ORIGINAL PAPER

EQUIPMENT SELECTION FOR AN E-COMMERCE COMPANY USING ENTROPY-BASED TOPSIS, EDAS AND CODAS METHODS DURING THE COVID-19

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ABSTRACT. **Background:** The importance and market share of e-commerce has been increasing with the COVID-19 pandemic in recent days. Employees sometimes cannot go to the workplace due to epidemics such as COVID-19 that is spreading rapidly around the world, natural disasters and accidents. Companies can continue to serve their customers with the internet infrastructure and computer technologies they will provide to their employees. Thus, e-commerce companies can provide a sustainable competitive advantage in the sector. Working with the right suppliers is one of the important decisions that will improve the service quality of the firms and affect the sustainability of the enterprise.

Methods: This study aims to select the best laptop for a company in the online trade industry using Entropy-based EDAS, CODAS and TOPSIS methods. In the study, 6 alternative laptops have been evaluated according to hard disk capacity, ram, battery power, processor speed, weight, price criteria. The Entropy method has been used to identify the weights of the criteria in the study. These criteria weights have been used in EDAS, CODAS and TOPSIS methods. TOPSIS, EDAS and CODAS methods have been used to determine the best alternative. Also, the correlation between the results of the TOPSIS, EDAS and CODAS methods has been examined with the Spearman Correlation approach.

Results: As a result of the Entropy method, it has been determined that the most important criterion is the hard disk capacity criterion. TOPSIS, EDAS and CODAS method results have been compared and the most suitable alternative has been selected. According to the results of the study, the best alternative has been selected as A5. Spearman Correlation analysis results show that there was a strong positive relationship between the methods used and the results obtained.

Conclusions: The study differs from existing studies in the literature in that it is the first study in which laptop selection was made using TOPSIS, EDAS and CODAS methods together. The results of this study can be compared with the results of future studies that will be carried out using different MCDM methods and different data.

Key words: CODAS; COVID-19; EDAS; Electronic commerce; Laptop selection; TOPSIS.

INTRODUCTION

Nowadays, the popularity of e-commerce has been growing [Urbancokova et al. 2020]. E-commerce sales of the business to consumer (B2C) have been increasing worldwide in recent years. E-commerce sales, which reached $ 3.535 trillion in 2019, are estimated to reach $ 6.542 trillion in 2023 [Statistica 2020, De Matos et al. 2020]. Different new application types emerging to increase customer engagement and gain more economic value contribute to e-commerce development [Xu et

al. 2020]. Customer engagement can be defined as a new concept that might comprise product testing, idea improvement, product support and service process development. Customer involvement provides companies with a competitive advantage in revealing customer demands [Chiang et al. 2020]. Consumers are faced with risks and uncertainties in the e-commerce environment, and the reputation of an e-commerce firm is an indicator of its product or service quality. Corporate reputation provides firms with a competitive advantage and reflects the degree

of customer satisfaction with a firm's products and services [Li et al. 2020]

Considering the concept of B2C and globalization, e-commerce companies need to offer customer participation-oriented products/services and pay attention to corporate reputation to gain a sustainable competitive advantage in the sector and to open up to new markets. E-commerce companies need to benefit from the latest technologies to establish uninterrupted communication with their customers. Firms can respond to customer expectations faster and make their production and service processes more flexible with the internet and computer technology infrastructure they will provide to their employees. Thus, e-commerce companies can achieve sustainable competitive advantage and more successful operation management in the sector. Employees are sometimes absent from their workplaces for reasons such as the COVID-19 epidemic, natural disasters and accidents.

COVID-19 was first reported in Wuhan, China in December 2019 and has spread to many countries around the world. The epidemic disrupted trade and made it compulsory for the working population to stay at home [Debata et al. 2020]. Millions of people were kept at home to prevent the spread of the COVID-19 epidemic. Many people lost their jobs due to the epidemic and the epidemic caused a change in people's lifestyles [Saadat el. 2020, Posel et al. 2021]. Besides, due to the COVID-19 outbreak, air quality has improved and water pollution has increased in some regions around the world as production facilities are closed and people spend more time at home [Saadat et al. 2020].

Many people today cannot imagine their lives without a computer. In-corporate terms, the computer has become an indispensable tool for all employees. The ability to perform complex and repetitive calculations in computers without errors and in a short time has increased the demand for computers. On the other hand, computer usage has become more portable due to developments in information and communication technologies. Furthermore, laptops have played an important role in human life in the information age due to

their capabilities and portability. Therefore, choosing an efficient laptop according to the needs of the buyers is critical. Multi-Criteria Decision Making (MCDM) methods are used to determine the most suitable alternative in cases where there are more than one alternative and criteria [Ulutaş and Cengiz 2018].

