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Multi-Criteria Decision-Making Methodology for Ranking and Selecting Optimal Metaverse Platform

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Abstract

This study adopted a decision-making model for ranking and sectioning the best Metaverse platforms. This section has various criteria such as effectiveness, safety, user experience, etc. So, the Multi-Criteria Decision-Making (MCDM) methodology is used to deal with multiple criteria. The MABAC method is an MCDM methodology used to rank the alternatives. The proposed methodology is applied to nine criteria and fifteen alternatives. The criteria weights are computed. The sensitivity analysis is conducted to show the stability of the final rank. The ten cases in criteria weights are proposed, and ten ranks are shown. The results show the rank of alternatives under different cases is stable. The comparative analysis is conducted with other MCDM methods such as TOPSIS, VIKOR, EDAS, and COPRAS. The results show the proposed methodology is effective with other MCDM methods.

Keywords: Multi-criteria decision making, Metaverse platform, Selection problem, MABAC method.

1 | Introduction

The term "Metaverse," first used in the 1992 Neal Stephenson book Snow Crash, is a relatively recent addition to technology experts' and scientists' everyday language. In Greek, "Meta" refers to a condition of existence that is higher or more sublime than what is now understood or experienced. Other levels of awareness or perception may be investigated and developed. A virtual environment that replaces the real world is called the "Metaverse" [1], [2].

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It offers a complete Virtual Reality (VR) experience with well-known characters, objects, user interfaces, and social networks. [3] and [4] scholarly contributions support the definition in question, which states that the Metaverse possesses several essential characteristics, including a pervasive presence, absorbed verisimilitude, and the ability to grow in terms of player count, intricate settings, and a vast range of interactive possibilities [3], [4]. The Metaverse has evolved as an essential route for brand marketing, given the increasing virtual interaction of consumers during the pandemic. The younger generation is projected to show more interest in digital ownership after the epidemic. People's engagement in the Metaverse is as meaningful as how they interact with the world [5], [6]. The best possible realization of the Metaverse depends on high-speed internet access. The VR platform "Second Life" serves as an instructive example. It was established before cell phones were widely used, and its popularity declined partly because it did not allow instantaneous mobile interactions. Technologies that enable sophisticated interactions with people, digital objects, and settings are VR and augmented reality. The book presents the Metaverse as a virtual world, an internet-based cosmos that combines software agents and avatars to create augmented reality[7], [8]. The term "Metaverse" refers to a network of permanent, socially linked immersive platforms allowing smooth communication and dynamic interactions with virtual items. It is a three-dimensional (3D) depiction of a simulation that interacts with the natural world via a variety of applications[9], [10]. Multi-Criteria Decision-Making (MCDM) is one of the best tools for effective Metaverse platform selection to tackle such complicated challenges. In essence, MCDA came from operations research, which uses a variety of approaches but also has a humorous rational base from other fields of study[11], [12]. MCDA methods are widely used in both public and commercial sectors to inform choices on resource management in agriculture, immigration, education, transportation, investment, environment, defense, and health care, among other topics[13]–[15]. This study aims to propose an MCDM methodology named MABAC for the section best Metaverse platform under different criteria.

2 | Materials and Methods

This section introduces the steps of the MABAC method. The MABAC method ranks the alternatives and selects the optimal option [16]–[18]. *Fig. 1* shows the steps of the MABAC method.

