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The Type-2 Q-rung Orthopair CoCoSo method for Workplace Design Problems on the Metaverse

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Abstract. *The development of technology is changing and transforming business models in the production and service sectors around the world. Especially in this age when the fourth industrial revolution is effective with different instruments such as artificial intelligence, internet of things, and cyber physical systems, the necessity of physical presence of people in the workplaces is gradually decreasing. Like many things developed in the virtual world, the virtual arrangement of workplaces is a very innovative undertaking. It is clear that the advantage of time and cost are the main reasons for the positive reception of the idea of workplace design in the metaverse environment. In this article, the criteria for workplace design in the metaverse environment of a company operating in the IT sector were examined and alternative metaverse platforms for workplace design using these criteria were evaluated. CoCoSo method based on the Interval Type-2 q-rung orthopair fuzzy sets is used in making the evaluations. Among the 6 criteria seen as important in the study, privacy and security, size and scale, and functionality were the three most important criteria. Among the alternative platforms evaluated, Rooom and Voxels are the first two platforms to be preferred.*

Keywords: Metaverse, Workplace Design, Type-2 Q-rung Orthopair CoCoSo, Multi-criteria Decision Making.

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Introduction

The metaverse, an immersive digital world where users interact with each other and the environment, has emerged as a new field of study in recent years due to its potential impacts

on various industries including education, health, finance and entertainment. With the rapid development of the Metaverse technology, there is growing interest in exploring how this technology can be used in workplace design to improve collaboration, communication, and innovation skills.

The concept of metaverse has been expressed in different ways in various studies. In general terms, the concept of metaverse can be defined as a network of virtual worlds that share an interconnected and consistent set of rules, standards, and protocols (Park & Kim, 2022; Al-Ghaili et al., 2022; Chinie et al., 2022; Choi et al., 2022; Wang et al., 2022; Riva & Wiederhold, 2022; Dahan et al., 2022; Novak, 2022; Zhang, 2022). Metaverse includes different components such as avatars, virtual environments, virtual economies, social networks, and virtual and augmented reality (Park & Kim, 2022). With these components, a wide variety of applications such as games, education, social networking, virtual commerce and even scientific research are developed (Wang et al., 2022).

In the context of the metaverse, various components contribute to the architectural structure of virtual environments (Al-Ghaili et al., 2022). These components include computer-generated environments that simulate real or imaginary worlds and provide a foundation for user interaction, as well as avatars that allow users to navigate and engage with other users in the virtual environment. Virtual currencies are also an essential element of the metaverse, as they facilitate transactions such as buying and selling of virtual goods and services. Additionally, social networks within the metaverse enable users to connect with each other and establish communities. Finally, interoperability standards play a crucial role in the metaverse by allowing different virtual worlds and platforms to interact with each other, which allows users to move seamlessly between them.

The adoption of metaverse technology comes with its own challenges. Security and privacy issues have been extensively discussed in the literature and authors' concerns are raised about data protection and user anonymity (Choi et al., 2022; Wang et al., 2022; Riva & Wiederhold, 2022; Dahan et al., 2022; Novak, 2022; Zhang, 2022; Fernandez & Hui, 2022). Governance and ethical considerations have also been highlighted as critical to ensure that the metaverse is a safe and inclusive space for all (Riva & Wiederhold, 2022; Dahan et al., 2022; Novak, 2022; Zhang, 2022; Fernandez & Hui, 2022). The report, which is still ongoing in the metaverse world, has not been able to reach a common point on issues such as establishing interoperability standards, ensuring privacy and security, developing sustainable business models, and ethical and legal issues (Park & Kim, 2022). Al-Ghaili et al. (2022) similarly identified several challenges that need to be addressed to make the metaverse a reality, such as scalability, interoperability, privacy and security, governance and regulation. It can be said that these difficulties make it hard to work in the metaverse environment and to create a solid working environment.

The world of the Metaverse is divided into various categories for different purposes. Social Virtual Worlds (Second Life, IMVU and VRChat, etc.), Game Worlds (World of Warcraft, Fortnite and Minecraft etc.), Augmented Reality (Pokemon Go, Snapchat filters and Google Lens etc.), Virtual Marketplaces (Decentraland, The Sandbox and Somnium Space etc.), Virtual Productivity (Spatial, AltspaceVR and MeetinVR etc.), Virtual Learning (Engage, Neos VR and VirBELA etc.), Scientific Research (Foldit, Eterna and Nanocrafter etc.) are available (Park & Kim, 2022).

In the metaverse environment, there are many criteria to be considered in order to carry out collaborative work in an integrated manner and to enable workspaces to function

in the real world. Some of these criteria are explained below and their effect on the success of workplace design in the metaverse environment is stated.