In today's competitive environment, business managers usually have to choose among alternatives for choosing raw materials, machinery and location. It is very important to work with the right suppliers in improving the service quality of the enterprises and ensuring the sustainability of the enterprise. Companies generally use MCDM methods for such selection problems. In this study, it was tried to determine the most suitable laptop by using Entropy-based EDAS, CODAS and TOPSIS methods for a company in the online trade sector.

The rest of this paper has been organized as follows. A literature review about studies conducted using CODAS, EDAS and TOPSIS methods was included in the second part. Entropy, EDAS, CODAS and TOPSIS methods were included in the methodology section, which is the third part of the study. The fourth part of the study consists of the application step in which the alternatives were ranked and the discussion part. In the fifth section, a general evaluation of the study has been made.

LITERATURE REVIEW

MCDM methods are widely used in many different areas. In the literature, there are many studies in which MCDM methods such as AHP, TOPSIS, EDAS, CODAS, ARCAS, COPRAS, VIKOR, ELECTRE and PROMETHEE are used [Mardani et al. 2015, Rezaei 2015, Chatterjee et al. 2018, Badi et al. 2018, Stanujkic et al. 2017, Jayant and Sharma 2018, Kaplinski et al. 2019, Zhang et al. 2019, Siksnelyte-Butkiene et al. 2021]. TOPSIS method is one of the MCDM methods widely used in the different application areas. EDAS and CODAS methods are new MCDM methods that have been implemented in different fields in the last few years [Behzadian et al. 2012, Stanujkic et al. 2017, Palczewski

and Salabun 2019, Zhang et al. 2019, Mathew and Thomas 2019, Aldalou and Perçin 2020, Aytekin and Durucasu 2021, Simic et al. 2021]. Some of the studies were carried out using TOPSIS, EDAS and CODAS methods can be seen in Table 1.

Table 1. Studies using TOPSIS, EDAS and CODAS methods

Author (Year)	Method	Application
Vimal at al. (2012)	TOPSIS	selection of the best supplier of a company in the manufacturing industry
Ghorabaee et al. (2015)	EDAS, VIKOR, TOPSIS SAW and COPRAS	inventory classification
Hanine et al. (2016)	AHP and TOPSIS	ETL software selection problem of a business intelligence project.
Chitnis and Vaidya (2016)	DEA and TOPSIS	measure the efficiency of bank branches in India.
Kahraman et al. (2017)	fuzzy EDAS	selection of solid waste disposal site
Juodagalvienė et al. (2017)	SWARA and EDAS	selection of the house shape
Ghorabaee et al. (2017)	EDAS, TOPSIS, COPRAS and WASPAS	evaluation of the airlines
Turskis et al. (2017)	AHP and EDAS	cultural heritage structures ranking problem of renovation projects
Stević et al. (2017)	DEMATEL, EDAS, MABAC, COPRAS and MULTIMOORA	supplier selection in a construction firm
Trinkūnienė et al. (2017)	fuzzy AHP, SAW, TOPSIS, COPRAS and EDAS	evaluation of quality assurance in contractor contracts
George et al. (2018)	TOPSIS	selection of portable generators in a manufacturer company
Ecer (2018)	fuzzy AHP and EDAS	selection the best third-party logistics provider
Karabasevic et al. (2018)	SWARA and EDAS	personnel selection in the IT sector
Erkayman et al. (2018)	fuzzy DEMATEL and EDAS	selection of the best ERP development strategy of a furniture company.
Liang et al. (2018)	EDAS and ELECTRE	evaluation of the cleaner production for gold mines
Ghorabaee et al. (2018)	fuzzy SWARA, fuzzy CRITIC and fuzzy EDAS	evaluation of construction equipment.
Badi et al. (2018)	CODAS	selection of the best desalination plant location
Mathew and Thomas (2018)	interval-valued EDAS, interval-valued TOPSIS and interval-valued CODAS methods	evaluation a flexible manufacturing system.
Aggarwal et al. (2018)	EDAS	selection of smartphones in the Indian market
Ulutaş (2019)	Entropy-based EDAS	performance analysis of logistics firms
Adalı and Tuş (2019)	CRITIC, EDAS, CODAS and TOPSIS	hospital site selection
Kundakcı (2019)	MACBETCH and EDAS	selection of the best boiler alternative
Yalçın and Pehlivan (2019)	fuzzy TOPSIS, fuzzy CODAS, fuzzy COPRAS, fuzzy EDAS, fuzzy ARAS, fuzzy WASPAS	personnel selection
Behzad et al. (2019)	EDAS, MABAC, CODAS and VIKOR	evaluation of waste management performance.
Altıntaş (2020)	Entropy-based TOPSIS and EDAS	evaluation of competition performance of G 7 countries.
Deng et al. (2020)	BWM and TOPSIS	comparing the hazardous waste inventory risk of different companies
Liang (2020)	intuitionistic fuzzy EDAS	evaluation of energy-saving design projects
Ecer et al. (2021)	interval rough CODAS	evaluation of renewable energy resources
Ersoy (2021)	DEA and TOPSIS	performance evaluation of distance education.

