PaKSoM 2021

Proceedings of the
3rd Virtual International Conference Path to a Knowledge Society-Managing Risks and Innovation

Editors:
Stanković, M. and Nikolić, V.

Publishers:
Complex System Research Center, Niš, Serbia
Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade, Serbia

November 15-16, 2021

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Editors:
Prof. Dr. Miomir Stanković and Prof. Dr. Vesna Nikolić
Technical Editor:
Dr. Lazar Z. Velimirović

Published by:
Complex System Research Centre, Niš, Serbia, and
Mathematical Institute of the Serbian Academy of Sciences and Arts

Printed by:
Copy House, Niš, Serbia

Number of copies printed: 100
The publishing year: 2022

Printing of this edition has been financially supported by
Serbian Ministry of Education, Science and Technological Development

ISBN 978-86-80593-72-2

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

005.94(082)(0.034.2)
005.591.6(082)(0.034.2)
007:004(082)(0.034.2)

VIRTUAL international conference Path to a knowledge society-managing risks and innovation PaKSoM (3 ; 2021)
Proceedings [Elektronski izvor] / 3rd Virtual international conference Path to a knowledge society - managing risks and innovation PaKSoM 2021, november 15-16, 2021 ; [organizers] Organizer: Mathematical Institute of the Serbian academy of sciences and arts ... [et al.] ; editors Stanković, M. Nikolić, V. - Niš : Mathematical Institute of the Serbian academy of sciences and arts : Complex system research centre, 2022 (Niš : Copy house). - 1 elektronski optički disk (CD-ROM) : tekst, slika ; 12 cm

Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-80593-72-2 (MISASA)

а) Знање -- Менаџмент -- Зборници б) Предузећа -- Пословање -- Иновације -- Зборници в) Информациона технологија -- Зборници

COBISS.SR-ID 57366537

PaKSoM 2021

3rd Virtual International Conference
Path to a Knowledge Society-Managing Risks and Innovation

Organizer:
Mathematical Institute of the Serbian Academy of Sciences and Arts

Co-organizers:
- Research and Development Center "IRC ALFATEC"
- Complex System Research Centre

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Serbian Ministry of Education, Science and Technological Development

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Anilambica Kata

Smartphone Selection based on the PIPRECIA and CoCoSo Methods

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Abstract—**The primary goal of this paper is to select the optimal smartphone for procurement by an organization. The choice is made between eight smartphones of different brands, different performances and prices. The Multiple-Criteria Decision-Making (MCDM) approach is used for the selection of the best alternative smartphone according to the defined requirements. *The PIvot Pairwise RElative Criteria Importance Assessment – PIPRECIA* method is used for determining the weights of the criteria, while *the Combined Compromise Solution – CoCoSo* method is used for final evaluation and ranking of the alternatives. Eight alternative smartphones are assessed relative to the five evaluation criteria, and the decision process involves three decision-makers with the aim of gaining the appropriate and reliable results.**

Keywords – MCDM, PIPRECIA method, CoCoSo method, smartphone, selection

I. INTRODUCTION

Everyday life, both private and business, could not be imagined without using the various types of gadgets. Thanks to computers, laptops, tablets and smartphones, people easier reach and shares the needed information and mutually communicate. Especially popular are smartphones which provide their users with different types of services [1]. Consequently, there are various types of smartphones with different features and possibilities. Because of that, it is very complex to select an appropriate one from a wide range of offered types and brands. Besides the price, an adequate smartphone should fulfil other users` requirements regarding its technical performances and possibilities. The fact that this decision requires involving a greater number of criteria leads to the conclusion that the application of the Multiple-Criteria Decision-Making (MCDM) methods is fully justified and necessary.

