UDK 629.366:631.372 DOI 10.7251/AP2401082

THE EFFECTS OF APPLYING OBJECTIVE CRITERIA WEIGHT DETERMINATION IN TRACTOR SELECTION

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Abstract

In this paper, the authors used multi-criteria decision-making to select among the offered types of tractors with the aim of determining the possible effects of certain weight coefficients on the final ranking of alternatives. For the purpose of determining the weights of the given criteria, three objective decision-making methods were used (Entropy, MEREC, and CRITIC), while the MABAC (Multi-Attributive Border Approximation Area Comparison) method was used for the final ranking. The results of the research show that different weights were obtained for individual criteria, but this did not significantly affect the choice of the best alternative. In all three cases of objective criteria evaluation, the X8 660 tractor was the best alternative in the final ranking. The results are important as they confirm the effective use of the mentioned methods. However, future research should compare these methods with a group of subjective methods to make the final decision in this field as rational as possible.

Key words: Tractors, MABAC method, Entropy method, MEREC method, CRITIC method

Introduction

Mechanization in modern agriculture plays the most important role, making its selection a complex and responsible task. Depending on the type of production we are engaged in, our choice of agricultural machinery should be aligned accordingly, aiming to achieve greater productivity and efficiency. Today, tractors are not just tools for carrying out the production process. Through their evolution, tractors have become modern instruments indispensable in every production process, and their use plays a central role in the activities of a farm. They are tools that improve productivity, reduce labour-intensive efforts, and enhance competitiveness within an agricultural process (Ahmed and Takeshima, 2020).

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According to Li et al. (2023), the careful selection of agricultural machinery, especially small tractors, is a critical concern for farms. The importance of their selection cannot be overstated, as it can lead to significant financial expenditures that might result in the failure of agricultural production. Therefore, special attention must be paid during the selection of these power machines, and advanced decision-making methods available should be applied. Additionally, the specific needs of the farm must be met when choosing a tractor. Durczak et al. (2020) argue that poor information when making purchase decisions can result in low productivity and further threaten the broader economic well-being of a community.

What is important to emphasize is that when selecting tractors, especially low-power ones for family farms, it is essential to apply a method that follows the complex selection process with rigor and precision. Therefore, the aim of this study is to examine the effects of applying objective criteria weighting methods in tractor selection to assist in making a rational decision.

In recent research, many domestic and international authors have addressed the significance and selection of agricultural machinery (Liao et al., 2022; Aryal et al., 2021; Matache et al., 2020; Birner et al., 2021; Lalghorbani and Jahan, 2022; Nedeljković et al., 2021). For instance, Lu et al. (2022) in their study identify challenges in the selection of agricultural machinery and introduce improved criteria evaluation by applying the CRITIC-GRA-TOPSIS multi-criteria decision-making method. Puška et al. (2022) introduce a new multi-criteria decision-making method, CRADIS, for evaluating criteria and selecting heavy tractors in Bosnia and Herzegovina. Using the SWARA multi-criteria decision-making method, Mishra and Stapathy (2022) investigated the selection of maintenance options for agricultural machinery on farms, while Houshyar et al. (2020) carried out the distribution selection of agricultural machinery in Iran based on the AHP and DEA methods. Puška and colleagues (2023) applied the fuzzy-rough multi-criteria decision-making method for selecting tractors in Bosnia and Herzegovina based on economic and technical criteria. In this study, the focus will be on five tractors from different manufacturers with power ranging from 150 to 200 kW. The criteria weighting will be based on the technical characteristics of the power machines as provided by their manufacturers' specifications.

Methodology

Given that purchasing a tractor often represents a significant investment for any agricultural enterprise, it is necessary to examine the many alternatives available on the market for these power machines. The selection process begins with setting the criteria for selection, evaluating each one individually, and choosing the given alternatives. Based on experience, we selected the following criteria for the chosen tractors: tractor power, fuel tank capacity, weight, engine displacement, and fuel consumption. In their previous research, some authors have focused on analyzing specific technical characteristics of tractors and tractor attachments (Lalremruata et al., 2019; Zhu et al., 2021; Russini et al., 2018; Ruiz-Garcia et al., 2022).

