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Selection of Portable Hard Disk Drive using ENTROPY-COBRA-MARCOS-MAIRCA: A Case of the Iranian Market

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ABSTRACT

There are many customer requirements met by the modern market today, such as in the hard disk drive market, where a variety of hard disks can be found along with several attributes associated with them, such as size, disk space, data transfer rate (DTR), color, weight, guarantee, and physical size. Therefore, it is necessary to present a comprehensive technique to select the best alternative for purchasers/retailers/wholesalers to satisfy their combined needs. This paper aims to combine the ENTROPY weighting method and three alternative assessment methods: COBRA, MARCOS, and MAIRCA. Additionally, for the first time, ENTROPY-COBRA integrated method has been introduced and utilized in this research to determine the best HDD available option. The information on six different hard disk drives available in Iran's market was collected and considered for further investigation. The research methodology is based on the ENTROPY weighting method to allocate criteria weights and its combination with COBRA, MARCOS, and MAIRCA for alternative evaluation. Furthermore, sensitivity analysis has been made to assess the robustness of our research. As a result, according to all hybrid techniques, the best choice is Western Digital-My Passport.

1. Introduction

A hard disk drive (HDD) is an electro-mechanical data storage device. IBM introduced the Hard Disk Drive (HDD) technology in 1956, and it has been the dominant secondary storage device for computers since the 1960s. Later, some companies produced and supplied hard drives due to non-volatile memory; Holst says hard disk drive sales peaked in 2010 at more than 600 million and sales are growing day by day, with about 83 million hard disk drives shipped globally in the third quarter of 2019 (Alsop, 2019). Expected revenue from external storage in Japan will be approx. US$ 3 billion by 2023 (Statista, 2019). The market for storing all kinds of data is expected to reach around US$ 78.1 billion by 2021 (Statista, 2019).

A hard drive is a device used to store digital data on one or more rigid, rapidly rotating disks (platters) coated with magnetic material. These disks are linked with magnetic heads arranged on a movable drive arm that reads and writes data on the surface of the disc (Arpaci, 2014). It is predicted that the hard drive will continue to grow in the next 15 years as at least one of the major hard drive manufacturers is constantly working to improve its capabilities and performance (Sukchannimit et al., 2018).

Many vendors worldwide manufacture HDDs, but some of the most important are Western Digital (WD), Seagate, SanDisk, Toshiba, Transcend, Lenovo, and many others. Various attributes such as HDD price, data transfer rate, disk space, the weight of HDD, size, etc. are associated with the HDD, which makes it a multiple-criteria decision (MCDM) issue for buyers/retailers/traders can also be used by expert system manufacturers and developers, or website developers who create websites that compare devices. Kumar et al. (2020) utilized the WASPAS method to select the best HDD option in an Indian market based on eight criteria.

Asih et al. (2014) employed a hybrid simulation approach to improve the throughput and tester utilization in the testing assembly line of HDD. Moreover, a mathematical model and AHP-TOPSIS integrated technique are utilized to assess the alternatives.

Rashid et al. (2020) utilized Fuzzy Analytic Hierarchy Process (F-AHP) to select the most appropriate maintenance contractor for a computer hard disk drive manufacturer and data-storage company. Five criteria (price, past performance, technical skills, availability, and financial stability) were considered to assess four contractors.

Furthermore, the AHP-TOPSIS hybrid has been used to select the best Desktop Computer according to essential measures such as RAM, Hard Disk Capacity, Processor type, Brand, and Screen size (Mitra & Goswami, 2019).

The paper structure is as follows: In Section 2, The Theoretical references are discussed, the literature has been reviewed, and the attributes of the problem are identified. Section 3 presents the implemented methodology of our research. Section 4 illustrates the research outcomes. A sensitivity analysis is utilized to assess the applied methodology robustness in Section 5. Finally, the research conclusion is presented in Section 6.

2. Theoretical references

2.1. HDD Market and Selection of the attributes

In the international HDD market, the countries like US, China, and Singapore are powerful markets. And the key manufacturers turned out to be from North America (Future Market Insights, 2014). Western Digital (WD), Seagate Technology LLC, and TOSHIBA companies are the main vendors in the global HDD market. In 2016, Western Digital transported the most HDDs, with 41% of the total while Seagate transported 37 percent, and Toshiba transported a minimum of 22% (Coughlin, 2017).

The long-term future of hard disk drives may rely on high-capacity HDDs, especially in data centers serving cloud storage applications. In 2015, ASTC (Advanced Storage Technology Consortium) - an international organization that brings together different companies which produce, design, or use hard disk drives - announced its vision for the future of HDDs. Considering this technology roadmap, hard disk drive storage is expected to become 100TB by 2025. In the near future, hard disk drives will apply many new recording technologies to increase data storage capacity (Shilov, 2015). Also, HDD manufacturers need to concentrate on product quality like durability, performance, warranties, and design because products play such an important role in customer purchase intent.

The external HDD has a lot of exploiters in industries/services fields for storing old recordings and is also very helpful in individuals' regular life as it is used to save documents and media files, etc. Portable HDDs are categorized into different models and have various criteria like disk memory space, size, DTR, physical dimensions, etc., to increase the ergonomy rate of the product. In MCDM, beneficial criteria have a high and positive value, such as the data transfer rate of HDD while cost criteria have a low and negative value, like, hard disk weight. Research criteria according to Kumar et al. (Kumar et al., 2020) are illustrated in Table 1:

Table 1: Research criteria

Research criteria	Type
Cost of HDD	Non-beneficial
Weight of HDD (g);	Non-beneficial
Dimensions of HDD; the volume of the HDD (cm^3);	Non-beneficial
Disk space of HDD (TB);	Beneficial
HDD Interface (USB);	Beneficial
HDD guarantee (years);	Beneficial
Data transfer rate (DTR) of the HDD (Gbps);	Beneficial
HDD variations in color (number).	Beneficial

2.2. MCDM literature

The MCDM is concerned with identifying appropriate options for mutual evaluation in different situations. Hard disk drive selection can be resolved using other noted or extended MCDM methods. Many researchers have recently attempted to develop, extend, suggest and use MCDM methods to solve project decision-making problems (Zavadskas et al., 2016).

Alternatives, attributes/criteria, the relative weight given to each feature, and performance measures of alternatives concerning various properties make up the four essential parts of each selection problem. This choice problem in the desired structure is well-suited to be solved using the MCDM technique. Therefore, the primary goal of the MCDM technique is to choose the best alternative from a set of feasible choices given various conflicting criteria (Chakraborty & Zavadskas, 2014).