TOPSIS, EDAS and CODAS methods were used in many different sectors. For determining the criteria used in this study, previous studies were examined for the selection of laptops. The methods and criteria used in the studies on laptop selection in the literature can be seen in Table 2.

It is understood from Table 2 that there is no study in which Entropy-based TOPSIS, EDAS and CODAS methods were used together for laptop selection. For this reason, it is thought that this study will be the first study for the laptop selection problem. Table 2 was used to determine the criteria used in the study.

Table 2. Criteria and methods for laptop selection

Author (Year)	Method	Criteria
Srichetta and Thurachon (2012)	Fuzzy AHP	Harddisk capacity, RAM capacity, CPU speed, monitor resolution, weight, price, durability, beauty
Pekkaya and Aktogan (2014)	AHP, DEA, TOPSIS and VIKOR	Speed, capacity, brand, image, peripherals and price
Lakshmi et al. (2015)	TOPSIS	Specification, size, weight, warranty, wi-fi, battery life, with or without OS, keyboard and touch board pad,
Kalyani et al. (2016)	TOPSIS	Design or style, technical support, memory, reviews
Kecek and Demirağ (2016)	MOORA and TOPSIS	Speed, brand, capacity, display, environmental equipment and other features, price
Siew et al. (2016)	AHP	Price, speed (RAM, dimension, etc.), weight, color, design, warranty period, technical service
Adalı and Işık (2017)	MULTIMOORA and MOOSRA	Processor speed, storage, memory (RAM), cache memory, display card memory, cost, screen resolution, screen size, weight, brand reliability
Aytekin and Kuvat (2018)	AHP	Operating system, processor features, RAM capacity, hard disk features, screen resolution, graphics card feature, battery life, brand, design, weight, screen size, price range, service support, product vendor, user comments and suggestions, warranty terms
Ulutaş and Cengiz (2018)	CRITIC and EVAMIX	Service, design, brand reliability, RAM, processor speed, cache, cost, graphics card memory, screen resolution, harddisk capacity, weight
Stanujkic et al. (2018)	PIPRECIA and EDAS	Manufacturer, diagonal screen size, processor type, processor tact, price, cache memory, RAM, battery, HDD, graphics, weight
Yorulmaz et al. (2019)	TOPSIS	Processor speed, number of processor cores, RAM, hard disk capacity
Mitra and Goswami (2019)	AHP and SAW	Processor, color, hard disk capacity, brand, operating system, screen size, RAM
Çakır and Pekkaya (2020)	AHP, Fuzzy AHP and DEMATEL	Price of the product, brand image, running speed, storage capacity, other properties and laptop peripherals, monitor properties

MATERIALS AND METHOD

This study was carried out in an e-commerce company in Turkey. Due to the rapidly spreading COVID 19 epidemic, natural disasters and accidents, employees sometimes cannot come to the workplace. The company managers want to take advantage of technology to keep track of customer orders and the online trade operation process in a quality and uninterrupted manner. For this reason, the company wants to buy a 15.6-inch laptop with an i5 processor and Windows operating system and weighing less than 2 kg for its employees. In this way, company employees will have the opportunity to do their work on the internet in some cases without going to the workplace, and it will be tried to ensure that the operation management continues uninterrupted for the customer order and delivery process. In the study, 6 alternative laptops were evaluated according to the 6 criteria.