As previously mentioned, we applied three objective multi-criteria decision-making methods to evaluate the criteria and one method to rank the alternatives, which will be briefly presented below.

For ranking the selected alternatives, we will use the MABAC (Multi-Attributive Border Approximation Area Comparison) method. Developed by Pamućar and Ćirović (2015), it is relatively easy to use, provides consistent solutions, and represents a rational choice in decision-making phases. The method defines the distance function of criteria for each alternative from the boundary fair value. In previous research, it has found application in agriculture and agribusiness contexts (Nedeljković et al., 2021; Puška et al., 2023; Pamučar et al., 2018; Božanić et al., 2018; Gong et al., 2019). The steps of the method can be defined through the following six steps:

1. The initial decision matrix,
2. Normalization of the element of the initial decision matrix,
3. Calculation of the weight matrix element,
4. Determination of the matrix of boundary approximate surfaces (Gi),
5. Calculation of elements of alternative distance matrices from the limit approximate domain,
6. Ranking of alternatives (Si).

As objective methods for evaluating criteria in this case, we used the Entropy method, CRITIC method, and MEREC method.

The Entropy method is based on the concept of entropy and finds application in numerous research fields. Essentially, lower entropy indicates greater differences in values that alternatives have for a specific criterion, thereby contributing significantly to the ranking process (Stojanović et al., 2019). The method is implemented through the following steps:

1. Normalization of the initial-decision matrix,
2. Determining the entropy value,
3. Calculation of the degree of diffraction,
4. Calculation of the final weights of the criteria.

The CRITIC method (*Criteria Importance Through Intercriteria Correlation*) was developed by Diakoulaki et al. (1995) and defines objective criteria weights, including the intensity of contrast and conflict inherent in the decision-making structure (Puška et al., 2018). To determine the contrast of criteria, we use the standard deviation of normalized values and the correlation coefficient. The steps of this method are outlined below:

1. Normalization of the initial-decision matrix,
2. Calculation of standard deviation and linear correlation matrix by columns,
3. Determining the amount of information,
4. Calculation of the final weights of the criteria.

The MEREC method (Method based on the Removal Effects of Criteria) represents another objective method for evaluating given criteria. Developed by Ghorabaee et al. (2021), it is based on the removal effect of criteria. They have demonstrated that the method is successfully used for assigning criterion weights, and correlation analysis confirms its alignment with existing methods for weight determination. Its application is defined by the following steps:

1. Normalization of the initial-decision matrix,
2. Calculation of the overall performance of the alternatives,
3. Calculate the effects of the alternatives for each criterion,
4. Calculate the sum of the deviations from the absolute values,
5. Calculate the final weights of the criteria.

In the following sections of the paper, the research results will be presented in tabular and graphical formats.

Research results

At the beginning, an initial decision matrix is formed containing data on selected technical characteristics of tractors. Five tractors with power ranging from 150 kW to 200 kW from different manufacturers are considered. Their names and technical details are presented in the following Table 1. Table 1 specifies which criteria need to be maximized or minimized for further calculations. The next step involves normalizing the initial decision matrix, which is presented in Table 2 in the paper.

