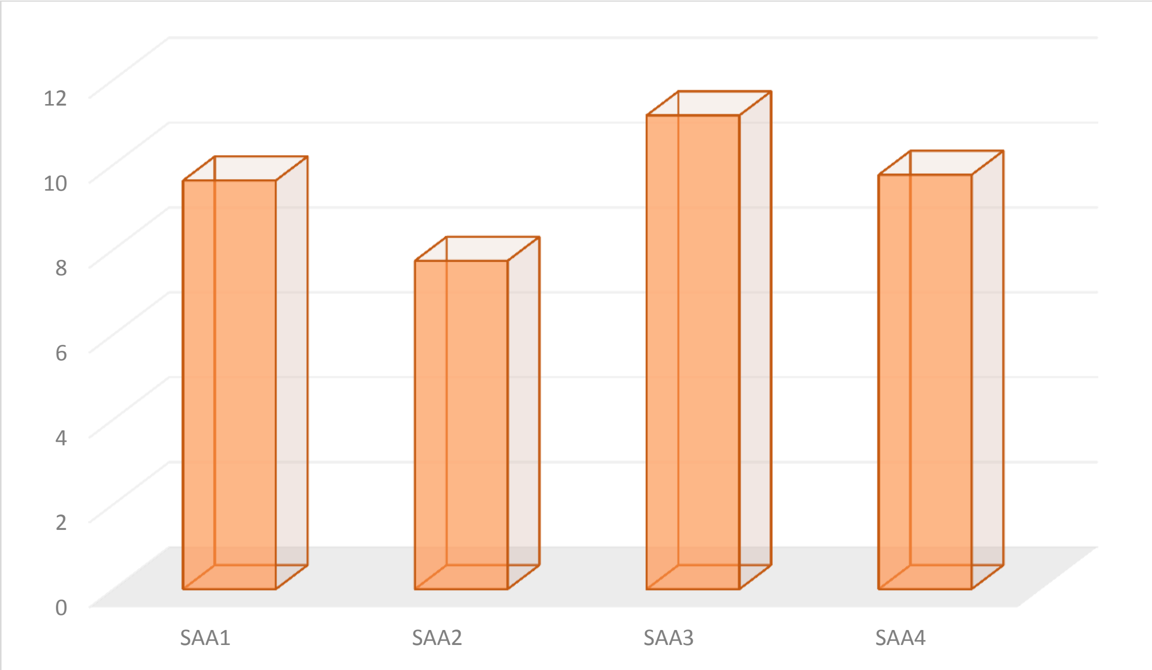


Figure 2: The rank of alternatives.

In order to be ready for the shift to smart agriculture, one agricultural company chooses four options from the market: Chinasoft , XAG, JXIOT, and Longsoft. It is determined by the assessment index system that the best solution is chosen from among the four options analysed. We assembled a three-person expert team to assess the indicators listed in Table 1 in order to collect the data. The expert group is made up of agricultural company CEOs, sales directors, finance directors, and agricultural trade group specialists, as well as academics and researchers with at least three years of relevant expertise from research universities. From figure 2. The SSA3 is the best alternatives followed by SSA1. The lowest rank id SSA2. The SSA3 is the most suitable alternative.

## 5. Conclusion

Using a fuzzy MARCOS method described in this research, multi-criteria decision-making may be supported, particularly when considering unknown parameters. An important benefit of TFNs is their ability to help people make sound judgments by showing how certain indications relate to both an ideal and an anti-ideal solution. In addition, decision-makers will be able to use this article to develop a novel fuzzy language measure for constraint assessment.

The ratio method and the good reference method were used to develop a revolutionary fuzzy MARCOS strategy that provides a fundamental, complete information system for decision-making in an uncertain environment. It is possible to accomplish many goals at once with Fuzzy MARCOS.

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Using Fuzzy MARCOS, we can examine how different options are related to one another and how the social environment affects decision making in MCDM. With the Fuzzy MARCOS method, the following factors are taken into account: the definition of points of reference (fuzzy ideal and fuzzy anti-ideal principles), the choice of links between alternatives, and the definition of the power extent of alternatives in relation to fuzzy ideal and fuzzy anti-ideal solutions for a robust decision. The proportion and references point filtering procedures are used in the fuzzy MARCOS methodology to generate more probable outcomes.

Results from the Fuzzy MARCOS technique are very robust and trustworthy, even in a dynamic environment. Furthermore, the author's work shows that perhaps the fuzzy MARCOS technique is robust in large data sets.Developing the MARCOS technique with additional theories, such as single-valued intuitionistic fuzzy integers, grey concept, and many others, may be the subject of future research. Granular fuzzy preference relations, where each comparison is structured as a distinct information granule, or the approach of making decisions and solving with granularity may also be used to generate agreement in groups.

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