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Article

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ORIGINAL RESEARCH

The multi-objective decision making methods based on MULTIMOORA and MOOSRA for the laptop selection problem

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Abstract A decision making process requires the values of conflicting objectives for alternatives and the selection of the best alternative according to the needs of decision makers. Multi-objective optimization methods may provide solution for this selection. In this paper it is aimed to present the laptop selection problem based on MOORA plus full multiplicative form (MULTIMOORA) and multi-objective optimization on the basis of simple ratio analysis (MOOSRA) which are relatively new multi-objective optimization methods. The novelty of this paper is solving this problem with the MULTIMOORA and MOOSRA methods for the first time.

Keywords Multi-objective decision making · MULTIMOORA method · MOOSRA method · Laptop selection

Introduction

Today many people cannot imagine their life without computers. This situation is the proof that the computers play an important role in the world. Because the computers make the people's lives easier and more comfortable in terms of searching and storing data, creating tables and diagrams, and editing pictures, audio, and video, etc. At the same time people communicate with the millions of people while they are in the different points of the world. Personal computers are generally classified by their sizes and cases. Laptops are one of the personal computer types. The people or organizations prefer laptops because of their ability, portability, and mobility (Srichetta and Thurachon 2012). In the market, there are numerous laptops with different brands and features. They also seem same to each other. So the selection of an effective laptop that suits the needs of buyers is essential but also the difficult problem. Like laptop selection problem, many problems in engineering, industry, and other fields involve the simultaneous optimization of several conflicting objectives. These problems are called multi-objective optimization problems (Jaimes et al. 2011). Maximizing profit and minimizing the cost of a product; maximizing performance and minimizing fuel consumption of a vehicle are the typical examples of multi-objective optimization problems (Chakraborty 2011). The objectives of these problems are measured in different units. One of the approaches to solve multi objective optimization problems is multi-criteria decision making (MCDM) (Jaimes et al. 2011). It requires using different methods which incorporate the conflicting criteria and help a decision maker for identifying the best alternative. In the literature, Erpolat and Cinemre (2011) proposed a hybrid approach based on data envelopment analysis (DEA) and analytic hierarchy process (AHP). They compared various laptop alternatives with two different DEA models as unrestricted and restricted on weights. Ertuğrul and Karakaşoğlu (2010) proposed the usage of Elimination Et Choix Traduisant la Realité (ELECTRE) and fuzzy analytic hierarchy process (FAHP) for ranking computers. Miranda Lakshmi et al. (2015) compared the laptop alternatives with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Pekkaya and Aktogan (2014) made laptop selection with TOPSIS and

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VIKOR methods. Srichetta and Thurachon (2012) applied FAHP for finding the relative importance of the decision criteria and selecting the best notebook computers. Finally, the literature shows that many authors have handled laptop selection problem but none of them tried to solve this problem with multi objective optimization methods. In this paper, laptop selection problem is solved with the multi-objective optimization by ratio analysis plus the full multiplicative form (MULTIMOORA) and multi-objective optimization on the basis of simple ratio analysis (MOOSRA) methods, which are multi-objective optimization methods. MULTIMOORA method summarizes MOORA method, including ratio system, reference point, and the full multiplicative form whereas MOOSRA method calculates the simple ratio of beneficial and non-beneficial criteria during decision making process (Balezentiene et al. 2013; Kumar and Ray 2015). A weight is assigned to each criterion according to their importance given by the decision maker. The pairwise comparison matrix of the AHP method is employed for the weight determination and finally laptop alternatives are ranked by MULTIMOORA and MOOSRA methods.

The rest of this paper is organized as follows: Firstly the methodological backgrounds of the MULTIMOORA and MOOSRA methods are provided, respectively. Then the applications of these methods are demonstrated with the laptop selection of a company. At last, the results of the applications are presented and recommendations for the future studies are discussed.