In the literature, MCDM techniques abound. SWARA, AHP, TOPSIS, ELECTRE, MULTIMOORA, ARAS and ANP techniques are a few of them. All approaches share the ability to list alternatives or options as a common element.

It is proven that the methods that use a linear input data normalization model have more stability and are more constant in the sensitivity analysis. As the model for MAIRCA is linear normalization, it has better stability than other methods like ELECTRE (Pamucar & Cirovic, 2015).

One of the objective decision approaches, the entropy method, utilizes the information in the decision matrix solely to compute the criterion weights in MCDM situations. Since it does not require additional subjective evaluation, the entropy method is frequently utilized in literature research. Since there is no need for further subjective evaluation, the method is straightforward and is therefore chosen.

Tables 2, 3 and 4 provide an overview of some studies in various domains that used the MCDM techniques MARCOS, MAIRCA and Entropy, respectively.

Table 2: A literature review of MARCOS' recent applications

Application Field(s)	Method(s)	Author(s)
Supplier selection in healthcare industries	MARCOS	Stević et al. (2020)
Stackers selection in a logistics system	CCSD-ITARA-MARCOS	Ulutas et al. (2020)

Human resources evaluation	FUCOM-MARCOS	Stević & Brković (2020)
Failure mode and effect analysis	F-AHP-MARCOS	Boral et al. (2020)
Iron and steel industry	D-MARCOS	Chakraborty et al. (2020)
Risk assessment of railway infrastructure	Picture fuzzy set-MARCOS	Simić et al. (2020)
Supplier selection for steelmaking company	Grey-MARCOS	Badi & Pamucar (2020)
Performance assessment of battery electric vehicles	SECA-MARCOS-MAIRCA, COCOSO-ARAS-COPRAS	Ecer (2021)
Failure analysis of CNC machines due to human errors	IT2F-AHP-DEMATEL-MARCOS	Boral & Chakraborty (2021)
Ranking major ports	SWARA-MARCOS-CoCoSo	Majidi et al. (2021)
Evaluation of safety degree at railway crossings	F-FUCOM–PIPRECIA–MARCOS	Blagojević et al. (2021)
Evaluation of information and communication technology development in G7 countries	LBWA-MARCOS	Torkayesh & Torkayesh (2021)
Sustainable production in the foresty industry	Rough PIPRECIA-RNDWGA-fuzzy MARCOS	Stević et al. (2021)
Risk assessment and control for dam construction safety	IT2F-BWM-MARCOS	Celik & Gul (2021)
Landfill location selection for healthcare waste	BWM-Grey MARCOS	Torkayesh et al. (2021)
Selection of reach stacker in a container terminal	F-FUCOM-MARCOS- Bonferroni Mean	Vesković et al. (2022)
Analysis of efficiency and productivity of commercial banks in Turkey	SWARA II-MEREC-MARCOS	Ünlü et al. (2022)
Evaluating Smart Agricultural Production Efficiency	F-MARCOS	Abualkishik et al. (2022)
Cotton fibre selection	MARCOS	Mitra (2022)
Determination of a used PPE kit disposal	Enhanced MARCOS	Kang et al. (2022)
Determination of the optimal lithium battery plant	SFA-BBWM-MARCOS	Hashemkhani Zolfani et al. (2022)
Risk evaluation	Improved MARCOS using Fermatean fuzzy prioritized weighted average operator and prospect theory	Wang et al. (2023)
Fuel supply system modeling	PPH–FWZIC-MARCOS	Qahtan et al. (2023)

Table 3: A literature review of MAIRCA Methodology in Various Study Fields

Application Field(s)	Method(s)	Author(s)
Security equipment-Railway accidents	Hybrid Dematel- MAIRCA	Pamučar et al. (2014)
Ammunition Depots	GIS- MAIRCA	Gigović et al. (2016)
Public procurements- Interval rough numbers	Hybrid DEMATEL-ANP- MAIRCA	Pamučar et al. (2017)
Location Planning	DEMATEL - MAIRCA	Pamučar et al. (2017)
Level crossing- Railway accidents	FUCOM- MAIRCA	Pamučar et al. (2018)
Supplier Selection- Management and Engineering	Rough BWM- MAIRCA	Badi & Ballem (2018)
Green supply chain in the electronics industry	R'amatel- MAIRCA	Chatterjee et al. (2018)
An approach to uncertainty	IVFRN- MAIRCA	Pamučar et al. (2019)
Creating Firm selection	DEMATEL and MAIRCA	Ulutaş (2019)
Tourism- Financial	Entropy-MAIRCA	Gunay & Ecer (2020)
Risk assessment	F-AHP and F-MAIRCA	Soumava Boral et al. (2020)
Green supplier selection	Plithogenic sets and MAIRCA	Özçil et al. (2020)
Human health and environment- Risk assessment	F-BWM and F- MAIRCA	Muhammet Gul et al. (2020)
Neighborhood selection	BWM-Revised MAIRCA	SH Zolfani et al. (2020)
Constructive elements	Hybrid LBWA-IR- MAIRCA	Božanić et al. (2020)
Cash flow evaluation of tourism companies in Turkey	Entropy- MAIRCA	Gunay & Fatih (2020)
Turning process experiments	MAIRCA, EAMR, MARCOS and TOPSIS	Tung & Thinh (2021)
Overtourism assessment in Malaga	F-AHP and MAIRCA	Mestanza et al. (2021)
Biological inspiration evaluation	FR-DEMATEL-MAIRCA	Zhu et al. (2021)
Coronavirus vaccine selection	IF-MAIRCA	Ecer (2022)
Evaluation of cryptocurrencies for investment	IF-EDAS-MAIRCA-MARCOS	Ecer et al. (2022)
Evaluating flood susceptibility	MAIRCA	Hadian et al. (2022)
Evaluation of airports in Turkey	F-FUCOM-MAIRCA	Baki (2022)

Table 4: A literature review of ENTROPY Methodology in Various Study Fields

Application Field(s)	Method(s)	Author(s)
Data envelopment analysis	ENTROPY	JieWu et al. (2011)
Supplier selection- Order allocation	ENTROPY -SWOT	Ghorbani et al. (2012)

