Original scientific paper
Оригиналан научни рад
UDC 339.13:631]:338.439.5
DOI: 10.7251/AGREN1802079N

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

Application of Multi-Criteria Decision-Making Methods for Supplier Selection in an Agricultural Enterprise

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Abstract

In today's turbulent market conditions, the selection of suppliers in an agricultural enterprise constitutes a primary function, and the entire supply chain with the necessary raw materials and intermediate goods plays an important role in the day-to-day functioning of the economic entity in this field. In order to successfully solve the problem of choosing a supplier, the decision maker uses the methods of multi-criteria analysis, and the corresponding software support. The subject of research in this paper is the selection of mineral fertilizer suppliers in the agricultural enterprise using the AHP methodology, which is one of the most commonly applied methods of multi-criteria analysis today. The aim of the research is to rank suppliers on the basis of the set criteria, and a supplier with the highest rating was selected for the supplier of mineral fertilizer as the observed enterprise.

Key words: multi-criteria decision making, AHP method, supplier selection

Introduction

Decision making and choosing the most favorable option (alternative) are present at all levels of business in the agricultural enterprise as one of the business entities in the agribusiness.

Daily changes in the market conditions of the economy have imposed an obligation to seriously approach the planning and organization of all segments of business in agriculture and agribusiness, and decision making has become something of great importance for any manager or business organizer (Nedeljković et al., 2017).

Due to frequent changes in demand and market offer, the supply chain in an enterprise must be fairly flexible, especially when it comes to purchasing the necessary raw materials. The greatest impact on the efficiency of a procurement system depends on the proper selection of appropriate suppliers (Zak, 2015). This is especially important when it comes to agricultural enterprises, because due to the often unpredictable weather conditions, financial flows, markets, long production processes, etc., they become very sensitive to inadequate business decisions.

In support of the above, decision-makers increasingly rely on the so-called Decision support systems, which, as part of the information systems, have become an indispensable factor in successful organization and optimization in an enterprise. The goal of this paper is to rank the mineral fertilizer suppliers in an agricultural enterprise from the area of Bijeljina municipality by applying the Decision support system.

Materials and Methods

The method used in this paper will be *the method of analytical processes* (AHP) developed by Tomas Saaty in the early 1970s. Today it represents one of the most important scientific decision-making methods. The method represents a multi-criteria procedure and belongs to the class of the so-called soft optimization for the formation and analysis of decision making hierarchies. The method is based on the mathematical and psychological basis for the analysis of complex decisions and mainly involves several parties and a number of alternatives, by using a hierarchical structure that facilitates the rigorous definition of priorities and preferences in decision-making processes (Saaty, 1991).

The method is based on the following four basic axioms:

- *Axiom of reciprocity*: If an X element is n-times more important than the Y element, then the Y element is 1 / n-times more important than the X element;
- *Axiom of homogeneity*: Comparing makes sense only if the elements are comparable - for example, the weight of the fly and the weight of the elephant cannot be compared.

- *Axiom of dependency*: It is possible to compare elements of one level only with the higher level element.
- *Axiom of Expectations*: Any change in the structure of the hierarchy of problem solving requires re-evaluation of elements of the hierarchy (Saaty, 1986; Harker & Vargas, 1987; Alphonce, 1997).

Initially, the decision maker decomposes the decision-making process in several decision-making elements and among them establishes a hierarchy of several levels. At the top of the hierarchical structure of the problem is the goal, while the given criteria are at the lower level, and alternatives are at the lowest. Naturally, cases from the practice are possible when there are several levels in the hierarchical structure (sub-criteria). After forming the hierarchical structure, the decision maker makes a comparison in the pairs of elements at a given level with respect to all the elements at a higher level. The elements are compared based on the numerical equivalents from the Saaty's scale. (Table 1). Integer values (e.g. 1, 3, 6, 9) are the linear part of the Saaty's scale, and reciprocal values (e.g. 1/2, 1/5, 1/9) make up its non-linear part.

Tab. 1. Saaty's intensity scale
Saaty-ева скала интензитета

The intensity of importance	Definition	Explanation
1	Equally important	Two criteria or alternatives equally contribute to the goal
3	Moderately important	A moderate advantage is given to one criterion or an alternative in contributing to the achievement of the goal
5	Strictly important	One criterion or alternative is more important in achieving the goal
7	Very strict, proven important	One criterion or alternative is strongly favored over the other
9	Extremely important	Favoring one criterion / alternative over the other with the utmost persuasiveness
2,4,6,8	-	Intermediate values

Source: Saaty, 1986.

