ISSN: 1304-4796
Manisa Celal Bayar Üniversitesi Sosyal Bilimler Dergisi
Manisa Celal Bayar University Journal of Social Sciences
2025; 23 (2);152-172

Selecting the Appropriate Machine Using the Entropy and Combined Compromise Solution Methods: An Application for A Steel-Fabrication Company

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ABSTRACT

Laser cutting machines play a critical role in modern manufacturing processes because of their ability to provide highly precise cuts, speed, and flexibility. Particularly in industries such as metalworking, automotive, and aerospace, laser cutting machines can perform highly accurate cuts on complex geometric shapes with minimal errors. As such, laser machines enhance production efficiency by reducing material waste and labor costs when compared with those with compared to manual cutting techniques. The aim of the present study was to provide information to a steel-fabrication company that would aid in purchasing the most efficient and cost-effective laser plate-cutting machine. In complex decision-making processes such as machine selection, managers must consider numerous criteria; therefore, entropy and combined compromise solution (CoCoSo) methods were used to rank the most suitable machines for the company. The criteria were weighted using the entropy calculation method, with positioning accuracy identified as the most important criterion. The importance weights of the criteria are calculated using the Entropy method, and positioning accuracy is identified as the most important criterion. These weighted criteria were then used in the CoCoSo method to establish the machine rankings. Based on the final ranking, machine 2 was identified as the most suitable option and was recommended to company management.

Keywords*: Cocoso, Decision making, Entropy, Laser cutting machine*

Entropi ve Birleşik Uzlaşma Çözüm Yöntemleri Kullanılarak Uygun Makinanın Seçimi: Bir Çelik İmalat Şirketinde Uygulama

ÖZET

Lazer kesim makineleri, yüksek hassasiyetli kesimler, hız ve esneklik sağlamaları nedeniyle modern üretim süreçlerinde kritik bir rol oynamaktadır. Özellikle metal işleme, otomotiv ve havacılık gibi sektörlerde, lazer kesim makineleri karmaşık geometrik şekiller üzerinde son derece hassas kesimler gerçekleştirebilmekte ve hata oranını en aza indirmektedir. Bu bağlamda, lazer kesim makineleri, manuel kesim tekniklerine kıyasla malzeme israfını ve işçilik maliyetlerini azaltarak üretim verimliliğini artırmaktadır. Bu çalışmanın amacı, bir çelik imalat şirketine en verimli ve maliyet açısından en uygun lazer sac kesme makinesinin satın alınmasına yönelik bilimsel bir karar destek sunmaktır. Makine seçimi gibi çok kriterli karar verme süreçlerinde yöneticilerin

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(Makale Gönderim Tarihi: 10.10.2024 / Yayın Tarihi:27.06.2025)
Doi Numarası: 10.18026/cbayarsos.1564646
Makale Türü: Araştırma Makalesi

birden fazla faktörü dikkate alması gerekmektedir. Bu doğrultuda, en uygun makinenin belirlenmesi amacıyla Entropi ve Birleşik Uzlaşık Çözüm (CoCoSo) yöntemleri kullanılmıştır. Kriterlerin ağırlıkları Entropi yöntemi ile hesaplanmış ve konumlandırma hassasiyeti, en önemli kriter olarak tespit edilmiştir. Hesaplanan ağırlıklar CoCoSo yöntemi ile değerlendirilerek makineler sıralanmıştır. Sonuçlar doğrultusunda, Makine 2 en uygun seçenek olarak belirlenmiş ve şirket yönetimine önerilmiştir.

Anahtar Kelimeler: *CoCoSo, Karar verme, Entropi, Lazer kesim makine,*

1.INTRODUCTION

In today’s era of modern technology, meeting ever-changing customer demands and maintaining competitiveness in a sustainable manner have become highly important. As in all industries greater focus must also be put on development in the steel-fabrication sector. The advancements in laser cutting machines technology used in steel-fabrication have accelerated in recent years, which has expanded the areas in which laser machines are used. Laser plate cutting machines, a type of machine that uses laser technology, have not been widely produced in Turkey until recently, but they have started to gain ground in the industry over the past 5-6 years. Laser plate cutting machines are used to cut sheet plates into desired shapes or images with high precision and speed under computer numerical control (CNC). Advancements in laser technology have enabled this technology to surpass the alternatives, allowing its application in numerous industrial sectors. One of the largest application areas of laser technology in industry is cutting metal and non-metal materials. Because no mechanical cutting forces are generated during laser cutting, this method allows for vibration-free and rapid operations. Metal cutting processes conducted using laser technology yield more successful results in many aspects compared to traditional methods. With laser plate cutting technology, material deformation is minimized, ensuring smooth and burr-free cuts, very small holes can be drilled, and because no mechanical tool contacts the material, there is no crushing or warping. For these reasons, this technology is applied globally in many fields in Turkey.