Designing a functional and user-friendly virtual workplace requires the consideration of various factors, including the ease of communication, the size and manageability of the sandbox, the realistic behaviour of objects, the performance and speed of the environment, the ability to collaborate and organize, and the overall user experience. Personalization options, aesthetic design, and avatar/UI customization can also contribute to a more enjoyable and engaging virtual work experience. Communication channels must be reliable, and the workspace must be functional and intuitive to ensure productive teamwork in the metaverse.

Against this backdrop, this study aims to explore the use of the Interval Type-2 Q-rung Orthopair CoCoSo method in solving workplace design problems on the metaverse. The Q-rung method is a decision-making tool that aids in selecting the best alternative in multicriteria decision-making situations. The Orthopair and CoCoSo techniques are extensions of the Q-rung method that aim to improve its efficiency when dealing with complex decision-making situations with many criteria and alternatives. The synergistic effect of these three techniques has shown promise in various fields, including city planning, environmental management, and healthcare.

Problem statement

Studies that shed light on today's discussion of the creation of working environments in the metaverse environment have proposed different concepts such as video technology, virtual world components, computer-assisted collaborative work, and different frameworks for a wide variety of fields such as education, health, and commerce. In this context, Winn and Bricken (1992) who claim that virtual worlds used in the education of students provide a more interactive and enjoyable experience, argue that concrete examples, instant feedback, multiple representations, interactive exploration and personalization criteria are effective in the design of this world. In another study, it was determined that the innovation in the way of doing business with video technology had positive results in many ways (Isaacs & Tang, 1993). Easier communication between team members and easier sharing of complex information have positive effects in terms of work efficiency. Issues that require technical expertise such as transferring non-verbal cues for the technology used, establishing the technology infrastructure, and using technology have been defined as challenges to be tackled (Isaacs & Tang, 1993). Gutwin and Greenberg (2002) proposed a comprehensive framework for computer-assisted collaborative work that identifies three distinct categories of awareness: spatial, data, and human. This framework provides a structured approach for analyzing and designing group software systems.

The idea that business should be carried out virtually before getting familiar with the concept of metaverse, and especially that internet technology helps to establish virtual teams regardless of the distance between employees, can be considered as a very important turning point. The creation and maintenance of virtual teams is directly related to ensuring an environment of trust. The formation of an environment of trust can be achieved by factors such as communication, competence, reliability, and personal relationships. The authors provide practical tips for building and maintaining trust in virtual teams, such as setting clear goals, regular feedback, and encouraging transparency (Greenberg et al., 2007). One of the areas where the virtual world attracts the most attention is undoubtedly the education

sector. Virtual worlds, which provide different technical and visualization abilities, have been an instrument that has been used and applied in various ways in the field of education. Gül et al. (2007) developed a design course in which students use virtual worlds to create and present design concepts and evaluated the effectiveness of this approach through surveys and analysis of students' work. They discovered that virtual worlds provided a more engaging and immersive learning environment, allowing students to experiment with design ideas and collaborate more effectively with one another. However, the authors also stated some challenges, such as technical difficulties and the need for additional training and support for students and instructors.

Electronic systems used in different areas enable to create a common understanding of user requirements among stakeholders, and to develop cooperation. In Sweden, electronic health records that patients can access have shown that virtual systems play an important role in meeting users' needs (Scandurra et al., 2008). Building a rich and immersive environment in virtual worlds is directly related to human behaviour, social interactions and the use of technology. In a virtual environment where these criteria are met and avatars are used correctly, it will be straightforward to conduct research with the potential to examine various topics (Davis et al., 2009).

The Building Information System (BIM), which was created in a virtual environment for the construction industry and continues to evolve, has been developed. BIM is a digital modeling tool that provides communication and coordination between all units in the world construction industry. It has the potential to facilitate more effective communication, problem-solving, and collaboration among project stakeholders. The need for open communication protocols when using BIM and the potential for conflict that arise when different team members interpret the model differently are defined as the challenges that arise (Dossick et al., 2011). In another study, Dossick et al. (2015) conducted a case study on a virtual team of designers, engineers and contractors who analyzed communication and collaboration processes across different software platforms. They discovered that shared visualizations enabled the team to engage in dispersed conversations that expressed the collaborative process of generating new ideas and perspectives through the exchange of diverse knowledge, experience, and perspectives.