The MULTIMOORA method

The MULTIMOORA method rose from the MOORA method. Brauers and Zavadskas (2010) added the full multiplicative form to the MOORA then the new method was called MULTIMOORA. The MOORA method is one of the multi objective optimization methods and it was first developed by Brauers and Zavadskas (2006). It requires a matrix of responses of the alternatives to the objectives. Then a ratio system is developed in which each response of an alternative on an objective is compared to a denominator, which is the representative for all alternatives concerning that objective. There are two different methods under the name of the MOORA as the ratio system and the reference point approaches (Brauers 2013). In the literature, the MOORA method has been applied successfully to many decision problems. Brauers and Zavadskas (2006) applied the MOORA method to the privatization in a transition economy. Brauers et al. (2008a) ranked the contractors with the MOORA method. Brauers et al. (2008b) evaluated the road design alternatives and selected the best road design alternative with the MOORA method. Chakraborty (2011) presented the solutions of the problems in manufacturing environment. Gadakh (2011) selected suitable milling process parameters in different milling processes. El-Santawy and El-Dean (2012) combined the MOORA method with the standard deviation weight method. They presented an example of consulting firm selection. Stanujkic et al. (2012a) proposed only grey extension of the ratio system of the MOORA method whereas Stanujkic et al. (2012b) proposed the grey extensions of the ratio system and the reference point approaches of the MOORA method. Stanujkic et al. (2013) ranked the Serbian banks with SAW, ARAS, COPRAS, MOORA, GRA, CP, VIKOR, and TOPSIS methods. Brauers (2013) evaluated the projects of seaport planning. Özdağoğlu (2014) investigated the effects of different normalization methods in MOORA method. Adhikary and Kundu (2014) evaluated and selected the small hydropower project alternatives with the weighted product and MOORA methods. Achebo and Odinikuku (2015) used the standard deviation and MOORA method to optimize the welding process parameters for gas metal arc welding of mild steel plates. Madić et al. (2015) solved the complex non-conventional machining processes selection with the MOORA method. In the literature some papers integrated the MOORA method and fuzzy set theory then the fuzzy MOORA method was applied for the selection of the ERP systems (Karande and Chakraborty 2012a), the supplier and warehouse locations (Dey et al. 2012), the manufacturing systems (Mandal and Sarkar 2012), the grinding circuits designs (Stanujkic 2014), the suppliers (Seema et al. 2014), the cutting-machines (Vatansever and Kazançoğlu 2014), and the administrators of vocational schools within universities (Özbek 2015).

The MULTIMOORA method also found wide application areas like the MOORA method. Brauers (2002) applied the MULTIMOORA method to rank the fighter planes. Kracka et al. (2010) presented the MOORA and MULTIMOORA methods for solving the energy heating loss problems in buildings. Brauers (2012) used the MULTIMOORA method for the project evaluation in a country with controlled market economy. Karande and Chakraborty (2012b) solved four real time material selection problems with the MULTIMOORA method. Streimikiene and Balezentis (2013) applied the MULTIMOORA method for the prioritization of the climate change. Brauers and Zavadskas (2012) presented the robustness of the MULTIMOORA method with an example. Aksoy et al. (2015) evaluated the performances of eight sub companies, operated by Turkish Coal Enterprises using the AHP-based MULTIMOORA and COPRAS methods. Lazauskas et al. (2015) applied the AHP, ARAS, MOORA, and

MULTIMOORA methods for unfinished building solutions. Brauers et al. (2011) proposed first fuzzy extension of the MULTIMOORA method and used the fuzzy number theory in all three parts of the MULTIMOORA method. Then, the fuzzy MULTIMOORA method was used for forming a multi-criteria decision making framework for the prioritization of energy crops (Balezentiene et al. 2013), clearing of oil palm plantations (Hamdani and Mustofa 2015), and the selection of personnel (Balezentis et al. 2012) and student (Deliktaş and Üstün 2015).

The general overview of the MULTIMOORA is shown in Fig. 1 (Brauers and Zavadskas 2012). The application steps of the ratio system, the reference point, and the full multiplicative form, which are the main parts of MULTIMOORA, are presented in the following (Brauers and Zavadskas 2006; Brauers 2002; Kracka et al. 2010).

The ratio system part of MOORA method

Step 1: The first step of the MOORA method is constructing the decision matrix of the problem. The criteria (objectives) and alternatives are listed in the column and row of the decision matrix, respectively. The decision matrix shows the performance of different alternatives with respect to the various criteria.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

x_{ij} presents the performance value of ith alternative on jth criterion, m and n are the numbers of alternatives and criteria, respectively.

Step 2: Each performance value of an alternative on a criterion against the other alternative performances on that criterion is computed as:

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \quad (2)$$

x_{ij}^* is a dimensionless number between [0,1] and the normalized performance of ith alternative on jth criterion.

