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The possibility of using multi-criteria decision-making methods in the supply chain of agricultural products

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ABSTRACT
This article presents an analysis of a multi-criteria optimal decision-making method based on the Analytical Hierarchy Process (AHP) and the superiority of the Top-Oriented Sequence of Methods (TOPSIS) in the context of supplying low-cost, high-quality fruit to fruit farms. A flowchart of each method's algorithm is developed. A tabular comparison of the ranking accuracy of alternatives between the AHP and TOPSIS methods is presented in the context of the fresh fruit and vegetable supply chain. Particular attention is paid to the aspect of decision-making under time constraints. The study demonstrated significant advantages for the TOPSIS method in the fruit supply context. Both AHP and TOPSIS methods are used to select low-cost, high-quality fruit for consumers. The results of the study demonstrate that the AHP-TOPSIS methodology can be considered a useful decision-making tool for managers and marketers of fruit processing companies.
KEYWORDS: *multi-criteria optimization, decision-making process, hierarchy process, fruit and vegetable supply, ranking of alternatives.*

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I. INTRODUCTION

The selection and supply of agricultural products by consumers are primarily determined by their type and the magnitude of the parameters that determine quality. Monitoring these parameters in supply chains using sensor and communication technologies enabled by the Internet of Things (IoT) facilitates product selection. Various wireless communication technologies are available for real-time data exchange, as well as for further processing and use of the data, which is a prerequisite for marketing. Ensuring efficient supply chains requires extensive communication and collaboration between buyers and sellers over a period of time. Frequently switching suppliers to obtain lower prices does not yield the best results in the long term [1].

To address these issues, we use multi-criteria decision making (MCD), an analytical hierarchy process and a method for determining the order of preferences based on similarity to an ideal solution [2,3].

Decision making is the process of choosing between alternative courses of action to achieve a goal or goals. Multi-criteria decision making (MCD) involves making decisions in the presence of multiple criteria. AHP is the most well-known and popular MCDM method. Since its inception, AHP has been applied in many situations with impressive results [1, 2].

TOPSIS is a well-established MCDM method used to rank alternatives according to their relative closeness to an ideal solution. The general TOPSIS procedure consists of the following steps: constructing and normalizing a decision matrix, applying criterion weights to obtain a weighted normalized matrix, identifying ideal and negative-ideal solutions, and calculating the relative closeness of each alternative to the ideal solution. The ideal solution represents the best achievable performance for each criterion among all alternatives, while the negative-ideal solution corresponds to the worst [3, 4].

[5] This article discusses a proposed prioritization of fresh palm fruit suppliers in an agro-industrial enterprise producing crude palm oil (CPO). The problem faced by the company is that its domestic FFB plantations cannot meet all fresh palm fruit requirements. Potential suppliers are identified through a supplier screening process based on relevant criteria. The analytic hierarchy process and weighted evaluation models are used to identify suppliers.

[6,7] The studies used the analytic hierarchy process and integrated proportional evaluation to evaluate suppliers and select the most suitable suppliers for manufacturing companies. The results of the study demonstrate that the integrated AHP-COPRAS method is an effective method that can be used in supplier selection.

[8] The article proposes taking into account consumer perceptions of fruit quality, particularly Valencia oranges, in the supplier selection process for retailers. A combination of consumer and trained sensory panels and the analytic hierarchy process were used for this purpose.

[9] The study examined two methodologies: a mixed method based on questionnaires and interviews to analyze stakeholder behavior, and a second AHP method involving collecting samples of retailers and consumers. The results obtained can be used for further analysis of the planning and design of new markets. [10,11] The articles develop algorithms for assessing the effectiveness of teachers and treatment methods in the healthcare sector. They are based on the hierarchical analysis method. The hierarchical model of teacher performance and the analytic hierarchy process algorithm are based on the current academic performance and attendance of students. An example of assessing the quality of teacher performance using the hierarchical model is presented.

[12] The article describes the use of the analytic hierarchy process to assess the contribution of student management team members. The results showed that student evaluations are most influenced by the relative importance of teamwork, computer skills, and management, as well as the subcriteria: communication, innovation, commitment, and collaboration.

[13] The article describes the theoretical foundations and the mechanism for the practical implementation of the analytic hierarchy process, as well as its potential application in the modern banking sector. The analytic hierarchy process is considered as a general measurement theory; It is used to derive ratio scales from discrete and continuous pairwise comparisons in multilevel hierarchical structures.

[14,15] Four criteria are used in articles to determine the best supplier: price, delivery time, payment terms, quality and service. Clients always expect reasonable prices after initial planning. Delivery time is an important factor to ensure timely delivery. AHP and TOPSIS methods are used to select and determine the best supplier for the company.

[16] The purpose of the article is to compare AHP and TOPSIS as methods of multi-criteria decision-making in the context of choosing a procurement method. The results show that the AHP method, based on pairwise comparisons, demonstrates the best results when choosing the procurement method compared to the TOPSIS method.