As Vincke stated in his paper [2], the MCDM could be precisely described as a set of multiple -criteria method. Since mid-50s a significant number of MCDM methods have been proposed, to mention some of the best known: *the Weighted Sum* – WS or *the Simple Additive Weighting* – SAW [3,4], *the Analytic Hierarchy Process* – AHP [5], *the Technique for Order of Preference by Similarity to Ideal Solution* – TOPSIS [6], *the Preference Ranking Organization METHod for Enrichment of Evaluations* – PROMETHEE [7], *ÉLimination et Choix Traduisant la REalité* – ELECTRE [8], and *Višekriterijumsko KOmpromisno Rangiranje* – VIKOR [9]. There are the new methods that have been recently proposed such as: *the Weighted Sum adapted for an analysis based on decision maker Preferred Levels of Performances* – WS PLP [10], *the Full Consistency Method* – FUCOM [11], the *Measurement of Alternatives and Ranking according to COmpromise Solution* – MARCOS [12], *the Integrated Simple Weighted Sum Product Method* – WISP [13], and *the MEthod based on the Removal Effects of Criteria* – MEREC [14]. The authors have proposed adequate extensions of the MCDM methods that make them more suitable for the application in the conditions of uncertainty [15].

MCDM methods have been used for the optimization of different business processes as well as for making different kind of decisions [16-18]. The main intention of this paper is to propose an MCDM approach for the evaluation and selection of an appropriate smartphone for procurement. Until now, the authors have

ISBN: 978-86-80593-72-2

observed decision-making regarding various issues relative to smartphones, which results in the following papers [19-22]. For the purpose of this paper, the selection of the adequate smartphone for purchase is performed by applying the The *PIvot Pairwise RElative Criteria Importance Assessment – PIPRECIA* [23] and *Combined Compromise Solution – CoCoSo* [24]. The weights of the criteria are determined by applying the PIPRECIA method, while the final ranking of the alternative smartphones is performed by using CoCoSo method. Eight smartphones are assessed against five criteria, by three decision-makers.

II. THE METHODOLOGY

A. The PIPRECIA method

In the application of any type of MCDM method the first step is the determination of the criteria weights. Until now, many different approaches have been proposed for that purpose, such as: AHP [5], the *KEmeny Median Indicator Ranks Accordance* – KEMIRA [25], FUCOM [11] and *the Stepwise Weight Assessment Ratio Analysis* – SWARA [26]. In this paper the PIPRECIA method [23] is used because of its simplicity and reliability. Maybe the dominant advantage of this method relies in its convenience for the application in a group decision environment. So far, the PIPRECIA method is used for defining the weights of different types of criteria as well as for the prioritization of various business options. Besides, the authors proposed certain extensions with the aim of incorporating the uncertainty of the decision environment to a higher degree.

The computation procedure of the PIPRECIA method can be explained in the following way.

***Step* 1.** Choosing the evaluation criteria. In the case of using the PIPRECIA method, there is no obligation for pre-sorting the criteria according to expected significance. mandatory.

***Step* 2.** Determining the relative importance s_j, beginning from the second criterion, as follows:

$$s_j = \begin{cases} >1 & when \quad C_j > C_{j-1} \\ 1 & when \quad C_j = C_{j-1} \\ <1 & when \quad C_j < C_{j-1} \end{cases}. \tag{1}$$

***Step* 3.** Defining the coefficient k_j using the Eq. (2):

$$k_j = \begin{cases} 1 & j=1 \\ 2-s_j & j>1 \end{cases}. \tag{2}$$

***Step* 4.** Computing the recalculated value q_j, in the following way:

$$q_j = \begin{cases} 1 & j=1 \\ \dfrac{q_{j-1}}{k_j} & j>1 \end{cases}. \tag{3}$$

***Step* 5.** Defining the relative criteria weights by using the Eq. (4):

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k}, \tag{4}$$

where w_j represents the relative weight of the criterion *j*.