The criteria used in the study have been determined based on expert opinions and the literature review. These criteria were hard disk capacity (C1) (in GB), RAM (C2) (in GB), battery power (C3) (in Wh), processor speed (C4) (in GHz), weight (C5) (in Kg) and price (C6) (in TL). Data regarding the alternatives and criteria used in the study were obtained on 06 November 2020 from different firms. The Entropy method has been used to identify the weights of the criteria in the study. Criteria weights obtained by the Entropy method have been used in EDAS, CODAS and TOPSIS methods. The 6 alternative laptops have been ranked according to EDAS, CODAS and TOPSIS methods. Microsoft Excel 2016 program has been used to apply Entropy, EDAS, CODAS and TOPSIS methods. The hierarchical structure of the study was shown in figure 1. the alternatives were respectively expressed as A1, A2 ….A6 in figure 1. Entropy, EDAS, CODAS and TOPSIS methods used in the study were explained below.
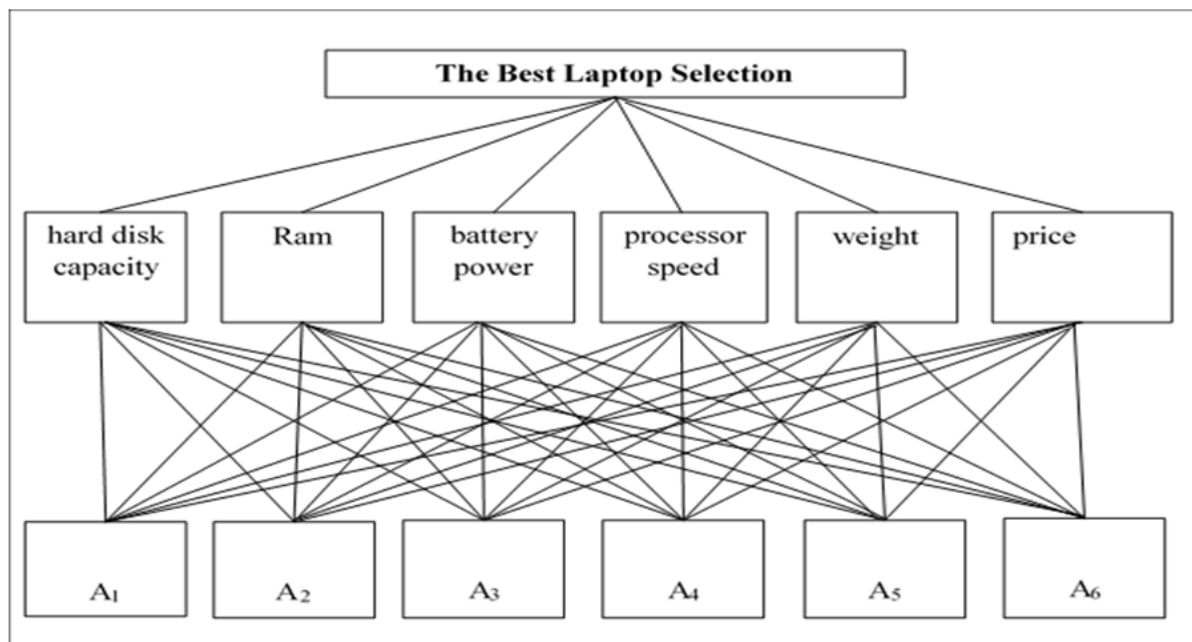
Fig. 1. The framework of laptop selection

ENTROPY METHOD

The concept of entropy, first proposed by Shannon in 1948, was developed as a weighting method by Wang and Lee in 2009 [Aytekin, Karamaşa 2017]. The Entropy method consists of the following steps [Wang and Lee 2009, Aytekin and Karamaşa 2017, Wang et al. 2017, Ulutaş 2019, Dehdasht et al. 2020]:

Step 1: Creation of decision matrix.

There are alternatives in the rows of the B_{ij} decision matrix and criteria in the columns. The decision matrix is shown below.

$$B_{ij} = \begin{bmatrix} b_{11} & b_{12} & \ldots & b_{1n} \\ b_{21} & b_{22} & \ldots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \ldots & b_{mn} \end{bmatrix} \qquad (1)$$

Step 2: Normalizing the decision matrix.

The B_{ij} decision matrix is normalized using equation 2.

$$t_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}} \qquad j = 1, 2, \ldots, n \qquad (2)$$

Step 3: Calculation of entropy values.

After normalizing the decision matrix, the entropy values for the criteria were calculated using equation (3).

$$e_j = -h \sum_{i=1}^{m} t_{ij} \ln t_{ij} \qquad j = 1, 2, \ldots, n \qquad (3)$$

Where h is a constant, let $h = (\ln(m))^{-1}$

Step 4: Calculating the degree of diversification.

The degree of divergence of the intrinsic information of each criterion calculated by using equation (4).

$$d_j = 1 - e_j \qquad (4)$$

Step 5: Calculation of objective weight of criterion

The objective weight for each criterion can be calculated from equation (5).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \qquad (5)$$

TOPSIS METHOD

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) method is a widely used MCDM method in different areas [Kolios et al. 2016, Wang et al. 2017, Mathew and Thomas 2019, Ersoy, 2021]. The TOPSIS method first was developed by Hwang and Yoon in 1981 [Hwang and Yoon 1981, Chen 2000, Ersoy 2021]. The TOPSIS method is based on the principle of determining the distances of the alternatives subjected to evaluation from the positive ideal solution and negative ideal solution [Chen 2000, Ersoy 2021]. The phases of the TOPSIS method have been given below [Hwang and Yoon 1981, Shih et al. 2007, Chitnis and Vaidya 2016, You et al. 2017, Ersoy 2021].