It is thought that the remote work of many people who have different needs and processes in business life will affect the performance of their work. Remote working has several positive effects, including improved work-life balance, increased job satisfaction, reduced stress and burnout, and improved performance. Achieving these positive effects depends on a number of factors such as the nature of the job, the characteristics of the employee, the culture and norms of the organization, and the quality of the technology used to support it (Allen et al., 2015). In addition to these conditions, there are also unique communication difficulties due to the lack of face-to-face interaction and the use of technology, especially in virtual teams. These difficulties increase and decrease depending on various factors that can affect communication in virtual teams, such as the type of communication channel used, the complexity of the message conveyed, the cultural differences of team members, and the level of trust and harmony within the team (Marlow et al., 2017). There are several other factors that facilitate and hinder the exchange of knowledge in the unique workspaces created for people with different backgrounds, skills, and experiences. While communication and interaction, common purposes, trust, similarity and technology facilitate information exchange, competition, language and cultural

differences, personal differences, information security and physical distance make information exchange difficult (Bouncken & Aslam, 2019). The formation and maintenance of virtual teams are facilitated by providing communication, trust, leadership, task characteristics, and team diversity. In addition, contextual factors such as culture, technology, and team size have moderator effects on these factors (Shaik & Makhecha, 2019). Finally, in a metaverse-based pilot study conducted recently to support collaboration between the research teams of a health informatics laboratory, it was found that the metaverse-based workspace, which allows virtual interactions and real-time collaboration, is beneficial in facilitating communication and information sharing among team members (Zhu et al., 2023).

This study draws on the pilot study by Zhu et al. (2023) which demonstrates the feasibility of implementing a metaverse-based workspace and its potential benefits for research collaboration. The proposed methodology aims to enhance the decision-making process for designing such a workspace by considering a few criteria, including user experience, privacy and security, functionality, personalization, communication, and size and scale of the virtual space. This study is limited to certain criteria and the method used. The use of different criteria and methods in the study may affect the results. In addition, the decision makers and the evaluation scale within the method also affect the result and limit the study.

Research questions/Aims of the research

The main research question of this study is to investigate the changes in workplace design problems when metaverse-based workplaces are used. In this context, the study has the following objectives:

- Explaining how the workplace design problem will change for metaverse-based businesses;
- Evaluating and weighting the criteria of workplace design problem considering metaverse specifications;
- Searching for a problem-specific solution by proposing a novel multi-criteria decision-making method;
- Proposing an approach based on Interval Type-2 q-ROFs in order to eliminate the uncertainty that may occur due to the lack of expertise in the metaverse field and inadequacy in data;
- Performing a workplace selection on a case study problem.

There are 6 criteria determined for the problem which are Size and scale of the virtual space (C1), Privacy and Security (C2), Personalization (C3), Functionality (C4), Communication (C5), User-experience (C6). Since the workplace design can be created using different metaverse platforms, the alternatives are chosen from these platforms. Namely, Decentraland (A1), Pavia (A2), Rooom (A3), Voxels (A4) and Meta (A5). In general, different platforms can be used for different purposes such as games and meetings. Furthermore, they can work with various blockchain structures. Hence, it is necessary to evaluate different platforms (www.decentraland.org; www.voxels.com; www.pavia.io; www.forwork.meta.com; www.rooom.com).

Research methods

In this study the CoCoSo method based on the Interval Type-2 q-rung orthopair fuzzy sets is used.

Q-rung Orthopair Fuzzy Sets

Q-rung Orthopair fuzzy sets introduced by Yager (2017) as the generalized form of intuitionistic fuzzy sets and Pythagorean fuzzy sets. Q-ROFs provide decision makers the ability to define a broader range of information. It can be seen in Equation (1).

$$A = \{x \in X\} \tag{1}$$

Here, $\mu_A(x)$ shows the degree of membership and $\nu_A(x)$ denotes the degree of non-membership. The degree of membership in Q-rung orthopair fuzzy sets is a measure indicating the strength of an element's membership in a particular fuzzy set. In traditional fuzzy sets, an element can have a degree of membership ranging between 0 to 1, where 0 indicates no membership, 1 indicates full membership, and values in between represent partial membership. Both membership and non-membership functions take values in the interval [0,1] and sum of their q^{th} powers cannot exceed 1 as seen in Equation 2.

$$(\mu_A(x))^q + (\nu_A(x))^q \leq 1 \tag{2}$$

The hesitation value is calculated as in Equation 3 (Pınar et al., 2021). Here, the hesitation value is a measure of the degree of uncertainty or hesitation associated with the membership of an element to a particular QROF. It provides information about the lack of confidence or certainty in assigning a specific degree of membership to an element.

$$\pi_A(x) = \left(1 - \left(\mu_A(x)\right)^q - \left(\nu_A(x)\right)^q\right)^{1/q} \tag{3}$$

Interval Type-2 Q-rung Orthopair Fuzzy Sets

Interval Type-2 fuzzy sets are defined by Mendel and John (2002) as given in Equation 4.