When evaluating *n* decision making elements on a given hierarchy level in relation to a higher level element of the scale (Table 1), their semantic ratings by the definitions from the left column are represented numerically by values from the right column and are entered in square matrix A.

The matrix is positive and reciprocal, which means that the elements from the upper triangle are reciprocal to elements from the lower triangle, while the elements on the main diagonal are equal to the unit (a*ij*=1/a*ji*, for each *i* and *j*; a*ii*=1 for each *i*).

The next step is prioritization, i.e. determination of the weight of computed elements based on the numerical values from the matrix A. After determining the local weights of decision-making elements by the prioritization method, synthesis is used to finally determine the weight alternatives at the lowest level in relation to the element at the highest level (set goal).

For the AHP method to be applied, it is important to note that no more than nine elements should be used at a given hierarchy level because man does not possess the mental strength of consistent valuation in pairs of a large number of elements: for example, for 9 elements 36 comparisons are necessary (9 * 8/2) which may be difficult for decision makers (Srđević et al., 2003).

Results and Discussion

At the stage of the upcoming fertilization of wheat on its cultivated areas, the agricultural company from Bijeljina plans to purchase a certain amount of mineral fertilizer for this purpose. Based on experience from the previous period, the enterprise management considers a group of four potential suppliers of mineral fertilizer.

The authors of the paper, based on their own experiences in the previous research, as well as in discussions with relevant persons from the procurement and management sector of the enterprise, defined the criteria on the basis of which suppliers would be evaluated (Table 2).

Tab. 2. Criteria for the selection of suppliers
Критеријуми за избор добављача

Characteristics	The criteria
K1	Product quality
K2	Price
K3	Delivery date
K4	Payment terms
K5	Vendor Reliability

Source: Authors

After defining the necessary criteria, the problem of choosing supplier can be shown in Figure 1:

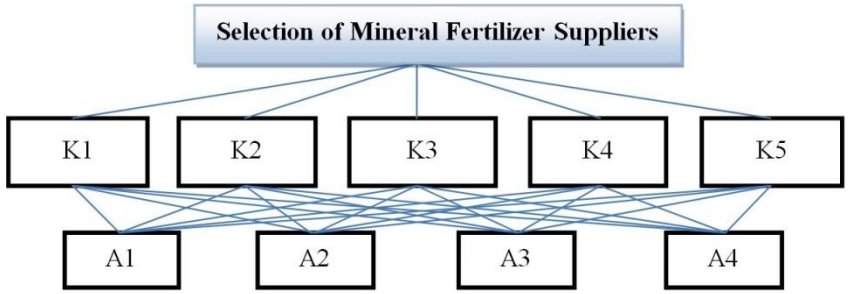

Fig. 1. Hierarchical Structure of Problem Solving
Хијерархијска структура проблема одлучивања
Source: Authors

After defining the criteria and determining the hierarchical structure of the problem, it is possible to determine a matrix of criteria comparison. The weight comparison matrix is also processed here based on the initial decision matrix, where the evaluation was performed on the basis of the Saaty's scale and in cooperation with the enterprise's management and the acquisition reference manager (Table 3).

Tab. 3. The matrix of the criteria comparison
Матрица поређења критеријума

Criteria	K1	K2	K3	K4	K5
K1	1	1	5	5	3
K2	1	1	5	2	2
K3	1/5	1/5	1	1/3	1/3
K4	1/5	1/2	3	1	1/3
K5	1/3	1/2	3	3	1

Source: Authors

By comparing the criteria, we get the relative importance of the supplier selection criteria, and we rank the weight coefficients thus obtained (Table 4).

Tab. 4. Relative importance of criteria
Релативни значај критеријума

Criteria	Weight coefficient	Rank
Quality	0,380	1
Price	0,286	2
Delivery date	0,054	5
Payment terms	0,104	4
Vendor Reliability	0,176	3

Source: Authors

The results of the current application of the AHP methodology show that *quality* and then the *price* are the most important criteria when choosing mineral fertilizer. The supplier choice is to a lesser extent influenced by criteria such as payment terms, supplier reliability and delivery deadline.

The next step is to evaluate suppliers in relation to each criterion in particular, in the same way as the previous step (by comparing in pairs and using the Saaty's scale). The results are shown in the tables below.

