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Research Article

A New Decision Support Framework with Picture Fuzzy Information: Comparison of Video Conferencing Platforms for Higher Education in India

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The purpose of this paper is to present a novel extension of a very recently developed multicriteria decision making (MCDM) algorithm known as the preference ranking on the basis of ideal-average distance (PROBID) method in a picture fuzzy (PF) environment. We use the full consistency method (FUCOM) with picture fuzzy numbers (PFNs) for deriving the criteria weights. We attempt to apply our proposed model for addressing a real-life complex decision making problem in social science research that gets influenced by the dynamics of discrete human behaviors. We compare eight popular video conferencing (VC) tools used for teaching-learning and meeting purposes in India using our novel integrated multicriteria decision making (MCDM) framework of FUCOM-PROBID with PF information. The criteria have been derived using the theoretical foundation of usability and user experience (UX). Based on the opinion of the decision makers (DM) or users who took part in the study, we find that ease of operations, compatibility with multiple systems and devices, quality of the voice, and video transmission and features are given more emphasis while Zoom, Microsoft Teams, and Google Meet are found to be preferable options to the users. The result of the proposed model shows stability and robustness as evident from the validation test and sensitivity analysis.

1. Introduction

The novel coronavirus has started spreading since January 2020 from Wuhan, China. This coronavirus has resulted in panic and fear among the people and shuttered all facets of the socioeconomic and cultural environment across the globe. However, over the ages, it is a proven fact that education is an essential requirement for protecting the humanity and development of society and nation. Even amidst the recent pandemic, the Governments of various countries have revamped the educational policies utilizing technical support using remote learning, online learning, and distance education. In fact, the recent pandemic has changed the landscape of teaching and learning in the last two years. Because of the Covid-19 pandemic, the schools and universities have moved from face-to-face to virtual mode of interaction and teaching-learning process. However, the radical change in the teaching and learning process has imposed significant challenges for the instructors and the students in terms of change in the traditional habits and pedagogy, adopting new technologies, student engagement, modification of the curriculum, and restoring the mental health, while maintaining social isolation [1, 2]. Experts contend that even after the end of Covid-19, online education will be a part of the next generation's education system [3]. The "now normal" age is characterized by a blended mode (online and offline) of learning. It is being adopted by academic institutions and universities. Many organizations are taking advantage of this new way to retrain and re-educate their employees and manage business operations virtually [4]. Moreover, the blended mode of operation has provided an opportunity to reduce operational costs in the long run, help prevent the spread of Covid-19-like viruses, and truly connect to remote people. As a result, the limited use of video conferencing (VC) platforms has been amplified manifold in quick time. VC platforms Google Meet, Zoom, BlueJeans, Webex, Microsoft Teams, and BigBlueButton have become essential tools for enduring education amidst utter uncertainty and disruption and maintaining business operations and virtual communications using audio, video, and seminars, exploring advanced features like built-in features, such as chat, screen sharing, and recording [5].

Although VC has become an advantageous and comfortable way of communication in recent times, it is not a new invention. Video conferencing was developed to facilitate international communications and increase productivity because it saves travel time and cost as one can meet virtually at any time. However, Covid-19 has changed the face of video communication. In effect, the extant literature has been witnessing a notable expansion. There has been a sizeable number of studies made about VC tools and their usefulness vis-à-vis consumers' behaviors. For instance, Matulin et al. [6] noted that, nowadays, VC is used as a daily application to keep in touch with friends and family, useful for work-from-home culture and distance learning techniques. The availability of a wide variety of tools and techniques has accelerated the usage. The authors carried out a comparative study of various learning tools, such as Zoom, Microsoft Teams, Google Meet, and Skype [6]. Correia et al. [7] mentioned the significance of VC tools in education in the context of Covid-19. VC tools have started gaining importance in the last decade with the advent of massive open online courses (MOOC). In their research, Boyatt et al. [8] pointed out that in the emergence of massive open online courses (MOOC), these tools are available to support the users in teaching-learning activities as the institutions and universities are concerned with e-learning and innovative programs. The online learning experience involves innovation during the transition from face-to-face to online. On the other hand, students can participate in various courses across the world. Archibald et al. [9] observed that candidates prefer video communication as an interviewing technique compared to face-to-face (FTF) or telephone. In addition, these VC platforms can be used to collect information relevant to academics and practice. It involves relative ease of use, cost-effectiveness, data management features, and security options. VC mode has certain strengths, such as being easy to use, flexible, convenient, time- and money-saving, and easily accessible. Most of the students are flexible and comfortable while attending the virtual classes. It identifies the levels of satisfaction of the students by online learning in educational institutions. Therefore, it is identified that many students prefer the implementation of online learning programs [10]. Talking about the advantages, Archibald et al. [9] mentioned that the main advantages of the e-learning platform are as follows:

(i) Simplicity and user friendliness: these tools are uncomplicated and easy to use
(ii) Accurate recording facility: it allows participants to record the lecture or lesson for future reference
(iii) Time-saving with no travel requirements: doing a meeting using video conference is more time-saving than a face-to-face meeting

Gray et al. [11] argued that using VC platforms, one can use these tools by phones, laptops, and computers. In this context, Parra and Granda [12] reported specific parameters that need to be considered for comparing different VC platforms, such as the attractiveness, efficiency, familiarity, and innovativeness of the product. However, this is not a one-sided story. There are certain drawbacks to using a virtual platform as a teaching method. Many times, it has been observed that students' participation is relatively low in the virtual platform. Also, internet connectivity posits significant challenges, especially in remote rural areas. Many students are not enthusiastic about the virtual classroom [3, 13].

For the successful utilization of VC tools and conduction of e-learning, Wang et al. [10] provided a list of requirements, which are as follows:

(i) Students' engagement is highly needed
(ii) The quality of audio and video should be good
(iii) Good communication between students and teachers

Nevertheless, video conferencing (VC) teaching has an overall positive outcome in teaching-learning activity. These learning tools and techniques support the educational activity in this new normal [14–16].

In this paper, we aim to compare a set of popular VC platforms used in India in higher education by instructors and students. Needless to mention that the acceptability of highly technological products, such as VC tools, depends not only on the technical know-how but also on users' experience and usability of the system. User experience is a complex subjective parameter that depends on several conflicting attributes. Therefore, the comparison of VC tools is an MCDM problem that involves a set of subjective and objective attributes. In this paper, we only consider the opinions of the users. Therefore, our analysis is limited to a multiattribute group decision making (MAGDM) scenario.

The MCDM algorithm enables to compare a set of available options with respect to the selected group of attributes or constraints with varying degrees of preference and objectives. The conflicting nature of the criteria and their interplay posit a challenge in deciding the combined effect on available alternatives for comparison purposes [17]. In other words, the DMs are confronted with imprecise information under uncertainty to arrive at a decision, and often, they land on improper conclusions [18, 19]. To prevent such situations, Zadeh's contribution of introducing the concept of fuzzy sets (FS) has been a major breakthrough since its inception [20]. To further enrich the stated field, Atanassov [21] contributed to the concept of intuitionistic fuzzy sets (IFS) that consider the degree of membership and nonmembership. Although FS and IFS have solved various practical problems over several decades, there are some situations wherein the basic assumption that the sum of both memberships equals one gets violated. In this regard, Yager [22] introduced the concept of the Pythagorean fuzzy set (PyFS) and its extended complex generalization, such as the q-rung orthopair fuzzy set (qROFS) with the condition $\mu^q + \vartheta^q \leq 1$ [23]. In this context, researchers have also developed and applied an extension of qROFS with $q = 3$, which is known as Fermatean fuzzy set (FFS) [18, 24]. However, because of its flexibility and simplicity, PyFS has been widely extended with different aggregation operators and variants of FS, such Dombi operator, probabilistic hesitant fuzzy, intuitionistic fuzzy soft sets, among others, and subsequently, it is applied in solving various real-life issues by many researchers [25–28].

The concept of picture fuzzy sets (PFS) has come into existence for further generalization of IFS to fill the gap in the literature. PFS not only includes the degree of nonmembership but also allows the DM more flexibility and granularity in the analysis of imprecise information by incorporating the degree of neutrality and refusal [29]. Over the years, there have been a substantial number of further extensions of PFS with generalized PF soft set [30], weighted geometric aggregation operators with t-norm and t-conorm [31], interval-valued picture uncertain linguistic set with generalized Hamacher aggregation operators [32], simple to understand and flexible distance-like measures, such as weak interval-valued pseudo-metrics [33] and Dempster–Shafer theory [34], which improved the actual score measures [35], and trapezoidal PFN with Dijkstra algorithm [36] to mention a few. In this context, it is noteworthy to compare PFS with another recently developed and popular variant of classical FS, namely the spherical fuzzy set (SFS) [37]. SFS is essentially a generalization of PFS, and also, it considers the degree of neutral membership [38]. However, in the case of SFS, the square sum of all three memberships is less than or equal to one. In effect, SFS provides more flexibility as compared to PFS in terms of the values of the membership grades. However, PFS provides a relatively lesser complex analysis and considers the refusal aspect as well. Nevertheless, the domain of SFS is a growing field of research that is contributed by several extensions and applications using grey theory, complex aggregation operators, distance measures, and algorithmic modifications of MCDM methods [39–45].

In this work, our analysis stands on users' views on their experiences and usability of the VC platforms. Moreover, VC tools are yet to be extensively used, and all of its features are yet to be known to the majority of the users. Hence, the opinions are associated with a substantial amount of impreciseness that only incorporates positive and negative expressions, however, neutrality and refusal also assume significant considerations. Therefore, for our analysis, we have felt the importance of using PFS in conjunction with MCDM techniques. For comparison purposes, we propose a novel extension of a very recently developed MCDM algorithm known as PROBID [46] in a PF environment. We use another recent algorithm called FUCOM [47] with PFN for deriving the criteria weights. Our initial proposition is that perhaps not all VC platforms are equally preferred by the users when multiple perspectives are considered. The criteria for comparing the VC platforms are selected on the basis of literature review and the theoretical foundation of usability and UX theory, which is an extension of the technology acceptance model (TAM) [48].

