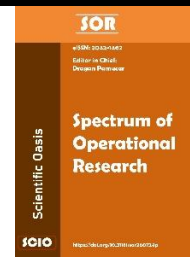




SCIENTIFIC OASIS

Spectrum of Operational Research

Journal homepage: www.sor-journal.org
ISSN: 3042-1470

Students' Perceptions About the Webinars: An Intuitionistic Fuzzy Force Field Analysis

Sanjib Biswas^{1,*}, Aparajita Sanyal¹, Dragan Pamucar²¹ Amity Business School, Amity University Kolkata, Major Arterial Road, AA II, Newtown, West Bengal 700135, India² Faculty of Organizational Sciences, Department of Operations Research and Statistics, Belgrade, Serbia

ARTICLE INFO

Article history:

Received 10 July 2024

Received in revised form 25 October 2024

Accepted 10 November 2024

Available online 12 November 2024

Keywords:

COVID-19; Webinars; Intuitionistic fuzzy sets; Forced field analysis; Full consistency method; FUCOM.

ABSTRACT

Aftermath of the recent pandemic, online learning has emerged as an essential aid that uses webinars frequently. However, there is a little or no evidence of work which discerned the usefulness of the webinars by considering both positive and negative forces. To this end, the present work exhibits a new Intuitionistic Fuzzy Number (IFN) based force field analysis (FFA) to compare the influences of both driving factors (DFs) and restraining factors (RFs). A group of 91 students participated in the study. The current work presents wherein the full consistency method (FUCOM) has been utilized to find the weights of the DFs and RFs. Overall, the current work shows that the aggregated score of DF is more than that of the opposing forces (i.e., RF). Therefore, it is evident that webinars are the accepted situation post-pandemic. The current study shall provide useful direction for designing hybrid learning.

1. Introduction

Since its first appearance in the Wuhan, China the novel coronavirus (aka COVID-19) quickly got spread over the entire world. The long lasting effect of COVID-19 has been witnessed in all spheres of the socio-cultural and economic environment [1]. To break the chain of transmission of the virus and curb the infection rate, the countries went into lockdown and imposed restrictions on social movements. As a result, the teaching and learning got suffered massively due to closure for prolonged period [2]. The effect of COVID 19 on education is immense, if not the worst. There have been several phases where the countries were compelled to declare short to medium term shutdown even after the vaccination drives for combating the effect of second, third and fourth waves. During all these shutdown phases, education got affected enormously.

To restore the continuity of education, universities and institutes started adopting digital platforms increasingly for teaching and learning [3]. The age-old traditional education system underwent a metamorphosis as the conventional face-to-face teaching and learning got changed to online learning. The transitions took place because of compulsion with little or no availability of other

* Corresponding author.

E-mail address: sanjibb@acm.org<https://doi.org/10.31181/sor21202513>

options. Of course, the technological developments have had supported the transition but, the pandemic played a role of a catalyst. To show the resilience, the educators were compelled to resort to online teaching and learning as an emergent necessity [4]. The experts believe that online learning has become a regular phenomenon now despite the world has been able to come out of the initial uncharted impact of coronavirus. The education system has been able to resume offline teaching and learning along with continuation of the online option.

However, the transition from offline to online and then resorting to hybrid mode has never been a smooth affair. The educators and learners had to face a lot of challenges to become aware of the new system, overcome the mental barrier for adaptation of the online learning and adjust and learn the *modus operandi*. Especially, the learners with rigid mind-set found the online learning very difficult to adopt. Besides, the educators had faced challenges to realign the pedagogy and assessment process [4].

The researchers have made a lot of efforts in discussing the impact of the coronavirus on education, designing the roadmap for new normal education system and formulating strategies. There has been a number of contributions made to explore the prospects and obstacles of online teaching and learning. For instance, a past work has designed an enquiry based on open ended semi-structured interviews to understand the user (educators and learners) perceptions about the online learning amidst the crisis [5]. The study reported similar type of perceptions of the educators and learners in terms of adaptability and requirement of support system for the new system. A past work mentioned some of the challenges of online learning such as difficulties in accessing and using technologies for online teaching and learning, adjustment to new system (especially for rural students and learners from low-income group) and mental anxiety [6]. Another study was done understanding the extent to which the learners accept the learning using the digital tools [7]. The authors noted that an appropriate mix of traditional face-to-face and new online teaching and learning is preferred by the students.

The institutions as well as the organizations had to rely on conducting the mass communications, events, meetings and teaching and learning using the online platforms conforming to the social distancing norms and COVID 19 protocols. After the rapid spread of the coronavirus, online teaching and learning through webinars have emerged as the only option to serve the purpose. Even today, webinars are being conducted extensively although institutions have returned to physical operations. In this context, questions may arise "Are these webinars effective? Do the users perceive the webinars as useful and acceptable?". In view of the same, there has been a number of studies conducted. For instance, an earlier work focused on investigating the perceptions of the post-graduate students about the effectiveness of the webinars and user satisfaction level for the course of mathematics [8]. The study considered three aspects such as user engagement, complexity of the use and fulfilment of the purpose or task. The authors argued for enhancing the engagement of the students through innovative teaching and learning activities, efficient use of learning hours and user-friendliness of the technology aids for ensuring the effectiveness of the webinars. A former study found favourable responses for the online teaching and learning through webinars [9,10]. The authors also compared a number of webinar tools and reported Go-To-Webinar platform as the most favoured option.

Given the complexities of the uncharted transition to the online teaching and learning, earlier research emphasized on hybrid mode of learning with both synchronous and asynchronous strategies based on Discover, Learn, Practice, Collaborate and Assess (DLPCA) [11]. The authors noted that DLPCA is positively accepted by both the educators and learners. However, the challenges are familiarity of the tools and internet connectivity. Another work further noted the complexity drivers such as inadequate facilities and dearth of the knowledge of the educators (especially elders) for

using advanced technological tools affecting the effectivity of the webinars [3]. To make the webinars useful and effective, it is important to focus on creating an enjoyable experience for both educators and learners [11]. Despite a number of challenges, the webinars have also opened several new opportunities. It allows the users to attend the remote classes as per their convenience (time and place) and ensure the continuity of learning [12]. To make the webinars effective for the students, it is important to consider the aspects like health conditions and economic situations besides the technical parameters [13]. The webinars need to be made simply accessible, lucid and engaging with feelings, innovative and precise [14].

1.1 Research Gap

From the discussions made above, it is evident that webinars are useful options for teaching and learning amidst the disruptions like COVID 19. Previous studies show that E-learning offers many benefits for students because it is more flexible, and it can also improve interaction with students by utilizing asynchronous and synchronous tools such as e-mail, forums, chats, videoconferences. Furthermore, the developments in the field of information and communication technology have helped in conducting the webinars. The internet technologies facilitate the distribution of content at the same time, to a large number of users. However, for achieving the effectivity, there is a requirement to understand the complexities and formulate countermeasures also. One of the major challenge lies in embracing the change and imbibing the new system for deriving maximum benefits. In this regard, there has not been significant contributions made for exploring the perceptions of the students about the online webinars experience during the coronavirus pandemic in order to improve and strengthen the online learning system. Some recent studies in the related field have attempted to address the concerned issue. For example, one study was conducted on classification of the online behaviours [15]. It is seen from their work that there is a gap between the behaviour toward the computer assisted communication and communicated message, especially the ambiguity in defining the nature of the online behaviour. The authors provided a new taxonomy based on the evolved behaviour (online or offline) and its effect on the interaction with the internet-based technologies. The attitude of the virtual followers and audiences also significantly influences the participation level [16]. Earlier research has examined the immediate aftershock response of the teachers in adopting the virtual medium for teaching and learning [17]. The authors found two major issues such as lack of digital competence and support from the institutions. In this regard, some researchers felt the need of utilization of the analytical tools and mechanisms to continuously monitor the behaviours of the students while using the virtual platform [18].