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} 1/(x,u) = \int_{x \in X} \left[\int_{u \in J_x} 1/u\right]/x \tag{4}$$

In given Equation 4, x denotes the primary variable having the domain X and u is the second variable having the domain J_x with the condition of each $x \in X$. Finally, J_x has the definition interval [0,1] and the $1/u$ denotes the secondary membership function of the x. According to this condition, the footprint of uncertainty of the $\tilde{\tilde{A}}$ can be calculated by $\cup_{x \in X} J_x$. The primary variable represents the traditional membership degree in the context of a Type-2 QROF. It reflects the degree to which an element belongs to a fuzzy set in a manner similar to traditional fuzzy sets. The secondary variable is introduced to indicate the uncertainty associated with the primary variable. It helps capture the uncertainty or variability in the primary membership degree. The use of the secondary variable allows for a more flexible representation of uncertainty, especially in situations where the primary variable's membership is imprecise or uncertain.

An interval Type-2 q-ROF set can be defined as in Equation 5 (Liu & Wang, 2018).

$$\tilde{\tilde{A}}(\tilde{x},\tilde{y}) = \{\tilde{x} \in X, \tilde{y} \in Y\} \quad (5)$$

$\mu_{\tilde{\tilde{A}}}(x)$ and $v_{\tilde{\tilde{A}}}(x)$ denotes membership and non-membership functions, respectively. These functions take values in the interval [0,1] and they need to satisfy the Equations 6-9.

$$0 \leq \mu_{\tilde{\tilde{A}}}(x) \leq \mu_{\tilde{\tilde{A}}}(y) \leq 1 \quad (6)$$

$$0 \leq v_{\tilde{\tilde{A}}}(y) \leq v_{\tilde{\tilde{A}}}(x) \leq 1 \quad (7)$$

$$(\mu_{\tilde{\tilde{A}}}(x))^{q_1} + (v_{\tilde{\tilde{A}}}(x))^{q_1} \leq 1 \quad (8)$$

$$\left(\mu_{\tilde{\tilde{A}}}(y)\right)^{q_2} + \left(v_{\tilde{\tilde{A}}}(y)\right)^{q_2} \leq 1 \quad (9)$$

The hesitation functions are calculated as in Equation 10-11.

$$\pi_A(x) = \left(1 - \left(\mu_A(x)\right)^{q_1} - \left(v_A(x)\right)^{q_1}\right)^{1/q_1} \quad (10)$$

$$\pi_A(y) = \left(1 - \left(\mu_A(y)\right)^{q_2} - \left(v_A(y)\right)^{q_2}\right)^{1/q_2} \quad (11)$$

The steps of the Interval Type-2 q-ROF CoCoSo method is as follows:

Step1. Calculate weights of decision-makers (DMs).

Since the decision-makers have different experiences and expertise, the decisions they make are not of the same importance. By assigning weights for each decision-maker, it becomes possible to reflect their experiences and knowledge to the result in an objective way (Pınar et al., 2021; Mendel & John, 2002; Janani et al., 2023; Liu & Wang, 2018). Each decision-maker has defined as $DM_i = [\mu_i, v_i, \pi_i]$ and effect of each DM has been calculated as in Equation 12.

$$\lambda_i = \frac{(1+\mu_i^q - v_i^q)}{\sum_{i=1}^{t}(1+\mu_i^q - v_i^q)} \text{ and } \sum_{i=1}^{t}\lambda_i = 1 \quad (12)$$

Step 2. Calculate criteria weights.

In this step, the rates given by DMs for each criterion are converted to q-ROF numbers by considering DMs' weights and the weight of each criterion is determined. The formulation to compute the weights of criteria for type-2 fuzzy numbers $(\mu_{1_i}, v_{1_i}, \mu_{2_i}, v_{2_i}, q_1, q_2)$ is given in Equation 13.

$$W = \frac{\left(\frac{\sum_{i=1}^{t}\lambda_i(1+\mu_{1_i}q_1 - v_{1_i}q_1)}{\sum_{j=1}^{n}\sum_{i=1}^{t}\lambda_i(1+\mu_{1_i}q_1 - v_{1_i}q_1)} + \frac{\sum_{i=1}^{t}\lambda_i(1+\mu_{2_i}q_2 - v_{2_i}q_2)}{\sum_{j=1}^{n}\sum_{i=1}^{t}\lambda_i(1+\mu_{2_i}q_2 - v_{2_i}q_2)}\right)}{2} \quad (13)$$

Here, n denotes the total number of criteria and $W = [w_1, w_2, w_3, \ldots, w_n]$.