Step 1: Creating the decision matrix (A).

There are $i, i = 1, 2,..., m$ alternatives in the rows of the decision matrix A_{ij} and $j, j = 1, 2,..., n$ criteria in the columns. The decision matrix is shown below.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \qquad (6)$$

Step 2: Creating the normalized decision matrix (R).

The normalized decision matrix is calculated using equation (7).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \qquad i = 1, 2,..., m \quad j = 1, 2,..., n \qquad (7)$$

R_{ij} normalized decision matrix is shown below.

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \qquad (8)$$

Step 3: Creating the weighted normalized decision matrix (Y).

First, the weight values (w_i) for the evaluation criteria are determined. Then the Y_{ij} matrix is created by multiplying the elements in each column of the matrix by the corresponding value of w_i. The weighted normalized value y_{ij} is obtained as in equation (9).

$$y_{ij} = w_j . r_{ij} \qquad (9)$$

Y_{ij} normalized decision matrix is shown below.

$$Y_{ij} = \begin{bmatrix} w_1 r_{11} & w_1 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \qquad (10)$$

Step 4: Creating a positive ideal set (A^*) and negative ideal set (A^-).

To create the ideal solution set, the largest of the weighted column values in Y_{ij} matrix is chosen. The positive ideal solution set is obtained from equation (11).

$$A^* = \left\{ (\max_i y_{ij} | j \in J), (\min_i y_{ij} | j \in J') \right\} \quad (11)$$

The negative ideal solution set is created by choosing the smallest of the weighted column values in Y_{ij} matrix. The negative ideal solution set is obtained from equation (12).

$$A^- = \left\{ (\min_i y_{ij} | j \in J), (\max_i y_{ij} | j \in J') \right\} \quad (12)$$

In both equations, J benefit (maximization) and J' loss (minimization) value.

Step 5: Calculating the distance of each alternative to the positive ideal solution and the negative ideal solution.

The distance to the positive ideal solution is S_i^* and the distance to the negative ideal solution is S_i^-. The distance to the positive ideal solution is calculated using equation (13) and the distance to the negative ideal solution is calculated using equation (14).

$$S^* = \sqrt{\sum_{j=1}^n \left(y_{ij} - y_j^* \right)^2} \quad (13)$$

$$S^- = \sqrt{\sum_{j=1}^n \left(y_{ij} - y_j^- \right)^2} \quad (14)$$

Step 6: Compute the relative proximity of each alternative to the ideal solution.

The relative closeness (C_i^*) of each alternative to the ideal solution is calculated as in equation (15).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (15)$$

Where, $0 \le C_i^* \le 1$.

EDAS METHOD

The Evaluation Based on Distance from Average Solution (EDAS) method was first developed by Ghorabaee et al. [2015]. In this developed method, the average solution is used to evaluate the alternatives. Positive distance average (PDA) and negative distance average (NDA) are two separate measures used to evaluate alternatives. The best alternative is chosen considering these two distances [Ghorabaee et al. 2015, Kahraman et al. 2017, Chatterjee et al. 2018, Adalı and Tus 2019). The phases of the EDAS method were as follows [Ghorabaee et al. 2015, Stanujkic et al. 2017, Chatterjee et al. 2018, Aggarwall et al. 2018, Adalı and Tuş 2019].

Step 1: Creation of decision matrix (X).

$$X = \left[X_{ij} \right]_{n \times m} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (16)$$

Where X_{ij} demonstrates the performance value of i th alternative on j th criterion.

Step 2: Determine the average solution considering to all criteria.

$$AV = \left[AV_j \right]_{1 \times m} \quad (17)$$

Where,

$$AV_j = \frac{\sum_{i=1}^m x_{ij}}{m} \quad (18)$$

Step 3: Calculate the positive distance from average (PDA) and the negative distance from average (NDA) matrices according to the sort of criteria (cost and benefit).

$$PDA = \left[PDA_{ij}\right]_{nxm} \qquad (19)$$

$$NDA = \left[NDA_{ij}\right]_{n \times m} \qquad (20)$$

If j th criterion is beneficial,

$$PDA_{ij} = \frac{\max(0, (x_{ij} - AV_j))}{AV_j} \qquad (21)$$

$$NDA_{ij} = \frac{\max(0, (AV_j - x_{ij}))}{AV_j} \qquad (22)$$

And if j th criterion is non-beneficial

$$PDA_{ij} = \frac{\max(0, (AV_j - x_{ij}))}{AV_j} \qquad (23)$$

$$NDA_{ij} = \frac{\max(0, (x_{ij} - AV_j))}{AV_j} \qquad (24)$$

where PDA_{ij} and NDA_{ij} demonstrate the positive and negative distance of i th alternative from average solution in terms of j th criterion, respectively

Step 4: Calculate the weighted sum of PDA and weighted sum of NDA for all alternatives.