Reaching a decision for the purchase of a the laser plate cutting machine requires a specific selection process that involves both expertise and time; because numerous factors, such as the layout, efficiency, and effectiveness of the production facility, as well as the number of workers to be employed (Arslan, Çatay and Budak, 2004, p.101) are directly affected. Managers responsible for making this decision should thoroughly evaluate this process and carefully examine the products offered by machine manufacturers to reach the final decision. To do this, multi-criteria decision-making (MCDM) methods are involved, which often simultaneously encompass both qualitative and quantitative criteria, such as product characteristics and cost. The aim of the present study was to provide information to a managers at a steel-fabrication company to aid them in selecting and purchasing a laser plate cutting machine. The current study used the integrated entropy and combined compromise solution (CoCoSo) methods, which are MCDM techniques, to determine the most suitable machine ranking for the company. The present study provided a unique contribution by integrating two methods not previously combined in the literature to aid in the selection of a laser cutting machine, offering an objective and systematic evaluation.In addition, it is distinguished by its real-life applicability and contribution to the sector.

The current study comprises five sections. The introduction provides information about the laser cutting machine, and the aim of the study is explained. The literature review presents studies from the literature related to both machine selection and the applied methods. The research methods describe the steps of the entropy and CoCoSo methods used in the study. The application section describes the applications, and the results section evaluates and discusses the results.

2. LITERATURE REVIEW

The literature review is structured into two subsections. The first subsection, "A review of studies employing the Entropy and CoCoSo methods", examines studies that have used the entropy and CoCoSo methods. The second subsection, "A review of studies on multi-criteria decision-making methods for machine selection", explores the applications of these methods in machine selection.

2.1. A Review of Studies Employing the Entropy and CoCoSo Methods

The literature includes numerous studies on the use of entropy and CoCoSo methods in various fields. Topal (2021) has employed the entropy and CoCoSo methods to evaluate the financial performance of electricity-generation companies in Turkey. Financial metrics, such as net sales revenues, total assets, and equity were analyzed to rank the companies. The analyses concluded that Enka demonstrated the highest performance. Görçün and Küçükönder (2022) have conducted a comparative analysis of the transportation performance of cities in Turkey using the best-worst method and CoCoSo methods. The evaluation considered criteria such as transportation infrastructure, public transportation usage rates, and traffic density. Yenilmezel and Ertuğrul (2022) have used multi-criteria decision-making methods to select an uninterruptible power supply (UPS) for a marble factory. By analyzing alternatives using the entropy and CoCoSo methods, the most suitable option was determined. Dağlı and Kuvvetli (2023) conducted a weighted analysis of the financial performance of participation banks in Turkey between 2018 and 2022 using entropy, criterian impact loss, and integrated determination of objective criteria weights methods. The banks' performance was evaluated using the CoCoSo method. The findings revealed that Kuveyt Türk Participation Bank was the most successful in over many years. Akpınar and Metin (2023) have aimed to develop a target market strategy for a company that produces cold storage and pre/post-cooling systems and plans to export them to international markets. The weights of the criteria were determined using the entropy method, and alternative markets were analyzed using the multi-objective optimization on the basis of the ratio analysis method, which found that Georgia(in Eurasia) was the most suitable market. Hadad et al. (2023) have used the S-PIPRECIA and CoCoSo methods to assess student performance. Criteria weights were determined using the S-PIPRECIA method, and students were ranked using CoCoSo. The results contributed to a more fair evaluation of student performance. Banadkouki (2023) has combined the entropy and fuzzy TOPSIS methods to determine strategies for improving energy efficiency in the industrial sector. Criteria weights were determined using the entropy method, while fuzzy TOPSIS was used to rank the most suitable strategies. This integrated approach provided decision-makers with guidance for energy savings. Şişman and Nebati (2024) have aimed to evaluate the logistical performance of Turkey and European Union countries using the entropy-based CoCoSo method. The weights of the criteria were determined using the entropy method, and countries were ranked using CoCoSo. Yücenur and Maden (2024) have applied the entropy and Aras methods to determine the optimal location for hydroponic greenhouses heated by geothermal energy. The model considered five main and 21 sub-criteria; the criteria weights were measured using entropy, and alternatives were ranked using Aras. The study concluded that Denizli province is the most suitable location for establishing geothermal hydroponic greenhouses. Meral (2024) has examined the sustainable development of the 2022 performance of Turkey and Turkic Republics. The analyses comprised 12 criteria; that encompassed economic, social, and environmental dimensions. The criteria weights were determined by integrating the criteria importance through inter-criteria correlation and logarithmic percentage change-driven objective weighting methods using the Bayesian approach. The CoCoSo method was used for performance ranking, which then identified Uzbekistan, Kyrgyzstan, and Kazakhstan as the top-performing countries.