Step 3: Normalized performance values of beneficial criteria are added. Then, the same procedure is repeated for the non-beneficial criteria. Finally, the sums for non-beneficial criteria are subtracted from the sums for beneficial criteria as seen Eq. (3). The result is the overall performance score of each alternative (y_i^*).

$$y_i^* = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{n} x_{ij}^* \quad (3)$$

In this formula, g and $(n - g)$ are the number of criteria to be maximized and minimized, respectively. Sometimes, decision makers want to give more importance to a criterion than the others. In this situation, Eq. (3) is reformulated by considering the weights of criteria as (Chakraborty 2011):

$$y_i^* = \sum_{j=1}^{g} w_j x_{ij}^* - \sum_{j=g+1}^{n} w_j x_{ij}^* \quad (4)$$

w_j is the weight of jth criterion (significance coefficient) and may be derived from weighting methods like the AHP or entropy methods (Madić et al. 2015). In this paper, criterion weights are derived from the AHP method because of its simplicity. More detailed information about

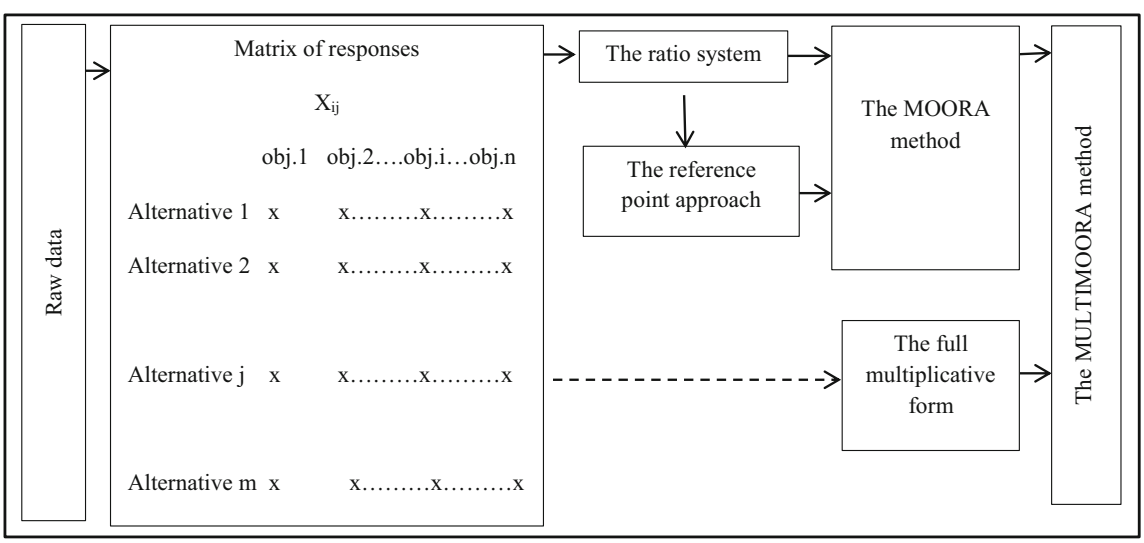

Fig. 1 The general overview of the MULTIMOORA method (Brauers and Zavadskas 2012)

the procedure of the AHP method is to be found in the paper of Saaty (1980).

Step 4: Finally, the alternatives are ranked in descending order of y_i^* values. For an alternative, the more y_i^* gives the higher rank. Obtaining the ranking of the alternatives terminates the ratio system part of the MOORA method.

The reference point part of MOORA method

The reference point approach uses the normalized performance of ith alternative on jth criterion which is calculated by Eq. (2). A maximum criterion reference point is determined among normalized performances and this point is more realistic and non-subjective as the coordinates (r_j) (Brauers et al. 2008a). Brauers and Zavadskas (2006, 2009) and Brauers et al. (2008a) emphasized that the Tchebycheff Min–Max metric is the most appropriate for the reference point approach and formulated as:

$$\min_i \left\{ \max_j \left| r_j - x_{ij}^* \right| \right\} \tag{5}$$

In this formula, x_{ij}^* is the normalized performance of ith alternative on jth criterion. r_j is the jth coordinate of the reference point, i.e., the most desirable performances of all alternatives with respect to jth criterion. For determining r_j, Eq. (6) may be used (Stanujkic et al. 2012a):

$$r_j \begin{cases} \max_i x_{ij}^* & \text{for criteria to be maximized} \\ \min_i x_{ij}^* & \text{for criteria to be minimized} \end{cases} \tag{6}$$

If the decision makers want to give more importance to a criterion than the others, Eq. (5) is reformulated by considering weights of criteria as:

$$\min_i \left\{ \max_j \left| w_j r_j - w_j x_{ij}^* \right| \right\} \tag{7}$$

Finally, the alternatives are ranked and the best alternative is chosen with the minimum total deviation from the reference points (Karande and Chakraborty 2012b).