Resource Planning	ENTROPY -Delphi	BehboudiAsl et al. (2012)
Likelihood estimation	ENTROPY	Han et al. (2015)
Digital image correlation	ENTROPY	Yong Liu et al. (2015)
Material selection	ENTROPY -MULTIMOORA	Hafezalkotob (2015)
Supplier selection-Risk management	ENTROPY and F-TOPSIS	Kiani Mavi et al. (2016)
Data development analysis	ENTROPY	Song et al. (2017)
Stock market	Multi-scale ENTROPY	Rongbao Gu (2017)
Economy and environment	ENTROPY	C.Busu & M.Busu (2018)
Performance evaluation of green suppliers	ENTROPY and F-TOPSIS	Miranda dos Santos et al. (2018)
Economic disparity-Risk analysis	ENTROPY	Mishra & M.Ayyub (2019)
Product design	ENTROPY and TOPSIS	Tiwari et al. (2019)
Renewable energy	ENTROPY -EDAS	Yazdani et al. (2020)
Strategy assessment	ENTROPY - MULTIMOORA	Fedajev et al. (2020)
Biology and medicine	ENTROPY and K-means clustering	Mullick et al. (2021)
Gamification app selection	F-TOPSIS, Macbeth and F- ENTROPY	Carmen Carnero (2021)
Supplier selection-Sustainable supply chains	BWM, F- ENTROPY , and F- MULTIMOORA	Shang et al. (2022)
Silent Genset (ŚĠ) evaluation	ENTROPY-VIKOR-WASPAS	Vaid et al. (2022)
Selection of industrial arc welding robot	ENTROPY-TOPSIS	Chodha et al. (2022)

Moreover, the COBRA technique is a novel MCDM method introduced by Krstić et al. (2022) and needs to be tested to solve different problems.

3. Methodology

A novel hybrid MCDM technique based on the ENTROPY weighting method and three alternative assessment methods (COBRA, MARCOS and MAIRCA) is implemented to determine the best HDD in the Iran market. First, the criteria weights are obtained using ENTROPY, and then, COBRA, MARCOS and MAIRCA are implemented to assess the alternatives.

3.1. Entropy method

ENTROPY method is one of the MCDM weighting methods that has been modified from thermodynamics to information systems (Shannon, 2001). “Information entropy” represents the uncertainty of the indications in communication processes, and it has an inverse relationship with weight. In a decision-making system, this information can be used successfully as, in information theory; it can be considered a criterion for the represented degree of uncertainty by a discrete probability distribution. Moreover, the contrasts between data sets can be measured by it (Maghsoodi et al., 2018).

Step 1. Standardization of indexes:

Assuming that there are m alternatives and n criteria, R=[r_{ij}]mxn; i = 1,2, ...,m; j = 1,2,...,n; is the initial decision matrix. In this context, by using relatively optimal membership degree equations, the indexes should be standardized to calculate criterion weights utilizing the Shannon entropy and eliminate the effect of the index size on immeasurableness (Li et al., 2011).

If the criteria are beneficial, the attribute value of the jth index in the ith R matrix can be normalized by;

$$x_{ij} = r_{ij} / \max ij \tag{1}$$

If the criteria are cost, the attribute value of the jth index in the ith R matrix can be normalized by;

$$x_{ij} = \min_{ij} / r_{ij} \tag{2}$$

Step 2. Normalizing the decision matrix:

$$p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij} \tag{3}$$

Step 3. The entropy of information, Ej of the jth factor, is defined:

$$E_j = -(\ln m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{4}$$

Step 4. Weight obtained from information entropy:

$$w_j = (1 - E_j) / \left(n - \sum_{j=1}^{n} E_j\right) \tag{5}$$

3.2. COBRA method

COmprehensive Distance Based RAnking (COBRA) is a newly developed MCDM technique that considers Euclidean and Taxicab distances from the best, the worst, and the average solutions to prioritize the alternatives (Krstić et al., 2022). COBRA steps are as follows:

Step 1. Set up the primary decision matrix based on *n* criteria and *m* alternatives.

$$P = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_m \end{array} \\ \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \end{array} p_{ij}, i = 1,2, \dots, n;\ j = 1,2, \dots, m \tag{6}$$

Step 2. Obtain the normalized decision matrix *N* = $[n_{ij}]_{n\times m}$ using Equation (7).

$$n_{ij} = \frac{p_{ij}}{\max_i p_{ij}} \tag{7}$$

Step 3. Calculate the weighted normalized decision matrix.

$$W = [w_j \times n_{ij}]_{n\times m} \tag{8}$$

where w_j is the relative weight of each criterion.

Step 4. Obtain the positive ideal solution (PIS_j), negative ideal (NIS_j) and average solution (AVS_j) for each criterion.

$$PIS_j = \max(_i\, w_j \times n_{ij}), \forall j = 1, \dots, n \ for\ beneficial\ criterion \tag{9}$$

$$PIS_j = \min(_i\, w_j \times n_{ij}), \forall j = 1, \dots, n \ for\ non-beneficial\ criterion \tag{10}$$

$$NIS_j = \min(_i\, w_j \times n_{ij}), \forall j = 1, \dots, n \ for\ beneficial\ criterion \tag{11}$$

$$NIS_j = \max(_i\, w_j \times n_{ij}), \forall j = 1, \dots, n \ for\ non-beneficial\ criterion \tag{12}$$

$$AVS_j = \frac{\sum_{i=1}^{n}(w_j \times n_{ij})}{n}, \forall j = 1, \dots, n \ for\ both\ type\ of\ criteria \tag{13}$$

Step 5. Determine the distances from positive ideal $(d(PIS_j))$ and negative ideal $(d(NIS_j))$ solutions, as well as positive $(d(AVS_j{}^+))$ and negative $(d(AVS_j{}^-))$ distances from average solution for each alternative using the following equation:

$$d(S_j) = dE(S_j) + \sigma \times dE(S_j) \times dT(S_j), \forall j = 1, \dots, n \tag{14}$$

where S_j shows any solution $(PIS_j, NIS_j\ or\ AVS_j)$, σ is the correction coefficient obtained by the following equation:

$$\sigma = \max_i dE(S_j) - \min_i dE(S_j) \tag{15}$$

Moreover, $dE(S_j)$ and $dT(S_j)$ show Euclidian and Taxicab distances, respectively.

$$dE(PIS_j)_i = \sqrt{\sum_{j=1}^{n}(PIS_j - w_j \times n_{ij})^2}, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{16}$$

$$dT(PIS_j)_i = \left|\sum_{j=1}^{n}(PIS_j - w_j \times n_{ij})\right|, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{17}$$

$$dE(NIS_j)_i = \sqrt{\sum_{j=1}^{n}(NIS_j - w_j \times n_{ij})^2}, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{18}$$

$$dT(NIS_j)_i = \left|\sum_{j=1}^{n}(NIS_j - w_j \times n_{ij})\right|, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{19}$$