Step 3. Normalize the evaluations made by DMs.

Normalized values are found using the q-ROFWA operator introduced by Liu and Wang (2018). Evaluations made by DMs based on linguistic terms and DMs' weights have been used for calculations as seen in Equation 14.

$$q - ROFWA(\alpha_1, .., \alpha_t) = \langle (1 - \prod_{i=1}^{t} (1 - \mu_i^q)^{\lambda_i})^{\frac{1}{q}}, \prod_{i=1}^{t} v_i^{\lambda_i} \rangle \quad (14)$$

In the following, q-ROF CoCoSo method is explained. It is adopted from Peng and Huang (2020).

Step 4. The score function matrix is formed for the Interval Type-2 q-ROF numbers using Equation 15. The score function provides a numerical measure of how well a model fits certain criteria or objectives. Here, the values are taken from the normalized matrix computed in Step 3.

$$r_{ij} = \frac{\mu_{1ij}^{q_1} - v_{1ij}^{q_1} ln\left(1 + \pi_{1ij}^{q_1}\right) + \mu_{2ij}^{q_2} - v_{2ij}^{q_2} - ln\,(1 + \pi_{2ij}^{q_2})}{2} \quad (15)$$

Step 5. The score function matrix is normalized using Equation 16. Normalizing the score function matrix involves adjusting the values in the matrix to a common scale or standard, to make the values comparable or to remove the effect of different scales between variables. The purpose of this normalization is to ensure that each element is transformed to a value between 0 and 1, making them comparable and removing the influence of different scales.

$$r'_{ij} = \{\frac{r_{ij} - r_j^-}{r_j^+ - r_j^-}, \quad r_j^- = r_{ij} \quad \frac{r_j^+ - r_{ij}}{r_j^+ - r_j^-}, \quad r_j^+ = r_{ij} \quad (16)$$

Step 6. The sum of the weighted comparability and power weight of comparability are denoted by Si and Pi, respectively and calculated using Equations 17-18. Weighted Comparability reflects the contribution of each variable's comparability to the overall score. Power Weight of Comparability emphasises the influence of variables with higher weights. The weights play a crucial role in determining the importance of each variable in the aggregation process.

$$S_i = \sum_{j=1}^{n} w_j * r'_{ij} \quad (17)$$

$$P_i = \sum_{j=1}^{n} (r'_{ij})^{w_j} \quad (18)$$

Step 7 - Step 8. The relative weights are found for each alternative and the best alternative is selected by computing the evaluation criterion for each alternative. The following Equations (19-22) are used for this purpose.

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \tag{19}$$

$$k_{ib} = \frac{S_i}{S_i} + \frac{P_i}{P_i} \tag{20}$$

$$k_{ic} = \frac{\lambda S_i + (1-\lambda)P_i}{\lambda S_i + (1-\lambda) max\ P_i}, 0 \leq \lambda \leq 1 \tag{21}$$

$$k_i = \sqrt[3]{k_{ia} * k_{ib} * k_{ic}} + \frac{k_{ia} + k_{ib} + k_{ic}}{3} \tag{22}$$

The value calculated in the above equations can be explained as follows;

k_{ia}: It represents the relative weight obtained by combining both the power weight of comparability and the weighted comparability of the i[th] alternative. The sum in the numerator considers both components, and the denominator is the sum of these combined values across all alternatives.

k_{ib}: It represents the relative weight obtained by normalizing the weighted comparability and the power weight of comparability separately. This normalization ensures that the weights contribute proportionally within their own categories.

k_{ic}: It represents the relative weight obtained by combining S_i and P_i with a parameter λ that adjusts the balance between the two. The result is normalized by the maximum value in P_i to ensure that the weights are within a certain range.

k_i : It is a combined measure that considers the geometric mean and arithmetic mean of the relative weights obtained from k_{ia} , k_{ib}, and k_{ic}.

Findings

The proposed problem is solved by the proposed type-2 q-ROF CoCoSo method and the results are described in this section. Five alternative metaverse platforms with the set of $A = \{A_1, A_2, A_3, A_4, A_5\}$ and the six criteria with the set of $C = \{C_1, C_2, C_3, C_4, C_5, C_6\}$ are defined. The findings of the study according to steps are described below. q-rung number values corresponding to linguistic variables used in the study of Deveci et al. (2022). q_1 and q_2 values are taken as 3.