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \qquad (25)$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \qquad (26)$$

Where w_j is the weight of j th criterion.

Step 5: Normalize the SP and SN values for all alternatives.

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \qquad (27)$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \qquad (28)$$

Step 6: Calculate the appraisal score (AS) for all alternatives.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \qquad (29)$$

Where $0 \leq AS_i \leq 1$

Step 7: Ranking of the alternatives considering the descending values of AS.

The alternative with the biggest AS value is the best.

CODAS METHOD

CODAS (Combinative Distance-based Assessment) method was first developed by Ghorabaee et al. [2016]. In the CODAS method, which is based on the choice of alternatives based on the distances to the negative ideal solution, the preference of the alternatives is determined by the Euclidean (Euclidean) and Taksicab (Taxicab) distances [Ghorabaee et al., 2016; Bakır and Alptekin, 2018]. The application steps of the CODAS method were given below [Ghorabaee et al. 2016, Badi et al. 2018, Mathew and Sahu 2018, Bakır and Alptekin 2018].

Step 1: Creating a decision matrix (X) with alternatives and criteria.

$$X = \left[x_{ij}\right]_{n \times m} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix} \qquad (30)$$

Where $x_{ij}(x_{ij} \geq 0)$ denotes the performance value of i th alternative on j th criterion.

Step 2: Compute the normalized decision matrix.

$$n_{ij} = \begin{cases} \dfrac{x_{ij}}{\max_i x_{ij}} & if \ j \in N_b \\ \dfrac{\min_i x_{ij}}{x_{ij}} & if \ j \in N_c \end{cases} \quad (31)$$

The values N_b and N_c in equation (31) express the benefit and criteria, respectively.

Step 3: Compute the weighted normalized decision matrix.

This calculation, which is based on multiplying the column elements belonging to the normalized decision matrix with the relevant weight coefficients, is realized with equation (32).

$$r_{ij} = w_j n_{ij} \quad (32)$$

Step 4: Determine the negative-ideal solution point (NIS).

Using equation (33), the smallest values of the columns in the weighted matrix are selected.

$$ns = \left[ns_j \right]_{1 \times m} \qquad ns_j = \min_i r_{ij} \quad (33)$$

Step 5: Calculate the Euclidean and Taxicab distances of alternatives from the negative-ideal solution.

Calculation of Euclidean distances (E_i) and Taxicab distances (T_i) values were shown in equations (34) and (35), respectively.

$$E_i = \sqrt{\sum_{j=1}^{m} (r_{ij} - ns_j)^2} \quad (34)$$

$$T_i = \sum_{j=1}^{m} \left| r_{ij} - ns_j \right| \quad (35)$$

Step 6: Creation of Comparative evaluation matrix.

A Comparative evaluation matrix is created from equation (36).

$$R_a = \left[h_{ik} \right]_{n \times n}$$
$$h_{ik} = (E_i - E_k) + (\psi(E_i - E_k) \times (T_i - T_k)) \quad (36)$$

Where $k \in \{1, 2, ..., n\}$ and ψ denotes a threshold function recognizes the equality of the Euclidean and as given equation (37).

$$\psi(x) = \begin{cases} 1, & if \ |x| \geq \tau \\ 0, & if \ |x| \leq \tau \end{cases} \quad (37)$$

In this function, τ is the threshold parameter that can be set by the decision-maker. It is recommended to set this parameter at a value between 0,01 and 0,05. If the difference between Euclidean distances of two alternatives is less than τ, these two alternatives are also compared by the Taxicab distance [Ghorabaee et al. 2016, Badi et al. 2018]. In this study τ value was taken 0,02.

Step 7: Calculate the assessment score of each alternatives.

$$H_i = \sum_{k=1}^{n} h_{ik} \quad (38)$$

By ranking the H_i scores of the alternatives in descending order, the alternatives are ranked from the best to the worst.

RESULTS AND DISCUSSION

The weight values of the criteria used in the study have been identified as a result of the Entropy method. In the decision matrix have used in EDAS, TOPSIS and CODAS method, some criteria should be expressed as benefit and others as cost. In the study, price and weight criteria were accepted as non-benefit (cost) criteria others were accepted as benefit criteria. The best alternative was determined by comparing EDAS, TOPSIS and CODAS methods. The results of Entropy, EDAS, TOPSIS and CODAS methods used in the study were given below, respectively.