2.2. A Review of Studies on Multi-Criteria Decision-Making Methods for Machine Selection

The problem of selecting machines is a crucial decision-making challenge for managers of manufacturing companies. The literature, indicates that MCDM methods have been used for selecting machines to be purchased across different industries. Perçin (2012) has utilized fuzzy analytic hierarchy process (AHP) and TOPSIS methods for machine-equipment selection. A survey was conducted with metal industry firms during the execution of the study. The criteria, determined by reviewing previous studies and consulting experts, were weighted using the fuzzy AHP method. The alternatives were ranked using the fuzzy TOPSIS method, which showed that the Mazak alternative ranked first. Özdağoğlu (2013) has used the preference ranking organization method for enrichment evaluation (PROMETHEE) method to select the most suitable laser cutting machine. He has evaluated three different machine alternatives based on five criteria as follows: working precision, cutting speed, positioning speed, acceleration, and axis depth. He has assigned equal importance to these criteria and identified the most suitable machine. Organ (2013) has applied the fuzzy decision making trial and evaluation laboratory (DEMATEL) method for loom selection in a textile company. Çakır (2016) has integrated fuzzy specific, measurable, achievable, realistic, and timely and fuzzy weighted axiomatic design techniques for machine selection in a tea factory. Uzun and Kazan (2016) have explored the issue of selecting suitable machinery for a fishing vessel project within the shipbuilding industry.They have applied AHP, TOPSIS, and PROMETHEE methods for making a selection, and identified 12 criteria and seven main machines. According to the ranking, Wartsila was identified as the best machine. Kabadayı and Dağ (2017) have addressed machine selection in a cable manufacturing facility. Using the DEMATEL and PROMETHEE methods. The criteria identified for machine selection were weighted using the DEMATEL method. The alternatives were ranked using PROMETHEE I and PROMETHEE II methods. According to this ranking, the superiority of the machine 1 (M1) brand over the others was highlighted. Gök Kısa and Perçin (2017) have used fuzzy DEMATEL and fuzzy VIKOR methods for the selection of a marble-cutting machine that would shape new desired products for a company operating within the natural stone sector. Özdağoğlu, Yakut, and Bahar (2017) have used the entropy and SAW methods together for machine selection in a dairy products company. Çakır and Sezen Akar (2017) have used the combined SWARA-TOPSIS approach to address a CNC machine acquisition challenge for a manufacturing firm.Akın (2019) has focused on the selection of a bed edge closing machine. Eight criteria and eight different models of sewing machines were identified. Although criteria weights were determined using the entropy and CRITIC methods, the alternative machine models were ranked using the ROV method. Through these methods, M2 was identified as the best alternative. Faydalı and Erkan (2020) have studied how to select machinery for a textile company focused on packaging products of different qualities. Considering seven criteria, four alternative companies were ranked using the Fuzzy VIKOR method. Gülçiçek, Tolun, and Tümtürk (2020) have used the AHP and Integrated Grey Relational Analysis methods to identify four alternatives for machine selection, and 10 criteria were determined to play a role in the selection of these alternatives. The criteria were weighted using AHP, while the Integrated Grey Relational method was used for selecting the identified alternatives. Li, Wang, Fan, Li, and Chen (2020) have focused on machine tool selection. Their study aimed to combine subjective and objective evaluations in machine tool selection. Subjective weights were calculated using the fuzzy DEMATEL method, while objective weights were calculated using the entropy method. Defuzzified VIKOR was then applied to rank the alternatives. Karakış (2021) has studied machine selection for a textile company, aiming to select a flat knitting machine for the company. The CRITIC and MAUT methods were used in the study. Criteria were weighted using the CRITIC method, and the alternatives were ranked using the MAUT method. According to the results, M2 was selected as the best among the four identified alternatives. Olabanji and Mpofu (2021) have evaluated conceptual designs for the acquisition of a tube-bending machine. After weighing the criteria using fuzzy AHP to achieve optimal results, the fuzzy GRA method was used to rank the alternatives. İç and Yurdakul (2022) have aimed to obtain a ranking for machine centers using fuzzy triangular numbers and identified the Mazak FJV 120 and Mazak FH 6000 machines,respectively, as having the highest-ranking.

The literature review revealed that MCDM methods are widely used in the selection of machines to be purchased across various sectors. However, studies that integrate the Entropy and CoCoSo methods in a combined framework are extremely limited. Existing research that employs these two methods together has predominantly focused on areas such as financial performance evaluation and strategic decision-making. Specifically, when the literature on laser cutting machine selection is examined, only a single study by Özdağoğlu (2013) was found, in which MCDM methods were applied. However, in that study, all criteria were assumed to have equal importance, and the integrated use of Entropy and CoCoSo methods was not considered. This highlights the methodological originality of the present study and underscores its aim to fill a significant gap in the literature. By combining the objective weighting capability of the Entropy method with the balanced and compromise-based evaluation approach of the CoCoSo method, this research offers a systematic, data-driven, and practical decision-making model for laser cutting machine selection. In this regard, the study provides a unique and valuable contribution to both academic literature and practical applications.

3. RESEARCH METHODS

The entropy and CoCoSo methods the present study are explained in this section.

3.1. Entropy Method

The concept of entropy was first introduced in the literature by Rudolf Clausius (1865) as a measure of disorder and uncertainty within a system (Zhang, et al., 2011, p. 444). Today, the concept of entropy is widely used in various fields and was later developed by Shannon (1948) as the foundation of information entropy theory.

The steps involved in the entropy method are detailed below (Shannon, 1948, p.380).

Step 1: To eliminate inconsistencies resulting from different units of measurement, normalization is conducted, and r_{ij} is calculated using Eq(1). In the formula, i represents the alternatives, j represents the criteria, and rij denotes the normalized values.

$$r_{ij} = \frac{x_{ij}}{\sum_{1}^{j} x_{ij}} \tag{1}$$

Step 2: The entropy values are determined using Eq(2).

$$e_j = -k\sum_{j=1}^{m} r_{ij} \ln(r_{ij}) \tag{2}$$

Where k represents the entropy coefficient, r_{ij} denotes the normalized values, and ej represents the entropy value.