***Step* 6.** Defining the relative criteria weights under group decision-making conditions. When a greater number of decision-makers are involved in the procedure, then the overall criteria weights are defined in the following manner:

$$w_j^* = \left(\prod_{r=1}^{R} w_j^{nr} \right)^{1/R}, \tag{5}$$

$$w_j = \frac{w_j^*}{\sum_{j=1}^{n} w_j^*}, \tag{6}$$

where w_j^{nr} denotes the weight of criterion *j* that is defined by the respondent *r*, *R* is the total number of the respondents, w_j^* is group weight of criterion *j* before its adjusting in order to fulfill the condition $\sum_{j=1}^{n} w_j = 1$, and w_j is the overall weight of criterion *j*.

B. The CoCoSo method

The CoCoSo method is introduced by Yazdani, Zarate, Zavadskas, and Turskis [24]. The essence of the CoCoSo method is the combination of weighted sum method and exponentially weighted product method. The computation procedure of the CoCoSo method could be precisely illustrate by following series of steps.

***Step* 1.** Defining the initial decision-making matrix. This matrix *X* could be shown as follows:

$$X = \begin{bmatrix} x & x & \cdots x & \cdots & x \\ x & x & \cdots x & \cdots & x \\ \vdots & \vdots & \ddots \vdots & \ddots & \vdots \\ x & x & \cdots x & \cdots & x \\ \vdots & \vdots & \ddots \vdots & \ddots & \vdots \\ x & x & \cdots x & \cdots & x \end{bmatrix}, \quad (7)$$

where x_{ij} denotes a performance rating of alternative *i* in relation to criterion *j* ($x_{ij} > 0$), *n* represents the number of alternatives and *m* denotes the number of criteria.

***Step* 2.** Normalization of the criteria performance ratings. Depend on the type of evaluation criteria, normalization procedure is performed by using Eq. (8) and (9), as follows:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \quad (8)$$

when criterion is benefit.

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \quad (9)$$

when criterion is cost.

***Step* 3.** Define the sum of weighted comparability sequence and power-weighted comparability sequences of alternative by using the following Eqs.:

$$S_j = \sum_{j=1}^{n} r_{ij} w_j , \quad (10)$$

$$P_i = \sum_{j=1}^{n} r_{ij}^{w_j} , \quad (11)$$

where *Si* and *Pi* represents the sum of weighted comparability sequence and power-weighted comparability sequences of alternative *i*, respectively, w_j is weight of criterion *j*, and r_{ij} denotes normalized rating of alternative *i* according to criterion *j*.

***Step* 4.** Ranking of the alternatives. For ranking of the alternatives, CoCoSo method uses relative performance score k_i, that is calculated based on three aggregated appraisal scores k_{ia}, k_{ib} and k_{ic}, as follows:

$$k_i = \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}) + (k_{ia} k_{ib} k_{ic})^{\frac{1}{3}}, \quad (12)$$

with:

$$k_{ia} = \frac{S_i + P_i}{\sum_{i=1}^{m}(S_i + P_i)}, \quad (13)$$

$$k_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i}, \quad (14)$$

$$k_{ic} = \frac{\lambda S_i + (1-\lambda) P_i}{\lambda \max_i S_i + (1-\lambda) \max_i P_i}, \quad (15)$$

where: λ is coefficient, $\lambda \in [0,1]$ and it is usually set to $\lambda = 0.5$.

III. Numerical Example

The applicability of the proposed methodology is presented by using a real case study pointed to the selection of an optimal smartphone for procurement by an organization. The alternative smartphones that will be assessed are:

- A_1 – Samsung Galaxy A52s 5G
- A_2 – Xiaomi Mi 10T
- A_3 – Realme GT
- A_4 – CAT S52
- A_5 –Vivo V21
- A_6 – BlackShark 4
- A_7 – Crosscall Trekker X4
- A_8 – Huawei P40

These alternative smartphones are evaluated against five criteria that are as follows:

- C_1 – Price (din.)
- C_2 – Weight (g)
- C_3 – RAM memory (GB)
- C_4 – Internal storage (GB)
- C_5 – Battery (mAh)

The list of the evaluation criteria is based on the one presented in the paper of Goswami and Mitra [27].