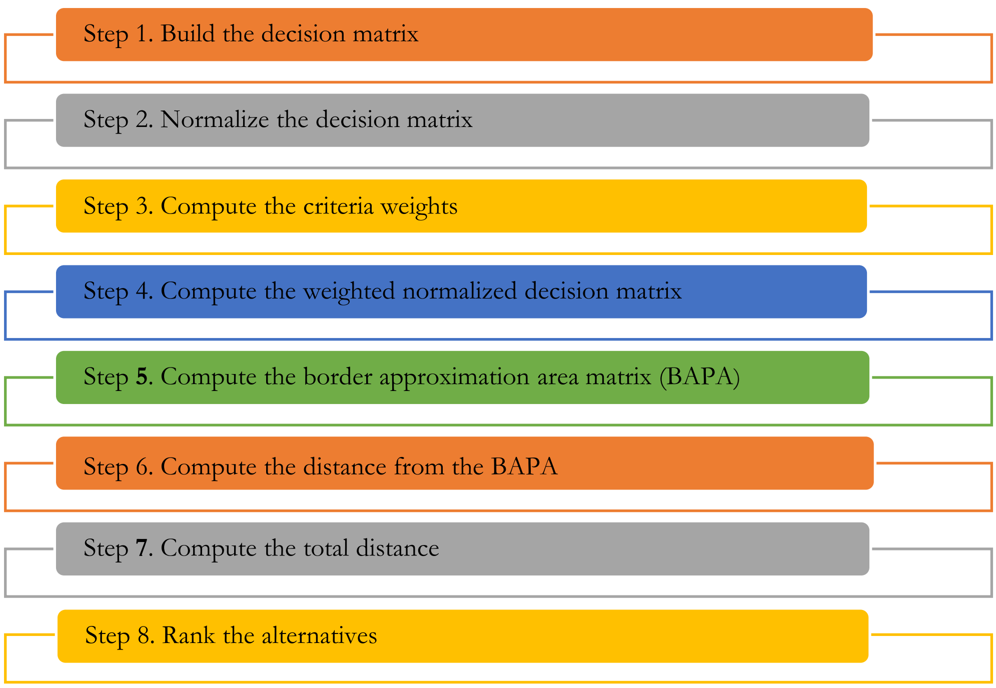

Fig. 1. The steps of the proposed MCDM methodology.

Step 1. Build the decision matrix

The experts and decision-makers build the decision matrix between criteria and alternatives. The experts used the crisp values between 1 and 9. The decision matrix is built using *Eq. (1)*.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix}_{m \times n} \quad i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{1}$$

Step 2. Normalize the decision matrix

The decision matrix is normalized for beneficial and non-beneficial criteria by using *Eqs. (2)* and *(3)*.

$$y_{ij}^{*} = \frac{a_{ij} - a_i^{-}}{a_i^{+} - a_i^{-}}; \quad i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{2}$$

$$y_{ij}^{*} = \frac{a_{ij} - a_i^{+}}{a_i^{-} - a_i^{+}}; \quad i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{3}$$

Where $a_i^{+} = \max(a_1, a_2, \dots a_m)$ *and* $a_i^{-} = \min(a_1, a_2, \dots a_m)$.

Step 3. Compute the criteria weights

The weight criteria weights are computed using the average method. The experts and criteria are evaluated the criteria, and then the mean of their evaluation is computed to obtain the criteria weights.

Step 4. Compute the weighted normalized decision matrix.

The criteria weights are multiplied by the normalization matrix to obtain the weighted normalized decision matrix using *Eq. (4)*.

$$t_{ij} = w_j + y_{ij}^{*} w_j \qquad i = 1,2,\dots,m;\ j = 1,2,\dots,n. \tag{4}$$

Step 5. Compute the border approximation area matrix (BAPA)

The BAPA is computed by using *Eq. (5)*.

$$\text{BAPA}_\text{j} = \left(\prod_{i=1}^{m} t_{ij} \right)^{\frac{1}{m}}; \quad j = 1,2,\dots,n. \tag{5}$$

Step 6. Compute the distance from the BAPA

The distance from the BAPA is computed using *Eq. (6)*.

$$d_{ij} = t_{ij} - \text{BAPA}_\text{j}\ ; i = 1,2,\dots,m. \tag{6}$$

Step 7. Compute the total distance

The total distance from the BAPA_j is computed by using *Eq. (7)*.

$$F_i = \sum_{j=1}^{n} d_{ij}; \quad i = 1,\dots,m. \tag{7}$$

Step 8. Rank the alternatives

The alternatives are ranked based on the total distance of F_i.

3 | Results and Discussion

This section introduces the results of the MCDM methodology to select the optimal Metaverse platform among various criteria and alternatives. The experts and decision-makers evaluated the nine criteria and 15 platforms. *Fig. 2* shows the list of criteria.