Step 3: The weight values are obtained using the formula in Eq (3).

$$w_j = \frac{1-e_j}{\sum_{1}^{m}(1-e_j)} \tag{3}$$

3.2. Combined Compromise Solution (CoCoSo) Method

The CoCoSo method, introduced by Zavadskas, Yazdani, Zarate, and Turskis in 2018, is characterized by high stability, robustness, and reliability in alternative ranking. Introducing a new alternative or eliminating an existing one exerts a relatively minor influence on the final ranking outcomes derived from this method, in contrast to that of other MCDM models. The method first calculates the utility values of alternatives from various perspectives using different aggregation operators, and then uses a fusion function to combine these utility values to obtain a compromise solution. (Ecer, 2020, p.299). The CoCoSo method is based on the integration of the weighted sum method and the exponential weighting method, outlined as follows (Yazdani et al., 2018, p.2509):

Step 1: Construction of the Decision Matrix.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} ; \quad i=1,2,\ldots m;\ j=1,2,\ldots n \tag{4}$$

Step 2: Normalization of the performance values of alternatives. Normalization is conducted based on the nature of the criteria. If the criterion is benefit-oriented, the normalization formula is:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \tag{5}$$

If the criterion is cost-oriented, the normalization formula is:

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \tag{6}$$

Step 3: First, calculations are performed using the combined compromise solution method. In this step, the total performance value (S_i) of the weighted comparability sequences is calculated for each alternative. The formula related to the Si value is shown below. Here, S_i represents the total performance of each alternative. It is calculated using the weights (w_j) and the normalized values (r_{ij}).

$$S_i = \sum_{j=1}^{n} (w_j r_{ij}) \tag{7}$$

Second, the overall value of the strength weight of the comparability sequences (P_i) is calculated for each alternative. The formula for the Pi value is provided below. This formula is based on the principle of the geometric mean and considers the multiplicative effects of the alternative across the criteria.

$$P_i = \sum_{j=1}^{n} (r_{ij})^{w_j} \tag{8}$$

Step 4: The relative weights of the alternatives are calculated. The relative weights k_{ia}, k_{ib}, and k_{ic} are computed using the formulas (9), (10), and (11) provided below.

k_{ia}: Arithmetic Mean Method. It is calculated by taking the average of the alternatives' normalized performance values with respect to the criteria.

k_{ib}: Multiplicative Method. It is calculated by taking the geometric mean of the products of the alternatives' normalized values.

k_{ic}: Optimal Combination Method. It is calculated by combining K_a and K_b with certain weights

(λ is typically taken as 0,5).

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \tag{9}$$

$$k_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i} \tag{10}$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{(\lambda \max_i S_i + (1-\lambda)\max_i P_i)}; 0 \leq \lambda \leq 1 \tag{11}$$

Step 5: Ranking of the alternatives. In this step, after calculating the ki values, the final ranking is determined, and all alternatives are ranked from highest to lowest based on these scores. The alternative with the highest ki value is the best option for the decision-maker. The final performance ranking of the alternatives is obtained using Eq (12).

$$k_i = \left(k_{ia}k_{ib}k_{ic}\right)^{1/3} + \frac{1}{3}\left(k_{ia} + k_{ib} + k_{ic}\right) \tag{12}$$

3.3. Comparative Evaluation of the CoCoSo Method with Other MCDM Methods

The CoCoSo method differs from commonly used MCDM methods such as AHP, TOPSIS, VIKOR, and PROMETHEE in several key aspects. Unlike AHP, which relies on subjective expert judgments for weighting criteria, CoCoSo operates based on objective data, minimizing subjectivity in the decision-making process. While methods like TOPSIS and VIKOR evaluate alternatives primarily based on their distance to an ideal solution, CoCoSo combines both additive (aggregation) and multiplicative evaluation approaches, offering a more comprehensive analysis. Furthermore, the computational structure of CoCoSo is simpler and more practical, allowing decision-makers to reach quick and consistent results. These features make the CoCoSo method particularly advantageous in complex decision-making processes, such as in production environments where multiple criteria must be balanced. In this study, the selection of CoCoSo is based on its ability to provide a balanced, reliable, and easily applicable decision-making framework.

4. APPLICATION

The present study was conducted to determine the most suitable laser plate cutting machine to be purchased by a steel-fabrication company. For the machine selection, the criteria and alternative machines were first identified, and the criteria related to the alternatives were weighted using the entropy method. The most appropriate machine ranking was obtained using the CoCoSo method. The weights of the criteria determined by the company were calculated using the entropy method, which is an objective approach for determining criterion weights; therefore it was applied in the present study. The machine alternatives were ranked using the CoCoSo method. Although relatively new, the CoCoSo method was preferred because it helped to make more balanced decisions by considering both individual and collective effects of the criteria. It was chosen because it supports decision-making in complex processes in which balancing different criteria, such as in production, is necessary. In addition, compared to other methods that require complex calculations, it is a simpler and more applicable approach.