For the positive and negative distance from the average solution, the equations are as follows:

$$dE(AVS_j^+)_i = \sqrt{\sum_{j=1}^{n}\tau^+(PIS_j - w_j \times n_{ij})^2}, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{20}$$

$$dT(AVS_j^+)_i = \left|\sum_{j=1}^{n}\tau^+(PIS_j - w_j \times n_{ij})\right|, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{21}$$

where $$\tau^+ = \begin{cases} 1 & , if\ AVS_j < w_j \times n_{ij} \\ 0 & , if\ AVS_j > w_j \times n_{ij} \end{cases} \tag{22}$$

$$dE(AVS_j^-)_i = \sqrt{\sum_{j=1}^{n}\tau^-(NIS_j - w_j \times n_{ij})^2}, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{23}$$

$$dT(AVS_j^-)_i = \left|\sum_{j=1}^{n}\tau^-(NIS_j - w_j \times n_{ij})\right|, \forall i = 1, \dots, m, \forall j = 1, \dots, n \tag{24}$$

where $$\tau^- = \begin{cases} 1 & , if\ AVS_j > w_j \times n_{ij} \\ 0 & , if\ AVS_j < w_j \times n_{ij} \end{cases} \tag{25}$$

Step 6. Prioritize the alternatives based on the comprehensive distances (dC_i) in ascending order.

$$dC_i = \frac{d(PIS_j)_i - d(NIS_j)_i - d(AVS_j^+)_i + d(AVS_j^-)_i}{4}, \forall i = 1, \dots, m \tag{26}$$

3.3. MARCOS method

Measurement Alternatives and Ranking according to the COmpromise Solution (MARCOS) is a recently introduced method that considers the ideal and anti-ideal solution from the begging phase of its procedure. This method benefits from the concept of utility degrees and functions to prioritize the alternatives and has been utilized by many researchers to solve decision-making problems. MARCOS steps are as follows (Stević et al., 2020):

$c_1 \quad c_2 \quad \cdots \quad c_m$

$$P = \begin{array}{c} A_1 \\ A_2 \\ \cdots \\ A_n \end{array} \begin{bmatrix} a_{11} & a_{12} & \cdots & p_{1m} \\ a_{21} & a_{22} & \cdots & p_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix} p_{ij}, i = 1,2,\dots,n;\ j = 1,2,\dots,m \quad (27)$$

Ideal (AI) and anti-ideal solutions (AAI) are calculated based on the type of each criterion (costs or benefits) using Equations (28), (29):

$$AI_j = max\ a_{ij}\ if\ j\ is\ a\ Benefit\ crierion\ /\ min\ a_{ij}\ if\ j\ is\ a\ Cost\ crierion.\ \ \forall j \in J \quad (28)$$

$$AAI_j = min\ a_{ij}\ if\ j\ is\ a\ Benefit\ crierion\ /\ max\ a_{ij}\ if\ j\ is\ a\ Cost\ crierion.\ \ \forall j \in J \quad (29)$$

Step 2. Normalize the decision Matrix A.

$$n_{ij} = \frac{x_{ij}}{AI_j}\ \ if\ j\ is\ a\ Benefit\ criterion \quad (30)$$

$$n_{ij} = \frac{AI_j}{x_{ij}}\ \ if\ j\ is\ a\ Cost\ criterion \quad (31)$$

Step 3. Calculate the weighted normalized decision matrix Y= $[\,y_{ij}]_{m\times n}$ using Equation (32).

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

where w_j represents the weight of criterion j.

Step 4. Compute the utility degree of each alternative by implementation of Equations (33) and (34).

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (35)$$

$$K_i^- = \frac{S_i}{S_{aai}} \quad (36)$$

where S_i is the sum of the values of alternative i (row i) from matrix Y. Also, S_{ai} and S_{aai} are respectively sum of the ideal and anti-ideal solutions from matrix Y.

Step 5. Calculate the utility function of each alternative utilizing Equation (36).

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \quad (37)$$

where $f(K_i^+)$ and $f(K_i^-)$ respectively show the utility function of each alternative in relation to the ideal (AI) and anti-ideal (AAI) solutions using Equations (37) and (38).

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (38)$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (39)$$

Step 6. Rank the alternatives based on the utility function values in descending order.

3.4. MAIRCA method

MAIRCA (MultiAtributive Ideal-Real Comparative Analysis) method was developed by Dragan Pamuĉar at the National Defense University of Belgrade Logistics Research Center in 2014. The MAIRCA method aims to determine the difference between the ideal and empirical weights. The total difference for every observed alternative calculates by the summation of the gaps for each criterion. After ranking all alternatives, the best-ranked alternative is the one with the smallest value in the total deviation. The MAIRCA method has been shown in six steps (Pamučar et al., 2014).

Step 1: Equation (6) shows the criteria values for alternatives in the Initial decision matrix X.

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} X_{ij}, i = 1,2, \dots, m;\ j = 1,2, \dots, n \tag{40}$$

In the X matrix, criteria are either qualitative or qualitative. While the values of quantitative criteria for an alternative are directly addressed, the values of qualitative criteria are formed by the decision-maker priorities.

Step 2. " P_{A_i} " is defined as Preference determination based on the alternative selection. Within alternative selection, the DM (Decision-makers) does not prefer any of the suggested alternatives more than the other. In this article, it is consumed that DM does not take into account the probabilities of any alternative selection. This means that the DM considers the alternatives as if each one of them can have the same probability of occurring, so the preference of choosing one of the m possible options is given in Equation (41):

$$P_{A_i} = \frac{1}{m};\ \sum_{i=1}^{m} P_{A_i} = 1, i = 1,2, \dots, m \tag{41}$$

As shown in Equation (41), all priorities are equal.

$$P_{A_1} = P_{A_2} = \cdots = P_{A_m} \tag{42}$$

Step 3. A theoretical evaluation matrix (T_p) is formed in $n \times m$ (n is the total number of criteria, m is the total number of alternatives) format. And by multiplying the preferences of alternatives P_{A_i} and criteria weights ($w_i, i = 1,2, \dots, n$), the theoretical evaluation matrix elements (t_{pij}) are calculated. The theoretical evaluation matrix (T_p) is as shown in Equation (43).