Table 1. Decision Matrix

Type of Tractor	**Criteria**				
	Power (kW)	Fuel tank capacity (l)	Tractor weight (kg)	Engine displacement (cm^3)	Fuel consumption (g/kWh)
FENDT 820 VARIO	166	505	9300	6057	192
7250 TTV Agrotron	181	400	9100	6057	264
Axion 800	151	455	8299	6728	248
X8.660	194	550	10800	6728	258
T7.230 New Holland	165	395	8140	6728	233
C/B	*Max.*	*Max.*	*Min.*	*Max.*	*Min.*
Max.	194	550	8140	6728	192
Min.	151	395	10800	6057	264

Source: Authors

Table 2. Normalized Decision Matrix

	Power (kW)	**Fuel tank capacity (l)**	**Tractor weight (kg)**	**Engine displacement (cm^3)**	**Fuel consumption (g/kWh)**
FENDT 820 VARIO	0,3488 37209	0,709677419	0,43609022 6	0	0
7250 TTV Agrotron	0,6976 74419	0,032258065	0,36090225 6	0	1
Axion 800	0	0,387096774	0,05977443 6	1	0,777777778
X8.660	1	1	1	1	0,916666667
T7.230 New Holland	0,3255 81395	0	0	1	0,569444444

Source: Authors

The weights of individual criteria obtained show variations across the methods used. According to the Entropy method, the "fuel tank capacity" criterion received the highest rating. In contrast, for the MEREC method, it was the "tractor weight" criterion, and for the CRITIC method, it was the "engine displacement" criterion. (Table 3)

Table 3. Weight criteria

Methods	**Criteria**				
	Power (kW)	Fuel tank capacity (l)	Tractor weight (kg)	Engine displacement (cm^3)	Fuel consumptio n (g/kWh)
Wj (Entropy)	0,149553	0,340082	0,213467	0,05283	0,244067
Wj (Merec)	0,202291	0,237211	0,287589	0,102205	0,170705
Wj (Critic)	0,192576	0,178049	0,217143	0,236163	0,176069

Source: Authors

Based on the obtained weighting coefficients, the next step involved ranking the offered alternatives by multiplying the scores of individual criteria with the normalized decision matrix using the MABAC method (Table 4, Table 6, Table 8), resulting in the final ranking order of alternatives. For instance, according to the Entropy method and MABAC, tractor X8.660 emerged as the best choice, followed by Agrotron 7250 TTV (Table 5). The visualization of the ranking order is provided in Graph 1 later in the paper.

Table 4. Weight Normalized Decision Matrix*

	Power (kW)	**Fuel tank capacity (l)**	**Tractor weight (kg)**	**Engine displacement (cm^3)**	**Fuel consumption (g/kWh)**
FENDT 820 VARIO	0,201723075	0,581430644	0,30655857	0,052830274	0,244066851
7250 TTV Agrotron	0,253892835	0,351052464	0,290508383	0,052830274	0,488133702
Axion 800	0,149553314	0,471726749	0,226227385	0,105660548	0,433896624
X8.660	0,299106628	0,68016415	0,426934972	0,105660548	0,467794798
T7.230 New Holland	0,198245091	0,340082075	0,213467486	0,105660548	0,383049363
Gi	***0,21449***	***0,46725***	***0,2836***	***0,08006***	***0,39204***

Source: Authors

**According to the entropy method*

Table 5. Distance of the Alternatives*

	Power (kW)	**Fuel tank capacity (l)**	**Tractor weight (kg)**	**Engine displacement (cm^3)**	**Fuel consumption (g/kWh)**	Si
FENDT 820 VARIO	-0,012766925	0,114180644	0,02295857	-0,027229726	-0,147973149	-0,05083
7250 TTV Agrotron	0,039402835	-0,116197536	0,006908383	-0,027229726	0,096093702	-0,00102
Axion 800	-0,064936686	0,004476749	-0,057372615	0,025600548	0,041856624	-0,05038
X8.660	0,084616628	0,21291415	0,143334972	0,025600548	0,075754798	0,542221
T7.230 New Holland	-0,016244909	-0,127167925	-0,070132514	0,025600548	-0,008990637	-0,19694