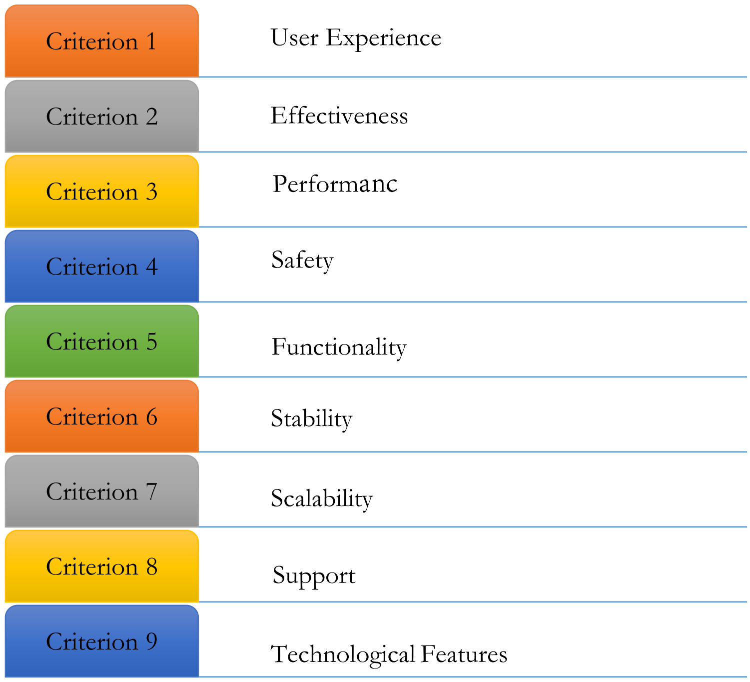

Fig. 2. The nine factors to evaluate the Metaverse platforms.

Step 1. Build the decision matrix

The experts and decision-makers build the decision matrix between criteria and alternatives. The experts used the crisp values between 1 and 9. The decision matrix is built using *Eq. (1)*.

Step 2. Normalize the decision matrix

The decision matrix is normalized for beneficial and non-beneficial criteria by using *Eqs. (2)* and *(3)*, as shown in *Table 1*.

Table 1. The normalization decision matrix.

	MPC_1	MPC_2	MPC_3	MPC_4	MPC_5	MPC_6	MPC_7	MPC_8	MPC_9
MPA_1	0.428571	1	0.857143	0.714286	0.285714	0.5	0.714286	0.857143	0.571429
MPA_2	0.428571	0.571429	0	0.142857	0	0.333333	0.428571	0.857143	1
MPA_3	0.571429	0.142857	0.142857	0.428571	0.285714	0.833333	0.857143	0.571429	1
MPA_4	0.428571	0	0	0.571429	0.428571	0	0.571429	0.428571	0.857143
MPA_5	0.285714	0.142857	0.428571	0	0.142857	0.166667	0.428571	0	0.285714
MPA_6	0.714286	0.571429	0.285714	0.142857	0.428571	0.666667	0	1	0
MPA_7	0.857143	0	0.714286	0.571429	0.571429	0	0.142857	0.571429	0.142857
MPA_8	1	0.428571	0.857143	1	0	1	0.571429	0.142857	0.428571
MPA_9	0.571429	0.428571	0.714286	0.857143	0.285714	0	1	0.428571	0.714286
MPA_{10}	0.142857	0.285714	1	0.428571	1	0.166667	0.857143	0	0.285714
MPA_{11}	0	0.714286	0.571429	0.571429	0.428571	0.666667	0.428571	1	0.857143
MPA_{12}	0.285714	0.857143	0.428571	0.285714	0	0.5	0.857143	0.571429	0.571429
MPA_{13}	0.857143	1	0	0.571429	0.285714	0.5	1	0.142857	1
MPA_{14}	0.714286	0.571429	0.428571	0.571429	0.285714	0.5	0.571429	0	0.428571
MPA_{15}	0.857143	0.571429	1	0.857143	0.714286	0.333333	0.428571	0.571429	0

Step 3. Compute the criteria weights

The weight criteria weights are computed using the average method. The experts and criteria are evaluated the criteria, and then the mean of their evaluation is computed to obtain the criteria weights. *Fig. 3* shows the criteria weights.