PROBID method offers the following advantages:

(i) It considers all possible ideal solutions and the average solution. Hence, it provides a comprehensive and holistic approach. In essence, this method combines the benefits of the technique for the order of preference by similarity to ideal solution (TOPSIS) and evaluation based on distance from average solution (EDAS) models. According to this model, the most positive ideal solution (PIS) is the one that offers the best possible solution with respect to the influence of the criteria. In the PROBID method, the whole spectrum of PIS, i.e., 1st, 2nd, 3rd, up to the most negative PIS (i.e., most negative ideal solution or NIS) are calculated with respect to the number of alternatives present in the study, which allows the risk-tolerant decision maker to have wider options. Furthermore, the average solution considers the perspectives of risk averters as well.

(ii) It provides a stable and consistent result, which is free from the rank reversal phenomenon, unlike TOPSIS.

On the other hand, FUCOM provides the following benefits:

(i) A reduced number of pairwise comparisons. FUCOM requires a total of $(n-1)$ number of comparisons, where n is the number of criteria. Therefore, it lowers the possibility of inconsistency in the result because of subjective bias and ambiguity in the judgments.

(ii) It has an inherent feature for determining the consistency by calculating the deviation from consistency (DFC) value, which enables to ensure the validity and robustness of the outcome.

(iii) Stability in the result.

(iv) Ability to work with a large number of criteria set with uncertain and imprecise information.

Because of its fundamental advantages, the FUCOM method has drawn significant interest from researchers and practitioners to solve complex real-life issues. Some of the recent applications of the FUCOM method are the selection of side-loading forklifts [49], supplier selection [50–52], material classification [53], facility location selection [54, 55], performance appraisal and compensation management [56], water system management [57], and mineral mapping issues [58]. The fundamental algorithm of FUCOM has witnessed a considerable number of extensions using, for example, the grey theory [59], Dombi-Bonferroni operators with fuzzy numbers [60], Z-numbers [61], fuzzy numbers [62, 63], and fuzzy Bonferroni Mean operator [64].

The present paper contributes to extant literature in the following ways:

(i) PROBID is a very recently developed algorithm. We have not found any application of PROBID method so far. The present paper is a first of its kind in applying the PROBID method with a novel extension using PFN to solve a user experience-based real-life issue.

(ii) Though FUCOM has been increasingly used by the researchers, it seems application with PFN is quite rare in the literature.

(iii) The integrated framework of FUCOM-PROBID is a newly proposed decision support system that shall enable the researchers to solve various complex problems.

(iv) Looking back at the past work, we have observed that the domain of VC has not been explored to a substantial extent. Furthermore, in this paper, a comprehensive MCDM-based approach using PFN is used, which provides a holistic assessment of the VC tools. Given the context of postpandemic era, the use of VC is quite promising, and hence, it is quite imperative to compare the VC tools from multiple perspectives. The present study fills the gap in the literature in this respect.

(v) Furthermore, the concept of usability and UX has not been exhaustively used in the literature, and application areas are quite narrow. The present study is an attempt to extend the application domain.

The remainder of this paper is organized as follows: in Section 2, we provide some preliminary concepts of PFN and PFS. Section 3 elaborates the research methodology used in this paper. We present the summary of findings and include necessary discussions including the results of the validation test and sensitivity analysis in Section 4. Section 5 briefly discusses some of the implications of this research and sheds light on some future scope. Finally, Section 6 concludes the paper.

2. Preliminaries

In this section, we discuss the definitions and some fundamental properties and operations of PFS and PFN.

2.1. Definition. Let $\widetilde{\mathrm{A}}$ denote PFS on a universe of discourse U. Then, $\widetilde{\mathrm{A}}$ is defined as [65, 66]

$$\widetilde{A} = x, \mu_{\widetilde{A}}(x), \eta_{\widetilde{A}}(x), \upsilon_{\widetilde{A}}(x), \tag{1}$$

$x \in U$; $\mu_{\widetilde{A}}(x), \eta_{\widetilde{A}}(x), \upsilon_{\widetilde{A}}(x) \in [0,1]$ are the degrees of positive, neutral, and negative membership of x in $\widetilde{A}$, respectively, with the condition that

$$0 \leq \mu_{\widetilde{A}}(x) + \eta_{\widetilde{A}}(x) + \upsilon_{\widetilde{A}}(x) \leq 1 \forall x \in U. \tag{2}$$

The degree of refusal is given by

$$\pi_{\widetilde{A}}(x) = 1 - \left(\mu_{\widetilde{A}}(x) + \eta_{\widetilde{A}}(x) + \upsilon_{\widetilde{A}}(x)\right) \forall x \in U. \tag{3}$$

For a given element x in U, a PFN is represented as

$$\begin{aligned} A = \{\{(\mu_A, \eta_A, \upsilon_A)|\mu_A, \eta_A, \upsilon_A \in [0,1] \text{ and } 0 \leq \mu_A \\ + \eta_A + \upsilon_A \leq 1\}\}. \end{aligned} \tag{4}$$

It is to be noted that PFS is an extended version of the traditional fuzzy sets (FS). For a PFS, if $\eta_{\widetilde{A}}(x) = 0$, then it becomes an intuitionistic fuzzy set (IFS), while if both $\eta_{\widetilde{A}}(x)$ and $\upsilon_{\widetilde{A}}(x) = 0$, $\widetilde{\mathrm{A}}$ represents a traditional fuzzy set. With the presence of $\eta_{\widetilde{A}}(x)$, PFS helps in carrying out more granular analysis reflecting on the available imprecise information, and it enhances the accuracy of the result [67]. Furthermore, the degree of refusal provides the opinion-makers the liberty not to express any opinion if they are unaware and/or not interested. It reduces the misinterpretation and error in the result. In summary, PFS deals with impreciseness and uncertainties with greater efficiency.

2.2. Properties. Some of the properties of PFS or PFN are described below [65, 66].

Let $\widetilde{A} = x, \mu_{\widetilde{A}}(x), \eta_{\widetilde{A}}(x), \upsilon_{\widetilde{A}}(x)$ and $\widetilde{B} = x, \mu_{\widetilde{B}}(x), \eta_{\widetilde{B}}(x), \upsilon_{\widetilde{B}}(x)$ be two PFS $\forall x \in U$; then,

$$\begin{aligned} \widetilde{A} \bigcup \widetilde{B} &= \left\{\left(x, \max\left(\mu_{\widetilde{A}}(x), \mu_{\widetilde{B}}(x)\right), \min\left(\eta_{\widetilde{A}}(x), \eta_{\widetilde{B}}(x)\right), \min\left(\upsilon_{\widetilde{A}}(x), \upsilon_{\widetilde{B}}(x)\right)\right)|x \in U\right\}, \\ \widetilde{A} \cap \widetilde{B} &= \left\{\left(x, \min\left(\mu_{\widetilde{A}}(x), \mu_{\widetilde{B}}(x)\right), \min\left(\eta_{\widetilde{A}}(x), \eta_{\widetilde{B}}(x)\right), \max\left(\upsilon_{\widetilde{A}}(x), \upsilon_{\widetilde{B}}(x)\right)\right)|x \in U\right\}, \end{aligned} \tag{5}$$

$$\widetilde{A}^c = \left\{x, \upsilon_{\widetilde{A}}(x), \eta_{\widetilde{A}}(x), \mu_{\widetilde{A}}(x)|x \in U\right\}, \tag{6}$$

$$\begin{aligned} &\widetilde{A} \subseteq \widetilde{B} \text{ if } \left(\mu_{\widetilde{A}}(x) \leq \mu_{\widetilde{B}}(x), \eta_{\widetilde{A}}(x) \leq \eta_{\widetilde{B}}(x), \upsilon_{\widetilde{A}}(x) \geq \upsilon_{\widetilde{B}}(x) \forall x \in U\right), \\ &\widetilde{A} = \widetilde{B} \text{ if } \widetilde{A} \subseteq \widetilde{B} \text{ and } \widetilde{B} \subseteq \widetilde{A}, \\ &\widetilde{A} \subseteq \widetilde{B} \text{ and } \widetilde{B} \subseteq \widetilde{C} \Rightarrow \widetilde{A} \subseteq \widetilde{C}, \\ &\left(\widetilde{A}^c\right)^c = \widetilde{A}. \end{aligned} \tag{7}$$

2.3. Operations [65, 66]. Let $A = (\mu_A, \eta_A, \upsilon_A)$ and $B = (\mu_B, \eta_B, \upsilon_B)$ be any two PFNs. The following are some of the basic operations:

$$\begin{aligned}
A\oplus B &= \left(\mu_A + \mu_B - \mu_A\mu_B, \eta_A\eta_B, \upsilon_A\upsilon_B\right),\\
A\otimes B &= \left(\mu_A\mu_B, \eta_A + \eta_B - \eta_A\eta_B, \upsilon_A + \upsilon_B - \upsilon_A\upsilon_B\right),\\
\lambda A &= \left(1 - \left(1 - \mu_A\right)^{\lambda}, \eta_A^{\lambda}, \upsilon_A^{\lambda}\right); \lambda > 0,\\
A^{\lambda} &= \left(\mu_A^{\lambda}, 1 - \left(1 - \eta_A\right)^{\lambda}, 1 - \left(1 - \upsilon_A\right)^{\lambda}; \lambda > 0,\right.\\
A\oplus B &= B\oplus A,\\
A\otimes B &= B\otimes A,\\
\left(A^{\lambda 1}\right)^{\lambda 2} &= A^{\lambda 1\lambda 2},\\
(A\otimes B)^{\lambda} &= A^{\lambda}\otimes B^{\lambda}.
\end{aligned} \tag{8}$$

2.4. Defuzzification [68, 69]. The two-stage defuzzification of a PFN is described below.

Step 1. Defining new positive and negative memberships:

$$\begin{aligned}
\mu_A^{'} &= \mu_A + \frac{\eta_A}{2},\\
\upsilon_A^{'} &= \upsilon_A + \frac{\eta_A}{2}.
\end{aligned} \tag{9}$$

Step 2. Calculation of the defuzzification value:

$$\gamma_A = \mu_A^{'} + \pi_A\left(\frac{1 + \mu_A^{'} - \upsilon_A^{'}}{2}\right). \tag{10}$$

2.5. Distance Measures [70, 71]. Let $\widetilde{A} = x, \mu_{\widetilde{A}}(x), \eta_{\widetilde{A}}(x), \upsilon_{\widetilde{A}}(x)$ and $\widetilde{B} = x, \mu_{\widetilde{B}}(x), \eta_{\widetilde{B}}(x), \upsilon_{\widetilde{B}}(x)$ be two PFS $\forall x \in U$, where $x = \{x_1, x_2, x_3, \ldots, x_n\}$.