However, there is a gap in the literature that examines the student's view on the use of online learning through webinars and how it influences their understanding and assimilation of information. The present work is motivated to fill the aforesaid gaps in literature.

1.2 Research objectives

The present work aims to investigate the effectiveness of the online webinars from higher education students' perspective. To this end the current study identifies the positive and negative aspects that students encountered while learning online through webinars. Next, an attempt has been made to compare the influence of supporting and restraining forces by carrying out the FFA. Since user opinions reflect the behavioral natures and are influenced by subjective bias, we carry out the FFA using IFS. In this way our work fills the gap in literature.

1.3 Contributions of the paper

In what follows are the main contributions of the paper.

- i. The world after COVID 19 has moved to blended mode for teaching and learning and organizing various events. However, despite of all apparent benefits and requirements of compelling situations, it may be noted that the impact of digital divide is still not exhaustively studied. In this regard, the current study is of importance in understanding the perception of the users (students) about the webinars.
- ii. From technical point of view, the extant literature does not show visible evidence of use of intuitionistic fuzzy sets in carrying out FFA for investigating perception of the users regarding a new way of technology driven operation.
- iii. The present work utilizes FUCOM for prioritizing the DFs and RFs.
- iv. The current study considers the opinions of a large number of respondents (91) wherein a significant consistency in group decision-making and reliable result is ensured.

The rest of the paper is presented as follows. In section 2 some preliminary concepts and definitions of IFS are provided. Section 3 discusses the research methodology. In section 4 a summary of the findings is given. Section 5 includes a brief discussion on the findings. Section 6 concludes the paper and mentions some of the future scope for further research.

2. Preliminaries: IFS

IFS has been developed to include the non-membership degree [19] which was not defined in the classical Fuzzy Set (FS) theory [20]. IFS provides the following advantages as compared with the classical FS [21,22]. First, IFS allows the decision-makers (DM) to separately find out the degree of membership, non-membership and subsequently, the degree of indeterminacy for some quantity. Secondly, using IFS the DM is able to carry out more granular analysis than classical FS with greater reliability. Because of its greater efficiency in analysing uncertain situations, IFS has been extensively used in various real-life problems. Some of the recent applications are comparing the restaurants based on their preparedness to protect from COVID exposure [23], identifying critical components of the products for reliability assessment [24], environmental planning for towns [25], comparative assessment of the coronavirus vaccines to test their efficiencies using intuitionistic fuzzy MAIRCA (IF-MAIRCA) [26], supplier selection from sustainability perspective [27], smart city planning and crowd behaviour analysis for better surveillance to prevent from the terrorist attacks using [28], assessment of software quality [29] and hospitalization decision-making for COVID patients [30] among others. IFS has also been used in the education management, for example, evaluation of teaching quality for the course of physical education [31,32], assessment of literacy levels of the rural residents related to health information [33] etc. In the area of consumer behaviour analysis, IFS has been utilized by many researchers, for instance, comparative ranking of the hospitals based on offered service quality [34], customer analysis and segmentation [35], consumer preference behaviour analysis for online shopping [36] to name a few.

In this section we exhibit some of the fundamental definitions and operations of IFS.

Definition 1. Let, X is the universe of discourse. Then a IFS A is defined as

$$A = \left\{ \langle x, \mu_A(x), \vartheta_A(x) \rangle \mid x \in X \right\} \quad (1)$$

Where, the functions are the following:

$\mu_A : X \rightarrow [0, 1]$ is describing the degree of membership and $\vartheta_A : X \rightarrow [0, 1]$ is describing the degree of non-membership of the element $x \in X$ to A , correspondingly, and for every $x \in X$

$$0 \leq \mu_A(x) + \vartheta_A(x) \leq 1 \quad (2)$$

For each IFS A in X, the degree of indeterminacy is derived as

$$\pi_A(x) = 1 - \mu_A(x) - \mathcal{G}_A(x) \quad (3)$$

For computational convenience, an IFS is expressed as $\alpha = (\mu, \mathcal{G})$ where, α is the intuitionistic fuzzy number (IFN) without losing the conventional meaning [37] where, $\mu \in [0,1]; \mathcal{G} \in [0,1]; \mu + \mathcal{G} \leq 1$

For instance, $\alpha = (\mu, \mathcal{G}) = (0.3, 0.2)$ means the degree of membership is 0.3, non-membership is 0.2 and the degree of abstentions is $(1 - 0.3 - 0.2) = 0.5$

Definition 2. Basic operations

Let, $\alpha = (\mu, \mathcal{G}), \alpha_1 = (\mu_1, \mathcal{G}_1)$ and $\alpha_2 = (\mu_2, \mathcal{G}_2)$ are the three IFNs

Then, following are basic operational laws [37,38].

$$\alpha_1 \oplus \alpha_2 = (\mu_1 + \mu_2 - \mu_1\mu_2, \mathcal{G}_1\mathcal{G}_2) \quad (4)$$

$$\alpha_1 \otimes \alpha_2 = (\mu_1\mu_2, \mathcal{G}_1 + \mathcal{G}_2 - \mathcal{G}_1\mathcal{G}_2) \quad (5)$$

$$\lambda\alpha = (1 - (1 - \mu)^\lambda, \mathcal{G}^\lambda); \lambda > 0 \quad (6)$$

$$\alpha^\lambda = (\mu^\lambda, 1 - (1 - \mathcal{G})^\lambda); \lambda > 0 \quad (7)$$

Definition 3. Score and Accuracy function

Following the definitions given to calculate the score, based on which the score of an IFS is expressed as [38,39]:

$$s(\alpha) = \mu - \mathcal{G} \quad (8)$$

Where, $s(\alpha) \in [-1, 1]$.

The larger is the dispersion of the degree of membership from the degree of non-membership, higher is the score value of an IFS.

The accuracy of an IFS is derived by using the following expression

$$h(\alpha) = \mu + \mathcal{G} \quad (9)$$

Where $h(\alpha) \in [0, 1]$.

The general comparison rule is as follows

- i. If $s(\alpha_1) > s(\alpha_2)$ then $\alpha_1 > \alpha_2$
- ii. If $s(\alpha_1) < s(\alpha_2)$ then $\alpha_1 < \alpha_2$
- iii. If $s(\alpha_1) = s(\alpha_2)$ then if $h(\alpha_1) < h(\alpha_2)$ then $\alpha_1 < \alpha_2$

Definition 4. Improved score function

In a recent paper, Chen *et al.*, [41] developed an improved score function which is given as

$$s^*(\alpha) = \mu - \mathcal{G} + (\mu^2 - \mathcal{G}^2)\pi \quad (10)$$

The extant literature shows several aggregation schemes for IFNs. Here, we provide some of the basic definitions [39-41].