$$T_p = \begin{array}{c} \\ P_{A_1} \\ P_{A_2} \\ \dots \\ P_{A_m} \end{array} \begin{array}{c} \begin{array}{cccc} w_1 & w_2 & \cdots & w_n \end{array} \\ \begin{bmatrix} t_{p11} & t_{p12} & \cdots & t_{p1n} \\ t_{p21} & t_{p22} & \cdots & t_{p2n} \\ \dots & \dots & \dots & \dots \\ t_{pm1} & t_{pm2} & \cdots & t_{pmn} \end{bmatrix} \end{array} = \begin{array}{c} \\ P_{A_1} \\ P_{A_2} \\ \dots \\ P_{A_m} \end{array} \begin{array}{c} \begin{array}{cccc} w_1 & w_2 & \cdots & w_n \end{array} \\ \begin{bmatrix} P_{A_1}w_1 & P_{A_1}w_2 & \cdots & P_{A_1}w_n \\ P_{A_2}w_1 & P_{A_2}w_2 & \cdots & P_{A_2}w_n \\ \dots & \dots & \dots & \dots \\ P_{A_m}w_1 & P_{A_m}w_2 & \cdots & P_{A_m}w_n \end{bmatrix} \end{array} \tag{43}$$

All preferences (P_{A_i}) are equal for all alternatives, as DM is neutral to the first choice of alternatives. So: (n is the total number of criteria, and t_{pi} is theoretical evaluation.)

$$T_p = P_{A_i} \begin{array}{c} \begin{array}{cccc} w_1 & w_2 & \cdots & w_n \end{array} \\ [t_{p1} \quad t_{p2} \quad \cdots \quad t_{pn}] \end{array} = P_{A_i} \begin{array}{c} \begin{array}{cccc} w_1 & w_2 & \cdots & w_n \end{array} \\ [P_{A_i}w_1 \quad P_{A_i}w_2 \quad \cdots \quad P_{A_i}w_n] \end{array} \tag{44}$$

Step 4. The creation of a real rating matrix (T_r) and its elements is shown in Equation (45). (n is the total number of criteria, m is the total number of alternatives)

$$T_r = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} t_{r11} & t_{r12} & \cdots & t_{r1n} \\ t_{r21} & t_{r22} & \cdots & t_{r2n} \\ \dots & \dots & \dots & \dots \\ t_{rm1} & t_{rm2} & \cdots & t_{rmn} \end{bmatrix} \end{array} \tag{45}$$

Then, real rating matrix elements (T_r) are calculated as the multiplication of the theoretical evaluation matrix (T_p) and elements of the initial decision-making matrix (X). Equations (46) and (47) show how the real rating matrix elements (T_r) are calculated.

For the "benefit" type criteria:

$$t_{r_{ij}} = t_{pij}\left(\frac{x_{ij}-x_i^-}{x_i^+-x_i^-}\right) \quad (46)$$

For the "cost" type criteria:

$$t_{r_{ij}} = t_{pij}\left(\frac{x_{ij}-x_i^+}{x_i^--x_i^+}\right) \quad (47)$$

The specified criterion's maximum values are given by its alternatives:

$$x_i^+ = \max(x_1, x_2, \ldots, X_m) \quad (48)$$

The specified criterion's minimum values are given by its alternatives:

$$x_i^- = \min(x_1, x_2, \ldots, X_m) \quad (49)$$

Step 5. The total gap matrix (G) is calculated as the gap between theoretical (t_{pij}) and real evaluations ($t_{r_{ij}}$), in other words by deducting the elements of the theoretical evaluation matrix (T_p) with the elements of the real evaluation matrix (T_r) and it is shown in Equation (50).

$$G = T_p - T_r = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} = \begin{bmatrix} t_{p11}-t_{r11} & t_{p12}-t_{r12} & \cdots & t_{p1n}-t_{r1n} \\ t_{p21}-t_{r21} & t_{p22}-t_{r22} & \cdots & t_{p2n}-t_{r2n} \\ \cdots & \cdots & \cdots & \cdots \\ t_{pm1}-t_{rm1} & t_{pm2}-t_{rm2} & \cdots & t_{pmn}-t_{rmn} \end{bmatrix} \quad (50)$$

Gap g_{ij} takes values from the interval $g_{ij} \in \left[0, \left(t_{pij} - t_{r_{ij}}\right)\right]$ while n is the total number of criteria and m is the total number of alternatives According to Equation (51).

$$g_{ij} = \begin{cases} 0 & , \; if\; t_{pij} = t_{r_{ij}} \\ t_{p_{ij}} - t_{r_{ij}}, & x \geq 0 \end{cases} \quad (51)$$

The alternative with a minimum difference between the theoretical (t_{pij}) and real evaluation ($t_{r_{ij}}$) is chosen, therefore it is desirable that g_{ij} goes to zero ($g_{ij} \rightarrow 0$). If the alternative A_i for the criterion C_i has a theoretical evaluation value equal to the real evaluation value ($t_{pij} = t_{r_{ij}}$), then the gap for the alternative A_i for the criterion C_i is $g_{ij} = 0$. In fact, the alternative A_i for the criterion C_i is the best (ideal) alternative (A_i^+).

Value $t_{ij} = 0$, then the gap for the alternative. A_i for the criterion C_i is $g_{ij} = t_{p_{ij}}$. In fact, the alternative A_i is for the criterion C_i the worst (anti-ideal) alternative (A_i^-).

Step 6. The last step is to calculate criterion functions (Q_i) matrix by the summation of the gap matrix (G) rows for each alternative, it is shown in Equation (52).

$$Q_i = \sum_{j=1}^{n} g_{ij} \quad i = 1,2,3, \ldots, m \quad (52)$$

Eventually, the alternatives are ranked due to the (Q_i) matrix values. The finest alternative is the one with the smallest final criterion function value.

4. The application of ENTROPY- COBRA-MARCOS-MAIRCA: (Selection of portable hard disk drive)

Six reachable portable HDDs in the Iranian market are shown in Table 5, from Alternative 1 to Alternative 6, and the information of eight considered criteria is illustrated for each alternative in Table 5. The eight criteria are the HDD's cost, the weight of the HDD, HDD's volume, disk space of HDD (storage), HDD Interface, HDD guarantee, HDD- DTR, and HDD variations in color. Table 6 is the initial or decision matrix for choosing the best HDD.