Normalized Hamming distance:

$$\begin{aligned}
d^H(\widetilde{A}, \widetilde{B}) = \frac{1}{n}\sum_{i=1}^{n}\Big(\left|\mu_{\widetilde{A}}(x_i) - \mu_{\widetilde{B}}(x_i)\right| + \left|\eta_{\widetilde{A}}(x_i) - \eta_{\widetilde{B}}(x_i)\right|\\
+ \left|\upsilon_{\widetilde{A}}(x_i) - \upsilon_{\widetilde{B}}(x_i)\right|\Big).
\end{aligned} \tag{11}$$

Normalized Euclidean distance:

$$d^E(\widetilde{A}, \widetilde{B}) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\left(\mu_{\widetilde{A}}(x_i) - \mu_{\widetilde{B}}(x_i)\right)^2 + \left(\eta_{\widetilde{A}}(x_i) - \eta_{\widetilde{B}}(x_i)\right)^2 + \left(\upsilon_{\widetilde{A}}(x_i) - \upsilon_{\widetilde{B}}(x_i)\right)^2\right)}. \tag{12}$$

2.6. Score and Accuracy Functions [66]. The score function of any PFN A is given as

$$S_A = \mu_A - \upsilon_A. \tag{13}$$

The accuracy function is defined as:

$$H_A = \mu_A + \eta_A + \upsilon_A. \tag{14}$$

In this regard, the rules for comparing any two PFNs, such as A and B are given as follows:

(i) If $S_A \prec S_B$, then $A \prec B$
(ii) If $S_A \succ S_B$, then $A \succ B$
(iii) If $S_A = S_B, H_A \prec H_B$, then $A \prec B$
(iv) If $S_A = S_B, H_A \succ H_B$, then $A \succ B$
(v) $If\ S_A = S_B, H_A = H_B$, then $A = B$

2.7. Absolute and Actual Score. The necessity of calculating the absolute and actual scores stems from the need to consider all three degrees of membership functions as one of the distinct features of PFS is neutrality [72]. Accordingly, the steps are described below.

Step 3. Identification of the positive ideal solution (PIS)

For a set of n number of PFNs, PIS is given as

$$Z^{+} = \left(\mu^{+}, \eta^{+}, \upsilon^{+}\right) = \left(\max_i \mu_i, \min_i \eta_i, \min_i \upsilon_i\right), \quad \text{where}\ i = 1, 2, \ldots, n. \tag{15}$$

Step 4. Find out goal differences for each PFN

Positive goal difference:

$$\mu_{i+} = \mu^{+} - \mu_i. \tag{16}$$

Negative goal difference:

$$\upsilon_{i-} = \upsilon_i - \upsilon^{+}. \tag{17}$$

Step 5. Find out the average neutral degree:

$$\overline{\eta} = \frac{1}{n}\sum_{i=1}^{n}\eta_i. \tag{18}$$

Step 6. Calculation of the absolute score for each PFN:

$$S_{i(abs)} = (1 - \mu_{i+}) - \upsilon_{i-}. \tag{19}$$

Step 7. Derive the actual score for each PFN:

$$S_{i(act)} = \frac{S_{i(abs)}}{1 - (\overline{\eta} - \eta_i)}. \tag{20}$$

Here, the rules applicable are as follows:

(i) If $S_{A(act)} \succ S_{B(act)}$, then $A \succ B$
(ii) If $S_{A(act)} = S_{B(act)}$, then if $\mu_A > \mu_B$ and $\eta_A \geq \eta_B$ then $A \succ B$
(iii) If $S_{A(act)} = S_{B(act)}$ and $\mu_A \geq \mu_B$ and $\eta_A < \eta_B$, then if $\upsilon_A \leq \upsilon_B$ then $A \succ B$, otherwise $A \prec B$

Also, $(\overline{\eta} - \eta_i) \neq 1$, $S_{i(act)}$ is always finite.

3. Materials and Methods

In this paper, we use a new decision support framework based on the extension of the PROBID method using PFNs, wherein the criteria weights are determined by applying the FUCOM algorithm with the actual score values of PFNs. The procedural steps followed to address the problem of comparing some of the popular VC platforms in India using our proposed methodology are presented pictorially in Figure 1. In this section, a detailed description of the research methodology is provided.

3.1. Criteria Selection. In this paper, we use the theoretical foundation of usability and user experience (UX) to understand the usefulness of some of the popular VC platforms to the users, more specifically, to the educators and students. In the post-Covid-19 phase, as the online medium has gained substantial importance in teaching-learning in higher education, the availability and stability have become two dominant features of quality service [73, 74]. According to ISO 9241–210, 2010 [75], the concept of UX entails the perception and responses of the users while using a given service or system. The ability of a service provider in achieving user satisfaction in a given use context determines the effectiveness and efficiency, and thereby, it enhances usability. In essence, the usability, affect, and user value are the subsets of the UX set [76, 77]. There are other perspectives on usability and UX as well, for instance, simplicity in use for providing a happy experience [78], fitness, suitability of use in terms of aesthetics, pleasure, and attractiveness [79], and flexibility of the service providers [1] among others. A number of studies are done using the UX concept, mostly in the domain of computer networking, transmission, mobile communication, and system design, using virtual reality [for example, [76–81]]. In line with the understanding of usability and UX theory and observations made in the extant literature, we select the list of criteria (see Table 1) for comparing a set of popular VC platforms (see Table 2) used in higher education in India.

3.2. Formation of the Group of DMs. The profile of the respondents is provided in Table 3. In our study, a group of 14 regular users have participated. The sample size meets the requirement in group decision-making [82–84]. A Google form-based online survey is administered.

3.3. FUCOM Method. The procedural steps of the FUCOM algorithm [47] are given in the following.

Step 8. Ordering of the criteria based on their relative priorities as defined by the DMs.

Suppose $C = \{C_1, C_2, C_3, \ldots, C_n\}$ represents the set of criteria. Let the order of the criteria based on the preference of the DMs be $C_j(1) \succ C_j(2) \succ C_j(3) \succ \cdots C_j(r)$, where r is the rank of the particular criterion. However, there may be the situations where any two criteria may hold the same preferential rank (in that case, an " = " may be used).

Step 9. Calculation of the comparative priority of the criteria.

The comparative priority (CP) of the criterion $C_j(r)$ as compared with $C_j(r+1)$ is given by $\Phi_{r/(r+1)}$.

The CP can be defined (a) according to DM's preference or (b) using a predetermined scale, wherein the criterion with $r = 1$ (i.e., ranked first) is the most preferred one. The other criteria are compared with the most preferred criterion. It is already mentioned that the FUCOM method requires a total of (n-1) number of pairwise comparisons.

Step 10. Calculation of the final weights of the criteria.

The final weights are derived subject to the following two conditions:

a)

$$\frac{w_r}{w_{r+1}} = \Phi_{r/(r+1)}. \tag{21}$$

b) Mathematical transitivity:

$$\frac{w_r}{w_{r+2}} = \Phi_{r/(r+1)} \otimes \Phi_{(r+1)/(r+2)}. \tag{22}$$

The full consistency or maximum possible consistency is obtained if DFC (χ) is minimum subject to the fulfilment of the conditions (refer the expressions (34) and (35)). The final model is constructed as

$$\begin{aligned}
&\text{Min}\,\chi,\\
&\text{s.t.}\\
&\left|\frac{w_{j(r)}}{w_{j(r+1)}} - \Phi_{r/(r+1)}\right| \leq \chi, \quad \forall j,\\
&\left|\frac{w_{j(r)}}{w_{j(r+2)}} - \Phi_{r/(r+1)} \otimes \Phi_{((r+1))/(r+2)}\right| \leq \chi, \quad \forall j,\\
&\sum w_j = 1, w_j \geq 0, \quad \forall j.
\end{aligned} \tag{23}$$

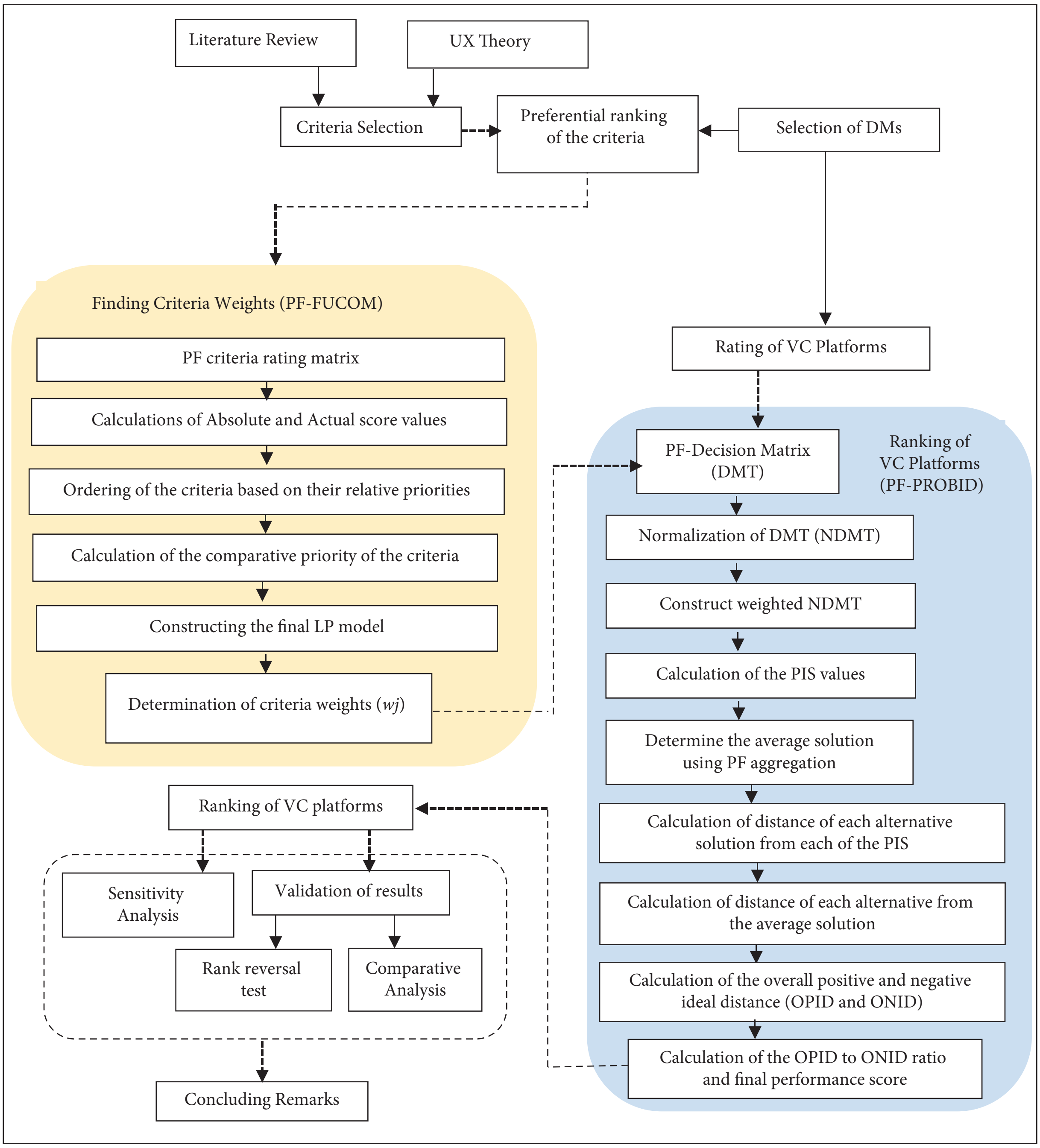

Figure 1: Flow of steps of the research framework.