Definition 5. Intuitionistic fuzzy weighted aggregation of IFNs

Let, $\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n$ be a set of n IFNs with usual definitions as provided in the expressions (1) to (3). Then, the intuitionistic fuzzy weighted average (IFWA) is expressed as

$$IFWA(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n) = \bigoplus_{i=1}^n (w_i \alpha_i) = \left(1 - \prod_{i=1}^n (1 - \mu_{\alpha_i})^{w_i}, \prod_{i=1}^n \mathcal{G}_{\alpha_i}^{w_i} \right) \quad (11)$$

Here, $\alpha_n = (\mu_{\alpha_i}, \mathcal{G}_{\alpha_i}); i = 1, 2, \dots, n$ is the set of IFNs with the weights $w_1, w_2, w_3, \dots, w_n (w_i \geq 0; \sum_{i=1}^n w_i = 1)$

Definition 6. Intuitionistic fuzzy weighted geometric aggregation of IFNs.

The definition 5 is further extended by combining IFWA and the geometric mean to define the Intuitionistic fuzzy weighted geometric (IFWG) aggregation.

$$IFWG(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n) = \bigotimes_{i=1}^n (\alpha_i^{w_i}) = \left(\prod_{i=1}^n \mu_{\alpha_i}^{w_i}, 1 - \prod_{i=1}^n (1 - \mathcal{G}_{\alpha_i})^{w_i} \right) \quad (12)$$

Here, $\alpha_n = (\mu_{\alpha_i}, g_{\alpha_i}); i = 1, 2, \dots, n$ is the set of IFNs with the weights $w_1, w_2, w_3, \dots, w_n (w_i \geq 0; \sum_{i=1}^n w_i = 1)$

Definition 7. Generalized Intuitionistic fuzzy weighted aggregation (GIFWA) of IFNs

In this context, the researcher generalized the basic definition of IFWA. Accordingly, the GIFWA operator is defined as [42]:

$$GIFWA(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_n) = \left(\left(\bigoplus_{i=1}^n (w_i \alpha_i^\lambda) \right)^{\frac{1}{\lambda}} = \left\langle \left(1 - \prod_{i=1}^n (1 - \mu_{\alpha_i}^\lambda)^{w_i} \right)^{\frac{1}{\lambda}}, 1 - \left(1 - \prod_{i=1}^n (1 - (1 - g_{\alpha_i})^\lambda)^{w_i} \right)^{\frac{1}{\lambda}} \right\rangle \right) \quad (13)$$

Here, $\alpha_n = (\mu_{\alpha_i}, g_{\alpha_i}); i = 1, 2, \dots, n$ is the set of IFNs with the weights $w_1, w_2, w_3, \dots, w_n (w_i \geq 0; \sum_{i=1}^n w_i = 1)$

and $\lambda > 0$; If $\lambda = 1$ then GIFWA becomes IFWA operator.

3. IFS based Force Field Analysis (IFS-FFA)

In this paper we use an IFS based FFA. FFA is one of the widely used framework to explain the process of the planned change. The classical FFA framework considers two forces such as driving forces (DF) that support the change and restraining forces (RF) that oppose the planned change from the present state of affairs toward a new direction or state [43,44]. FFA has been widely used in social science, engineering and business management in the context of explaining the behaviour of change management [45-47].

The proposed methodology of IFS-FFA is carried out through following steps:

Step 1. Selection of the respondents

The respondent group is a mix of school students (higher standards like 11th and 12th grade), under-graduate and post-graduate students. The students are from various backgrounds like basic science, arts, social science, commerce, engineering and management. The data collection was done from 91 school students through a structured questionnaire electronically.

Step 2. Identification of the positive and negative aspects of webinars.

The positive aspects act as the driving forces (DF) in favour of the webinars while the negative aspects or problems stand as the restraining forces (RF) against the webinars. We find out the factors in tune with the previous work and subsequently, select the final list of major factors through a comprehensive discussion with a focus group of 20 students studying at post-graduate and graduate levels. The list of the DFs and RFs are summarized in Table 1.

Table 1
List of DFs and RFs

S/L	Description	Type
DF1	Greater Flexibility and Convenience	DF
DF2	Budget Friendly	DF
DF3	Collaborative and Discussion Based Learning	DF
DF4	Can use to gather knowledge in the professional field	DF
DF5	Provide access from anywhere	DF
RF1	Workload	RF
RF2	Inadequate support from instructor s and friends	RF
RF3	Technology and Internet Connectivity	RF
RF4	Distraction and Reduced Focus	RF

The respondents rate all these factors on a five point Likert scale. The linguistic scale and their corresponding IFNs [48,49] are given in Table 2.

Table 2
Linguistic variables and IFNs

Linguistic Scale	IFN	
Strongly Agree	0.90	0.10
Agree	0.75	0.20
Neither Agree nor Disagree	0.50	0.45
Disagree	0.35	0.60
Strongly Disagree	0.10	0.90

The responses of 91 respondents (in terms of IFNs corresponding to the linguistic variables as given in Table 2) for the DFs and RFs are given in Appendix A.

Step 3. Aggregation of the responses for each DF and RF.

We use the IFWA operator (see the expression (11)) to aggregate the responses of the students for each DF and RF. It may be noted that each aggregated variable is also an IFN.

$$\begin{aligned}\alpha_k &= (\mu_{\alpha_k}, \mathcal{G}_{\alpha_k}) = IFWA(\alpha_{k1}, \alpha_{k2}, \alpha_{k3}, \dots, \alpha_{kn}) \\ &= \bigoplus_{i=1}^n (w_i \alpha_{ki}) = \left(1 - \prod_{i=1}^n (1 - \mu_{\alpha_{ki}})^{w_i}, \prod_{i=1}^n \mathcal{G}_{\alpha_{ki}}^{w_i} \right)\end{aligned}\quad (14)$$

Here, $\alpha_{in} = (\mu_{\alpha_{in}}, \mathcal{G}_{\alpha_{in}}); (i=1, 2, \dots, n); (n=91)$ is the set of IFNs with the weights $w_1, w_2, w_3, \dots, w_n$ ($w_i \geq 0; \sum_{i=1}^n w_i = 1$) for k^{th} DF or RF (in our case, $k=5$ for DF and $k=4$ for RF). We give equal importance to all the respondents. Hence, $w_1 = w_2 = w_3 = \dots = w_{91}$.

Step 4. Find out the score values of the DFs and RFs

We utilize the improved score function (see expression (10)) to calculate the score values of all DFs and RFs. For instance, the score value of k^{th} DF or RF is found as

$$s^*(\alpha_k) = \mu_{\alpha_k} - \mathcal{G}_{\alpha_k} + (\mu_{\alpha_k}^2 - \mathcal{G}_{\alpha_k}^2) \pi_{\alpha_k} \quad (15)$$

Step 5. Calculate the relative priorities of the DFs and RFs separately.

The relative priorities are decided according to the weights of the DFs and RFs. We carry out the calculation of weights for DFs and RFs separately. To determine the weight of k^{th} DF or RF (i.e., w_k) we use a newly development algorithm such as FUCOM [50]. In comparison with other popular MCDM models like AHP and BWM, FUCOM provides a number of benefits [50] such as:

- Comparatively lesser number of pairwise comparison. FUCOM requires only $(n-1)$ number of pairwise comparisons for n criteria which is much lesser than AHP and BWM. As a result, FUCOM generates comparatively robust solution even under presence of a large number of criteria and decision makers. Further, the computational complexity is also less.
- FUCOM algorithm has an inbuilt mechanism for checking the validity and consistency. By calculating the value of the Deviation from Full Consistency (DFC), FUCOM ensures the reliability of the solution. The value of DFC tends to zero for reliable solutions.