Evaluations are made with 3 decision makers. They have expertise in academia (DM1), software entrepreneur (DM2) and software developing (DM3). Since each decision-maker has different areas of expertise, there is a need to evaluate the decision-maker's influence. To weigh the decision makers, the numerical values of the linguistic variable formed were determined as 2,4 and 3, respectively. Accordingly, the weights were calculated with Equation 12, and obtained as $\lambda_i = [0.3842, 0.2844, 0.3314]$. According to these results, the most influential decision maker is the academician (DM1) and the second one is the developer (DM3). Each decision maker was asked to evaluate each criterion as both primary and secondary variables. Table 1 shows the evaluation of criteria made by decision-makers.

Table 1. Decision matrix for weighting criteria

Criteria	Primary variable			Secondary variable		
	DM1	DM2	DM3	DM1	DM2	DM3
C1	4	3	5	5	4	6
C2	5	1	3	6	2	4
C3	6	5	7	7	6	8
C4	3	4	4	4	5	5
C5	8	8	8	9	9	9
C6	7	6	6	8	7	7

Source: Authors' own research.

Using the decision matrix, Step 1 and Step 2 of the interval Type-2 q-ROF set are applied and then the criteria are weighted and ranked using results obtained from these steps. Figure 1 shows the weight and rank of the criteria. Considering the weights of the criteria, decision-makers found C2 (privacy and security) as the most important criterion and C5 (communication) as the least important criterion. C4 (functionality), C1 (size and scale), C3 (personalization) and C6 (user-experience) are ranked as the 2nd, 3rd, 4th and 5th important criteria, respectively according to the decision maker's evaluation.



Figure 1. Criteria Weights

Source: Authors' own research.

Decision-makers are then asked to evaluate each alternative according to each criterion. Table 2 shows the result of this evaluation.

Table 2. Evaluation of Alternatives by Decision Makers

Criteria	Alternatives	Primary variable			Secondary variable		
		DM1	DM2	DM3	DM1	DM2	DM3
C1	A1	3	6	5	4	7	6
	A2	5	5	6	6	6	7
	A3	7	4	8	8	5	9
	A4	8	7	4	9	8	5
	A5	1	8	3	2	9	4
C2	A1	3	6	2	4	7	3
	A2	4	4	4	5	5	5
	A3	6	8	6	7	9	7
	A4	7	7	8	8	8	9
	A5	5	3	7	6	4	8
C3	A1	2	5	7	3	6	8
	A2	4	4	5	5	5	6
	A3	6	6	3	7	7	4
	A4	8	7	4	9	8	5
	A5	7	8	6	8	9	7
C4	A1	8	7	6	9	8	7
	A2	4	5	4	5	6	5
	A3	6	4	3	7	5	4
	A4	7	3	5	8	4	6
	A5	5	2	7	6	3	8
C5	A1	3	4	5	4	5	6
	A2	6	6	7	7	7	8
	A3	4	7	6	5	8	7
	A4	8	5	4	9	6	5
	A5	7	8	3	8	9	4
C6	A1	3	5	4	4	6	5
	A2	7	4	6	8	5	7
	A3	8	6	7	9	7	8
	A4	5	2	3	6	3	4
	A5	6	3	5	7	4	6

Source: Authors' own research.

Considering the evaluation results shown in Table 2, Steps 3-8 of the interval Type-2 q-ROF set are applied. As a result of these steps, alternatives were ranked as shown in Table 3. The final result of the proposed method shows that A3 (Room) and A4 (Voxels) are the best two alternatives while A1 (Decentraland) is the least favourable one. A5 (Meta) and A2(Pavia) are found to be the 3rd and 4th best alternatives.

Table 3. Results of type-2 q-rung CoCoSo method

	S_i	P_i	$k1_i$	$k2_i$	$k3_i$	k_i	Order
A1	0.528	5.325	0.187	2.000	0.696	1.600	5
A2	0.621	5.534	0.197	2.216	0.819	1.787	4
A3	0.758	5.710	0.207	2.509	1.000	2.042	1
A4	0.747	5.669	0.205	2.481	0.986	2.019	2
A5	0.713	5.643	0.203	2.410	0.940	1.957	3

Source: Authors' own research.

The results are compared to that of the classical TOPSIS method and are given in Table 4. The weights are obtained from steps 1 and 2 which are also used for the type-2 q-rof CoCoSo method. According to the results, the order of the alternatives differs from the one obtained from the type-2 q-rof CoCoSo method. The best alternative is A4 and the least favourable alternative is A2. The results show that the method used to solve the problem affects the order. The alternatives in the first two rows are A3 and A4, although their order is different for both methods. However, there are significant differences in the other rows. A1 is the third alternative for TOPSIS, while A1 is the last one for type-2 q-rof CoCoSo method.