In the beginning, there is a need for defining the criteria weights which is done by the help of three decision-makers who are managers in the organization. The reason for involving more than one decision-maker is minimizing the subjectification of the gained results. The weights obtained from the first decision-maker are presented in Table I.

TABLE I. THE CRITERIA WEIGHTS OBTAINED BY THE FIRST DECISION-MAKER.

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.17
C_2	1.10	0.90	1.11	0.19
C_3	1.10	0.90	1.23	0.21
C_4	1.00	1.00	1.23	0.21
C_5	1.10	0.90	1.37	0.23
			5.95	1

As Table I shows, the most important criterion according to the first decision-maker is C_5 – *Battery*. Criterion C_1 – *Price* is the least significant according to the opinion of this decision-maker.

Table II contains the criteria weights defined by the second decision-maker.

TABLE II. THE CRITERIA WEIGHTS OBTAINED BY THE SECOND DECISION-MAKER.

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.21
C_2	0.90	1.10	0.91	0.19
C_3	1.00	1.00	0.91	0.19
C_4	1.10	0.90	1.01	0.21
C_5	0.90	1.10	0.92	0.19
			4.75	1

The second decision-maker considers the criteria C_1 – *Price* and C_4 – *Internal storage* as the most significant and influential.

The criteria weights according to the third decision-maker are presented in Table III.

TABLE III. THE CRITERIA WEIGHTS OBTAINED BY THE THIRD DECISION-MAKER.

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.16
C_2	1.20	0.80	1.25	0.20
C_3	1.05	0.95	1.32	0.21
C_4	1.00	1.00	1.32	0.21
C_5	1.00	1.00	1.32	0.21
			6.20	1

Third decision-maker assigned equal significance to the three criteria namely: C_3 – *RAM memory*, C_4 – *Internal storage*, and C_5 – *Battery*.

It is easy to conclude that the different decision-makers prioritize the criteria in different way. In order to elicit the overall weight of criteria we applied Eqs. (5) and (6), and obtain the final results that are presented in Fig. 1.

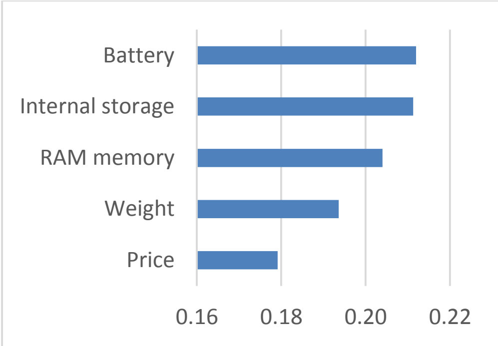

Figure 1. The overall criteria weights.

As the final results show, the greater significance has the criterion C_5 – *Battery*, while the criterion C_1 – *Price* is the least important in this case.

When the calculation of criteria weights is performed, we have all the needed data for the final ranking of the considered alternatives. The features of alternative smartphones that are submitted under evaluation are presented in Table IV. Data about considered smartphones are retrieved from an online shop that is not mentioned to avoid its promotion.

TABLE IV. INICIAL DECISION-MAKING MATRIX.

	C_1	C_2	C_3	C_4	C_5
	0.179	**0.194**	**0.204**	**0.211**	**0.212**
	din.	***g***	***GB***	***GB***	***mAh***
	min	***min***	***max***	***max***	***max***
A_1	52990	189	8	256	4500
A_2	56990	194	6	128	5000
A_3	74990	186	12	256	4500
A_4	49990	210	4	64	3100
A_5	49990	176	8	128	4000
A_6	84990	210	12	256	4500
A_7	82990	253	2	64	4400
A_8	99990	175	8	128	3700

The normalized performance ratings of the considered alternatives are calculated by using Eqs. (8) – (9) and they are presented in Table V.