Table 1: List of criteria considered to compare VC platforms.

S/L	Criteria	Description	Effect direction
C1	User friendliness	Minimal action, easy access	Max
C2	Compatibility	Operations from multiple types of devices, applications through web, multipurpose use	Max
C3	Quality of transmission	Voice and video quality	Max
C4	Features	File transfer, recording, break-rooms, playback, screen sharing, remote control, etc.	Max
C5	Bandwidth consumption	Requirement for Internet speed	Min
C6	Awareness	Degree of popularity/familiarity, number of users	Max
C7	Security and privacy	Security of data, private credentials, etc.	Max
C8	Cost	Subscription, cost for large scale operations	Min

Note: the criteria are identified using the premise of the UX theory and in tune with past work. Descriptions are summarized as per the understanding of the authors and with reference to extant literature.

Table 2: List of VC platforms under comparison.

S/L	VC platform
A1	Zoom
A2	Microsoft Teams
A3	Google Meet
A4	Webex
A5	GotoMeeting
A6	We Chat
A7	WhatsApp
A8	Skype

Table 3: Respondents' profile.

Decision maker	Gender	Total professional experience (in years)	Role	No. of years in using VC platforms
DM1	Male	6–10 years	Instructor/educators	2–5 years
DM2	Female	6–10 years	Instructor/educators	More than 5 years
DM3	Male	More than 20 years	PG student	2–5 years
DM4	Male	10–15 years	Instructor/educators	1–2 years
DM5	Male	0–5 years	PG student	2–5 years
DM6	Male	10–15 years	Instructor/educators	More than 5 years
DM7	Male	0–5 years	PG student	1–2 years
DM8	Male	0–5 years	PG student	1–2 years
DM9	Male	5–10 years	Instructor/educators	More than 5 years
DM10	Male	16–20 years	Instructor/educators	More than 5 years
DM11	Female	0–5 years	PG student	1–2 years
DM12	Female	0–5 years	PG student	2–5 years
DM13	Male	5–10 years	Instructor/educators	2–5 years
DM14	Male	More than 20 years	Instructor/educators	More than 5 years

By solving the final model as described above, we obtain the weights of the criteria (w_j).

3.4. PROBID Method. The PROBID algorithm works on a combined essence of TOPSIS and EDAS methods. The steps to compute the results using the classic PROBID method [46] are described in the following.

Step 11. Normalization of DMT.

Using the vector normalization scheme, DMT $X = [x_{ij}]_{m\times n}$ can be converted into a normalized DMT (NDMT) $N = [n_{ij}]_{m\times n}$, where the elements are given by

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \tag{24}$$

Step 12. Formation of the weighted NDMT.

The weighted NDMT (WNDMT) is represented by $V = [v_{ij}]_{m\times n}$, where the elements are derived as

$$\begin{gathered} v_{ij} = n_{ij} \times w_j, \\ i \in \{1,\ 2,\ 3, \ldots, m\};\ j \in \{1,\ 2, 3, \ldots, n\}; \\ w_j \text{ is the weight of } j^{th} \text{ criterion.} \end{gathered} \tag{25}$$

Step 13. Calculation of the PIS values.

Let $P_{k(j)}; k = 1, 2, \ldots, m$ be the PIS values, where $P_{1(j)}$ is the most favorable PIS value. Therefore, $P_{m(j)}$ is the most nonfavorable PIS, i.e., most NIS value. The k^{th} PIS value is given by

$$P_{k(j)} = \left\{\left(\max\left(v_j, k\right); j \in j^+\right), \left(\min\left(v_j, k\right);\right); j \in j^-\right\}, \tag{26}$$

j^+ is the set of maximizing criteria and j^- is the set of minimizing criteria from the criteria set for $j \in \{1, 2, 3, \ldots, n\}$.

Step 14. Determine the average solution.

The average solution $v_{avg(j)}$ is given by

$$v_{avg(j)} = \frac{\sum_{k=1}^{m} P_{k(j)}}{m} \text{ for } j \in \{1, 2, 3, \ldots, n\}. \tag{27}$$

Step 15. Calculation of the distance of each alternative solution from each of the m number of PIS.

Applying the standard formula of Euclidean distance of the i^{th} alternative from each of the PIS is derived as

$$\begin{gathered} d_{i(k)} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - P_{k(j)}\right)^2}; i \in \{1, 2, \ldots m\}; \\ k \in \{1, 2, 3, \ldots, m\}. \end{gathered} \tag{28}$$

Step 16. Calculation of distance of each alternative from the average solution.

In the same way, the Euclidean distances are calculated as

$$d_{i(avg)} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_{avg(j)}\right)^2}; \quad i \in \{1, 2, \ldots, m\}. \tag{29}$$

Step 17. Calculation of the overall positive ideal distance (OPID).

The OPID is essentially the weighted sum distance of an alternative from the first half of the PIS values and is expressed as

$$d_{i(\text{pos-ideal})} = \begin{cases} \displaystyle\sum_{k=1}^{(m+1)/2} \frac{d_{i(k)}}{k}, & i \in \{1, 2, \ldots m\}; m \text{ is odd}; k = 1, 2, 3, \ldots, \\ \displaystyle\sum_{k=1}^{m/2} \frac{d_{i(k)}}{k}, & i \in \{1, 2, \ldots m\}; m \text{ is even}; k = 1, 2, 3, \ldots. \end{cases} \tag{30}$$

Step 18. Calculation of the overall negative ideal distance (ONID).

The ONID is essentially the weighted sum distance of an alternative from the second half of the PIS values and is expressed as

$$d_{i(\text{neg-ideal})} = \begin{cases} \displaystyle\sum_{k=(m+1)/2}^{m} \frac{d_{i(k)}}{m-k+1}, & i \in \{1, 2, \ldots, m\}; m \text{ is odd}; k = 1, 2, 3 \ldots, \\ \displaystyle\sum_{k=(m/2)+1}^{m} \frac{d_{i(k)}}{m-k+1}, & i \in \{1, 2, \ldots, m\}; m \text{ is even}; k = 1, 2, 3, \ldots. \end{cases} \tag{31}$$

Unlike OPID, in case of ONID, the weight increases as k approaches m.

Step 19. Calculation to OPID to ONID ratio.

The ratio of OPID to ONID is given by

$$R_i = \frac{d_{i(\text{pos-ideal})}}{d_{i(\text{neg-ideal})}}. \tag{32}$$

Step 20. Determine the final performance score.

The final performance score PS_i is given by

$$PS_i = \frac{1}{1 + R_i^2} + d_{i(avg)}; \quad i \in \{1, 2, \ldots, m\}. \tag{33}$$

It may be noted that if $R_i \longrightarrow 0$, PS_i increases, which means the respective alternative solution becomes closer to most PIS. Hence, the higher the value of PS_i, the more preferable the corresponding alternative.

3.5. The Proposed PF-FUCOM-PROBID Methodology. In this subsection, we shall elaborate the steps of our proposed methodology. In our study, we have the following:

C_j, where $j = 1, 2, \ldots, n$ (n is finite and ≥ 2): the number of criteria or attributes

A_i, where $i = 1, 2, \ldots, m$ (m is finite and ≥ 2): the number of alternatives or VC platforms

E_t, where $t = 1, 2, \ldots, p$ (p is finite and ≥ 2): the number of DMs participated

Step 21. Formation of the linguistic response matrix for criteria rating.

Let ∂_j^t be the relative importance of the j^{th} criterion as opined by t^{th} DM, where ∂_j^t may be positive, negative, neutral, and no response or refusal. In this paper, for criteria rating, refusal is not considered. Hence, for rating, there are three options: H (if the corresponding criterion is highly significant; positive membership), L (if the corresponding criterion is less significant; negative membership), and N (if the significance is indeterminate, i.e., not possible to say significant or nonsignificant; neutral membership). The linguistic response matrix for t^{th} DM is formed as

$$\partial^t = \begin{pmatrix} \partial_1^t \\ \partial_2^t \\ \ldots \\ \ldots \\ \partial_j^t \end{pmatrix}_{n\times 1}. \tag{34}$$

Table 4 provides the rating of the DMs with respect to different criteria.

Step 22. Construction of the PF rating matrix for the criteria.

After aggregating the responses of all DMs considering the proportion of type of responses (positive, neutral, and negative) [85], we get the PF rating matrix, which is expressed as

$$\tilde{\partial} = \begin{pmatrix} \tilde{\partial}_1 \\ \tilde{\partial}_2 \\ \cdots \\ \tilde{\partial}_n \end{pmatrix}_{n\times 1}. \tag{35}$$

It may be noted that $\tilde{\partial}_j\,(j = 1, 2, \ldots, n)$ is also a PFN.

Step 23. Calculation of the actual score values for the criteria.

Using the PF rating matrix, the actual score values are calculated using the expressions from (15) to (20).