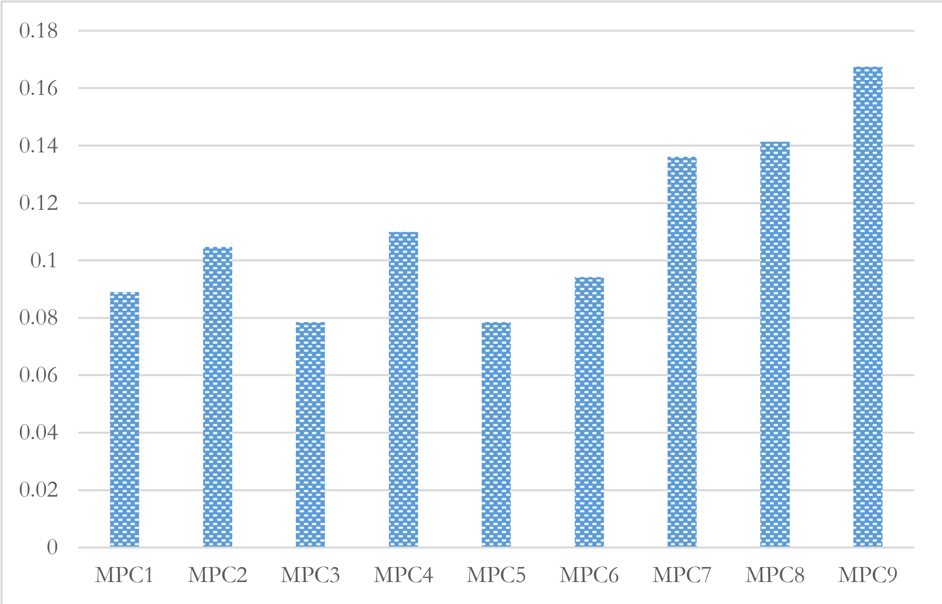

Fig. 3. The criteria weights of Metaverse platforms.

Step 4. Compute the weighted normalized decision matrix.

The criteria weights are multiplied by the normalization matrix to obtain the weighted normalized decision matrix using *Eq. (4)*, as shown in *Table 2*.

Table 2. The weighted normalized decision matrix.

	MPC_1	MPC_2	MPC_3	MPC_4	MPC_5	MPC_6	MPC_7	MPC_8	MPC_9
MPA_1	0.12715	0.209424	0.145849	0.188482	0.100972	0.141361	0.233358	0.262528	0.263276
MPA_2	0.12715	0.164547	0.078534	0.125654	0.078534	0.125654	0.194465	0.262528	0.335079
MPA_3	0.139865	0.119671	0.089753	0.157068	0.100972	0.172775	0.252805	0.222139	0.335079
MPA_4	0.12715	0.104712	0.078534	0.172775	0.112191	0.094241	0.213912	0.201945	0.311144
MPA_5	0.114435	0.119671	0.112191	0.109948	0.089753	0.109948	0.194465	0.141361	0.215408
MPA_6	0.15258	0.164547	0.100972	0.125654	0.112191	0.157068	0.136126	0.282723	0.167539
MPA_7	0.165295	0.104712	0.13463	0.172775	0.123411	0.094241	0.155572	0.222139	0.191473
MPA_8	0.17801	0.149589	0.145849	0.219895	0.078534	0.188482	0.213912	0.161556	0.239342
MPA_9	0.139865	0.149589	0.13463	0.204188	0.100972	0.094241	0.272251	0.201945	0.28721
MPA_{10}	0.10172	0.13463	0.157068	0.157068	0.157068	0.109948	0.252805	0.141361	0.215408
MPA_{11}	0.089005	0.179506	0.123411	0.172775	0.112191	0.157068	0.194465	0.282723	0.311144
MPA_{12}	0.114435	0.194465	0.112191	0.141361	0.078534	0.141361	0.252805	0.222139	0.263276
MPA_{13}	0.165295	0.209424	0.078534	0.172775	0.100972	0.141361	0.272251	0.161556	0.335079
MPA_{14}	0.15258	0.164547	0.112191	0.172775	0.100972	0.141361	0.213912	0.141361	0.239342
MPA_{15}	0.165295	0.164547	0.157068	0.204188	0.13463	0.125654	0.194465	0.222139	0.167539

Step 5. Compute the border approximation area matrix (BAPA).

The BAPA is computed by using *Eq. (5)*.

Step 6. Compute the distance from the BAPA

The distance from the BAPA is computed using *Eq. (6)*. As shown in *Table 3*.

Table 3. The distance matrix.