The full multiplicative form

The full multiplicative form of multiple criteria consists both maximization and minimization of a purely multiplicative utility function. It was first developed by Miller and Starr (1969). The main characteristics of this form are being nonlinear, non-additive, and not using attribute weights (Kracka et al. 2010). Overall utility of the ith alternative (U_i) is computed as:

$$U_i = \prod_{j=1}^{n} x_{ij} \quad i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \tag{8}$$

In this formula, m and n are the numbers of alternatives and criteria, respectively, and x_{ij} is the performance of ith alternative on the jth objective. The overall utilities are obtained by the multiplication of different units of measurement and become dimensionless. If the decision makers want to combine the minimization problem with the maximization of other criteria then Eq. (8) becomes Eq. (9) (Brauers and Zavadskas 2012):

$$U_i = \frac{A_i}{B_i} \tag{9}$$

In this formula A_i and B_i are found as $A_i = \prod_{j=1}^{g} x_{ij}$ and $B_i = \prod_{j=g+1}^{n} x_{ij}$. g and $(n - g)$ are the number of criteria to be maximized and minimized, respectively (Brauers 2012). If x_{ij} equals 0 then withdrawal of that criterion from the decision matrix was suggested by Brauers (2002), because taking 0 value means the absence of a particular criterion in the decision matrix (Karande and Chakraborty 2012b).

The MOOSRA method

The MOOSRA method is one of the multi objective optimization methods. If the MOOSRA method is compared to the MOORA method, the negative performance scores in the MOORA method do not appear and the MOOSRA method is less sensitive to large variation in the values of the criteria (Jagadish and Ray 2014). It was used for forming a multi-criteria decision making framework for obtaining the optimum cutting parameters on surface roughness (Bhowmik 2014), selecting the optimum cutting fluid for a gear hobbing process among three types of cutting fluid (Jagadish and Ray 2014), selecting material (Kumar and Ray 2015), and non-traditional machine (Sarkar et al. 2015).

The application steps of MOOSRA method are similar to the MOORA method. Namely, the first step is constructing the decision matrix of the problem and the second step is the normalization of the decision matrix. While calculating the overall performance score of each alternative (y_i^*), the MOOSRA method uses simple ratio of the sum of normalized performance values for beneficial criteria to the sum of normalized performance values for non-beneficial criteria. Then formula becomes as (Kumar and Ray 2015):

$$y_i^* = \frac{\sum_{j=1}^{g} x_{ij}^*}{\sum_{j=g+1}^{n} x_{ij}^*} \tag{10}$$

In this formula, g and $(n - g)$ are the number of criteria to be maximized and minimized, respectively. When the weights of criteria are considered, Eq. (4) becomes Eq. (5) as:

$$y_i^* = \frac{\sum_{j=1}^{g} w_j x_{ij}^*}{\sum_{j=g+1}^{n} w_j x_{ij}^*} \quad (11)$$

w_j is the weight of jth criterion. Ranking of the alternatives is obtained according to the overall performance score of each alternative (y_i^*). The alternative with the highest overall performance score is the best (Jagadish and Ray 2014).