Step 24. Priority-based ordering of the criteria.

The relative priority order is decided on the basis of the calculated actual scores of the criteria.

Step 25. Defining the comparative priority (CP) of the criteria.

Firstly, the most significant criterion having the highest actual score value is identified. Then, all other criteria are compared with the same for getting the proportional CP values.

Step 26. Formation of the final linear programming (LP) model.

Using conditions (21) and (25), the final LP model is formulated in the form of expression (26).

Step 27. Determining the criteria weights.

We determine the weights of the criteria by solving the final LP model using the Lingo (version 19) software.

Step 28. Formation of the linguistic response matrix for the rating of the alternatives.

Suppose ℓ^{t}_{ij} is the relative significance of A_i with respect to C_j (on linguistic scale) as given by t^{th} DM. In this study, ℓ^{t}_{ij} may be H or *G* (if the corresponding criterion is highly significant or good; positive membership), *L* or B (if the corresponding criterion is less significant or bad; negative membership), and N (if the significance is indeterminate, i.e., not possible to say significant or nonsignificant; neutral membership). The linguistic response matrix for the rating of the alternatives is given by

$$\ell^{t} = \begin{pmatrix} \ell^{t}_{11} & \cdots & \ell^{t}_{1j} \\ \vdots & \ddots & \vdots \\ \ell^{t}_{i1} & \cdots & \ell^{t}_{ij} \end{pmatrix}_{m\times n}. \tag{36}$$

Table 5 provides the linguistic response matrix.

Table 4: Rating of the criteria using linguistic scale.

Decision maker	Rating of the criteria							
	C1	C2	C3	C4	C5	C6	C7	C8
DM1	H	N	N	H	L	L	H	L
DM2	H	H	N	N	H	H	H	N
DM3	N	H	L	L	L	L	N	L
DM4	H	N	H	H	N	N	H	N
DM5	H	H	H	L	L	H	N	H
DM6	H	H	H	H	H	N	H	H
DM7	H	H	H	H	N	N	L	N
DM8	H	H	H	N	N	L	N	N
DM9	H	H	H	H	N	L	H	H
DM10	H	L	N	H	H	L	N	H
DM11	H	H	H	H	H	N	H	N
DM12	N	H	H	N	N	H	N	N
DM13	H	H	H	N	N	L	N	H
DM14	L	H	H	H	H	N	H	N

Note: the colors are representing the nature of the criteria. Green: maximizing criteria, and red: minimizing criteria.

Step 29. Deriving the PF decision matrix (PF-DMT).

The PF decision matrix is given as

$$\tilde{X} = \begin{pmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1j} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{i1} & \cdots & \tilde{x}_{ij} \end{pmatrix}_{m\times n}. \tag{37}$$

Here, $\tilde{x}_{ij} = \mu_{ij}, \eta_{ij}, \upsilon_{ij}$ is the PFN that indicates the rating of A_i with respect to C_j after aggregating the linguistic responses of individual DMs and calculation of the proportion of the type of responses (positive, neutral, and negative).

Step 30. Normalization of the elements of PF-DMT.

The normalized PF decision matrix (NPF-DMT) $\tilde{N}$ is represented by its elements as given in the following:

$$\tilde{N} = \left[\widetilde{\aleph_{ij}}\right]_{m\times n}. \tag{38}$$

Here,

$$\widetilde{\aleph_{ij}} = \widetilde{x_{ij}}\ (\text{for maximizing criteria}) \text{ and } \widetilde{x_{ij}}^{c} \cdot (\text{for minimizing criteria}). \tag{39}$$

The value for $\widetilde{x_{ij}}^{c}$ is derived using the expression (6). It may be noted that $\widetilde{\aleph_{ij}}$, $\widetilde{x_{ij}}$, and $\widetilde{x_{ij}}^{c}$ are PFNs.

Step 31. Construct the weighted normalized decision matrix $\widetilde{\text{NW}}$.

The elements of $\widetilde{\text{NW}}$ are given as

$$\widetilde{nw_{ij}} = w_j \widetilde{\aleph_{ij}}. \tag{40}$$

Here, w_j is derived in Step 27, and $\widetilde{\aleph_{ij}}$ is obtained at Step 30. It may be noted that $\widetilde{nw_{ij}}$ is also a PFN.

Step 32. Calculation of the PIS values.

As described in the Step 23, (Section 3.4), using the expressions (28) and (39) in this step, we calculate the PIS values $\check{P}_{k(j)}$, which are also PFNs.

Step 33. Find the average solution.

Table 5: Linguistic response matrix for rating the alternatives.

Decision maker	C1								C2							
	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
DM1	G	N	G	B	N	G	G	B	G	N	G	N	N	B	B	B
DM2	N	N	G	N	N	N	G	N	G	N	N	N	N	N	G	G
DM3	N	N	G	B	N	B	N	N	G	G	N	G	N	B	B	N
DM4	G	G	G	B	B	N	G	B	G	G	G	G	G	N	N	G
DM5	N	G	G	B	B	N	N	N	G	N	B	B	B	B	G	N
DM6	G	G	G	N	N	N	G	N	G	N	G	G	N	N	B	N
DM7	B	G	B	N	N	N	G	G	B	G	G	N	N	N	G	G
DM8	G	N	G	N	N	N	G	N	N	B	G	G	N	N	G	G
DM9	G	G	N	N	N	B	B	N	G	G	G	N	B	B	B	B
DM10	G	N	N	B	N	N	G	N	G	N	G	B	B	N	G	G
DM11	G	B	G	B	B	B	N	B	G	G	B	N	N	B	N	B
DM12	N	G	G	N	N	N	G	B	N	G	G	N	N	G	G	N
DM13	G	N	G	G	N	B	G	B	G	G	G	G	N	N	N	N
DM14	G	G	G	G	G	N	G	N	G	G	G	N	N	N	G	N
Decision maker	C3								C4							
	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
DM1	N	G	G	G	N	N	B	N	G	N	N	G	N	B	B	N
DM2	N	N	G	G	N	N	G	N	G	N	G	N	N	N	G	G
DM3	N	G	G	N	B	B	B	N	N	G	N	G	N	B	B	N
DM4	B	G	G	N	N	N	G	G	N	G	G	B	B	N	B	N
DM5	G	G	G	G	N	N	N	B	B	G	G	N	B	N	G	N
DM6	N	N	G	G	N	N	N	G	G	G	G	G	B	N	N	B
DM7	N	B	B	B	B	B	N	G	N	G	G	N	G	N	N	N
DM8	G	G	G	G	N	N	N	G	G	G	N	G	N	B	B	N
DM9	G	G	G	N	B	G	B	N	G	B	B	B	B	B	B	N
DM10	G	N	N	B	N	B	G	N	B	G	N	N	B	B	N	G
DM11	G	G	N	B	G	B	B	G	G	G	G	N	N	N	G	N
DM12	G	G	G	N	N	N	G	N	G	G	G	N	N	G	N	G
DM13	G	N	N	G	N	N	N	B	G	N	G	N	N	N	N	B
DM14	G	G	G	G	B	N	G	B	B	N	B	G	G	N	N	N
Decision maker	C5								C6							
	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
DM1	L	H	L	H	N	N	N	N	H	H	H	H	N	H	H	H
DM2	H	N	H	N	N	N	H	N	N	N	H	N	N	N	H	H
DM3	L	N	H	H	H	H	H	H	N	H	N	N	L	L	L	L
DM4	N	N	H	N	H	N	H	H	H	H	H	N	L	L	H	H
DM5	H	N	L	N	H	N	L	L	H	H	H	L	L	L	H	H
DM6	H	H	L	N	N	N	N	N	H	H	H	N	L	L	N	N
DM7	H	H	L	L	N	N	N	H	H	N	H	L	L	L	N	H
DM8	N	N	H	N	L	N	H	N	H	H	L	N	L	L	H	N
DM9	N	L	H	L	N	L	N	H	L	H	H	L	L	L	N	L
DM10	N	H	N	N	H	H	N	H	H	L	H	L	H	L	H	H
DM11	H	H	N	H	N	N	H	N	L	H	H	H	N	L	N	N
DM12	H	H	N	N	N	N	H	N	H	H	N	H	N	H	L	N
DM13	N	H	H	N	L	N	L	H	H	H	H	N	L	L	H	N
DM14	L	N	L	N	L	L	H	L	H	H	H	N	N	L	H	H
Decision maker	C7	C8														
	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
DM1	B	G	N	G	B	N	B	G	L	N	L	H	N	L	L	H
DM2	B	N	G	N	N	N	G	N	N	N	H	H	L	N	H	H
DM3	N	G	N	G	N	N	N	G	N	H	N	H	N	H	N	N
DM4	N	G	N	N	N	N	N	N	N	H	N	N	N	N	L	N
DM5	N	N	G	N	B	N	N	G	H	N	N	L	N	N	H	N
DM6	G	G	N	N	N	N	N	G	N	N	H	N	N	N	H	N
DM7	B	G	G	G	G	N	G	N	H	H	L	N	N	N	L	L
DM8	G	G	N	B	N	G	N	N	H	H	H	N	H	N	H	H
DM9	G	B	N	N	B	B	B	N	H	H	L	N	N	L	L	H
DM10	N	G	N	N	B	B	G	G	N	H	L	N	N	N	L	L
DM11	N	G	B	N	N	N	N	B	H	H	H	N	N	N	N	H

Table 5: Continued.

Decision maker	C1								C2							
	A1	A2	A3	A4	A5	A6	A7	A8	A1	A2	A3	A4	A5	A6	A7	A8
DM12	N	G	G	N	N	N	G	N	L	N	N	N	N	N	N	N
DM13	G	G	N	N	N	B	G	N	H	L	N	N	N	N	L	H
DM14	N	G	G	G	B	N	N	B	N	L	L	H	L	L	L	L

Note: the colors are representing the nature of the criteria; green: maximizing criteria and red: minimizing criteria.

As described in Step 24 (Section 3.4), the average solution AV is calculated using the following expression [86]:

$$AV = \left[AV_j\right]_{1\times n} = \left\{1 - \prod_{i=1}^{m}\left(1 - \mu_{ij}^{'}\right)^{1/m}, \prod_{i=1}^{m}\left(\eta_{ij}^{'}\right)^{1/m}, \prod_{i=1}^{m}\left(v_{ij}^{'}\right)^{1/m}\right\}_{1\times n}, \tag{41}$$

$\left\{\mu_{ij}^{'}, \eta_{ij}^{'}, v_{ij}^{'}\right\}$ are the elements of the PIS matrix.