Table 5: List of alternatives

Alternatives	Alternative number
Toshiba-Canvio Advance	Alternative1
Silicon Power-Stream S03 2TB	Alternative2
Western Digital-My Passport	Alternative3
Apacer-AC732	Alternative4
Seagate-Expansion Portable STEA2000400	Alternative5
ADATA-HD830	Alternative6

Table 6: Initial decision matrix

Alternative	Storage (TB)	Cost	Weight (gr)	Volume (cm3)	Interface (USB)	guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative 1	1	$52.99	149	119.03	3.20	2	5	4
Alternative 2	2	$77.86	168	126.27	3.00	3	5	2
Alternative 3	2	$79.99	120	89.60	3.20	3	5	4
Alternative 4	5	$156.00	420	315.84	3.20	3	5	1
Alternative 5	1.5	$122.99	170	138.53	3.00	3	1.2	1
Alternative 6	4	$130.87	600	444.44	3.20	3	5	2

4.1. Calculation of criteria weights using ENTROPY method

The weight of each criterion was estimated by the entropy method. The Shannon-Entropy process of evaluation was shown as follows: First, the analysis began with creating a decision matrix. The matrix is shown in Table 3. In the second step, five criteria out of eight, like storage, HDD Interface, guarantee, DTR and color variation, are evaluated as benefit criteria. While the rest of them, cost, weight and volume, are evaluated as cost criteria. Equation (1) is applied for normalizing beneficial criteria and Equation (2) for cost criteria. The normalized decision matrix is shown in Table 7.

Table 7: Normalized decision matrix

Alternative	Storage (TB)	Cost	Weight (gr)	Volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.065	0.085	0.092	0.096	0.170	0.118	0.191	0.286
Alternative2	0.129	0.125	0.103	0.102	0.160	0.176	0.191	0.143

Alternative3	0.129	0.129	0.074	0.073	0.170	0.176	0.191	0.286
Alternative4	0.323	0.251	0.258	0.256	0.170	0.176	0.191	0.071
Alternative5	0.097	0.198	0.104	0.112	0.160	0.176	0.046	0.071
Alternative6	0.258	0.211	0.369	0.360	0.170	0.176	0.191	0.143

In the third step, Equation (4) is used to calculate the E_{ij}. And the last step calculates criterion weights using the Equation (5). Both steps three and four are calculated in Table 8.

Table 8: Criteria weight for HDD selection

	Storage (TB)	Cost	Weight (gr)	Volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
E_J	0.919	0.832	0.769	0.775	0.861	0.857	0.828	0.793
W_J	0.060	0.123	0.169	0.165	0.101	0.105	0.126	0.152

The most important criteria in this decision-making problem is the weight, followed by the Volume and Color variation. The paramount pattern of the criteria in this essay is as follows:

Weight > Volume > Color variation > DTR > Cost > Guarantee > Interface > Storage

4.2. Ranking alternatives with ENTROY-COBRA-MARCOS-MAIRCA Method

4.2.1. *ENTROPY-COBRA*

For the first time, ENTROPY-COBRA integrated method is described in this subsection. First, Table 6 is taken as the primary decision matrix. Then, by utilizing Equations (7) and (8), the weighted normalized decision matrix was built, which is shown in Table 9.

Table 9: COBRA weighted normalized decision matrix

Alternative	Storage (TB)	Cost	Weight (gr)	volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.024	0.041	0.03	0.032	0.12	0.08	0.12	0.16
Alternative2	0.048	0.06	0.034	0.034	0.113	0.12	0.12	0.08
Alternative3	0.048	0.062	0.024	0.024	0.12	0.12	0.12	0.16
Alternative4	0.12	0.12	0.084	0.085	0.12	0.12	0.12	0.04
Alternative5	0.036	0.095	0.034	0.037	0.113	0.12	0.029	0.04
Alternative6	0.096	0.101	0.12	0.12	0.12	0.12	0.12	0.08

Furthermore, Table 10 shows positive, negative and average solutions according to research criteria by employing Equations (9) to (13).

Table 10: *COBRA weighted normalized decision matrix*

Solutions	Storage (TB)	Cost	Weight (gr)	**V**olume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
PIS_J	0.12	0.041	0.024	0.024	0.12	0.12	0.12	0.16
NIS_J	0.024	0.12	0.12	0.12	0.1125	0.08	0.0288	0.04
AVS_J	0.062	0.08	0.054	0.055	0.1175	0.113	0.105	0.093

Finally, by implementing Equations (14) to (26), the Eclucidean and Taxicab distances are calculated, and COBRA prioritization is obtained. The results are shown in Table 11.

Table 11: COBRA results

Alternative	*d(PIS)*	*d(NIS)*	*d(AVS^+)*	*d(AVS^-)*	*d(C)*	Rank
Alternative1	0.106153	0.2206	0.0692	0.07281	-0.02771	2
Alternative2	0.112748	0.18132	0.01658	0.04092	-0.01106	4
Alternative3	0.075611	0.22632	0.0696	0.04925	-0.04276	1
Alternative4	0.17304	0.15121	0.08535	0.05324	-0.00257	5
Alternative5	0.188974	0.13164	0.01623	0.10186	0.035741	6
Alternative6	0.176663	0.13398	0.10405	0.01301	-0.01209	3

4.2.2. *ENTROPY-MARCOS*

The integrated ENTROPY-MARCOS method is utilized in this subsection to assess some available HDD options in Iran. In the first step, Table 3 is considered the primary decision matrix. Then, a weighted normalized decision matrix along with ideal and anti-ideal solutions have been driven by implementing Equations (28) to (32). Table 12 shows this procedure's results.

Table 12: MARCOS weighted normalized decision matrix

Alternative	Storage (TB)	Cost	Weight (gr)	Volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.012	0.123	0.136	0.124	0.101	0.07	0.126	0.152
Alternative2	0.024	0.084	0.121	0.117	0.095	0.105	0.126	0.076
Alternative3	0.024	0.081	0.169	0.165	0.101	0.105	0.126	0.152
Alternative4	0.06	0.042	0.048	0.047	0.101	0.105	0.126	0.038
Alternative5	0.018	0.053	0.119	0.107	0.095	0.105	0.03	0.038
Alternative6	0.048	0.05	0.034	0.033	0.101	0.105	0.126	0.076
AI	0.06	0.123	0.169	0.165	0.101	0.105	0.126	0.152
AAI	0.018	0.042	0.034	0.033	0.095	0.105	0.03	0.038

Finally, Equations (33) to (39) are employed to calculate the utility functions and prioritize the options. Table 13 shows ENTROPY-MARCOS outcomes.