[17] The purpose of the study is to clarify the effectiveness of the TOPSIS method and the combined AHP-TOPSIS method, as well as to compare the best TOPSIS methods and the combined AHP-TOPSIS method when selecting outstanding students.

Basically, the strategic criteria for selecting suppliers assess how important the purchasing mechanism is for suppliers to get the status of a preferred client, which can be a sufficient condition for successful cooperation. Companies should choose the most suitable supplier, because the selection of suppliers that can significantly reduce purchase costs and increase the company's profit [1, 4].

Scientific novelty is the possibility of using multi-criteria decision-making methods (AHP and TOPSIS) when choosing high-quality and inexpensive fruits in the supply chain of fresh agricultural products from plantations based on comparative analysis.

The purpose of the work is to develop a structure that will allow you to evaluate and choose fruits and vegetables of the best quality and at the best price, with minimal delivery time and the best service. The proposed methodology represents the integration of two methods of multi-criteria decision making (MCDM) — AHP and TOPSIS — for the evaluation of potential farmers — in the context of fruit supply.

II. MAIN SECTION

2.1 Decision Support Systems

Multi-criteria decision-making methods allow researchers and experts to make decisions based on qualitative or quantitative data. To achieve optimal decision-making results, we determined during our analysis that a series of steps using various methods or stages is necessary (Fig. 2.1) [2, 5].

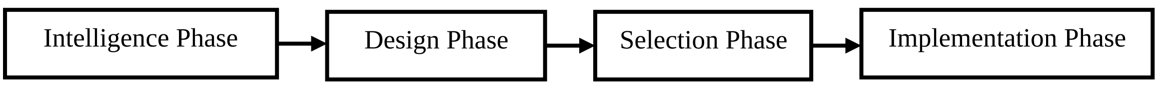

Figure 2.1: Stages of the decision-making process

1.2 Analytic Hierarchy Algorithm (AHP)

On the basis of the conducted analysis, we determined that the analytical hierarchy method (AHP) can solve complex tasks, where there are many criteria, the structure of the task is unclear, and the availability of accurate statistical data is uncertain. As a result of the research, we developed a block diagram of the decision-making algorithm using the AHP method, which is presented in Fig. 2.2 [5–8].

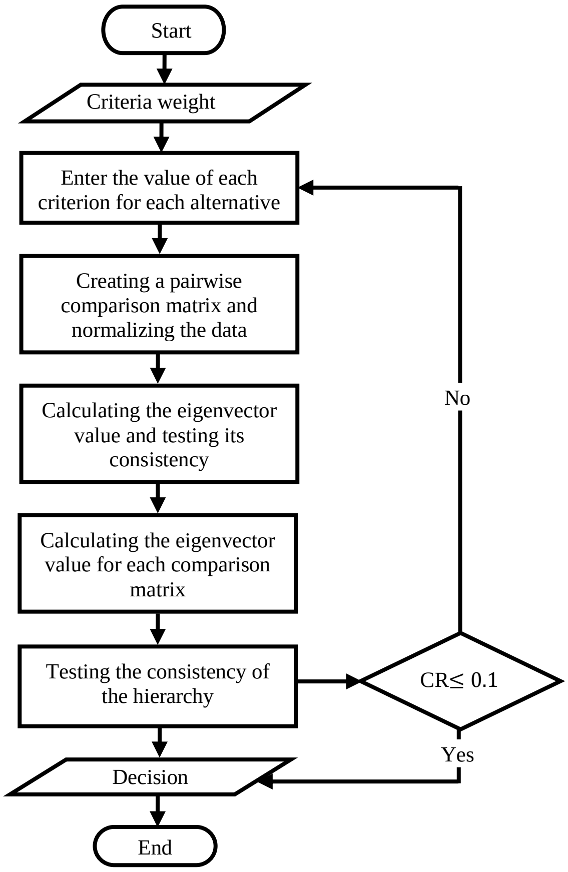

Figure 2.2: AHP decision-making algorithm flowchart

2.3. The Technique of Ordinal Preference for Similarity to the Ideal Solution (TOPSIS) algorithm

We established that TOPSIS is based on the concept that the best alternative is selected not only by the shortest distance from the positive ideal solution, but also by the greatest distance from the negative ideal solution. This concept is widely used in several MADM models to solve practical decision-making tasks. Based on the analysis, a general flowchart of the TOPSIS process algorithm was developed, which is presented in Fig. 2.3 [12 - 15].