Step 34. Calculation of distance of each alternative solution from each of the PIS.

We calculate the Euclidean distances using expression (12) for each alternative from each of the PIS as found in Step 33.

Step 35. Calculation of distance of each alternative from the average solution.

Now, in a similar way, using expression (12), we calculate the distance of each alternative from the average solution as derived in Step 34.

Step 36. Calculation of the overall positive ideal distance (OPID) and overall negative ideal distance (ONID)

In our study, a total of eight alternatives and eight criteria are considered. Therefore, using the expressions (30) and (31) with $m = 8$ (even number), we calculate OPID and ONID.

Step 37. Calculation of OPID to ONID ratio.

In the next step, we determine R_i values for each alternative using expression (32).

Step 38. Determine the final performance score.

The PS_i values are derived using expression (33), and the alternatives are ranked. The alternative whose PS_i value is the highest is ranked first and so on.

4. Results and Discussion

After aggregating the responses of all DMs considering the proportion of the type of responses (positive, neutral, and negative) [85], we get the PF rating matrix as given in Table 6.

Now, we proceed to find the absolute and actual scores of the criteria as mentioned in Step 23 (Section 3.5) using the expressions from (15) to (20). Table 7 exhibits the values of the PGD, NGD, absolute scores (Abs_Score), and actual scores (Act_Score) for the criteria $C_1, C_2, C_3, \ldots, C_8$. Here, the average of η values (Avg_η) is 0.313, and the PIS (Z^{+}) is found as (0.786, 0.143, 0.071).

Now, we order the criteria as per the preferences of the DMs (as per Act_Score values). It may be noted that C_1 and C_2 hold equal Act_Score values. Let us consider that C_1 is the most preferred criterion over the others. The descending order of the criteria starting from C_1 is, $C_1 \succ C_2 \succ C_3 \succ C_4 \succ C_7 \succ C_8 \succ C_5 \succ C_6$

Next, we move to derive the CP of the criteria and carry out a comparison of the criteria. Table 8 shows the CP of the criteria and the results of checking of the conditions as per expressions (34) and (35). The final LP-based model is

Table 6: Criteria rating matrix in terms of PFNs (calculated by aggregating responses on linguistic scales).

Criteria	PFN		
	μ	η	ν
C1	0.786	0.143	0.071
C2	0.786	0.143	0.071
C3	0.714	0.214	0.071
C4	0.571	0.286	0.143
C5	0.357	0.429	0.214
C6	0.214	0.357	0.429
C7	0.500	0.429	0.071
C8	0.357	0.500	0.143

Note: the colors are representing the nature of the criteria; green: maximizing criteria and red: minimizing criteria.

Table 7: Absolute and actual scores of respective PFNs representing the criteria.

Criteria	PGD	NGD	Abs_Score	Act_Score
C1	0.000	0.000	1.000	1.20430
C2	0.000	0.000	1.000	1.20430
C3	0.071	0.000	0.929	1.02970
C4	0.214	0.071	0.714	0.73394
C5	0.429	0.143	0.429	0.38400
C6	0.571	0.357	0.071	0.06838
C7	0.286	0.000	0.714	0.64000
C8	0.429	0.071	0.500	0.42105

Table 8: Comparative priority of the criteria.

Criteria	Priority	$\varnothing_{(k/k+1)}$	(W_k/W_{k+1})	(W_k/W_{k+2})
C1	1.2043	1.0000	1.0000	1.1696
C2	1.2043	1.1696	1.1696	1.6409
C3	1.0297	1.4030	1.4030	1.6089
C4	0.7339	1.1468	1.1468	1.7431
C7	0.6400	1.5200	1.5200	1.6667
C8	0.4211	1.0965	1.0965	6.1579
C5	0.3840	5.6160	5.6160	
C6	0.0684			

formulated as per expression (36) for obtaining the criteria weights and is given in expression (55).

$$
\begin{aligned}
&\operatorname{Min}\chi\\
&\text{S.T.}\begin{cases}
\left|\dfrac{w_1}{w_2}\right|-1.0000\le\chi;\left|\dfrac{w_2}{w_3}\right|-1.1696\le\chi;\left|\dfrac{w_3}{w_4}\right|-1.4030\le\chi;\left|\dfrac{w_4}{w_7}\right|-1.1468\le\chi;\\[2ex]
\left|\dfrac{w_7}{w_8}\right|-1.5200\le\chi;\left|\dfrac{w_8}{w_5}\right|-1.0965\le\chi;\left|\dfrac{w_5}{w_6}\right|-5.6160\le\chi,\\[2ex]
\left|\dfrac{w_1}{w_3}\right|-1.1696\le\chi;\left|\dfrac{w_2}{w_4}\right|-1.6409\le\chi;\left|\dfrac{w_3}{w_7}\right|-1.6089\le\chi;\left|\dfrac{w_4}{w_8}\right|-1.7431\le\chi;\\[2ex]
\left|\dfrac{w_7}{w_5}\right|-1.6667\le\chi;\left|\dfrac{w_8}{w_6}\right|-6.1579\le\chi,\\[2ex]
\sum_{j=1}^{8}w_j=1;w_j\ge0\,\forall j.
\end{cases}
\end{aligned}
\tag{42}
$$

Now, we solve the expression (42) using Lingo 19 software and obtain the criteria weights as mentioned in Table 9.

The DFC (χ) value is calculated as $\chi = 0.00001701 \approx 0$, which indicates the validity of the criteria weight calculation using PF-FUCOM. We observe that C1 and C2

Table 9: Criteria weights.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
Weight	0.2120	0.2120	0.1810	0.1290	0.0660	0.0120	0.1130	0.0740

C1: user friendliness; C2: compatibility; C3: quality of transmission; C4: features; C5: bandwidth consumption; C6: awareness; C7: security and privacy; C8: cost.

hold the same weight values. It is noticed that $C_1 \approx C_2 \succ C_3 \succ C_4 \succ C_7 \succ C_8 \succ C_5 \succ C_6$.

We find that the users have given more emphasis on the ease of operations, compatibility with multiple systems and devices, quality of the voice and video transmission, and features, which is in sync with the general propositions of usability and UX theory.

Now, we move to rank the VC platforms under comparison. For that, we obtain the rating of the DMs for the alternatives subject to the criteria for comparison. After aggregating the responses in the same way as we did for the PF rating matrix, we construct PF-DMT, which is given in Table 10.

Next, we normalize PF-DMT and construct the weighted NPF-DMT as described in Steps 10 and 11 (Section 3.5) using the expressions (6) and (51–53). Table 11 provides the weighted NPF-DMT.

Next, we find the PIS values as described in Step 22 (Section 3.5) using the expression (12). Table 12 exhibits the PIS values for the alternatives subject to the criteria.

Now, we follow Steps 23 and 24 (Section 3.5) for deciding the final order of the VCs under comparison. Table 13 shows the distance values of the alternatives with respect to the PIS and the average solution point. Table 14 highlights the OPID, ONID, R_{I}, and $\mathrm{PS_i}$ values and the final ranks of the VCs.

It is seen that $A_3 > A_1 > A_2 > A_7 > A_4 > A_8 > A_5 > A_6$. Hence, Google Meet, Zoom, and Microsoft Teams are found to be more popular than others. However, being a more sophisticated tool, Webex stands at position 5 because of its cost element. It is interesting to note that WhatsApp holds the 4th position perhaps because of its wide availability and better mobility.

4.1. Validation. The reliability of the results obtained from any MCDM model depends on various underlying assumptions, such as criteria selection and their interrelationship, choice of the algorithm given the context and its ability to reflect the true picture, variations in the criteria weights, change in the alternative and criteria, and so on [87, 88]. Hence, it is necessary to carry out the validation test for ensuring the robustness and stability in the final solution [89–91]. We check the validity in the following ways:

(a) Comparing the results obtained from our method with those derived using other established algorithms [92–95].

(b) Checking for rank reversal test. Rank reversal is a phenomenon, wherein the original order of the alternatives gets disturbed with the effect of change in the given conditions, e.g., change in the alternative set. In effect, we get an illogical and unreliable result [96].

In the present study, we carry out the comparative analysis of the VC platforms using the PF-TOPSIS method [97] and MABAC [98] algorithm using the actual scores of PFNs. Table 15 shows that there are no variations in the comparative positions of the alternatives. Figure 2 reflects the findings.

To test the existence of any rank reversal phenomenon, we deliberately remove alternative A_2 from the list and carry out the comparative analysis using the PF-FUCOM-PROBID model. Following are the findings:

Original ranking (with A_2): $A_3 > A_1 > A_2 > A_7 > A_4 > A_8 > A_5 > A_6$

New ranking (without A_2): $A_3 > A_1 > A_7 > A_4 > A_8 > A_5 > A_6$

The findings clearly suggest that there is no evidence of rank reversal. Hence, we may conclude that our model provides valid and reliable results.

4.2. Sensitivity Analysis. Sensitivity analysis is carried out to check the extent the original ranking provided by a MCDM model may get distorted because of the variations in the given conditions, and thereby, ascertaining the robustness and stability in the results [99–101]. There are a number of ways the sensitivity analysis is performed in the extant literature, such as proportionate change in the criteria weights, while maintaining the sum of the weights equal to 1, exchange of weights among the criteria, and so on [96, 101, 102].

In this paper, we generate the following scenarios:

(i) Decrease the weight of C1 (highest priority criterion) by 10% and adjust the amount of decrease in the total weight by increasing the weights of other criteria proportionately for ensuring the sum of weights = 1

(ii) Decrease the weight of C3 (the next highest priority criterion) by 10% and adjust the amount of decrease in the total weight by increasing the weights of other criteria proportionately for ensuring the sum of weights = 1

(iii) Increase the weight of C1 (highest priority criterion) by 10% and adjust the amount of increase in the total weight by decreasing the weights of other criteria proportionately for ensuring the sum of weights = 1

(iv) Increase the weight of C3 (the next highest priority criterion) by 10% and adjust the amount of increase

Table 10: Decision matrix expressed in the PF domain.