	MPC_1	MPC_2	MPC_3	MPC_4	MPC_5	MPC_6	MPC_7	MPC_8	MPC_9
MPA_1	0.12715	0.209424	0.145849	0.188482	0.100972	0.141361	0.233358	0.262528	0.263276
MPA_2	0.12715	0.164547	0.078534	0.125654	0.078534	0.125654	0.194465	0.262528	0.335078
MPA_3	0.139865	0.119671	0.089753	0.157068	0.100972	0.172775	0.252805	0.222139	0.335078
MPA_4	0.12715	0.104712	0.078534	0.172775	0.112191	0.094241	0.213912	0.201945	0.311144
MPA_5	0.114435	0.119671	0.112191	0.109948	0.089753	0.109948	0.194465	0.141361	0.215408
MPA_6	0.15258	0.164547	0.100972	0.125654	0.112191	0.157068	0.136126	0.282722	0.167539
MPA_7	0.165295	0.104712	0.13463	0.172775	0.123411	0.094241	0.155572	0.222139	0.191473
MPA_8	0.17801	0.149589	0.145849	0.219895	0.078534	0.188482	0.213912	0.161556	0.239342
MPA_9	0.139865	0.149589	0.13463	0.204188	0.100972	0.094241	0.272251	0.201945	0.28721
MPA_{10}	0.10172	0.13463	0.157068	0.157068	0.157068	0.109948	0.252805	0.141361	0.215408
MPA_{11}	0.089005	0.179506	0.123411	0.172775	0.112191	0.157068	0.194465	0.282722	0.311144
MPA_{12}	0.114435	0.194465	0.112191	0.141361	0.078534	0.141361	0.252805	0.222139	0.263276
MPA_{13}	0.165295	0.209424	0.078534	0.172775	0.100972	0.141361	0.272251	0.161556	0.335078
MPA_{14}	0.15258	0.164547	0.112191	0.172775	0.100972	0.141361	0.213912	0.141361	0.239342
MPA_{15}	0.165295	0.164547	0.157068	0.204188	0.13463	0.125654	0.194465	0.222139	0.167539

Step 7. Compute the total distance.

The total distance from the $BAPA_j$ is computed using *Eq. 7,* as shown in *Fig. 4*.

Step 8. Rank the alternatives

The alternatives are ranked based on the total distance of F_i as shown in *Fig. 5*. Alternative 1 is the best, and alternative 5 is the worst.

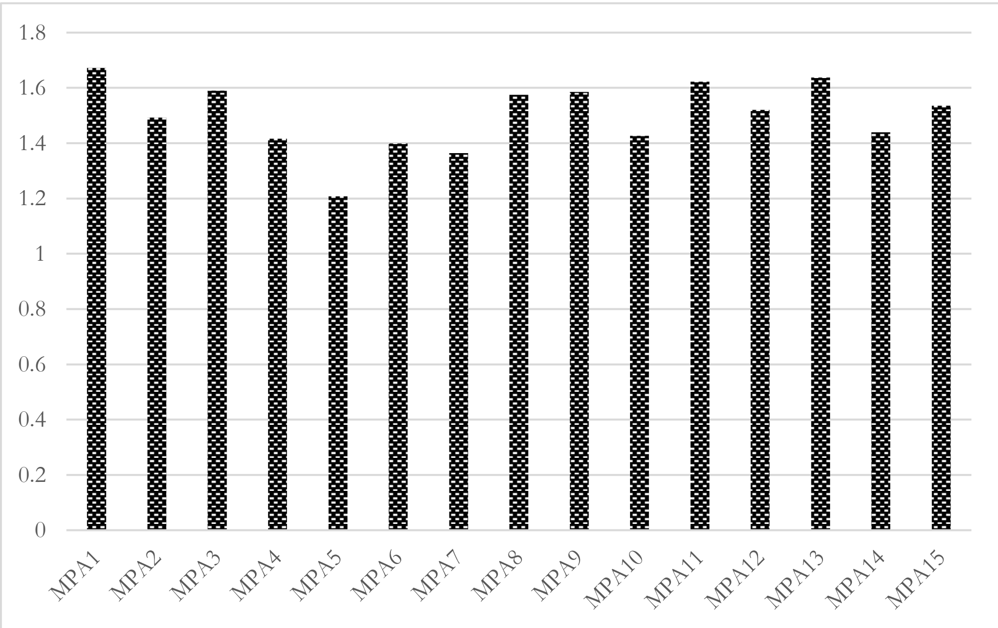

Fig. 4. The values of the total distance from the $BAPA_j$.