TABLE V. NORMALIZED DECISION-MAKING MATRIX.

	C_1	C_2	C_3	C_4	C_5
	0.179	**0.194**	**0.204**	**0.211**	**0.212**
A_1	0.94	0.82	0.60	1.00	0.74
A_2	0.86	0.76	0.40	0.33	1.00
A_3	0.50	0.86	1.00	1.00	0.74
A_4	1.00	0.55	0.20	0.00	0.00
A_5	1.00	0.99	0.60	0.33	0.47
A_6	0.30	0.55	1.00	1.00	0.74
A_7	0.34	0.00	0.00	0.00	0.68
A_8	0.00	1.00	0.60	0.33	0.32

Now, the rank of the considered alternatives will be defined by using the CoCoSo method. In Table VI the calculation details regarding the used method are presented.

TABLE VI. CALCULATION DETAILS WERE OBTAINED USING THE COCOSO METHOD.

	S_i	P_i	k_{ia}	k_{ib}	k_{ic}
A_1	0.039	3.28	0.156	6.709	0.998
A_2	0.031	2.20	0.145	5.827	0.927
A_3	0.037	2.95	0.157	6.760	1.000
A_4	0.040	3.64	0.082	3.081	0.523
A_5	0.038	3.42	0.145	5.823	0.927
A_6	0.036	2.55	0.150	6.207	0.955
A_7	0.039	3.27	0.055	2.000	0.348
A_8	0.038	2.81	0.110	4.192	0.700

Finally, by using Eq. (12) we achieved the final results relative the ranking order of the considered alternative smartphones.

TABLE VII. THE FINAL RANK OF ALTERNATIVES.

	k_i	Rank
A_1	3.637	2
A_2	3.222	4
A_3	3.659	1
A_4	1.738	7
A_5	3.221	5
A_6	3.398	3
A_7	1.137	8
A_8	2.352	6

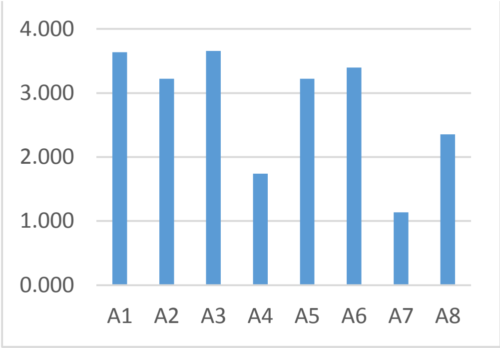

Figure 2. The rank of the alternative smartphones.

According to the given results, the optimal choice is the alternative A_3 – *Realme GT*, while the least desirable is the alternative A_7 – *Crosscall Trekker X4*. According to the input data, it could be concluded that this option fulfills the set requirements. The obtained result is presented graphically, as well (Fig. 2).

IV. CONCLUSION

This paper was pointed to the identification of the optimal smartphone for purchase by using MCDM techniques. The evaluation and selection process is based on the application of the PIPRECIA and CoCoSo methods. The weights of the criteria are defined with the help of the PIPRECIA method, while the final ranking is performed by using CoCoSo method. Eight smartphones are assessed regarding to five criteria in the group decision environment. The used methodology proved its applicability because it facilitated decision process and enabled finding such a solution that fulfils the requirements.

The main limitation of this paper is reflected through using crisp numbers. The vagueness of the environment could be better expressed if the fuzzy, grey or neutrosophic numbers are applied. The aforementioned also is the first preposition for future work. Secondly, it would be desirable to involve a greater number of the criteria in the evaluation process because the results would be more representative in that case. Here, the criteria weights are determined by using the subjective weighting method; it would be interesting to observe the case of using a combination of the subjective and objective weighting methods.

Finally, the conclusion is that the proposed MCDM approach proved its simplicity and efficiency in the case of selecting the optimal smartphone. It provides reliable and adequate results which candidates it for application in the resolving of various perceived problems in other fields.

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