Application

To demonstrate the applicability of the MULTIMOORA and MOOSRA methods in solving multi-objective decision making problems, real case study is considered. The case study is associated with the supermarket which is the member of a supermarket chain. The supermarket management wants to purchase the laptops for their administrative offices. The purchasing department is responsible from this task namely identifying the alternatives and selecting the best laptop. There are three employees, in other words, three decision makers, in the purchasing department. First of all, they determine the criteria according to the needs of the company. The criteria are processor speed (C_1) (in Ghz), cache memory (C_2) (in MB), storage (C_3) (in GB), display card memory (C_4) (in GB), memory (RAM) (in GB) (C_5), screen resolution (C_6) [value judgment on a scale of 1–3; 1: the worst (1366 × 768 pixels), 2: medium (1600 × 900 pixels), 3: the best (1920 × 1080 pixels)], screen size (C_7) (in inches), brand reliability (C_8) (value judgment on a scale of 1–10; 1: the worst and 10: the best), weight (C_9) (in kg), and cost (C_{10}) (in Turkish Liras). The first eight criteria are beneficial whereas the last two ones are non-beneficial. Then seven laptop alternatives are determined. Their common features are running i7 processors and having 2 year warranty. Necessary data are collected from www.vatanbilgisayar.com and shown in Table 1. Table 1 shows the decision matrix of the problem which summarizes the performance of each alternative with respect to each criterion. Before applying MULTIMOORA and MOOSRA methods, pairwise comparison matrix between criteria is constructed and shown in Table 3. While comparing the alternatives, Saaty's nine-point scale shown in Table 2 is adopted. The consistency ratio (CR) is calculated as 0.032. As a result of AHP method, criteria weights are shown in the last column of Table 3.

Table 1 Decision matrix of the laptop selection problem

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	3.5	6	1256	4	16	3	17.3	8	2.82	4100
A_2	3.1	4	1000	2	8	1	15.6	5	3.08	3800
A_3	3.6	6	2000	4	16	3	17.3	5	2.9	4000
A_4	3	4	1000	2	8	2	17.3	5	2.6	3500
A_5	3.3	6	1008	4	12	3	15.6	8	2.3	3800
A_6	3.6	6	1000	2	16	3	15.6	5	2.8	4000
A_7	3.5	6	1256	2	16	1	15.6	6	2.9	4000

Table 2 Saaty's scale

Degree preferences	Verbal judgment of preference
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate preferences between the two judgments

The application of the MULTIMOORA method

For the ratio system of the MOORA method, first, the decision matrix is normalized using Eq. (2) as seen in Table 4. The normalized decision matrix is weighted and shown in Table 5.

Table 6 shows the overall performance and the rankings of the alternatives. A_3 is the best laptop alternative according to the ratio system part of MOORA.

The reference point approach uses the weighted normalized decision matrix shown in Table 5 as an initial step. Then reference points are determined among normalized and weighted performances and stated last row of the Table 7.

Table 7 presents the deviations from the maximum and minimum values for the beneficial and non-beneficial criteria, respectively. For each alternative, maximum deviation among them is determined and maximum deviation is ranked in descending order. Finally, A_3 is the best laptop alternative according to the reference point part of MOORA.

For the full multiplicative form, first, the initial decision matrix shown in Table 1 is taken into consideration. The degree of utility value of each alternative is computed by taking the beneficial and non-beneficial values on the numerator and denominator, respectively. The necessary operations are shown in Table 8. According to the full multiplicative form, A_3 is the best laptop alternative.

Finally, the overall ranks are obtained and shown in Table 9. MULTIMOORA is the summary of three distinct approaches as stated by Brauers (2012).

Table 3 Pairwise comparison matrix of the criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Weight
C_1	1	8	7	5	3	6	4	9	8	2	0.297
C_2	1/8	1	1/2	1/4	1/6	1/3	1/4	2	1	1/7	0.025
C_3	1/7	2	1	1/3	1/5	1/2	1/4	3	2	1/7	0.035
C_4	1/5	4	3	1	1/3	2	1/2	5	4	1/4	0.076
C_5	1/3	6	5	3	1	4	2	7	6	1/2	0.154
C_6	1/6	3	2	1/2	1/4	1	1/3	4	3	1/4	0.053
C_7	1/4	4	4	2	1/2	3	1	6	4	1/3	0.104
C_8	1/9	1/2	1/3	1/5	1/7	1/4	1/6	1	1/2	1/8	0.017
C_9	1/8	1	1/2	1/4	1/6	1/3	1/4	2	1	1/7	0.025
C_{10}	1/2	7	7	4	2	4	3	8	7	1	0.214

CR = 0.032

Table 4 Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	0.392	0.412	0.376	0.500	0.444	0.463	0.400	0.492	0.383	0.398
A_2	0.347	0.275	0.299	0.250	0.222	0.154	0.361	0.308	0.419	0.369
A_3	0.403	0.412	0.598	0.500	0.444	0.463	0.400	0.308	0.394	0.389
A_4	0.336	0.275	0.299	0.250	0.222	0.309	0.400	0.308	0.353	0.340
A_5	0.369	0.412	0.302	0.500	0.333	0.463	0.361	0.492	0.313	0.369
A_6	0.403	0.412	0.299	0.250	0.444	0.463	0.361	0.308	0.381	0.389
A_7	0.392	0.412	0.376	0.250	0.444	0.154	0.361	0.369	0.394	0.389