Though in our case, we do not have a large number of DFs and RFs, but due to its computational benefits the use of FUCOM is justified. We use the score values of the individual DFs and RFs to calculate their weights by using FUCOM method.

FUCOM has been extensively found in the extant literature for solving various real-life complex problems. Some of the recent applications are comparing the video conferencing tools used in teaching and learning [51], assessment of attractiveness of the video streaming platforms for entertainment [52], smartphone selection [53], prioritization of the factors influencing the investment in the cryptocurrencies [54], finding out the best instrument aiding healthcare waste

disposal process [55] among others. The procedural steps for the computational algorithm are described below.

Step i) Ranking of the criteria according to their relative importance.

Suppose, $C = \{C_1, C_2, C_3, \dots, C_n\}$ is the set of criteria and following is the order of the criteria as per the preference of the decision maker $C_j(1) \succ C_j(2) \succ C_j(3) \succ \dots \succ C_j(r)$ where, r is the rank of the particular criterion. However, there may be possibility that any two criteria hold the same rank (in that case, an "=" may be used)

Step ii) Set the comparative priorities of the criteria.

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

The CP can be defined in two ways: a) based on decision-maker's rating/opinions or b) based on a predetermined scale and/or scores. The first positioned criterion is the most significant one and is compared with itself which leads to a total of $(n-1)$ number of comparisons

Step iii) Calculation of the final weight coefficients of the criteria.

The final weight values are calculated based on following two conditions:

$$\text{i. } \frac{w_r}{w_{r+1}} = \xi_{r/r+1} \quad (16)$$

$$\text{ii. Mathematical transitivity: } \frac{w_r}{w_{r+2}} = \xi_{r/r+1} \otimes \xi_{r+1/r+2} \quad (17)$$

Step iv) Formulation of the final model.

The full consistency is achieved if DFC (χ) is minimum subject to satisfaction of both the conditions as mentioned in the step 3. The final model is given by

Min χ

s.t

$$\left| \frac{w_{j(r)}}{w_{j(r+1)}} - \xi_{r/r+1} \right| \leq \chi, \forall j \quad (18)$$

$$\left| \frac{w_{j(r)}}{w_{j(r+2)}} - \xi_{r/r+1} \otimes \xi_{r+1/r+2} \right| \leq \chi, \forall j$$

$$\sum w_j = 1; w_j \geq 0 \forall j$$

Step 6. Aggregation of the individual DFs and RFs

Separately, the DFs and RFs are aggregated using IFWA to derive the total DF and total RF. We use the weights as calculated in step 5 for carrying out the IFWA operations. Both the total DF and total RF are also IFNs (see expressions (19) and (20))

$$\begin{aligned} \alpha_{DF} &= (\mu_{\alpha_{DF}}, g_{\alpha_{DF}}) = IFWA(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_m) \\ &= \bigoplus_{j=1}^m (w_j \alpha_j) = \left(1 - \prod_{j=1}^m (1 - \mu_{\alpha_j})^{w_j}, \prod_{j=1}^m g_{\alpha_j}^{w_j} \right) \end{aligned} \quad (19)$$

$$\begin{aligned} \alpha_{RF} &= (\mu_{\alpha_{RF}}, g_{\alpha_{RF}}) = IFWA(\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_t) \\ &= \bigoplus_{j=1}^t (w_j \alpha_j) = \left(1 - \prod_{j=1}^t (1 - \mu_{\alpha_j})^{w_j}, \prod_{j=1}^t g_{\alpha_j}^{w_j} \right) \end{aligned} \quad (20)$$

Here, $m (= 5)$ is the number of DFs and $t (= 4)$ is the number of RFs.

Step 7. Calculation of the score values for the total DF and total RF

In a similar way (as described in step 4) the score values are calculated as

$$s^*(\alpha_{DF}) = \mu_{\alpha_{DF}} - \vartheta_{\alpha_{DF}} + (\mu_{\alpha_{DF}}^2 - \vartheta_{\alpha_{DF}}^2)\pi_{\alpha_{DF}} \quad (21)$$

$$s^*(\alpha_{RF}) = \mu_{\alpha_{RF}} - \vartheta_{\alpha_{RF}} + (\mu_{\alpha_{RF}}^2 - \vartheta_{\alpha_{RF}}^2)\pi_{\alpha_{DF}} \quad (22)$$

The conclusion is drawn on the basis of the comparison of both these score values.

If $s^*(\alpha_{DF}) \succ s^*(\alpha_{RF})$, then it is inferred that the webinars are favourable (i.e., effective) as perceived by the students.

4. Results

In this section we present the results of the step by step analysis. Refer to the responses as given in Appendix A, we proceed for carrying out the analysis for DF and RF separately.

Given the responses recorded in an organized and formatted way in Table A1 and A2 (see Appendix A), we apply expression (14) to get the IFWA for all DFs. For instance, the IFWA for 1st DF (i.e., $k = 1$) is obtained as

$$\begin{aligned} \alpha_1 &= (\mu_{\alpha_1}, \vartheta_{\alpha_1}) = IFWA(\alpha_{11}, \alpha_{12}, \alpha_{13}, \dots, \alpha_{1n}) \\ &= \bigoplus_{i=1}^n (w_i \alpha_{1i}) = \left(1 - \prod_{i=1}^n (1 - \mu_{\alpha_{1i}})^{w_i}, \prod_{i=1}^n \vartheta_{\alpha_{1i}}^{w_i} \right) \\ &(n = 1, 2, \dots, 91) \\ &= IFWA((0.1, 0.9), (0.1, 0.9), \dots, (0.75, 0.2), \dots, (0.9, 0.1)) \\ &= (0.674, 0.295) \end{aligned}$$

In this way, we derive $\alpha_2, \alpha_3, \alpha_4$ and α_5 for the DFs. Table 3 summarizes the result of aggregation of the responses. Note that all the aggregated variables corresponding to DF1 to DF5 are also IFNs.

Table 3

Aggregated responses for DFs

DF1		DF2		DF3		DF4		DF5	
μ	ϑ	μ	ϑ	μ	ϑ	μ	ϑ	μ	ϑ
0.674	0.295	0.636	0.330	0.647	0.314	0.643	0.319	0.673	0.291

Now, we calculate the aggregated values for the responses of the RFs (see Table 4) using similar process.

Table 4

Aggregated responses for RFs

RF1		RF2		RF3		RF4	
μ	ϑ	μ	ϑ	μ	ϑ	μ	ϑ
0.546	0.408	0.577	0.377	0.613	0.343	0.556	0.398

Next, we proceed for calculating the score values of the DFs and RFs using the definition provided by the expression (15). Example of one such calculation is given below.