Tab. 5. Evaluation of suppliers based on criterion K1 (quality)
Вриједновање добављача на основу критеријума К1 (квалитет)

Criterion 1	A1	A2	A3	A4	Rank/Weight
A1	1	2	3	2	0,405
A2	1/2	1	5	3	0,355
A3	1/3	1/5	1	1	0,106
A4	1/2	1/3	1	1	0,134

Source: Authors

Tab. 6. Evaluation of suppliers based on criterion K2 (price)
Вриједновање добављача на основу критеријума К2 (цијена)

Criterion 2	A1	A2	A3	A4	Rank/Weight
A1	1	1	3	5	0,394
A2	1	1	3	3	0,357
A3	1/3	1/3	1	4	0,173
A4	1/5	1/3	1/4	1	0,076

Source: Authors

Tab. 7. Evaluation of suppliers based on criterion K3 (delivery deadline)
Вриједновање добављача на основу критеријума К3 (рок испоруке)

Criterion 3	A1	A2	A3	A4	Rank/Weight
A1	1	2	3	4	0,484
A2	1/2	1	2	1	0,220
A3	1/3	1/2	1	1	0,139
A4	1/4	1	1	1	0,157

Source: Authors

Tab. 8. Evaluation of suppliers based on criterion K4 (payment terms)
Вриједновање добављача на основу критеријума К4 (услови плаћања)

Criterion 4	A1	A2	A3	A4	Rank/Weight
A1	1	2	5	3	0,496
A2	1/2	1	2	1	0,213
A3	1/5	1/2	1	2	0,151
A4	1/3	1	1/2	1	0,140

Source: Authors

Tab. 9. Evaluation of suppliers based on criterion K4 (reliability)
Вриједновање добављача на основу критеријума К5 (поузданост)

Criterion 5	A1	A2	A3	A4	Rank/Weight
A1	1	1	2	1	0,281
A2	1	1	3	1	0,319
A3	1/2	1/3	1	1	0,157
A4	1	1	1	1	0,243

Source: Authors

After comparing the alternatives (suppliers) on the basis of all the criteria, we complete the synthesis of the problem of choosing a supplier based on the set of criteria, which is equal to the sum of the product weight within the observed criterion. This gives the composite weighting coefficients based on which we rank the analyzed suppliers.

Tab. 10. Weight coefficients and rankings of suppliers
Тежински коефицијенти и рангови добављача

Supplier	Composite weighting coefficients	Rank
A1	0,3937	1
A2	0,3271	2
A3	0,1406	3
A4	0,1347	4

Source: Authors

By reading the results from Table 10, the decision maker will not have a problem to determine which supplier has an advantage over others and will be able to easily make the right decision.

Conclusion

Criteria for selecting the best supplier of mineral fertilizer were selected in cooperation with experts from the observed enterprise. Then a hierarchy of decision-making was defined followed by an assessment of the relation between the comparison criteria with the proposed Saaty's scale.

From the results obtained it can be concluded that the most important criterion for the selection of the supplier in this enterprise is the *quality* and then the *price* expected from the purchased product. The least important criterion in this case is the *delivery time* of mineral fertilizers.

The next step was to compare alternatives (suppliers) on the basis of all the criteria set.

It is interesting that the supplier monitored first is preferable to other vendors in almost all criteria, even when it comes to *reliability*, where the second vendor is in favor of the first.

After that, at the very end, we calculated the value of the product weight within each criterion, and the ranking of the supplier was displayed in which a higher value provider has a ranking priority. The results have shown that in this case the first supplier has been given the highest value and will be the first choice of the company in the case of supplying the required mineral fertilizer.

The analysis and use of this method in a specific example of choosing the mineral fertilizer supplier in the agricultural enterprise illustrates some of the features of this multi-criteria decision making method recommended for further use in agribusiness practices.

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Примена метода вишекритеријумског одлучивања при избору добављача у пољопривредном предузећу

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Сажетак

У данашњим турбулентним тржишним условима, избор добављача у једном пољопривредном предузећу представља примарну функцију, а цијели ланац снабдјевања потребним сировинама и репроматеријалима има битну улогу у свакодневном функционисању привредног субјекта у овој области. Да би се успјешно ријешио задати проблем избора добављача, доносилац одлуке користи методе вишекритеријумске анализе, те одговарајућу, пратећу софтверску подршку. Предмет истраживања овог рада представља одабир добављача минералног ђубрива у пољопривредном предузећу применом AHP методологије, која је данас једна од најчешће примјењиваних метода вишекритеријумске анализе. Циљ истраживања је рангирање добављача на основу постављених критеријума, а добављач са највећом оцјеном је одабран за снабдјевача посматраног предузећа минералним ђубривом.

Кључне ријечи: вишекритеријумско одлучивање, AHP метод, избор добављача.

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Received: February 27, 2018
Accepted: May 18, 2018