VC type		*C1*			*C2*			*C3*			*C4*	
A1	0.643	0.286	0.071	0.786	0.143	0.071	0.571	0.357	0.071	0.571	0.214	0.214
A2	0.500	0.429	0.071	0.571	0.357	0.071	0.643	0.286	0.071	0.643	0.286	0.071
A3	0.786	0.143	0.071	0.714	0.143	0.143	0.714	0.214	0.071	0.571	0.286	0.143
A4	0.143	0.429	0.429	0.357	0.500	0.143	0.500	0.286	0.214	0.357	0.500	0.143
A5	0.071	0.714	0.214	0.071	0.714	0.214	0.071	0.643	0.286	0.143	0.500	0.357
A6	0.071	0.643	0.286	0.071	0.571	0.357	0.071	0.643	0.286	0.071	0.571	0.357
A7	0.714	0.214	0.071	0.500	0.214	0.286	0.357	0.357	0.286	0.214	0.429	0.357
A8	0.071	0.571	0.357	0.357	0.429	0.214	0.357	0.429	0.214	0.214	0.643	0.143
VC type		C5			C6			C7			C8	
A1	0.429	0.357	0.214	0.714	0.143	0.143	0.286	0.500	0.214	0.429	0.429	0.143
A2	0.500	0.429	0.071	0.786	0.143	0.071	0.786	0.143	0.071	0.500	0.357	0.143
A3	0.429	0.214	0.357	0.786	0.143	0.071	0.357	0.571	0.071	0.286	0.357	0.357
A4	0.214	0.643	0.143	0.214	0.500	0.286	0.286	0.643	0.071	0.286	0.643	0.071
A5	0.286	0.500	0.214	0.071	0.500	0.571	0.071	0.571	0.357	0.071	0.786	0.143
A6	0.143	0.714	0.143	0.143	0.071	0.786	0.071	0.714	0.214	0.071	0.714	0.214
A7	0.500	0.357	0.143	0.571	0.286	0.143	0.357	0.500	0.143	0.286	0.214	0.500
A8	0.429	0.429	0.143	0.500	0.357	0.143	0.357	0.500	0.143	0.429	0.357	0.214

Note: the colors are representing the nature of the criteria; green: maximizing criteria and red: minimizing criteria.

Table 11: Weighted normalized PF-DMT (NPF-DMT).

Criteria/alternatives		C1			C2			C3			C4	
A1	0.1363	0.0606	0.0151	0.1666	0.0303	0.0151	0.1034	0.0646	0.0129	0.0737	0.0276	0.0276
A2	0.1060	0.0909	0.0151	0.1211	0.0757	0.0151	0.1164	0.0517	0.0129	0.0829	0.0369	0.0092
A3	0.1666	0.0303	0.0151	0.1514	0.0303	0.0303	0.1293	0.0388	0.0129	0.0737	0.0369	0.0184
A4	0.0303	0.0909	0.0909	0.0757	0.1060	0.0303	0.0905	0.0517	0.0388	0.0461	0.0645	0.0184
A5	0.0151	0.1514	0.0454	0.0151	0.1514	0.0454	0.0129	0.1164	0.0517	0.0184	0.0645	0.0461
A6	0.0151	0.1363	0.0606	0.0151	0.1211	0.0757	0.0129	0.1164	0.0517	0.0092	0.0737	0.0461
A7	0.1514	0.0454	0.0151	0.1060	0.0454	0.0606	0.0646	0.0646	0.0517	0.0276	0.0553	0.0461
A8	0.0151	0.1211	0.0757	0.0757	0.0909	0.0454	0.0646	0.0776	0.0388	0.0276	0.0829	0.0184
Criteria/alternatives		C5			C6			C7			C8	
A1	0.0141	0.0236	0.0283	0.0086	0.0017	0.0017	0.0323	0.0565	0.0242	0.0106	0.0317	0.0317
A2	0.0047	0.0283	0.0330	0.0094	0.0017	0.0009	0.0888	0.0161	0.0081	0.0106	0.0264	0.0370
A3	0.0236	0.0141	0.0283	0.0094	0.0017	0.0009	0.0404	0.0646	0.0081	0.0264	0.0264	0.0211
A4	0.0094	0.0424	0.0141	0.0026	0.0060	0.0034	0.0323	0.0726	0.0081	0.0053	0.0476	0.0211
A5	0.0141	0.0330	0.0189	0.0009	0.0060	0.0069	0.0081	0.0646	0.0404	0.0106	0.0581	0.0053
A6	0.0094	0.0471	0.0094	0.0017	0.0009	0.0094	0.0081	0.0807	0.0242	0.0159	0.0529	0.0053
A7	0.0094	0.0236	0.0330	0.0069	0.0034	0.0017	0.0404	0.0565	0.0161	0.0370	0.0159	0.0211
A8	0.0094	0.0283	0.0283	0.0060	0.0043	0.0017	0.0404	0.0565	0.0161	0.0159	0.0264	0.0317

Note: the colors are representing the nature of the criteria; green: maximizing and red: minimizing criteria.

Table 12: PIS values.

	PIS		C1			C2			C3			C4	
1st PIS (i.e., most PIS)	PIS 1	0.1666	0.0303	0.0151	0.1666	0.0303	0.0151	0.1293	0.0388	0.0129	0.0829	0.0276	0.0092
2nd PIS	PIS 2	0.1514	0.0454	0.0151	0.1514	0.0303	0.0151	0.1164	0.0517	0.0129	0.0737	0.0369	0.0184
3rd PIS	PIS 3	0.1363	0.0606	0.0151	0.1211	0.0454	0.0303	0.1034	0.0517	0.0129	0.0737	0.0369	0.0184
	PIS 4	0.1060	0.0909	0.0151	0.1060	0.0757	0.0303	0.0905	0.0646	0.0388	0.0461	0.0553	0.0184
	PIS 5	0.0303	0.0909	0.0454	0.0757	0.0909	0.0454	0.0646	0.0646	0.0388	0.0276	0.0645	0.0276
	PIS 6	0.0151	0.1211	0.0606	0.0757	0.1060	0.0454	0.0646	0.0776	0.0517	0.0276	0.0645	0.0461
	PIS 7	0.0151	0.1363	0.0757	0.0151	0.1211	0.0606	0.0129	0.1164	0.0517	0.0184	0.0737	0.0461
Most NIS	PIS 8	0.0151	0.1514	0.0909	0.0151	0.1514	0.0757	0.0129	0.1164	0.0517	0.0092	0.0829	0.0461
	PIS		C5			C6			C7			C8	
1st PIS (i.e., most PIS)	PIS 1	0.0236	0.0141	0.0094	0.0094	0.0009	0.0009	0.0888	0.0161	0.0081	0.0370	0.0159	0.0053
2nd PIS	PIS 2	0.0141	0.0236	0.0141	0.0094	0.0017	0.0009	0.0404	0.0565	0.0081	0.0264	0.0264	0.0053
3rd PIS	PIS 3	0.0141	0.0236	0.0189	0.0086	0.0017	0.0017	0.0404	0.0565	0.0081	0.0159	0.0264	0.0211
	PIS 4	0.0094	0.0283	0.0283	0.0069	0.0017	0.0017	0.0404	0.0565	0.0161	0.0159	0.0264	0.0211
	PIS 5	0.0094	0.0283	0.0283	0.0060	0.0034	0.0017	0.0323	0.0646	0.0161	0.0106	0.0317	0.0211
	PIS 6	0.0094	0.0330	0.0283	0.0026	0.0043	0.0034	0.0323	0.0646	0.0242	0.0106	0.0476	0.0317
	PIS 7	0.0094	0.0424	0.0330	0.0017	0.0060	0.0069	0.0081	0.0726	0.0242	0.0106	0.0529	0.0317
Most NIS	PIS 8	0.0047	0.0471	0.0330	0.0009	0.0060	0.0094	0.0081	0.0807	0.0404	0.0053	0.0581	0.0370

Table 13: Distance values of each alternative from the PIS and average solution.

VC type	Distance from PIS #								Distance from avg. solution
	1	2	3	4	5	6	7	8	
A1	0.10422	0.05193	0.0586651	0.10291	0.1785	0.20684	0.27749	0.30472	0.1180
A2	0.12171	0.11391	0.0887917	0.09009	0.15321	0.17765	0.25227	0.27726	0.1055
A3	0.07896	0.04143	0.0652824	0.12673	0.20519	0.23986	0.30885	0.33532	0.1444
A4	0.23892	0.19737	0.1653009	0.12223	0.06792	0.07522	0.14386	0.16437	0.0988
A5	0.34357	0.29917	0.2619837	0.2018	0.13961	0.1137	0.06117	0.07208	0.1817
A6	0.33947	0.29238	0.2554872	0.19882	0.12938	0.10887	0.04411	0.0645	0.1745
A7	0.15199	0.11339	0.0941239	0.09224	0.15028	0.18325	0.23285	0.26011	0.1006
A8	0.25753	0.21838	0.1837943	0.12758	0.05435	0.04936	0.11265	0.13675	0.1040

Table 14: Ranking of the VCs.

VC type	OPID	ONID	R_i	PS$_\mathrm{i}$	Rank
A1	0.1755	0.5570	0.3150	1.0278	2
A2	0.2308	0.5009	0.4607	0.9304	3
A3	0.1531	0.6210	0.2466	1.0871	1
A4	0.4233	0.2784	1.5206	0.4007	5
A5	0.6309	0.1755	3.5957	0.2535	7
A6	0.6205	0.1552	3.9985	0.2334	8
A7	0.2631	0.4752	0.5537	0.8659	4
A8	0.4599	0.2231	2.0612	0.2945	6

Table 15: Results of the comparative analysis of results.