In the present study, the data were collected to determine the most suitable laser-cutting machine for a steel-fabrication company planning to make a purchase. Alternative machines and evaluation criteria were identified based on data obtained from the catalogs and technical reports of machine manufacturers operating in the sector. In addition, to determine the preferred criteria in practice, the opinions were gathered from procurement specialists and the production team directly involved in the manufacturing process. The decision-makers and their professional experience are presented in Table 1. In addition, to strengthen the scientific foundation of this process, data collection methods used in similar studies were examined and supported by the literature (Perçin, 2012; Özdağoğlu, 2013).

Table 1. Decision-Makers and Their Professional Experience

Decision Maker	Area of Expertise	Years of Experience
General manager	Steel -fabrication and assembly sector	25
Procurement manager	Steel-fabrication sector	15
Operations manager	Steel-fabrication and assembly sector	18
Production manager	Steel-fabrication sector	10

Maintenance manager	Steel-fabrication sector	15

Source: Created by the author

In the sampling process, the technical specifications determined by fabrication companies for laser cutting machines were selected from widely used models in the market. When identifying alternative machines, seven different models that are most commonly used in the sector were examined, and a decision matrix was constructed based on the criteria considered significant by the companies.The desired motor power for the laser cutting machines to be purchased was 12 kilowatts. Accordingly, machine alternatives from seven different brands were evaluated based on eight criteria. The criteria considered for the machine selection were as follows: price, width, length, maximum loading weight, maximum axis speed, positioning accuracy, maximum cutting thickness for stainless steel and maximum cutting thickness for carbon steel. The criteria of price and positioning accuracy were cost-oriented, whereas those of width, length, maximum loading weight, maximum axis speed, and maximum cutting thickness for stainless steel and carbon steel were benefit-oriented. The information related to these criteria is presented in Table 2. The machine alternatives are denoted as M1, M2, M3, M4, M5, M6, and M7.

Table 2. Selected Criteria, Unit and Description

Criterion Code	Criterion	Unit	Description
C1	Price	Dollar	The purchase cost of the laser cutting machine: This refers to the initial investment cost of the machine and its impact on the budget.
C2	Width	Milli meter	The horizontal space occupied by the laser cutting machine (width dimension): This measures the width of the machine along the horizontal axis.
C3	Length	Milli meter	The vertical space occupied by the laser cutting machine (length dimension): This measures the length of the machine along the vertical axis.
C4	Maximum loading weight	Kilo gram	The maximum material weight that can be loaded onto the machine: This value represents the maximum material weight that the machine can process during cutting operations.

C5	Maximum axis speed	Meters/Minute	The maximum speed at which the laser cutting machine can move along its axes: This value indicates how quickly cutting operations can be performed.
C6	Positioning accuracy	Millimeter	The positioning accuracy of the laser cutting machine during operations: Typically measured in millimeters, this value shows the precision with which the machine can position the material during cutting.
C7	Maximum cutting thickness for stainless steel	Millimeter	The maximum cutting thickness for stainless steel materials: This refers to the maximum cutting thickness the laser cutting machine can achieve when processing stainless steel.
C8	Maximum cutting thickness for carbon steel	Millimeter	The maximum cutting thickness for carbon steel materials: This refers to the maximum cutting thickness the laser cutting machine can achieve when processing carbon steel.

Source: Created by the author

The data in the decision matrix were obtained from the catalogs of technical information prepared by the machine manufacturers for their products. The decision matrix created based on this information is presented in Table 3. After constructing the decision matrix, the steps of the entropy method were applied to calculate the weights of the criteria.

Table 3. The Decision Matrix Prepared for Laser Cutting Machines

Alternative Machines	C1	C2	C3	C4	C5	C6	C7	C8
M1	125.000	2.030	6.050	4.900	100	0.05	30	40
M2	155.000	2.500	6.000	4.500	220	0.02	30	30
M3	165.000	2.000	6.000	4.500	120	0.02	40	35
M4	176.000	2.530	6.050	4.000	120	0.03	30	30
M5	195.000	2.500	6.500	5.100	200	0.05	40	45
M6	300.000	2.000	6.000	4.000	120	0.03	25	35
M7	327.000	2.000	6.150	4.000	100	0.03	25	30

Source: Created by the author

First, the decision matrix was normalized using the formula provided in Eq.(1). The normalized matrix is presented in Table 4.

Table 4. The Normalized Matrix

Alternative Machines	C1	C2	C3	C4	C5	C6	C7	C8
M1	0.087	0.130	0.142	0.158	0.102	0.217	0.136	0.163
M2	0.107	0.161	0.140	0.145	0.224	0.087	0.136	0.122
M3	0.114	0.129	0.140	0.145	0.122	0.087	0.182	0.143
M4	0.122	0.163	0.142	0.129	0.122	0.130	0.136	0.122
M5	0.135	0.161	0.152	0.165	0.204	0.217	0.182	0.184
M6	0.208	0.129	0.140	0.129	0.122	0.130	0.114	0.143
M7	0.227	0.129	0.144	0.129	0.102	0.130	0.114	0.122

Source: Created by the author

After the normalized matrix was obtained, the entropy value for each value was calculated using Eq.(2). These values are presented in Table 5.