Source: Authors

**According to the entropy method*

Graph 1. Ranking alternatives

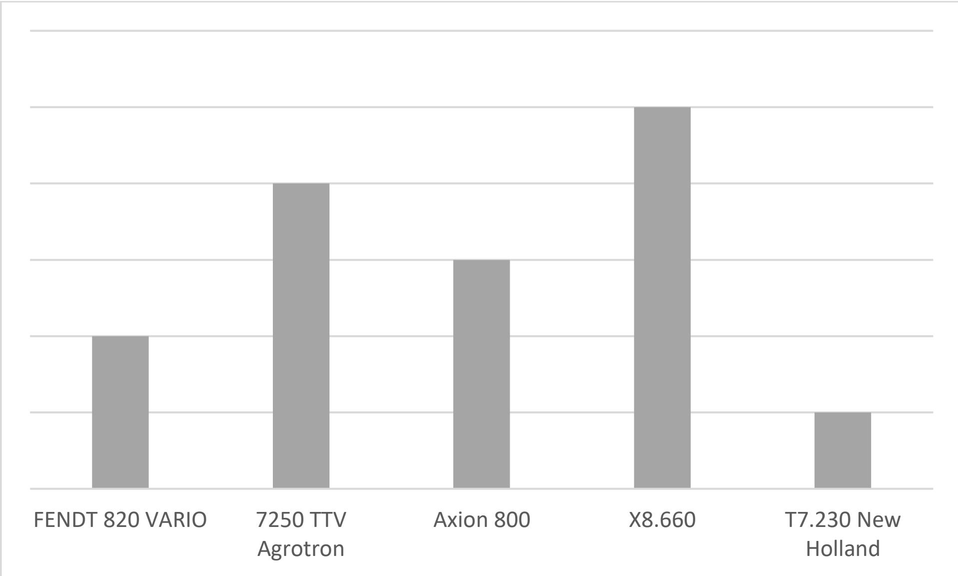


Table 6. Weight Normalized Decision Matrix*

	Power (kW)	**Fuel tank capacity (l)**	**Tractor weight (kg)**	**Engine displacement (cm^3)**	**Fuel consumption (g/kWh)**
FENDT 820 VARIO	0,272857035	0,405553838	0,413003133	0,102205389	0,170704746
7250 TTV Agrotron	0,34342351	0,244862694	0,391379932	0,102205389	0,341409492
Axion 800	0,20229056	0,329034246	0,304779013	0,204410779	0,303475104
X8.660	0,404581121	0,47442147	0,575177138	0,204410779	0,327184097
T7.230 New Holland	0,268152603	0,237210735	0,287588569	0,204410779	0,267911615
Gi	***0,2901***	***0,3259***	***0,38213***	***0,1549***	***0,2741***

Source: Authors

**According to the MEREC method*

When applying the MEREC method to assess weighting coefficients and the MABAC method for ranking, once again, tractor X8.660 and tractor Agrotron 7250 TTV received the highest scores. Similar to the ranking with the integrated Entropy method, the tractor T7.230 New Holland was ranked the lowest (Table 7). The overview of the rankings can be observed in Graph 2.

Table 7. Distance of the Alternatives*

	Power (kW)	**Fuel tank capacity (l)**	**Tractor weight (kg)**	**Engine displacement (cm³)**	**Fuel consumption (g/kWh)**	Si
FENDT 820 VARIO	-0,017242965	0,079653838	0,030873133	-0,052694611	-0,103395254	-0,06281
7250 TTV Agrotron	0,05332351	-0,081037306	0,009249932	-0,052694611	0,067309492	-0,00385
Axion 800	-0,08780944	0,003134246	-0,077350987	0,049510779	0,029375104	-0,08314
X8.660	0,114481121	0,14852147	0,193047138	0,049510779	0,053084097	0,558645
T7.230 New Holland	-0,021947397	-0,088689265	-0,094541431	0,049510779	-0,006188385	-0,16186