Calculation of score value for 1st DF (i.e., $k = 1$)

$$\begin{aligned} s^*(\alpha_1) &= \mu_{\alpha_1} - \vartheta_{\alpha_1} + (\mu_{\alpha_1}^2 - \vartheta_{\alpha_1}^2)\pi_{\alpha_1} \\ &= \mu_{\alpha_1} - \vartheta_{\alpha_1} + (\mu_{\alpha_1}^2 - \vartheta_{\alpha_1}^2)(1 - \mu_{\alpha_1} - \vartheta_{\alpha_1}) \\ &= (0.674 - 0.295) + (0.674^2 - 0.295^2)(1 - 0.674 - 0.295) \\ &= 0.390 \end{aligned}$$

In the similar way we calculate the score values for all DFs and RFs and summarize in Table 5 and

6.

Table 5

Score values for DFs

DF	DF1	DF2	DF3	DF4	DF5
Score	0.390	0.316	0.346	0.336	0.395

Table 6

Score values for RFs

RF	RF1	RF2	RF3	RF4
Score	0.145	0.209	0.281	0.165

Based on the score values of the DFs and RFs we apply the computational steps of FUCOM (see expressions (16) to (18)) to calculate weights. Table 7 and 8 exhibit the weights for DFs and RFs respectively.

Table 7

Calculation of weights for DFs

DF	Priority	$\xi_{\frac{k}{k+1}}$	$\frac{W_k}{W_{k+1}}$	$\frac{W_k}{W_{k+2}}$	W
DF5	0.395	1.0139	1.0139	1.1427	0.2230
DF1	0.390	1.1271	1.1271	1.1601	0.2141
DF3	0.346	1.0293	1.0293	1.0951	0.1951
DF4	0.336	1.0640	1.0640		0.1896
DF2	0.316				0.1782

The final model for calculating the weights for DFs is given below. Solving the model using Lingo 19 software we get the value of DFC (χ) as 0.00004395 which confirms the consistency and reliability of the model.

$Min \chi$

s.t

$$\left| \frac{w_5}{w_1} - 1.0139 \right| \leq \chi; \left| \frac{w_1}{w_3} - 1.271 \right| \leq \chi; \left| \frac{w_3}{w_4} - 1.0293 \right| \leq \chi; \left| \frac{w_4}{w_2} - 1.0640 \right| \leq \chi$$

$$\left| \frac{w_5}{w_3} - 1.1427 \right| \leq \chi; \left| \frac{w_1}{w_4} - 1.1601 \right| \leq \chi; \left| \frac{w_3}{w_2} - 1.0951 \right| \leq \chi$$

$$\sum w_j = 1; w_j \geq 0 \forall j$$

Table 8

Calculation of weights for RFs

RF	Priority	$\xi_{\frac{k}{k+1}}$	$\frac{W_k}{W_{k+1}}$	$\frac{W_k}{W_{k+2}}$	W
RF3	0.281	1.3445	1.3445	1.7030	0.3512
RF2	0.209	1.2667	1.2667	1.4414	0.2613
RF4	0.165	1.1379	1.1379		0.2062
RF1	0.145				0.1813

The final model is given below

Min χ

s.t

$$\left| \frac{w_3}{w_2} - 1.3445 \right| \leq \chi; \left| \frac{w_2}{w_4} - 1.2667 \right| \leq \chi; \left| \frac{w_4}{w_1} - 1.1379 \right| \leq \chi;$$

$$\left| \frac{w_3}{w_4} - 1.7030 \right| \leq \chi; \left| \frac{w_2}{w_1} - 1.4414 \right| \leq \chi$$

$$\sum w_j = 1; w_j \geq 0 \forall j$$

The DFC value is $\chi = 0.000021641$.

Now, by using the expressions (19) and (20) and values given in Tables 3 and 4, we find the total DF and RF respectively. To this end, we use calculated weights (using FUCOM).

Total DF:

$$\begin{aligned} \alpha_{DF} &= (\mu_{\alpha_{DF}}, g_{\alpha_{DF}}) = IFWA(\alpha_{DF1}, \alpha_{DF2}, \alpha_{DF3}, \alpha_{DF4}, \alpha_{DF5}) \\ &= \bigoplus_{j=1}^5 (w_j \alpha_{DFj}) = \left(1 - \prod_{j=1}^5 (1 - \mu_{\alpha_{DFj}})^{w_j}, \prod_{j=1}^5 g_{\alpha_{DFj}}^{w_j} \right) \\ &= (0.656, 0.308) \end{aligned}$$

Total RF:

$$\begin{aligned} \alpha_{RF} &= (\mu_{\alpha_{RF}}, g_{\alpha_{RF}}) = IFWA(\alpha_{RF1}, \alpha_{RF2}, \alpha_{RF3}, \alpha_{RF4}) \\ &= \bigoplus_{j=1}^4 (w_j \alpha_{RFj}) = \left(1 - \prod_{j=1}^4 (1 - \mu_{\alpha_{RFj}})^{w_j}, \prod_{j=1}^4 g_{\alpha_{RFj}}^{w_j} \right) \\ &= (0.580, 0.374) \end{aligned}$$

Then, we proceed to calculate the score values of the total DF (representing the total effect of the DFs) and total RF (representing the total effect of the RFs) respectively using the expressions (21) and (22)

Score value of total DF

$$\begin{aligned} s^*(\alpha_{DF}) &= \mu_{\alpha_{DF}} - g_{\alpha_{DF}} + (\mu_{\alpha_{DF}}^2 - g_{\alpha_{DF}}^2) \pi_{\alpha_{DF}} \\ &= (\mu_{\alpha_{DF}} - g_{\alpha_{DF}}) + (\mu_{\alpha_{DF}}^2 - g_{\alpha_{DF}}^2)(1 - \mu_{\alpha_{DF}} - g_{\alpha_{DF}}) \\ &= (0.656 - 0.308) + (0.656^2 - 0.308^2)(1 - 0.656 - 0.308) \\ &= 0.360 \end{aligned}$$

Score value of total RF

$$\begin{aligned} s^*(\alpha_{RF}) &= \mu_{\alpha_{RF}} - g_{\alpha_{RF}} + (\mu_{\alpha_{RF}}^2 - g_{\alpha_{RF}}^2) \pi_{\alpha_{RF}} \\ &= (\mu_{\alpha_{RF}} - g_{\alpha_{RF}}) + (\mu_{\alpha_{RF}}^2 - g_{\alpha_{RF}}^2)(1 - \mu_{\alpha_{RF}} - g_{\alpha_{RF}}) \\ &= (0.580 - 0.374) + (0.580^2 - 0.374^2)(1 - 0.580 - 0.374) \\ &= 0.215 \end{aligned}$$

It is evident that $s^*(\alpha_{DF}) > s^*(\alpha_{RF})$

Hence, it is concluded that the effect of DF is higher than RF.

To check the comprehensibility of the criteria weight calculation, we follow a comparison of our result with other methods as a practice followed in the extant literature [56-58]. We calculate the weights using the methods like SWARA, CIMAS and LBWA. We then compare the weights using Kruskal Wallis Test. We notice that there are no significant differences in the calculated weights.