VC type		Rank		
		PF-PROBID	PF-TOPSIS	PF-MABAC
A1	Zoom	2	2	2
A2	Microsoft Teams	3	3	3
A3	Google Meet	1	1	1
A4	Webex	5	5	5
A5	GotoMeeting	7	7	7
A6	We Chat	8	8	8
A7	WhatsApp	4	4	4
A8	Skype	6	6	6

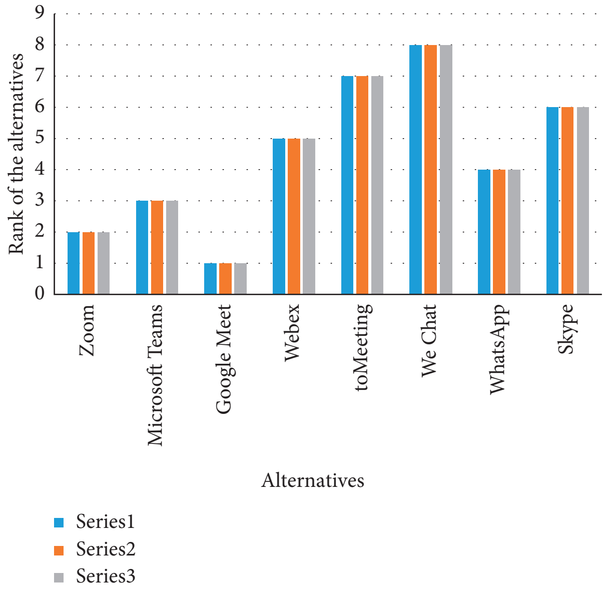

Figure 2: Results of the comparison of results of different MCDM algorithms (Series 1: PF-PROBID; Series 2: PF-TOPSIS; Series 3: PF-MABAC).

Table 16: Sensitivity analysis scenarios.

Scenario	Criteria weights							
	C1	C2	C3	C4	C5	C6	C7	C8
Original	0.2120	0.2120	0.1810	0.1290	0.0660	0.0120	0.1130	0.0740
Case I	0.1908	0.2150	0.1840	0.1320	0.0690	0.0150	0.1160	0.0770
Case II	0.2146	0.2146	0.1629	0.1346	0.0716	0.0176	0.1186	0.0796
Case III	0.2332	0.2090	0.1780	0.1260	0.0630	0.0090	0.1100	0.0710
Case IV	0.2094	0.2094	0.1991	0.1264	0.0634	0.0094	0.1104	0.0714
Case V	0.2118	0.2118	0.1808	0.1288	0.0658	0.0132	0.1128	0.0738
Case VI	0.2111	0.2111	0.1801	0.1281	0.0726	0.0111	0.1121	0.0731

in the total weight by decreasing the weights of other criteria proportionately for ensuring the sum of weights = 1

(v) Increase the weight of C6 (the least priority criterion) by 10% and adjust the amount of increase in the total weight by decreasing the weights of other criteria proportionately for ensuring the sum of weights = 1

(vi) Increase the weight of C5 (the minimizing criterion having low weight) by 10% and adjust the amount of increase in the total weight by decreasing the weights of other criteria proportionately for ensuring the sum of weights = 1

Table 16 exhibits the different scenarios for sensitivity analysis. We carry out the comparative analysis of VC platforms under all the above-mentioned situations using the PF-PROBID method.

Table 17 confirms that there is no change in the comparative positions of the VC types despite variations in the criteria weights. Figure 3 also pictorially reflects the same fact. We further check for any significant variations in the performance scores for the alternatives obtained from various algorithms. Figure 4 confirms that there is no substantial variation too. Hence, we conclude that our model provides a notably robust and stable solution.

5. Research Implications

The present research provides a number of implications. Firstly, we have extended the fundamental model of PROBID method using PFN. PROBID is a useful method combining the features of two other powerful models, namely TOPSIS and EDAS. Within our limited search, we could not notice any single application of PROBID. The present paper shall provide a robust and reliable decision support framework to the researchers for solving complex real-life problems with imprecise information under uncertainty. Secondly, usability and UX are powerful frameworks for analyzing user behaviors. A plethora of work has been conducted using traditional models like TAM. Furthermore, the applications of UX so far have been restricted to the engineering domain. We believe that UX has a promising future for application in social science research. Thirdly, as we are moving toward a digitally operated world, there is a need to investigate from every perspective to define a user-friendly and technologically sound teaching-learning mechanism. We address a contemporary problem of comparison of VC platforms in the context of higher education, which has undergone a paradigm shift with the effect of Covid-19. VC is a necessity today for education. In this regard, the present work provides a new perspective to the decision makers and policy makers. The findings of this paper suggest that the factors like wide availability, flexibility, cost, quality of transmission, and ease of use are required to be given emphasis for effective teaching and learning using VC tools. In this context, the present study allures us to investigate the criteria determining the efficacy of the teaching and learning using virtual media vis-à-vis its offline counterpart. It is evident that our model is useful in providing directions for effective management of virtual offices and workforces which would play critical roles for ensuring business success in future.

Table 17: Result of sensitivity analysis.

VC type	Ranking						
	Original	Case I	Case II	Case III	Case IV	Case V	Case VI
A1	2	2	2	2	2	2	2
A2	3	3	3	3	3	3	3
A3	1	1	1	1	1	1	1
A4	5	5	5	5	5	5	5
A5	7	7	7	7	7	7	7
A6	8	8	8	8	8	8	8
A7	4	4	4	4	4	4	4
A8	6	6	6	6	6	6	6

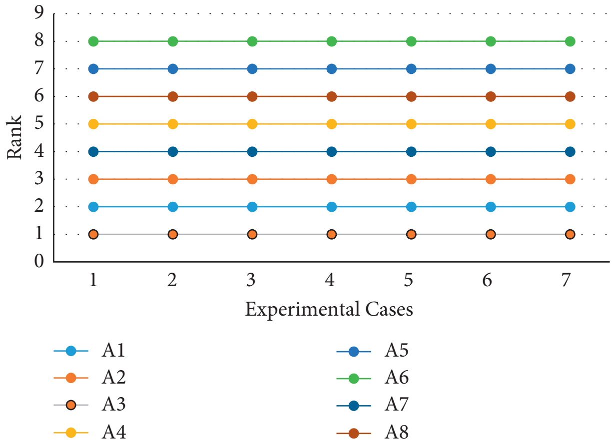

Figure 3: Sensitivity analysis.

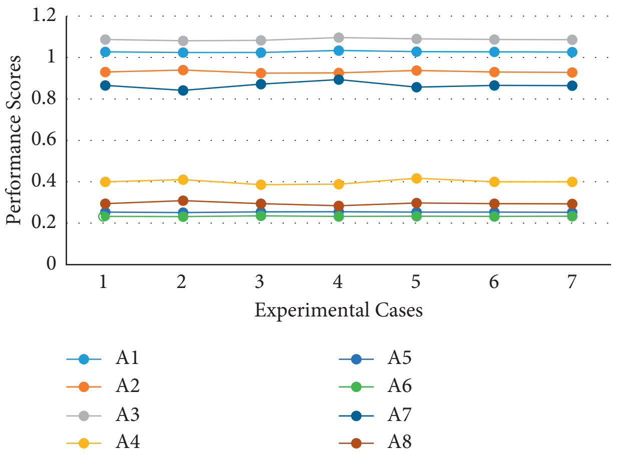

Figure 4: Variations in the performance scores during sensitivity analysis.

6. Conclusion

In this paper, we select a set of popular VC platforms used in higher education in India, such as Zoom, Microsoft Teams, Google Meet, Webex, GotoMeeting, We Chat, WhatsApp, and Skype. We use the theoretical foundation of usability and user experience (UX) and the opinions of the past work to identify eight criteria, namely user friendliness, compatibility, quality of transmission, features, bandwidth consumption, awareness, security and privacy, and cost to compare the VC platforms. We provide a novel extension of a very recently developed MCDM method called PROBID with PFN for comparison. The FUCOM method with the actual score measures of PFN is used to derive the criteria weights. We find that users have given more emphasis on the ease of operations, compatibility with multiple systems and devices, quality of the voice and video transmission, and features. While comparing, we notice that Zoom, Microsoft Teams, and Google Meet are preferred by the users. It is interesting to note that WhatsApp comes under the top five bracket because of its wide awareness and availability at less cost. It suggests that only features are not the deciding factors. Wide availability, flexibility, cost, quality of transmission, and ease of use differentiate the VC platforms, which supports our initial proposition. The result of the proposed model shows stability and robustness as evident from the validation test and sensitivity analysis.

The advantage of our proposed PF-FUCOM-PROBID framework are as follows: (a) the model provides a better ability to analyze user experiences regarding the use of VC tools with PFNs, (b) a lesser number of pairwise comparisons, which, in turn, hold better control over subjective bias and decision inconsistency, (c) ability to work with larger criteria set without losing stability and provision of reasonable robustness, (d) both positive ideal and average solutions are considered, which, in turn, broaden the perspective, and (e) free from rank reversal issue. However, some of the limitations of our analysis are as follows: (a) for a large number of criteria set, FUCOM works equally well, however, PROBID incorporates a little bit of added computational complexity as it requires to formulate a PIS matrix and calculation of the distances of the alternatives from each PIS value, (b) a small group of respondents took part in the study, which invokes the necessity of the model to be tested with a large-scale group decision-making scenario.

Furthermore, we find some scope of extensions for our work. Firstly, one of the observed limitations of the PROBID method is its computational complexity, which may be further tested with larger alternatives and criteria sets. Since PROBID has not been utilized in various kinds of problems, future applications may test its efficacy. It is the second scope. Thirdly, our model may be extended by various other fuzzy numbers, such as SFS, PyFS, and qROFS, to name a few. The fourth point is that other aggregations operators, such as Dombi-Bonferroni aggregation and Hamacher aggregation, among others, may be applied, and the results may be compared. The fifth point is that, in our work, we observe a very limited number of responses. The understanding of the comparative utility of VC tools may be further examined using more heterogeneous groups of a large number of respondents. The sixth point is that we have used only the UX theory. However, consumers also show a varying level of adaptability to various technologies. Hence, the theories, such as UTAUT2 and TAM, may also be utilized for formulating the criteria set. The seventh point is that there are some operational criteria in measurable terms. For example, the category of subscription, number of participants allowed, security options, transmission bandwidth, system requirement, and package-wise cost involvement are some of the operational criteria that may be included to compare the VC tools. In this research work, we have provided a primary level analysis through the lens of the UX theory alone. In an extended work, we plan to incorporate measurable operational criteria and user experience-based attributes to provide a more exhaustive analysis. Nevertheless, though the present paper has some future scopes, we believe that the usefulness and implications of our research do not get undermined because of that. We are hopeful that the present work shall find its relevance in formulating online communication and designing the VC products for facilitating remote teaching-learning in the future.

Data Availability

The data used to support the findings of this study are included within this article. However, the reader may contact the corresponding author for more details on the data.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

All authors contributed equally and significantly in conducting this research work and writing this paper.

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