Source: Authors

**According to the MEREC method*

Graph 2. Ranking alternatives

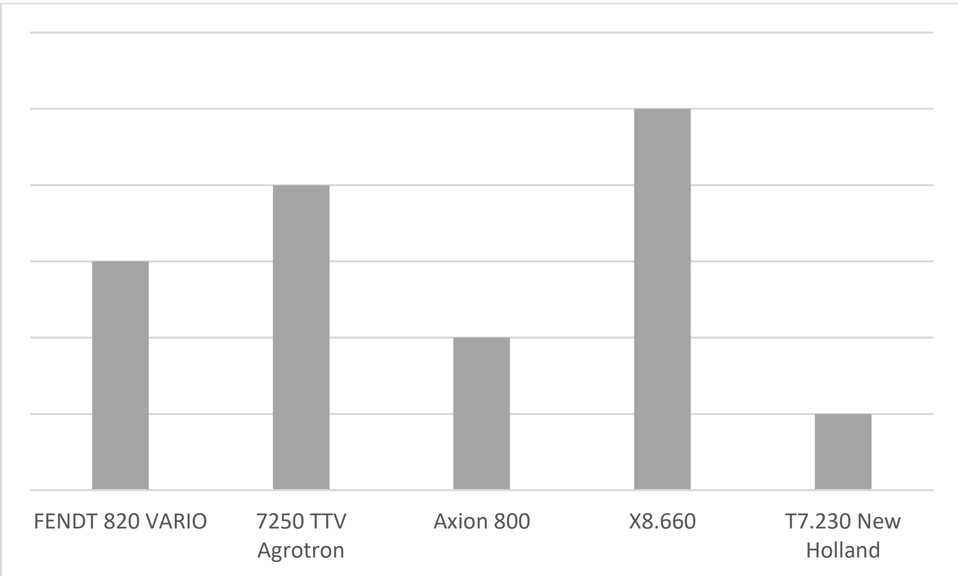


Table 8. Weight Normalized Decision Matrix*

	Power (kW)	Fuel tank capacity (l)	Tractor weight (kg)	Engine displacement (cm^3)	Fuel consumption (g/kWh)
FENDT 820 VARIO	0,259754063	0,304405818	0,311836488	0,236163017	0,176069324
7250 TTV Agrotron	0,326931838	0,183792192	0,29550997	0,236163017	0,352138647
Axion 800	0,192576288	0,246970758	0,230122267	0,472326033	0,313012131
X8.660	0,385152577	0,356097372	0,434285371	0,472326033	0,337466204
T7.230 New Holland	0,255275545	0,178048686	0,217142685	0,472326033	0,276331022
Gi	***0,2759***	***0,24462***	***0,28851***	***0,3579***	***0,2828***

Source: Authors

**According to the Critic method*

As in the previous two cases of weighting coefficient assessment and ranking, with the CRITIC method, tractor X8.660 received the highest rating again. However, this time, the lowest-rated tractor is FENDT 810 Vario (Table 9). In Graph 3, we observe that in this case, the second-highest rated tractor compared to the previous two cases is tractor Axion 800.