Entropy Method Results

In the first stage of the Entropy method, the decision matrix, which includes the criteria and alternatives, was created in Table 3. In Table 3, alternatives were respectively expressed as A1, A2, …., A6 and criteria as C1, C2, …., C6.

After the decision matrix was created, the normalized decision matrix shown in Table 4 was obtained using equation (2).

Table 3. Decision Matrix

Alternative	Criteria					
	Hard disk capacity (GB)	Ram (GB)	Battery power (Wh)	Processor speed (GHz)	Weight (Kg)	Price (TL)
	C1	C2	C3	C4	C5	C6
A1	256	8	41	1,6	1,77	7347,16
A2	256	8	32	1,0	1,8	6919,99
A3	256	8	53	1,6	1,9	8400
A4	256	8	41	1,0	1,75	6808,9
A5	512	8	35	1,6	1,7	8479,99
A6	256	4	35	1,6	1,7	7499,99

Table 4. Normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0,1429	0,1818	0,1730	0,1905	0,1667	0,1616
A2	0,1429	0,1818	0,1350	0,1190	0,1695	0,1522
A3	0,1429	0,1818	0,2236	0,1905	0,1789	0,1848
A4	0,1429	0,1818	0,1730	0,1190	0,1648	0,1498
A5	0,2857	0,1818	0,1477	0,1905	0,1601	0,1866
A6	0,1429	0,0909	0,1477	0,1905	0,1601	0,1650

Table 5. Entropy values and criteria weights

Results	C1	C2	C3	C4	C5	C6
e_j	0,976	0,987	0,992	0,988	1,000	0,998
$d_j = 1 - e_j$	0,024	0,013	0,008	0,012	0,000	0,002
w_j	0,405	0,221	0,134	0,199	0,007	0,034

After the decision matrix was normalized, entropy values and criterion weights were calculated. These calculated values were given in Table 5.

It is understood from Table 5 that the criteria with the highest weight is C1. Criteria weights obtained as a result of the Entropy method were used in EDAS, CODAS and TOPSIS methods.

TOPSIS Method Results

TOPSIS method has been implemented to the decision matrix given in Table 3. The normalized decision matrix shown in Table 6 has been obtained using equation (7).

Table 6. Normalized decision matrix

	C1	C2	C3	C4	C5	C6
A1	0,3333	0,4364	0,4175	0,4573	0,4079	0,3944
A2	0,3333	0,4364	0,3258	0,2858	0,4149	0,3715
A3	0,3333	0,4364	0,5397	0,4573	0,4379	0,4510
A4	0,3333	0,4364	0,4175	0,2858	0,4033	0,3655
A5	0,6667	0,4364	0,3564	0,4573	0,3918	0,4553
A6	0,3333	0,2182	0,3564	0,4573	0,3918	0,4027

Table 7. Ranking of the alternatives according to the TOPSIS method

Alternatives	S_i^*	S_i^-	C_i^*	Rank
A1	0,136	0,060	0,308	3
A2	0,142	0,048	0,254	5
A3	0,135	0,066	0,327	2
A4	0,140	0,050	0,263	4
A5	0,025	0,147	0,857	1
A6	0,145	0,034	0,192	6

Then, the distance to the positive ideal solution (S_i^*), the distance to the negative ideal solution (S_i^-) and the relative proximity of each alternative to the ideal solution (C_i^*) were calculated. Values of S_i^*, S_i^-, C_i^* and ranking of the alternatives were given in Table 7.

According to the ranking in Table 7, it was understood that the best alternative is A5, third place is A1 and fourth is A4.

EDAS Method Results

EDAS method has been applied to the decision matrix can be seen in Table 3. Average solutions of the criteria were calculated with equation (18). Table 8 shows the average solutions (AV_j) of the criteria.

Table 8. Average solutions of criteria

Criteria	C1	C2	C3	C4	C5	C6
AV_j	298,667	7,333	39,500	1,400	1,770	7576,005

Table 9. Ranking of the alternatives according to the EDAS method

Alternatives	SP_i	SN_i	NSP_i	NSN_i	AS_i	Rank
A1	0,055	0,058	0,162	0,667	0,414	3
A2	0,023	0,140	0,068	0,192	0,130	5
A3	0,094	0,062	0,279	0,643	0,461	2
A4	0,029	0,115	0,085	0,339	0,212	4
A5	0,338	0,019	1,000	0,889	0,944	1
A6	0,029	0,174	0,086	0,000	0,043	6

After calculating the PDA and NDA, weighted total positive values (SP_i), weighted total negative values (SN_i), weighted normalized positive values (NSP_i), weighted normalized negative values (NSN_i) and appraisal scores (AS_i) were calculated. Table 9 shows the EDAS method results and the ranking of alternatives. It is understood from Table 9 that the best alternative is A5. The second rank is A3, and the last is A6.