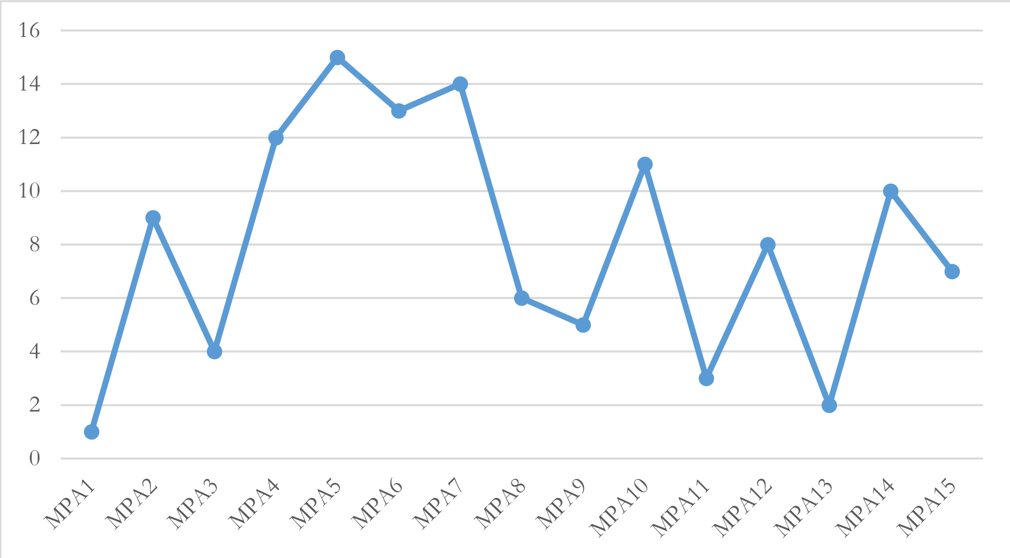

Fig. 5. The rank of Metaverse platforms.

4 | Sensitivity Analysis

This section shows the rank of alternatives under different cases in criteria weights. We proposed ten cases in criteria weights. *Fig. 6* shows the ten instances in criteria weights. *Fig. 7* shows the rank of alternatives under different cases. The results show the rank of other options is stable.

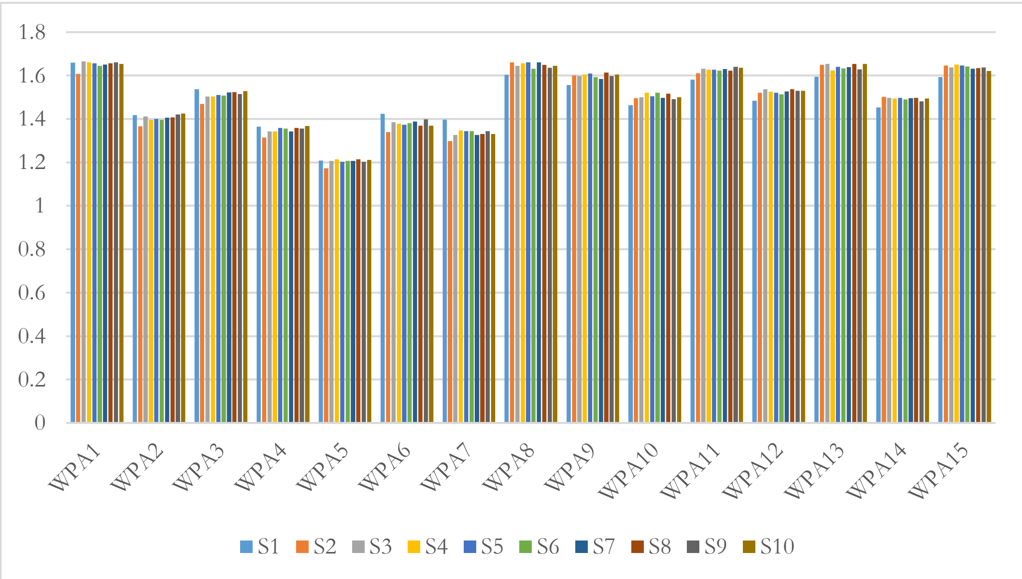

Fig. 6. Values of the total distance from the $BAPA_j$ under different cases.