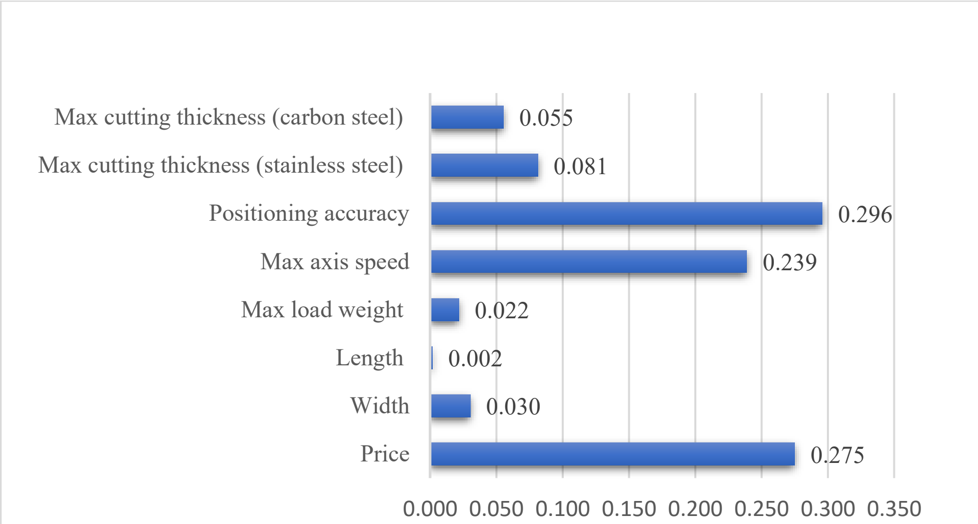
Table 5. Entropy Values

Entropy	C1	C2	C3	C4	C5	C6	C7	C8
ej	0.971	0.997	1.000	0.998	0.975	0.969	0.991	0.994
1-ej	0.029	0.003	0.000	0.002	0.025	0.031	0.009	0.006

Source: Created by the author

The weight values of the criteria were calculated using the formula provided in Eq.(3). The weights of the criteria determined using the entropy method are presented in Fig.1.

Figure 1. Weights of the criteria



As a result of the calculations performed using the entropy method, it was concluded that the most important criterion was positioning accuracy. This was followed by price, maximum axis speed, maximum cutting thickness for stainless steel, maximum cutting thickness for carbon steel, width, maximum loading weight, and length, respectively. After determining the weights using the entropy method, the rankings of the alternative machines were established with the help of the CoCoSo method.

First, the decision matrix was constructed as shown in Table 6, using Eq. (4).

Table 6. The Decision Matrix Prepared for Laser Cutting Machines

wj	0,275	0,030	0,002	0,022	0,239	0,296	0,081	0,055
Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
M1	125.000	2.030	6.050	4.900	100	0.05	30	40
M2	155.000	2.500	6.000	4.500	220	0.02	30	30
M3	165.000	2.000	6.000	4.500	120	0.02	40	35
M4	176.000	2.530	6.050	4.000	120	0.03	30	30
M5	195.000	2.500	6.500	5.100	200	0.05	40	45
M6	300.000	2.000	6.000	4.000	120	0.03	25	35
M7	327.000	2.000	6.150	4.000	100	0.03	25	30

Source: Created by the author

The data in the decision matrix were analyzed using Equations (5) and (6), and the normalized decision matrix was generated. The normalized decision matrix, constructed using the CoCoSo method, is presented in Table 7.

Table 7. The Normalized Decision Matrix

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
M1	1.000	0.057	0.100	0.818	0.000	0.000	0.333	0.667
M2	0.851	0.943	0.000	0.455	1.000	1.000	0.333	0.000
M3	0.802	0.000	0.000	0.455	0.167	1.000	1.000	0.333
M4	0.748	1.000	0.100	0.000	0.167	0.667	0.333	0.000
M5	0.653	0.943	1.000	1.000	0.833	0.000	1.000	1.000
M6	0.134	0.000	0.000	0.000	0.167	0.667	0.000	0.333
M7	0.000	0.000	0.300	0.000	0.000	0.667	0.000	0.000

Source: Created by the author

After the normalization process, the weights of the decision-making criteria were incorporated into the algorithm to generate the comparability ranking matrix. The total weighted comparability sequence for each alternative and the overall power weight of the comparability sequences were calculated as the S_i and P_i vectors, respectively, using Eqs. (7) and (8). The resulting values are presented in Tables 8 and 9.