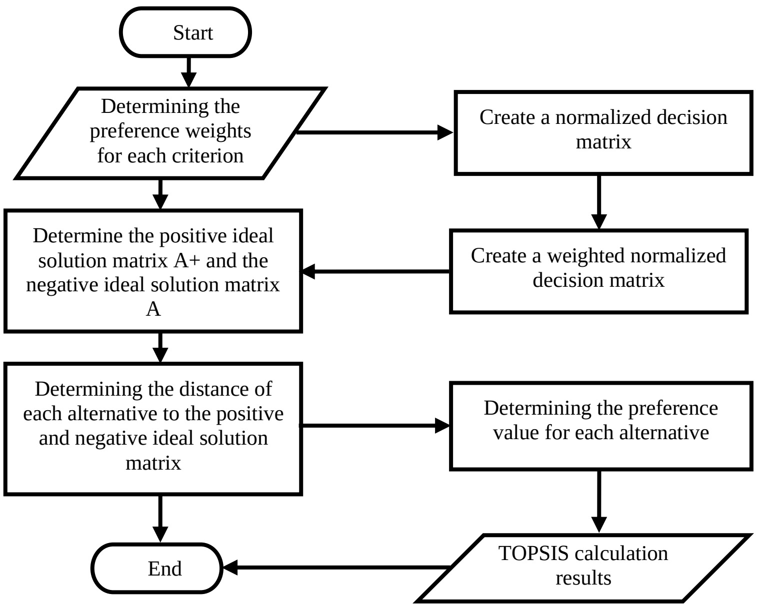

Figure 2.3: TOPSIS decision-making algorithm flowchart

2.4. Comparison of the Performance of Multi-Criteria Decision Making Methods: AHP and TOPSIS

This study yielded significant results comparing the performance of the analytic hierarchy process (AHP) and the preference selection method (TOPSIS) in the context of agricultural commodity selection and supply. The analysis was conducted based on three main aspects: alternative ranking accuracy, result consistency, and computational efficiency. In terms of alternative ranking accuracy, both methods demonstrated good ability to identify and rank potential agricultural commodity suppliers. However, AHP provides more stable and reliable results, especially when considering criteria with widely varying levels of importance.

This can be attributed to AHP's ability to structure the problem into a clear hierarchy and perform pairwise comparisons between criteria. On the other hand, TOPSIS demonstrates advantages in handling situations where there is a significant trade-off between criteria, as this method explicitly takes into account the distance between positive and negative ideal solutions. Table 2.1 presents a comparison of the alternative ranking accuracy between AHP and TOPSIS based on three different decision making scenarios [14–17].

Table 2.1. Comparison of alternative ranking accuracy between AHP and TOPSIS methods

Scenario	AHP Accuracy (%)	TOPSIS Accuracy (%)	Accuracy Difference (%)
1	92	90	2
2	88	91	-3
3	96	93	3
Medium	**92**	**91**	**1**

Table 2.1 shows that the AHP method has a slightly higher average accuracy (92%) than the TOPSIS method (91%). However, this difference is statistically insignificant ($p > 0.05$), which indicates comparable effectiveness of both methods from the point of view of accuracy of ranking alternatives. Consistency of results is the most important aspect of decision-making, especially when working with complex and multidimensional data, such as the selection of high-quality and inexpensive fresh fruits from plantations. The consistency analysis is carried out by checking the stability of the alternative ranking with small changes in the input data. The results show that the AHP method has a higher level of consistency than the TOPSIS method.

The advantage of the AHP method in this aspect is explained by the process of pairwise comparison, which allows decision-makers to systematically check the consistency of their decisions. Computational efficiency is an important factor, especially when working with large data sets or when decisions need to be made in limited time. In this regard, the TOPSIS method demonstrates significant advantages, as shown in Table 2.2.

Table 2.2 Improvement of alternatives and criteria

Alternatives Quantity	Criteria Quantity	AHP calculation Time (sec)	TOPSIS Calculation time (sec)
3	3	1,0	0,4
5	4	2,2	0,8
7	5	3,5	1,1

Table 2.2 shows that while the computation time of both methods increases with increasing problem complexity, TOPSIS demonstrates superior scalability, especially for problems with a large number of alternatives and criteria.

The results of a comparison of AHP and TOPSIS in the context of selecting high-quality, affordable fresh fruit from orchards revealed important information about the strengths and weaknesses of each method. AHP demonstrates advantages in terms of the consistency of results and the ability to structure complex problems into a clear hierarchy. This is consistent with the findings of [10, 11, 18], which highlighted the strengths of AHP in handling highly complex multi-criteria problems. However, AHP also demonstrates greater sensitivity to changes in criterion weights, which can be a disadvantage in situations where decision makers' preferences are unstable or difficult to determine with certainty. On the other hand, TOPSIS demonstrates advantages in computational efficiency and robustness to input data outliers.

III. CONCLUSION

This study successfully achieved its primary objective, which was to conduct a comprehensive comparative analysis of the AHP and TOPSIS methods in the context of a decision support system for selecting high-quality, affordable fresh fruit from orchards. The key results demonstrate that AHP copes well with the hierarchical complexity of criteria and provides higher consistency in results, while TOPSIS demonstrates advantages in computational efficiency and robustness to data outliers. The study also successfully identified the key factors influencing the performance of each method, which will significantly contribute to the development of decision support systems and a better understanding of their application in the context of supplying high-quality, affordable fresh fruit fromorchards.

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