CODAS Method Results

The CODAS method was applied to the decision matrix given in Table 3. The decision matrix shown in Table 10 was obtained using equation (31).

Later, Euclidean distances (Ei) and Taxicab distances (Ti) values and the assessment score (H_i) of each alternative were calculated. Table 11 shows the results of the CODAS method and the ranking of the alternatives.

Table 10. Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6
A1	0,5	1	0,77358	1	0,96045	0,92674
A2	0,5	1	0,60377	0,625	0,94444	0,98395
A3	0,5	1	1	1	0,89474	0,81058
A4	0,5	1	0,77358	0,625	0,97143	1
A5	1	1	0,66038	1	1	0,80294
A6	0,5	0,5	0,66038	1	1	0,90785

Table 11. Ranking of the alternatives according to the CODAS method

Alternatives	E_i	T_i	H_i	Rank
A1	0,13553	0,21279	-0,00720	3
A2	0,11082	0,11717	-0,15518	5
A3	0,14365	0,23861	0,04159	2
A4	0,11315	0,14059	-0,14129	4
A5	0,24259	0,39608	0,63766	1
A6	0,07525	0,08664	-0,36802	6

DISCUSSION

In the study, 6 alternative laptops were ranked according to EDAS, CODAS and TOPSIS methods. Comparison of the alternatives according to the results of EDAS, CODAS and TOPSIS methods can be seen in Table 12.

Table 12. Comparison of the ranking results

Alternative	TOPSIS	EDAS	CODAS
A1	3	3	3
A2	5	5	5
A3	2	2	2
A4	4	4	4
A5	1	1	1
A6	6	6	6

It can be understood from Table 12 that while A5 is in the first place in all three methods, A6 is in the last place. According to the TOPSIS, EDAS and CODAS methods results, the ranking of the alternatives was A5 > A3 > A1 > A4 > A2 > A6. Besides, the correlation between the results of the TOPSIS, EDAS and CODAS methods has been examined with the Spearman Correlation approach. The correlation results can be seen in Table 13. When Table 13 is examined, it is possible to say that there is a strong positive relationship between the methods used and the results obtained.

Table 13. The Spearman's correlation coefficient between the methods and the results

Correlations				TOPSIS	EDAS	CODAS
Spearman's rho	TOPSIS	Correlation Coefficient		1,000	1,000**	1,000**
		Sig. (2-tailed)		.	.	.
		N		6	6	6
	EDAS	Correlation Coefficient		1,000**	1,000	1,000**
		Sig. (2-tailed)		.	.	.
		N		6	6	6
	CODAS	Correlation Coefficient		1,000**	1,000**	1,000
		Sig. (2-tailed)		.	.	.
		N		6	6	6
**. Correlation is significant at the 0.01 level (2-tailed).						

Source: Author's calculation in the SPSS24 statistics software

CONCLUSIONS

Nowadays, the demand for computers is increasing day by day with personal or corporate needs and developments in science and technology. This demand for computer technologies has led to the diversification of computer types such as desktop computers, laptops, tablets, netbooks, gaming computers and network computers. Laptops are preferred over desktop computers due to their lightweight and portable features. Choosing the most suitable laptop for businesses is a decision-making problem. MCDM methods are generally used in cases where there are multiple criteria and alternatives. TOPSIS, EDAS and CODAS methods are some of the MCDM methods.

In this study, 6 different laptop alternatives were evaluated by TOPSIS, EDAS and CODAS methods according to the criteria of hard disk capacity, RAM, battery power, processor speed, weight and price for the laptop selection of an e-commerce company. The weights of the criteria used in the study have been calculated by the Entropy method. According to the Entropy method results, the criteria with the highest weight is the hard disk capacity criterion with 0.405. This criterion is followed by ram, processor speed, battery power, price, weight criteria. The alternatives were ranked according to the TOPSIS, EDAS and CODAS method results and the best alternative was selected as A5. According to the results of the study, the last alternative in the ranking was A6. According to the result of Spearman Correlation analysis, it is possible to say that there is a strong positive relationship between the methods used and the results obtained.

As with many other studies, this study has some limitations. The use of 6 criteria and 6 alternatives in the study is one of the limitations of the study. The other limitation is that the work has been carried out in Turkey. Another limitation is that the study was conducted in the field of online commerce. Future studies on this subject can be carried out in different sectors and different countries.

Besides, different MCDM methods and different criteria can be used in future studies. There may be future work topics in applications for the selection of different machinery and equipment, location selection, or supplier evaluation. By taking different values in future studies, the CODAS method can be used with other MCDM methods.

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