Table 8. Weighted Comparability Sequence and S_i

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	S_i
M1	0.275	0.002	0.000	0.018	0.000	0.000	0.027	0.037	0.359
M2	0.234	0.029	0.000	0.010	0.239	0.296	0.027	0.000	0.834
M3	0.220	0.000	0.000	0.010	0.040	0.296	0.081	0.018	0.666
M4	0.206	0.030	0.000	0.000	0.040	0.197	0.027	0.000	0.500
M5	0.180	0.029	0.002	0.022	0.199	0.000	0.081	0.055	0.567
M6	0.037	0.000	0.000	0.000	0.040	0.197	0.000	0.018	0.292
M7	0.000	0.000	0.001	0.000	0.000	0.197	0.000	0.000	0.198

Source: Created by the author

Table 9. Exponentially Weighted Comparability Sequence and P_i

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	P_i
M1	1.000	0.917	0.996	0.996	0.000	0.000	0.915	0.978	5.800
M2	0.957	0.998	0.000	0.983	1.000	1.000	0.915	0.000	5.853
M3	0.941	0.000	0.000	0.983	0.652	1.000	1.000	0.941	5.517
M4	0.923	1.000	0.996	0.000	0.652	0.887	0.915	0.000	5.372
M5	0.890	0.998	1.000	1.000	0.957	0.000	1.000	1.000	6.845
M6	0.575	0.000	0.000	0.000	0.652	0.887	0.000	0.941	3.055
M7	0.000	0.000	0.998	0.000	0.000	0.887	0.000	0.000	1.885

Source: Created by the author

Table 10 displays the ranking of machine alternatives derived from the final aggregate scores calculated using the CoCoSo method

Table 10. Final Aggregation and Cocoso Ranking of The Alternatives

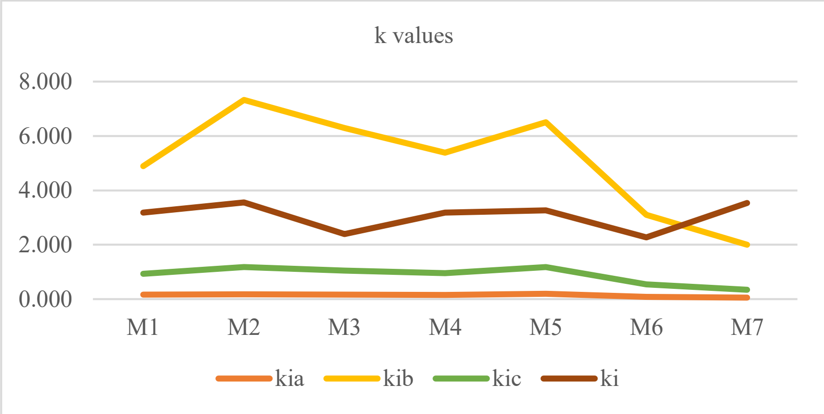
Alternatives	S_i	P_i	k_{ia}	Ranking	k_{ib}	Ranking	k_{ic} (λ=0,5)	Ranking	k_i	Final Ranking
M1	0.359	5.800	0.163	4	4.891	5	0.935	5	3.812	5
M2	0.834	5.853	0.177	2	7.326	1	1.179	1	4.949	1
M3	0.666	5.517	0.164	3	6.294	3	1.051	3	4.461	3
M4	0.500	5.372	0.156	5	5.380	4	0.950	4	4.027	4
M5	0.567	6.845	0.196	1	6.502	2	1.175	2	4.614	2
M6	0.292	3.055	0.089	6	3.099	6	0.544	6	2.795	6
M7	0.198	1.885	0.055	7	2.000	7	0.344	7	2.139	7

Source: Created by the author

According to the ranking results, M2 was identified as the most suitable option for the manufacturing company, followed by M5, M3, M4, M1, M6, and M7 machines, respectively.

In Fig. 2, the graphical representation of the k performance values is provided. The placement of the k_{ia} values at the bottom indicates that the alternatives do not exhibit significantly high performance compared to the average. The k_{ib} values at the top suggest that the multiplicative method had a stronger influence on the performance of the alternatives. The positioning of k_{ic} between k_{ia} and k_{ib} implies an optimal balance, indicating that the final performance ranking was reasonable. In other words, this reflects the consistency of the results. The final score, represented by the k value, was derived from a balanced combination of these three values and represents the most accurate outcome.

Figure 2. Comparison of k values



We previously noted that the value of λ is typically taken as 0,5 when calculating the final performance rankings. Here, a sensitivity analysis (Zolfani et al., 2019) has been conducted based on varying λ values between 0 and 1, as shown in Table 11. According to the sensitivity analysis results presented in this table, M2 consistently ranked first across all λ values, and the rankings of the other alternative machines remained unchanged. These results demonstrate that the model applied in this study was both reliable and valid.

Table 11. Sensitivity Analysis

	λ Values											Ranking
Alternative Machines	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	
M1	3.774	3.785	3.795	3.803	3.809	3.812	3.811	3.802	3.778	3.722	3.560	5
M2	4.815	4.845	4.874	4.901	4.927	4.949	4.967	4.978	4.975	4.941	4.807	1
M3	4.358	4.381	4.404	4.425	4.445	4.461	4.474	4.479	4.471	4.433	4.299	3
M4	3.956	3.973	3.989	4.004	4.016	4.027	4.033	4.032	4.017	3.973	3.833	4
M5	4.541	4.559	4.576	4.591	4.604	4.614	4.619	4.614	4.594	4.536	4.359	2
M6	2.749	2.760	2.770	2.780	2.788	2.795	2.799	2.799	2.790	2.763	2.675	6
M7	2.103	2.111	2.119	2.126	2.133	2.139	2.142	2.143	2.138	2.120	2.062	7

Source: Created by the author

5. CONCLUSION AND DISCUSSION

Machine selection for manufacturing companies is a complex process that requires the consideration of numerous conflicting criteria and choosing from a wide range of alternatives. To ensure the most suitable choice for the company, it is crucial to accurately evaluate the alternatives based on the defined criteria. Using a scientific method to assess and analyze all the criteria influencing the decision-making process is more advantageous than relying on intuitive or experience-based decisions. For this reason, MCDM methods are frequently used.