Table 5 Weighted normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	0.116	0.010	0.013	0.038	0.068	0.025	0.042	0.008	0.010	0.085
A_2	0.103	0.007	0.010	0.019	0.034	0.008	0.038	0.005	0.010	0.079
A_3	0.120	0.010	0.021	0.038	0.068	0.025	0.042	0.005	0.010	0.083
A_4	0.100	0.007	0.010	0.019	0.034	0.016	0.042	0.005	0.009	0.073
A_5	0.110	0.010	0.011	0.038	0.051	0.025	0.038	0.008	0.008	0.079
A_6	0.120	0.010	0.010	0.019	0.068	0.025	0.038	0.005	0.010	0.083
A_7	0.116	0.010	0.013	0.019	0.068	0.008	0.038	0.006	0.010	0.083

The application of the MOOSRA Method

The beginning steps of MOOSRA method are the same with the MOORA method namely acquiring weighted normalized decision matrix and finding the sum of performance scores for beneficial and non-beneficial criteria, respectively. Then, for each alternative, the sum of the beneficial criteria is divided by the sum of non-beneficial criteria and the result is the overall performance score of each alternative shown in Table 10.

According to the MOOSRA method, A_3 is the best laptop alternative. For the laptop selection problem, the MULTIMOORA and MOOSRA methods produce same rankings.

Conclusion

In this paper, multi-objective decision making problem for the laptop selection is handled and solved by the MULTIMOORA and MOOSRA methods. The results of the methods suggest that the third laptop alternative is the best alternative. This paper is the first in the literature for solving the laptop selection problem by MULTIMOORA and MOOSRA methods which are relatively new methods.

The MULTIMOORA and MOOSRA, which are core methods of this paper, are chosen because they have some advantages over other multi objective methods. MULTIMOORA is composed of the full multiplicative form of

Table 6 Overall performances of the alternatives

	$\sum_{j=1}^{g} x_{ij}^*$	$\sum_{j=g+1}^{n} x_{ij}^*$	y_i^*	Ranking
A_1	0.321	0.095	0.226	2
A_2	0.224	0.089	0.135	7
A_3	0.329	0.093	0.236	1
A_4	0.233	0.082	0.152	6
A_5	0.290	0.087	0.203	3
A_6	0.295	0.093	0.202	4
A_7	0.279	0.093	0.186	5

multiple objectives and MOORA method. The MOORA method handles both beneficial and non-beneficial criteria and employs separate mathematical processes in contrast to other methods. For example, the SAW method does not treat the beneficial and non-beneficial criteria separately and during the normalization process the non-beneficial criteria are transformed into the beneficial criteria (Stanujkic et al. 2012a). The procedure of the MOORA method produces the overall performance of alternatives with respect to various criteria. So these advantages make the MOORA method easy to apply and flexible. The MOORA method reflects the subjective part of the selection process

Table 7 Deviations from the reference points

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Max. value	Ranking
A_1	0.003	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.002	0.012	0.012	2
A_2	0.017	0.003	0.010	0.019	0.034	0.016	0.004	0.003	0.003	0.006	0.034	5
A_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.002	0.010	0.010	1
A_4	0.020	0.003	0.010	0.019	0.034	0.008	0.000	0.003	0.001	0.000	0.034	5
A_5	0.010	0.000	0.010	0.000	0.017	0.000	0.004	0.000	0.000	0.006	0.017	3
A_6	0.000	0.000	0.010	0.019	0.000	0.000	0.004	0.003	0.002	0.010	0.019	4
A_7	0.003	0.000	0.008	0.019	0.000	0.016	0.004	0.002	0.002	0.010	0.019	4
r_j	0.120	0.010	0.021	0.038	0.069	0.025	0.042	0.008	0.008	0.073		