Table 4. Results of TOPSIS method

	d_i^-	d_i^+	C_i	Order
A1	0.0517	0.0881	0.3697	3
A2	0.0379	0.0868	0.3040	5
A3	0.0819	0.0529	0.6077	2
A4	0.0883	0.0490	0.6430	1
A5	0.0436	0.0773	0.3606	4

Source: Authors' own research.

Managerial implications

Metaverse is seen as one of the most important technology candidates with disruptive innovation for today and tomorrow. While being on the Metaverse has become a necessity, it also creates new issues that need to be taken into consideration. In this study, a decision problem is proposed for workplace design, which is one of the issues that arise because of the Metaverse. The problem was chosen among workplace design alternatives in 5 different metaverse environments, taking into account the criteria of privacy and security, communication, functionality, size and scale, personalization, and user experience. Using this approach, decision-makers should make choices by paying attention to privacy, security, and functionality criteria. In addition, since the proposed approach is created in a q-rof fuzzy environment, it also focuses on reducing the subjectivity of decision-makers. Accordingly, the proposed approach can be extended for different metaverse platforms. Decision makers can test their alternatives by scoring them according to a simple scale to their own conditions.

Conclusions

The impact of the Covid-19 pandemic and the fourth industrial revolution, which is effective in the world, has been an indicator showing that it is possible for employees to work remotely. With the various opportunities provided by different metaverse platforms, businesses can carry out some or all of their work remotely and in a virtual environment. In this article, the workplace design problem in the metaverse environment for a business operating in the IT sector is discussed. The weights of 6 criteria and the order of preference of 5 different metaverse platforms were determined as a result of the evaluations made with the CoCoSo method based on Interval Type-2 q-Rung orthopair fuzzy sets. Among the criteria, the weight of the privacy and security criteria, which is considered to be very important in the literature, had the highest value, followed by functionality and size, and scale criteria. Among the alternative platforms, the first two places were Rooom and Voxels, respectively.

It is thought that in future studies, changing technology and increasing alternatives and more criteria and alternative evaluations will guide the best workplace design.

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References

Al-Ghaili, A. M., Kasim, H., Al-Hada, N. M., Hassan, Z., Othman, M., Hussain, T. J., Kasmani R., & Shayea, I. (2022). A Review of Metaverse's Definitions, Architecture, Applications, Challenges, Issues, Solutions, and Future Trends. IEEE Access, 10, 125835 – 125866.

Allen, T. D., Golden, T. D., & Shockley, K. M. (2015). How effective is telecommuting? Assessing the status of our scientific findings*. Psychological science in the public interest*, 16(2), 40-68.

Bouncken, R., & Aslam, M. M. (2019). Understanding knowledge exchange processes among diverse users of coworking-spaces. *Journal of Knowledge Management, 23(10), 2067-2085.*

Chinie, C., Oancea, M., & Todea, S. (2022). The adoption of the metaverse concepts in Romania. *Management & Marketing. Challenges for the Knowledge Society*, 17(3), 328-340.

Choi, M., Azzaoui, A. E., Singh, S. K., Salim, M. M., Jeremiah, S. R., & Park, J. H. (2022). The Future of Metaverse: Security Issues, Requirements, and Solutions. *Human-Centric Computing and Information Sciences*, 12(60), 1-14.

Dahan, N. A., Al-Razgan, M., Al-Laith, A., Alsoufi, M. A., Al-Asaly, M. S., & Alfakih, T. (2022). Metaverse framework: A case study on E-learning environment (ELEM). *Electronics*, 11(10), Article number 1616.

Davis, A., Murphy, J., Owens, D., Khazanchi, D., & Zigurs, I. (2009). Avatars, people, and virtual worlds: Foundations for research in metaverses. *Journal of the Association for Information Systems*, 10(2), 1.

Deveci, M., Pamucar, D., Cali, U., Kantar, E., Kölle, K., & Tande, J. O., 2022. Hybrid q-Rung Orthopair Fuzzy Sets Based CoCoSo Model for Floating Offshore Wind Farm Site Selection in Norway. *CSEE Journal of Power and Energy Systems*, 8(5), 1261-1280.

Dossick, C. S., & Neff, G. (2011). Messy talk and clean technology: communication, problem-solving and collaboration using Building Information Modelling. *The Engineering Project Organization Journal*, 1(2), 83-93.

Dossick, C. S., Anderson, A., Azari, R., Iorio, J., Neff, G., & Taylor, J. E. (2015). Messy talk in virtual teams: Achieving knowledge synthesis through shared visualizations. *Journal of Management in Engineering*, 31(1), A4014003.

Fernandez, C. B., & Hui, P. (2022). Life, the Metaverse and everything: An overview of privacy, ethics, and governance in Metaverse. *IEEE 42nd International Conference on Distributed Computing Systems Workshops (ICDCSW),* 272-277.