Table 13: MARCOS results

Alternative	K_i^+	K_i^-	$f(K_i^+)$	$f(K_i^-)$	$f(K_i)$	Rank
Alternative1	0.84316	2.13671	0.71705	0.28295	0.75847	2
Alternative2	0.74725	1.89367	0.71705	0.28295	0.6722	3
Alternative3	0.92208	2.33671	0.71705	0.28295	0.82946	1
Alternative4	0.56643	1.43544	0.71705	0.28295	0.50954	5
Alternative5	0.56444	1.43038	0.71705	0.28295	0.50774	6
Alternative6	0.57243	1.45063	0.71705	0.28295	0.51493	4

4.2.3. *ENTROPY-MAIRCA*

Firstly, the decision matrix was developed using Equation (40). And secondly, Equation (41) is utilized to determine the decision maker's preferences for alternatives, and the probability occurring (P_{Ai}) for alternatives. The (P_{Ai}) is obtained as follows;

$P_{Ai} = 1/6 = 0.17$

In the third step, the theoretical evaluation matrix (T_p) is formed using equation (43), and equation (44), the calculated matrix (T_p) is shown in Table 14.

Table 14: Theoretical evaluation matrix

Alternative	Storage (TB)	Cost	Weight (gr)	Volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025
Alternative2	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025
Alternative3	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025
Alternative4	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025
Alternative5	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025
Alternative6	0.010	0.020	0.028	0.027	0.017	0.017	0.021	0.025

In the fourth step, Equation (46) and (47) is used, and the normalization process is applied. Next, the real rating matrix (T_r) was obtained and it is shown in Table 15.

Table 15: Real Rating Matrix

Alternative	Storage (TB)	Cost	Weight (gr)	volume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.000	0.020	0.026	0.025	0.017	0.000	0.021	0.025
Alternative2	0.002	0.016	0.025	0.025	0.000	0.017	0.021	0.008
Alternative3	0.002	0.015	0.028	0.027	0.017	0.017	0.021	0.025
Alternative4	0.010	0.000	0.011	0.010	0.017	0.017	0.021	0.000
Alternative5	0.001	0.007	0.025	0.024	0.000	0.017	0.000	0.000
Alternative6	0.007	0.005	0.000	0.000	0.017	0.017	0.021	0.008

In the fifth step, the total gap matrix (G) was calculated using the equation (50 & 51) and the result can be seen in Table 16.

Table 16: Total Gap Matrix

Alternative	Storage (TB)	Cost	Weight (gr)	**V**olume (cm3)	Interface (USB)	Guarantee (years)	DTR (Gbps)	Color variation (number)
Alternative1	0.010	0.000	0.002	0.002	0.000	0.017	0.000	0.000
Alternative2	0.007	0.005	0.003	0.003	0.017	0.000	0.000	0.017
Alternative3	0.007	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Alternative4	0.000	0.020	0.018	0.018	0.000	0.000	0.000	0.025
Alternative5	0.009	0.014	0.003	0.004	0.017	0.000	0.021	0.025
Alternative6	0.002	0.015	0.028	0.027	0.000	0.000	0.000	0.017

In the last step, using Equation (52) and calculating the criterion functions (Q_i) matrix, the final criteria function values are obtained for each portable HDD. The performance ranking of the alternatives is shown in Table 17.

Table 17: The ranked alternatives using the MAIRCA method

Alternative model	Q_i	Rank
Toshiba-Canvio Advance	0.031	2
Silicon Power-Stream S03 2TB	0.052	3
Western Digital-My Passport	0.013	1
Apacer-AC732	0.081	4
Seagate-Expansion Portable STEA2000400	0.093	6
ADATA-HD830	0.090	5

Alternative 3 (Western Digital-My Passport) is the top preference with all utilized MCDM techniques in this research. The results indicate that COBRA and MARCOS have the same prioritization of alternatives in the case of HDDs according to Figure 1.

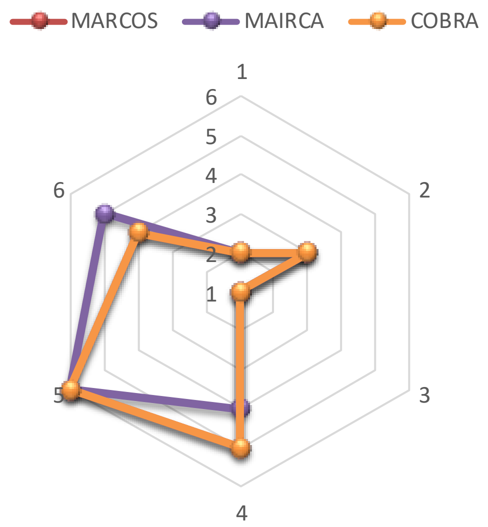

Figure 1. COBRA, MARCOS, and MAIRCA results comparison

5. Sensitivity analysis

A sensitivity analysis was conducted to examine the impact of weight on the optimum HDD selection criteria. Consequently, ten experiments concerning criteria weights were examined, with each being declared a state. The results are displayed in Table 17.

ENTROPY-COBRA and ENTROPY-MARCOS have more fluctuations in the outcomes than ENTROPY-MAIRCA while testing the experiments. Moreover, Toshiba-Canvio Advance (A_1) becomes the first rank while trying experiment 4 in ENTROPY-MARCOS.

According to MAIRCA outcomes, It is determined that Alternative 3 has the lowest score in the criterion function value throughout all ten simulations. That is, Alternative 3 is the first choice in all experiments. Thus, it is concluded the proposed ENTROPY-MAIRCA method is relatively insensitive to the weight of criteria, with A3 standing out from the alternatives A_1, A_2, A_3, A_4, A_5, and A_6, with a clear preference of (100%).

As a result, the considered method, the ENTROPY-MAIRCA performs best in selecting the best alternative (HDD).

Even though the first option is unobtainable, the second best option can be chosen. Also, it can be concluded that the ranks obtained using the Mairca method are stable.

As mentioned, the first rank is Western Digital-My Passport, and the following preferences are Toshiba-Canvio Advance, Silicon Power-Stream S03 2TB, Apacer-AC732, ADATA-HD830, and Seagate-Expansion Portable STEA2000400, respectively. These ranks do not change in all ten simulations except experiment number 5, which is only a slight change between Alternative 5 and Alternative 6. Sensitivity analysis results are shown in Table 18.