5. Discussions

After the rapid spread of the COVID 19 the institutions had to rely on e-learning or online mode of teaching and learning for continuation. However, online education is not the precedent of the

recent pandemic. It has been into existence for last many years. The recent health issue and social distancing has accelerated the adaptation of online mode [59]. The online mode of education has a number of advantages such as accessibility to a large amount of information and variety of courses across the world virtually through internet, easy way to exchange of ideas and communicate, convenience and flexibility (comfort, anywhere and anytime), opportunities to participate in the choice-based and quality courses to enhance the knowledge level, free time, and budget friendliness (due To absence of physical appearances and movements) [60-62]. To this end, from the data analysis (see table 7), we notice that easy accessibility from anywhere (DF5) and flexibility and convenience (DF1) hold the top two positions based on the calculated weights. Hence, our work is in sync with the previous findings. However, the respondents put lesser emphasis on budget friendliness (DF2) which is found to have least preference.

On the other hand, the extant literature also highlighted some concerns about the online format of education. The researchers have mentioned that technological challenges such as internet connectivity issue, lack of awareness and knowledge about new technology, pedagogical issues like less interaction, difficulty in maintaining academic integrity, difficulty to cope us asynchronous learning, improper planning to utilize the courses, lack of interaction in groups, workload (in terms of assignments), poor engagement and lack of innovative delivery and contents in many instances, mental issues like social barrier, mental distress, loss of concentration, social challenges like inadequate physical space in family set up, lack of peer support among others [61-65] in our case, Table 8 indicates that technology and internet connectivity (RF3) and distraction and loss of focus (RF2) are the biggest challenges. Therefore, our work is also contemplating the past observations.

It is evident that the present world after Covid-19 has moved forward to blended mode of learning and organizing various events. However, despite of all apparent benefits and requirements of compelling situations it may be noted that the impact of digital divide is still not exhaustively studied. Further, the extant literature is silent about the interplay of the positive factors favoring online learning through webinars and challenges. Hence, the present work is topical. The outcome of the current work shows that the aggregated score of the DF is more than that of negative forces (i.e., RF). Therefore, it is evident that webinars are the accepted situations post pandemic. However, there is a marginal difference between positive and negative aspects, which suggests the case of diminishing marginal utility. So, blended mode is suggested with proper mix of face-to-face interaction, virtual delivery and asynchronous learning while considering convenience and cost. We support the opinions of the researchers that while enjoying the benefits of the webinars, one must not ignore the need of face-to-face interactions (“a human touch”), collaborative learning, peer support, extensive training and awareness building, structured planning to balance the cognitive load, maintenance of academic integrity and ethics to build a robust ecosystem under visionary academic leadership for holistic development. The impact of COVID 19 will not fade away permanently [62,66].

From the technical point of view also, the present research shows a new direction. For any MCDM related analysis (specifically in group decision making scenario), it is important to achieve group harmony for achieving a reliable solution [67-69]. The current work involves a large group of 91 respondents. Hence, it is noteworthy to mention that the outcome of FUCOM is an indicator of significant consistency and reliability (for both DF and RF, the value of DFC is close to zero).

6. Conclusion and Future Scope

The present paper aims to enfold the usefulness of the webinars from the perspective of the students (i.e., users). Aftermath of the recent pandemic, online learning has emerged as an essential aid that uses webinars frequently. The extant literature shows that there has been a plethora of work

conducted to unveil the utilities and challenges of online learning using electronic medium. The researchers have also attempted to extend the corresponding strand of literature by exploring the effectiveness of the webinars in the post COVID 19 phase. However, there is a little or no evidence of work which discerned the usefulness of the webinars by considering both positive and negative forces. To this end, the present work is one of its kind that exhibits the application of FFA to examine the influences of both DFs and RFs on the change from traditional offline to new format of online learning through webinars. To carry out a granular analysis of user opinions while offsetting the subjective bias, IFS has been considered. In that way, the current work presents a new IFS based FFA wherein FUCOM has been utilized to find the weights of the DFs and RFs. We consider five DFs such as greater flexibility and convenience, budget friendliness, collaborative and discussion-based learning, utility to gather knowledge in the professional field and access from anywhere whereas workload, distraction and reduced focus, technology and internet connectivity and inadequate support from instructors and friends have been listed as the RFs.

The analysis reveals that easy accessibility from anywhere (DF5) and flexibility and convenience (DF1) hold the top two positions based on the calculated weights. However, the respondents put lesser emphasis on budget friendliness (DF2) which is found to have least preference. In our case, it has been found that technology and internet connectivity (RF3) and distraction and loss of focus (RF2) are the biggest challenges. Overall, the outcome of the current work shows that the aggregated score of the DF is more than that of negative forces (i.e., RF). Therefore, it is evident that webinars are the accepted situations post pandemic.

The present work provides an exciting IFS based analysis that considers the views of a large number of respondents (91 respondents) while the DFC values obtained by using FUCOM confirm the reliability and consistency of the results. Further, the current work has observed that there is a marginal difference between positive and negative aspects, which suggests the case of diminishing marginal utility. So, blended mode is suggested with proper mix of face-to-face interaction, virtual delivery and asynchronous learning while considering convenience and cost.

However, we do notice some of the limitations of our work which open the avenues for further work. For instance, our work has considered only handful of DFs and RFs. In that sense, the current work may be further extended by including more factors. Secondly, we have not carried out any causal analysis to discern the effect of DFs and RFs on level of adaptation of the webinars. Third, a future work may use a theoretical lens of Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), Theory of Reasoned Action (TRA), User Experience and Usability (UX) and Quality of Experience (QoE) to examine the effectiveness of online learning and webinars. Fourth, we have not considered any refusal option for the respondents. Hence, a future work may deploy the other variants of fuzzy sets, such picture fuzzy or spherical fuzzy sets etc to carry out the FFA. Nevertheless, the proposed IFS-FFA analysis shall encourage future applications in various domains and we are hopeful that the findings of the present work shall provide new directions to the policy makers.

Appendix A

Formatted Response Tables

Table A1
Responses of the students for DFs

[illegible]

[illegible]

Table A2
Responses of the students for RFs

RF1		RF2		RF3		RF4	
μ	ϑ	μ	ϑ	μ	ϑ	μ	ϑ
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.10	0.90	0.10	0.90	0.10	0.90	0.10	0.90
0.35	0.60	0.35	0.60	0.10	0.90	0.35	0.60
0.35	0.60	0.35	0.60	0.10	0.90	0.35	0.60
0.35	0.60	0.35	0.60	0.10	0.90	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.35	0.60	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.35	0.60	0.50	0.45	0.35	0.60
0.35	0.60	0.50	0.45	0.50	0.45	0.35	0.60
0.35	0.60	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.50	0.45	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.50	0.45	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.50	0.45
0.50	0.45	0.75	0.20	0.75	0.20	0.75	0.20

[illegible]

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Biswas, S. (2020). Exploring the Implications of Digital Marketing for Higher Education using Intuitionistic Fuzzy Group Decision Making Approach. BIMTECH Business Perspective (BSP), 2(1), 33-51.
<https://bsp.bimtech.ac.in/doi/pdf/10.1177/bsp.2020.2.1.33.pdf>
- [2] Tarkar, P. (2020). Impact of COVID-19 pandemic on education system. International Journal of Advanced Science and Technology, 29(9), 3812-3814.
- [3] Batubara, B. M. (2021). The Problems of the World of Education in the Middle of the Covid-19 Pandemic. Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences, 4(1), 450-457.