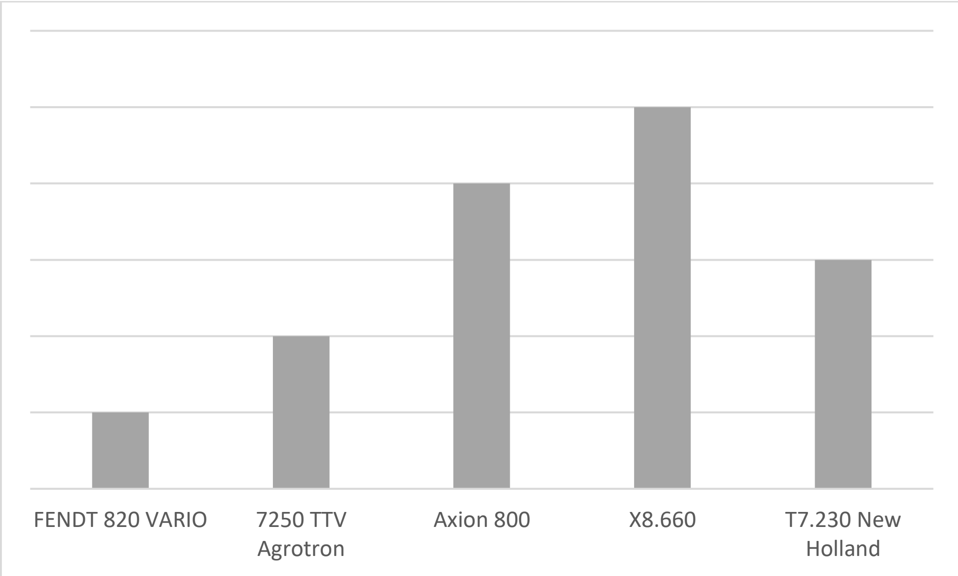
Table 9. Distance of the Alternatives*

	Power (kW)	Fuel tank capacity (l)	Tractor weight (kg)	Engine displacement (cm^3)	Fuel consumption (g/kWh)	Si
FENDT 820 VARIO	-0,016145937	0,059785818	0,023326488	-0,121736983	-0,106730676	-0,1615
7250 TTV Agrotron	0,051031838	-0,060827808	0,00699997	-0,121736983	0,069338647	-0,05519
Axion 800	-0,083323712	0,002350758	-0,058387733	0,114426033	0,030212131	0,005277
X8.660	0,109252577	0,111477372	0,145775371	0,114426033	0,054666204	0,535598
T7.230 New Holland	-0,020624455	-0,066571314	-0,071367315	0,114426033	-0,006468978	-0,05061

Source: Authors

**According to the MEREC method*

Graph 3. Ranking alternatives



Conclusion

Based on the findings presented in the paper, we can conclude that selecting agricultural tractors is a complex process that requires careful consideration due to its potential financial implications for small or medium-sized farms. Various multi-criteria decision-making methods have been developed to aid in making rational decisions during the selection process. These methods evaluate predefined criteria before finalizing the ranking of alternatives.

In this study, five criteria were selected based on manufacturer's technological specifications to assess the impact of objective criteria assessment methods on the ranking of tractors. Different criteria received the highest ratings across the three methods used, but the final ranking among the alternatives for the best choice remained consistent.

In practical applications, it is essential to utilize multi-criteria decision-making methods for evaluating and ranking alternatives, and to compare them with subjective methods to further enhance the decision-making process. This is particularly crucial in sectors such as agriculture and agricultural mechanization, where informed decision-making is vital for optimizing operations and investments.

ACKNOWLEDGEMENTS

Paper is a part of research financed by the MSTDI RS, agreed in decision no. 451-03-66/2024-03/200009 from 5.2.2024.

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EFEKTI PRIMENE OBJEKTIVNOG ODREĐIVANJA TEŽINE KRITERIJUMA KOD IZBORA TRAKTORA

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U radu su autori primenom višekriterijalnog odlučivanja vršili izbor ponuđenih tipova traktora sa ciljem utvrđivanja eventualnih efekata određenih težinskih koeficijenata na konačni poredak alternativa. U svrhu određivanja težina zadatih kriterijuma korišćene su tri objektivne metode odlučivanja (Entropy, MEREC i CRITIC), dok je u svrhu konačnog rangiranja korišćena metod MABAC (Multi-Attributive Border Approximation Area Comparison). Rezultati dobijeni istraživanjem pokazuju da su dobijene različite težine za pojedine kriterijume ali da to nije uticalo u meri izbora najbolje alternative, odnosno da je kod sva tri slučaja objektivnog ocenjivanja kriterijuma traktor X8 660 bio najbolja alternativa u konačnom rangiranju. Rezultati su bitni zbog potvrde prakse dobrog korišćenja predmetnih metoda, ali je u budućim istraživanjima potrebno njihovo poređenje sa grupom subjektivnih metoda da bi konačna odluka o izboru u ovoj oblasti bila što racionalnija.

Ključne reči: Traktori, MABAC metod, entropy metod, MEREC metod, CRITIC metod.

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