Table 18: Sensitivity analysis experiments

Exp.	Definition	COBRA Ranking	MARCOS Ranking	MAIRCA Ranking
E_1	WC1-C8= 0.125	A3>A1>A6>A2>A4>A5	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5
E_2	WC1=0.090, WC2-C8=0.130	A3>A1>A2>A6>A4>A5	A3>A1>A2>A6>A4>A5	A3>A1>A2>A4>A6>A5
E_3	WC1=0.055, WC2-C8=0.135	A3>A1>A2>A6>A4>A5	A3>A1>A2>A6>A4>A5	A3>A1>A2>A4>A6>A5
E_4	WC2=0.300, WC1,WC3-C8=0.100	A3>A1>A2>A6>A4>A5	A1>A3>A2>A6>A4>A5	A3>A1>A2>A6>A4>A5
E_5	WC3=0.300, WC1-C2,WC4-C8=0.100	A3>A1>A2>A4>A5>A6	A3>A1>A2>A5>A4>A6	A3>A1>A2>A4>A5>A6
E_6	WC4=0.230, WC1-C3,WC5-C8=0.110	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5
E_7	WC5=0.055, WC1-C4,WC6-C8=0.135	A3>A1>A2>A6>A4>A5	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5
E_8	WC6=0.076, WC1-C5,WC8=0.132	A3>A1>A6>A2>A4>A5	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5
E_9	WC7=0.209, WC1-C6,C8=0.113	A3>A1>A6>A2>A4>A5	A3>A1>A2>A4>A6>A5	A3>A1>A2>A4>A6>A5
E_{10}	WC8=0.160, WC1-C7=0.120	A3>A1>A6>A2>A4>A5	A3>A1>A2>A6>A4>A5	A3>A1>A2>A4>A6>A5

Moreover, Figures (2) to (4) show sensitivity analysis outcomes.

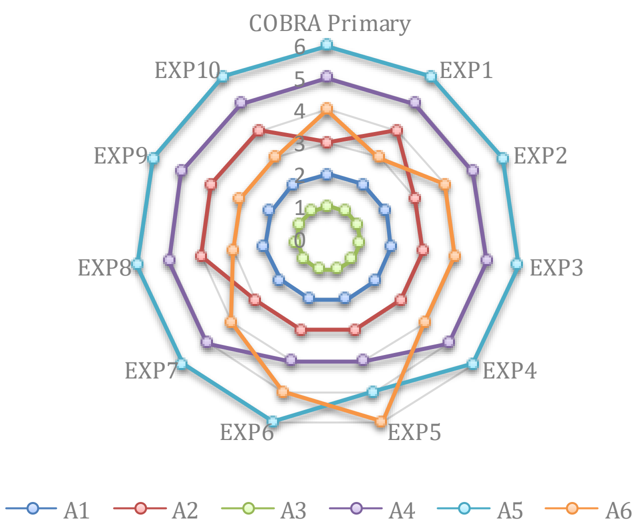

Figure 2. ENTROPY-COBRA sensitivity analysis

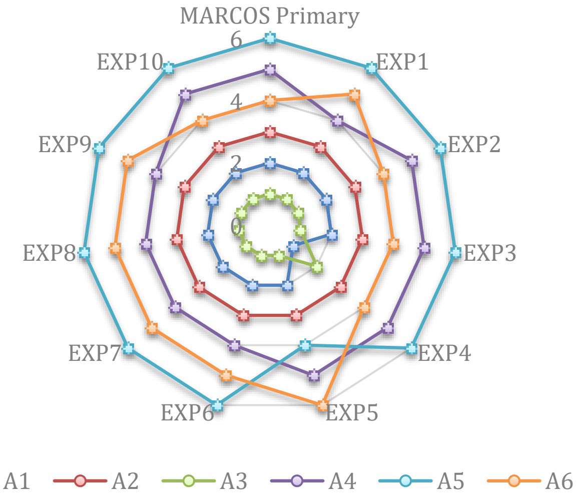

Figure 3: ENTROPY-MARCOS sensitivity analysis

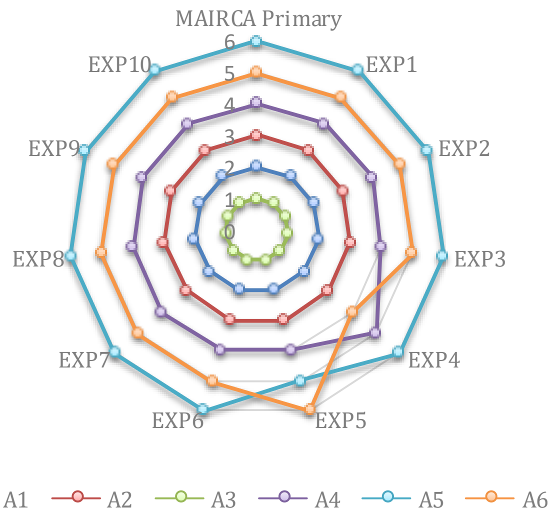

Figure 4. ENTROPY-MAIRCA sensitivity analysis

6. Conclusion

This article aims to identify the best portable hard disk drive alternative available on the Iranian market, meanwhile taking into account a variety of decision criteria. The information of six alternatives of six dissimilar brands of hard disk drives was assembled.

MCDM methods are an efficient solution for issues containing multiple alternatives and criteria. Moreover, Novel integrated ENTROPY-COBRA has been introduced and utilized in this research for the first time.

In this case study, criteria weights were obtained by the ENTROPY method, and alternatives were ranked using three hybrid techniques: ENTROPY-COBRA, ENTROPY-MARCOS, and ENTROPY-MAIRCA. The results reveal that the Western Digital - My Passport (Alternative3) comes out to be the first choice. The Western Digital-My Passport has 2 TB of capacity, a cost of $79.99, a weight of 120 g, a volume of 89.60 cm3, an

Interface of USB 3.20, and a data transfer rate of 5 Gbps, a guarantee of 3 years, and is available in five different colors.

According to the criteria and alternatives established in the study, the MAIRCA method was estimated to be proper. And the sensitivity analysis illustrates that the alternative ranking obtained using the MAIRCA method are robust.

A sensitivity analysis based on ten experiments was implemented to assess the research methodology's robustness. Results showed that ENTROPY-MAIRCA had the most negligible fluctuation in rankings while trying the experiments.

The applied method, Entropy-COBRA-MARCOS-MAIRCA, for selecting the best portable hard disk drive is quite rational and effective. This method of MCDM is particularly helpful for users, vendors, and retailers, as well as website designers and sites that compare similar and dissimilar goods in order to make sales. In addition, this approach can be a useful aid for manufacturers, engineers, managers, and programmers in various fields to make logical decisions. Furthermore, the research outcomes can be compared with different MCDM approaches in future investigations while considering different weighting methods and fuzzy techniques when the data are flawed.

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