Table 8 The degree of utilities

	1 Max C_1	2 Max C_2	2.1 2.1 = 2.1	3 Max C_3	3.1 3.1 = 2.1.3	4 Max C_4	4.1 4.1 = 3.1.4	5 Max C_5	5.1 5.1 = 4.1.5	6 Max C_6
A_1	3.5	6	21	1256	26,376	4	105,504	16	1,688,064	3
A_2	3.1	4	12.4	1000	12,400	2	24,800	8	198,400	1
A_3	3.6	6	21.6	2000	43,200	4	172,800	16	2,764,800	3
A_4	3	4	12	1000	12,000	2	24,000	8	192,000	2
A_5	3.3	6	19.8	1008	19,958.4	4	79,833.6	12	958,003.2	3
A_6	3.6	6	21.6	1000	21,600	2	43,200	16	691,200	3
A_7	3.5	6	21	1256	26,376	2	52,752	16	844,032	1

	6.1 6.1 = 5.1.6	7 Max C_7	7.1 7.1 = 6.1.7	8 Max C_8	8.1 8.1 = 7.1.8	9 Min C_9	9.1 9.1 = 8.1:9	10 Min C_{10}	10.1 10.1 = 9.1:10	Ranking
A_1	5,064,192	17.3	87,610,522	8	700,884,173	2.82	248,540,487	4100	60,619,63	2
A_2	198,400	15.6	3,095,040	5	15,475,200	3.08	5,024,415.6	3800	1322,215	7
A_3	8,294,400	17.3	143,493,120	5	717,465,600	2.9	247,401,931	4000	61,850.48	1
A_4	384,000	17.3	6,643,200	5	33,216,000	2.6	12,775,385	3500	3650.11	6
A_5	2,874,010	15.6	44,834,550	8	358,676,398	2.3	155,946,260	3800	41,038.49	3
A_6	2,073,600	15.6	32,348,160	5	161,740,800	2.8	57,764,571	4000	14,441.14	4
A_7	844,032	15.6	13,166,899	6	79,001,395	2.9	27,241,860	4000	6810,465	5

Table 9 The ranking of alternatives by the MULTIMOORA method

	MOORA: ratio system	MOORA: reference point	The full multiplicative form	MULTIMOORA
A_1	2	2	2	2
A_2	7	5	7	7
A_3	1	1	1	1
A_4	6	5	6	6
A_5	3	3	3	3
A_6	4	4	4	4
A_7	5	4	5	5

Table 10 The ranking of the alternatives by the MOOSRA method

	$\sum_{j=1}^{g} x_{ij}^*$	$\sum_{j=g+1}^{n} x_{ij}^*$	y_i^*	Ranking
A_1	0.321	0.095	3.382	2
A_2	0.224	0.089	2.509	7
A_3	0.329	0.093	3.533	1
A_4	0.233	0.082	2.860	6
A_5	0.290	0.087	3.343	3
A_6	0.295	0.093	3.184	4
A_7	0.279	0.093	3.001	5

by integrating the criteria weights to the computational procedure (Mandal and Sarkar 2012). The mathematical background of MOORA method is not complex so it is easily understandable. The steps of the computational procedure do not require a software package, namely they are performed using Microsoft Excel programme (Madić et al. 2015). The necessary time for making the final selection is not too long. There is no limit about the number of the criteria and alternatives of the problem. Adding of any extra parameter does not affect the computational procedure (Chakraborty 2011). The multiplicative form of the MULTIMOORA method does not require criteria weights or normalization procedure. And also being non-linear is an advantage because human behavior is considered as nonlinear. But this form is suitable only for the problems with alternatives are known in detail beforehand. If any criteria are missing in an alternative, this alternative should be withdrawn from the decision process or given an extremely low symbolic value to the missing criterion. Finally, this form produces only ordinal outcomes (Brauers 2002).

The MOOSRA method holds all advantages of the MOORA method mentioned above and some additional advantages are also gained. For the MOORA method, the overall performance score of each alternative is computed as the differences between the overall scores of the beneficial and non-beneficial criteria, respectively, and the result may be positive or negative. For avoiding the negative values, the MOOSRA method uses the simple ratio of the overall scores of the beneficial and non-beneficial criteria. This procedure is based on output and input evaluation (Kumar and Ray 2015).

Finally these methods are seen as appropriate tools for ranking or selecting the best alternative from a set of alternatives because of satisfactory results. In future studies, the same laptop selection problem may be solved by other multi-objective methods and the performances of these methods may be comparable with the existing methods. The MULTIMOORA and MOOSRA methods may be applied to the other decision making problems with any number of criteria and alternatives.

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