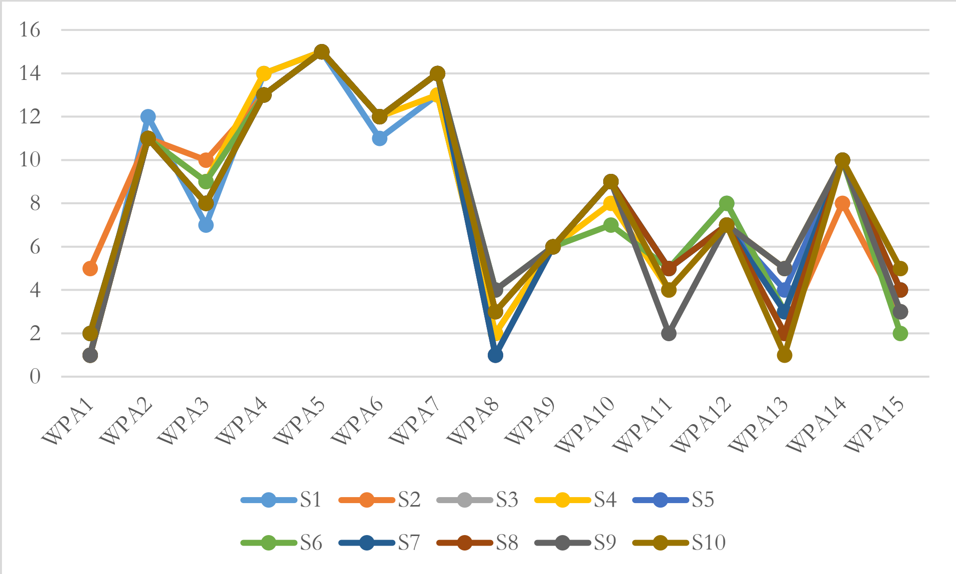

Fig. 7. The rank of alternatives under different cases.

5 | Comparative Analysis

In this section, we compare the MCDM methodology with other MCDM methods, such as TOPSIS, VIKOR, EDAS, and COPRAS methods, to show the effectiveness of the proposed MCDM methodology. *Fig. 8* shows the rank of alternatives under comparative analysis. The results show the proposed method is robust compared with other MCDM methods.

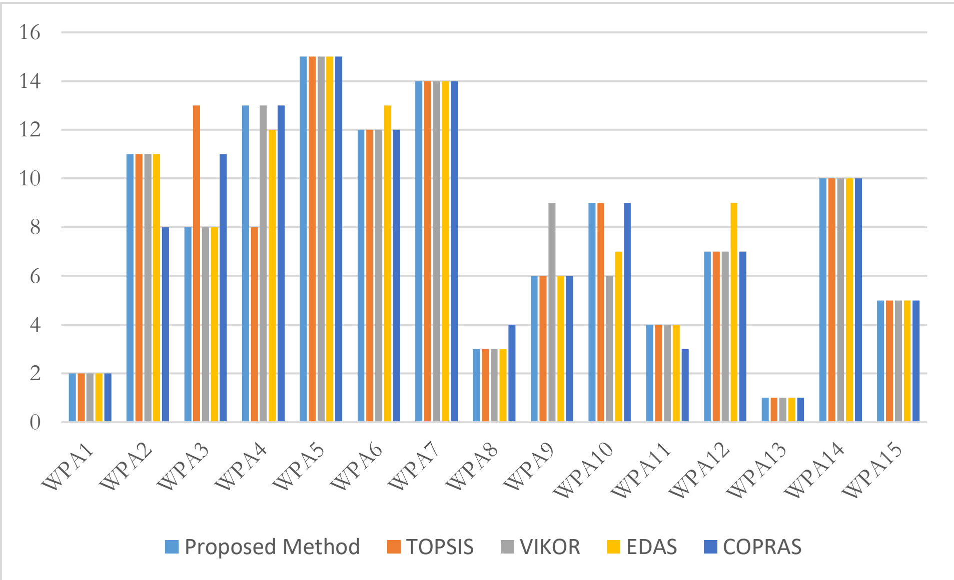

Fig. 8. The rank of alternatives under comparative analysis.

6 | Conclusion

The Metaverse platforms are evaluated, and the optimal one is selected among various criteria. The MCDM methodology is used to deal with multiple criteria. The MABAC method is used as an MCDM methodology to rank the alternatives. The nine criteria and 15 alternatives are used in this study. The experts and decision-makers evaluate the requirements and options based on their opinions. Then, this study used a crisp value from 1 to 9 to assess the criteria and alternatives to build the decision matrix. The decision matrix is normalized based on the positive and negative criteria. This study used all positive requirements. The criteria weights are computed by using the mean method. The criteria weights multiply the normalization matrix to show the weighted normalization decision matrix. The results show that alternatives 13 and 5 are the best.

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