The present study aimed to assist a steel-producing company in selecting a laser-plate cutting machine. To this end, the integrated entropy and CoCoSo methods were used to determine the most suitable machine for the company. First, the entropy method was used to analyze and establish weighted criteria. Using the entropy method, positioning accuracy (0.296) was identified as the most significant criterion in the selection of a laser machine. The prominence of this criterion highlighted its critical role in precision-dependent tasks, particularly in cutting operations that require high accuracy. Minimizing positioning errors was of great importance, especially in detailed and delicate work. The second most significant criterion was price (0.275), emphasizing that the machine's cost was a key factor that influenced investment decisions. As such, it was essential to consider the price-performance balance. The third criterion, maximum axis speed (0.239), was another critical factor affecting production efficiency because cutting speed plays an important role in situations involving high production volumes. Maximum cutting thickness for stainless steel (0.081) and carbon steel (0.055) were also considered important criteria because the material thickness that the machine can handle influences its cutting capacity. Other criteria, such as width (0.030), maximum loading weight (0.022), and length (0.002), were assigned lower weights and were deemed less critical in the selection process.

The analysis results revealed that positioning accuracy, price, and maximum axis speed were the top priority criteria in the selection of a laser cutting machine. After determining the weights of the criteria by importance, the integrated CoCoSo method was used to evaluate the various machines that the company was considering for purchase. According to the results, M2 was identified as the most suitable option for the company. M2 was followed by Machines 5, 3, 4, 1, 6, and 7, respectively, and this ranking was reported to company management. Finally, a sensitivity analysis based on λ values was conducted to test the results of the decision-making model applied in the present study. It was observed that alternatives ranks remained unchanged across all λ values, demonstrating the reliability and validity of the study's findings. In the literature, only one study was found related to the selection of a laser cutting machine (Özdağoğlu, 2013); however, in that study, it was presumed that the criteria had equal weights of importance. Thus, a comparison with the results of the present study was not possible.

The present study would make a significant contribution to the literature as one of the limited studies using multi-criteria decision-making techniques in the selection of laser cutting machines. From a managerial perspective, the practical applications of the present study provide direct benefits to various stakeholders. Production managers can adopt a systematic approach to selecting laser cutting machines, enabling them to make more informed investment decisions and enhance operational efficiency. For example, selecting the most suitable machine could reduce energy consumption and optimize production costs.

Procurement departments could facilitate the selection process among alternative machines, ensuring a more effective balance between cost and performance. The applied method considered not only the technical specifications of machines but also economic factors thereby assisting in making the most appropriate decision. Moreover, company executives would be able to make more rational and well-founded investment decisions by utilizing scientific methods based on objective criteria. Particularly in large-scale investments, such multi-criteria decision-making methods could help minimize financial risks associated with poor selection choices. In addition, managers at other companies operating in the sector could apply the proposed method to their own investment decisions, contributing to a more informed decision-making process at an industry-wide level. In this regard, the present study serves not only as a theoretical contribution but also as a practical guide for managers.

The selection of M2 as the most suitable option offers significant operational improvements for the company's production processes due to its high positioning accuracy and maximum axis speed. In particular, the reduction in error rates in precision cutting tasks is expected to lower quality control costs. The high axis speed will shorten cutting times, increase production capacity, and reduce order delivery times. Furthermore, the favorable cost-performance balance of Machine 2 will enable a quicker return on investment, thereby optimizing the company’s capital utilization. These advantages will contribute to reducing material waste and improving energy efficiency, leading to lower overall production costs and enhanced competitiveness. Thus, M2 represents not only a technically sound choice but also a strategic investment that aligns with the company’s long-term goals in terms of cost efficiency and productivity.

The present study has some limitations. First, the exclusive use of the entropy and CoCoSo methods did not allow for a comparison of the results with those of other methods. Future studies could enhance the comprehensiveness of the analysis by using different multi-criteria decision-making methods such as PROMETHEE, DEMATEL, and fuzzy logic-based approaches. In addition, the selected criteria and analyzed alternatives were determined based on the needs of steel fabrication companies; therefore, the findings can not be directly applied for use in other sectors. In particular, different criteria may become priorities when selecting laser-cutting machines in the automotive, aerospace, or defense sectors. In addition, it should be considered that changes in the technical specifications of alternative machines or in the weightings of the criteria may influence the results.

Statement of Research and Publication Ethics

In all process of the article, the principles of research and publication ethics of the Manisa Celal Bayar University Journal of Social Sciences Institute were followed.

Authors’ Contribution Rates to the Article

The entire of the article was written by the Author.

Statement of Interest

The author has no conflict of interest with any person or organization.

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