Greenberg, P. S., Greenberg, R. H., & Antonucci, Y. L. (2007). Creating and sustaining trust in virtual teams. Business Horizons, 50(4), 325-333.

Gutwin, C., & Greenberg, S. (2002). A descriptive framework of workspace awareness for real-time groupware. *Computer Supported Cooperative Work (CSC*W), 11, 411-446.

Gül, L. F., Gu, N., & Maher, M. L. (2007). Designing virtual worlds: A case study of design education in and of 3D virtual worlds. *CONNECTED 07, International Conference on Design Education, Sydney.*

https://decentraland.org/. Access date: 25.04.2023

https://forwork.meta.com/horizon-workrooms/ Access date: 25.04.2023

https://www.pavia.io/ Access date: 25.04.2023

https://www.rooom.com/ Access date: 26.04.2023

https://www.voxels.com/ Access date: 26.04.2023

Isaacs, E. A., & Tang, J. C. (1993). What video can and can't do for collaboration: a case study. *Proceedings of the first ACM International Conference on Multimedia,* 199-206.

Janani, K., Vignesh, A., Veerakumari, K. P., Vasanth, K., & Rakkiyappan, R. (2023). Identifying native endemic plant species in Nilgiris using the interval type 2 q-rung orthopair fuzzy Bonferroni mean operator. *Computational and Applied Mathematics*, 42(1), 55.

Liu, P., & Wang, P. (2018). Some q-rung orthopair fuzzy aggregation operators and their applications to multiple-attribute decision making. *International Journal of Intelligent Systems*, 33(2), 259-280.

Marlow, S. L., Lacerenza, C. N., & Salas, E. (2017). Communication in virtual teams: A conceptual framework and research agenda. *Human Resource Management Review*, 27(4), 575-589.

Mendel, J. M., & John, R. B. (2002). Type-2 fuzzy sets made simple. *IEEE Transactions on fuzzy systems*, 10(2), 117-127.

Novak, K. (2022). Introducing the Metaverse, Again!. TechTrends, 66(5), 737-739.

Park, S. M., & Kim, Y. G. (2022). A metaverse: taxonomy, components, applications, and open challenges. *IEEE access*, 10, 4209-4251.

Peng, X., & Huang, H., 2020. Fuzzy decision making method based on CoCoSo with critic for financial risk evaluation. *Technological and Economic Development of Economy*, 26(4), 695.

Pınar, A., Babak Daneshvar, R., & Özdemir, Y. S. (2021). q-Rung Orthopair Fuzzy TOPSIS Method for Green Supplier Selection Problem. *Sustainability*, 13(2), 985.

Riva, G., & Wiederhold, B. K. (2022). What the metaverse is (really) and why we need to know about it. *Cyberpsychology, behavior, and social networking*, 25(6), 355-359.

Scandurra, I., Hägglund, M., & Koch, S. (2008). From user needs to system specifications: Multi-disciplinary thematic seminars as a collaborative design method for development of health information systems. Journal of Biomedical Informatics, 41(4), 557-569.

Shaik, F. F., & Makhecha, U. P. (2019). Drivers of employee engagement in global virtual teams. *Australasian Journal of Information Systems*, 23.

Wang, Y., Siau, K. L., & Wang, L. (2022). Metaverse and Human-Computer Interaction: A Technology Framework for 3D Virtual Worlds. In Chen, J.Y.C., Fragomeni, G., Degen, H., Ntoa, S. (Eds.). *HCI International 2022 – Late Breaking Papers: Interacting with eXtended Reality and Artificial Intelligence* (pp. 213-221). Cham: Springer Nature Switzerland.

Winn, W., & Bricken, W. (1992). Designing virtual worlds for use in mathematics education: The example of experiential algebra. *Educational Technology*, 32(12), 12-19.

Yager, R. R. (2017). Generalized orthopair fuzzy sets. *IEEE Transactions on Fuzzy Systems*, 25(5), 1222-1230

Zhang, L. J. (2022). MRA: Metaverse Reference Architecture. In Tekinerdogan, B., Wang, Y., Zhang, L. J. (Eds.). *Internet of Things–ICIOT 2021: 6th International Conference, Held as Part of the Services Conference Federation, SCF 2021, Virtual Event, December 10–14, 2021, Proceedings* (pp. 102-120). Cham: Springer International Publishing.

Zhu, S., Vennemeyer, S., Xu, C., & Wu, D. T. (2023). Adopting a metaverse-based workspace to support research team collaboration: a pilot study from an academic health informatics laboratory. *JAMIA open*, 6(1), Article number ooad010.