- [4] Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of COVID-19 pandemic on teaching and learning. *Higher Education for the Future*, 8(1), 133-141. <https://doi.org/10.1177/2347631120983481>
- [5] Popa, D., Repanovici, A., Lupu, D., Norel, M., & Coman, C. (2020). Using mixed methods to understand teaching and learning in Covid 19 times. *Sustainability*, 12(20), 8726. <https://doi.org/10.3390/su12208726>
- [6] Mseleku, Z. (2020). A literature review of E-learning and E-teaching in the era of Covid-19 pandemic. *International Journal of Innovative Science and Research Technology*, 5(10), 588-597.
- [7] Beckmann, A. (2020). Students views on digital tools in university lectures. *Proceedings of INTED2020 Conference, 2nd-4th March 2020, Valencia, Spain* (pp. 0375-0382). <https://doi.org/10.21125/inted.2020.0159>
- [8] Sugilar, S. (2020). Effectivity and students' satisfaction to a tutorial in statistics through a webinar. In *Journal of Physics: Conference Series* (Vol. 1663, No. 1, p. 012035). IOP Publishing. <https://doi.org/10.1088/1742-6596/1663/1/012035>
- [9] Kumar, A., Malhotra, S., Katoch, A., Sarathkar, A., & Manocha, A. (2020). Webinars: An assistive tool used by higher education educators during Covid19 case study. In *2020 12th International Conference on Computational Intelligence and Communication Networks (CICN)* (pp. 1-6). IEEE. <https://doi.org/10.1109/CICN49253.2020.9242597>
- [10] Lapitan Jr, L. D., Tiangco, C. E., Sumalinog, D. A. G., Sabarillo, N. S., & Diaz, J. M. (2021). An effective blended online teaching and learning strategy during the COVID-19 pandemic. *Education for Chemical Engineers*, 35, 116-131. <https://doi.org/10.1016/j.ece.2021.01.012>
- [11] Lei, S. I., & So, A. S. I. (2021). Online teaching and learning experiences during the COVID-19 pandemic—A comparison of teacher and student perceptions. *Journal of Hospitality & Tourism Education*, 33(3), 148-162. <https://doi.org/10.1080/10963758.2021.1907196>
- [12] Tanidir, Y., Gokalp, F., Akdogan, N., Batur, A. F., Sekerci, C. A., Egriboyun, S., Deger, M., Sahin, B., Akarken, I., Aydin, C., Altan, M., Ozman, O., Ucar, M., Gudeloglu, A., Ongun, S., Akbal, C., & Esen, A. (2021). How did the COVID-19 pandemic affect audience's attitudes in webinars?. *International Journal of Clinical Practice*, 75(7), e14239. <https://doi.org/10.1111/ijcp.14239>
- [13] Ahrens, A., Zascierinska, J., Bhati, P. P., Zascierinskis, M., & Aleksejeva, A. (2021). Comparative studies of covid-19 impact on students'views on digital higher education. in society. integration. education. *Proceedings of the International Scientific Conference* (Vol. 5, pp. 19-29). <https://doi.org/10.17770/sie2021vol5.6277>
- [14] Pedroso, J. E. P. (2021). Students' Views from Webinars: A Qualitative Study. *International Journal of Arts and Humanities Studies*, 1(1), 36-44. <https://doi.org/10.32996/ijahs.2021.1.1.6>
- [15] Kaye, L. K., Rousaki, A., Joyner, L. C., Barrett, L. A., & Orchard, L. J. (2022). The Online Behaviour Taxonomy: A conceptual framework to understand behaviour in computer-mediated communication. *Computers in Human Behavior*, 137, 107443. <https://doi.org/10.1016/j.chb.2022.107443>
- [16] Munnukka, J., Maity, D., Reinikainen, H., & Luoma-aho, V. (2019). "Thanks for watching". The effectiveness of YouTube vlogendorsements. *Computers in human behavior*, 93, 226-234. <https://doi.org/10.1016/j.chb.2018.12.014>
- [17] Damşa, C., Langford, M., Uehara, D., & Scherer, R. (2021). Teachers' agency and online education in times of crisis. *Computers in Human Behavior*, 121, 106793. <https://doi.org/10.1016/j.chb.2021.106793>
- [18] Pospíšilová, L., & Rohlíková, L. (2023). Reforming higher education with ePortfolio implementation, enhanced by learning analytics. *Computers in Human Behavior*, 138, 107449. <https://doi.org/10.1016/j.chb.2022.107449>
- [19] Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 20(1), 87-96.
- [20] Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, 8(3), 338-353.
- [21] Kumar, P. S. (2020). Algorithms for solving the optimization problems using fuzzy and intuitionistic fuzzy set. *International Journal of System Assurance Engineering and Management*, 11(1), 189-222. <https://doi.org/10.1007/s13198-019-00941-3>
- [22] Biswas, S., Majumder, S., & Dawn, S. K. (2022). Comparing the socioeconomic development of G7 and BRICS countries and resilience to COVID-19: An entropy–MARCOS framework. *Business Perspectives and Research*, 10(2), 286-303. <https://doi.org/10.1177/22785337211015406>
- [23] Ocampo, L., Tanaid, R. A., Tiu, A. M., Selerio Jr, E., & Yamagishi, K. (2021). Classifying the degree of exposure of customers to COVID-19 in the restaurant industry: A novel intuitionistic fuzzy set extension of the TOPSIS-Sort. *Applied Soft Computing*, 113, 107906. <https://doi.org/10.1016/j.asoc.2021.107906>
- [24] Yang, N., Zhang, M., Wangdu, F., & Li, R. (2021). Identification of critical components of complex product based on hybrid intuitionistic fuzzy set and improved Mahalanobis-Taguchi system. *Journal of Systems Science and Systems Engineering*, 30(5), 533-551. <https://doi.org/10.1007/s11518-021-5503-7>
- [25] Adamu, I. M. (2021). Application of intuitionistic fuzzy sets to environmental management. *Notes on Intuitionistic Fuzzy Sets*, 27(3), 40-50. <https://doi.org/10.7546/nifs.2021.27.3.40-50>

- [26] Ecer, F. (2022). An extended MAIRCA method using intuitionistic fuzzy sets for coronavirus vaccine selection in the age of COVID-19. *Neural Computing and Applications*, 34(7), 5603-5623. <https://doi.org/10.1007/s00521-021-06728-7>
- [27] Perçin, S. (2022). Circular supplier selection using interval-valued intuitionistic fuzzy sets. *Environment, Development and Sustainability*, 24(4), 5551-5581. <https://doi.org/10.1007/s10668-021-01671-y>
- [28] Goala, S., Prakash, D., Dutta, P., Talukdar, P., Verma, K. D., & Palai, G. (2022). A decision support system for surveillance of smart cities via a novel aggregation operator on intuitionistic fuzzy sets. *Multimedia Tools and Applications*, 81, 22587–22608. <https://doi.org/10.1007/s11042-021-11522-7>
- [29] Thao, N. X., & Chou, S. Y. (2022). Novel similarity measures, entropy of intuitionistic fuzzy sets and their application in software quality evaluation. *Soft Computing*, 26(4), 2009-2020. <https://doi.org/10.1007/s00500-021-06373-1>
- [30] Si, A., Das, S., & Kar, S. (2023). Preferred hospitalization of COVID-19 patients using intuitionistic fuzzy set-based matching approach. *Granular Computing*, 8(3), 525-549. <https://doi.org/10.1007/s41066-022-00339-w>
- [31] Liu, S. (2021). Research on the teaching quality evaluation of physical education with intuitionistic fuzzy TOPSIS method. *Journal of Intelligent & Fuzzy Systems*, 40(5), 9227-9236. <https://doi.org/10.3233/JIFS-201672>
- [32] Qi, Q. (2022). Investigation and Analysis of Classroom Teaching Quality in Universities in an Interval Intuitionistic Fuzzy Environment. *Mobile Information Systems*, 2022(1), 1950877. <https://doi.org/10.1155/2022/1950877>
- [33] Zhao, X., Ding, S., & Zuo, L. (2022). Evaluation of Health Information Literacy of Rural Community Residents Based on Intuitionistic Fuzzy Set Multicriteria. *Mathematical Problems in Engineering*, 2022(1), 8232766. <https://doi.org/10.1155/2022/8232766>
- [34] Serrano-Guerrero, J., Bani-Doumi, M., Romero, F. P., & Olivas, J. A. (2021). An Algorithm for Ranking Hospitals based on Intuitionistic Fuzzy Sets and Sentiment Analysis. In 2021 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) (pp. 1-6). IEEE. <https://doi.org/10.1109/FUZZ45933.2021.9494552>
- [35] Dogan, O., Seymen, O. F., & Hizioglu, A. (2022). Customer Behavior Analysis by Intuitionistic Fuzzy Segmentation: Comparison of Two Major Cities in Turkey. *International Journal of Information Technology & Decision Making*, 21(2), 707-727. <https://doi.org/10.1142/S0219622021500607>
- [36] Selvachandran, G., Quek, S. G., Thong, P. H., Vo, B., Hawari, T. A. A., & Salleh, A. R. (2022). Relations and compositions between interval-valued complex fuzzy sets and applications for analysis of customers' online shopping preferences and behavior. *Applied Soft Computing*, 114, 108082. <https://doi.org/10.1016/j.asoc.2021.108082>
- [37] Xu, Z. S. (2007). Models for multiple attribute decision making with intuitionistic fuzzy information. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 15(3), 285-297. <https://doi.org/10.1142/S0218488507004686>
- [38] Xu, Z., & Yager, R. R. (2006). Some geometric aggregation operators based on intuitionistic fuzzy sets. *International journal of general systems*, 35(4), 417-433. <https://doi.org/10.1080/03081070600574353>
- [39] Hong, D. H., & Choi, C. H. (2000). Multicriteria fuzzy decision-making problems based on vague set theory. *Fuzzy sets and systems*, 114(1), 103-113. [https://doi.org/10.1016/S0165-0114\(98\)00271-1](https://doi.org/10.1016/S0165-0114(98)00271-1)
- [40] Xu, Z., & Cai, X. (2010). Recent advances in intuitionistic fuzzy information aggregation. *Fuzzy Optimization and Decision Making*, 9(4), 359-381. <https://doi.org/10.1007/s10700-010-9090-1>
- [41] Chen, L., Chen, R., & Lin, J. (2021). A Ranking of Software Reliability Evaluation Based on Intuitionistic Fuzzy Aggregation Technique. In 2021 4th International Conference on Algorithms, Computing and Artificial Intelligence (pp. 1-8). <https://doi.org/10.1145/3508546.3508647>
- [42] Zhao, H., Xu, Z. S., Ni, M. F., & Liu, S. S. (2010). Generalized aggregation operators for intuitionistic fuzzy sets. *International Journal of Intelligent Systems*, 25, 1–30. <https://doi.org/10.1002/int.20386>
- [43] Lewin, K. (1951). *Field Theory in Social Science*, Harper Row, London.
- [44] Baulcomb, J. S. (2003). Management of change through force field analysis. *Journal of Nursing Management*, 11(4), 275-280. <https://doi.org/10.1046/j.1365-2834.2003.00401.x>
- [45] Hlalele, B. M. (2019). Application of the force-field technique to drought vulnerability analysis: A phenomenological approach. *Jàmbá: Journal of Disaster Risk Studies*, 11(1), 1-6. <https://doi.org/10.4102/jamba.v11i1.589>
- [46] Youssef, A. E., & Mostafa, A. M. (2019). Critical decision-making on cloud computing adoption in organizations based on augmented force field analysis. *IEEE Access*, 7, 167229-167239. <https://doi.org/10.1109/ACCESS.2019.2954415>
- [47] Mak, A. H., & Chang, R. C. (2019). The driving and restraining forces for environmental strategy adoption in the hotel industry: A force field analysis approach. *Tourism Management*, 73, 48-60. <https://doi.org/10.1016/j.tourman.2019.01.012>

- [48] Sangaiah, A. K., Gao, X. Z., Ramachandran, M., & Zheng, X. (2015). A fuzzy DEMATEL approach based on intuitionistic fuzzy information for evaluating knowledge transfer effectiveness in GSD projects. *International Journal of Innovative Computing and Applications*, 6(3-4), 203-215. <https://doi.org/10.1504/IJICA.2015.073006>
- [49] Topgul, M. H., Kilic, H. S., & Tuzkaya, G. (2021). Greenness assessment of supply chains via intuitionistic fuzzy based approaches. *Advanced Engineering Informatics*, 50, 101377. <https://doi.org/10.1016/j.aei.2021.101377>
- [50] Pamučar, D., Stević, Ž., & Sremac, S. (2018). A new model for determining weight coefficients of criteria in MCDM models: Full consistency method (FUCOM). *Symmetry*, 10(9), 393. <https://doi.org/10.3390/sym10090393>
- [51] Biswas, S., Pamucar, D., Chowdhury, P., & Kar, S. (2021). A new decision support framework with picture fuzzy information: comparison of video conferencing platforms for higher education in India. *Discrete Dynamics in Nature and Society*, 2021(1), 2046097. <https://doi.org/10.1155/2021/2046097>
- [52] Biswas, S., Pamucar, D., & Kar, S. (2022). A preference-based comparison of select over-the-top video streaming platforms with picture fuzzy information. *International Journal of Communication Networks and Distributed Systems*, 28(4), 414-458. <https://doi.org/10.1504/IJCNDS.2022.123872>
- [53] Biswas, S., Pamucar, D., Kar, S., & Sana, S. S. (2021). A New Integrated FUCOM–CODAS Framework with Fermatean Fuzzy Information for Multi-Criteria Group Decision-Making. *Symmetry*, 13(12), 2430. <https://doi.org/10.3390/sym13122430>
- [54] Böyükaslan, A., & Ecer, F. (2021). Determination of drivers for investing in cryptocurrencies through a fuzzy full consistency method-Bonferroni (FUCOM-F'B) framework. *Technology in Society*, 67, 101745. <https://doi.org/10.1016/j.techsoc.2021.101745>
- [55] Puška, A., Stević, Ž., & Pamučar, D. (2022). Evaluation and selection of healthcare waste incinerators using extended sustainability criteria and multi-criteria analysis methods. *Environment, Development and Sustainability*, 24(9), 11195-11225. <https://doi.org/10.1007/s10668-021-01902-2>
- [56] Biswas, S., Biswas, B., & Mitra, K. (2025). A novel group decision making model to compare online shopping platforms. *Spectrum of decision making and applications*, 2(1), 1-27. <https://doi.org/10.31181/sdmap2120259>
- [57] Sanyal, A., Biswas, S., & Sur, S. (2024). An Integrated Full Consistent LOPCOW-EDAS Framework for Modelling Consumer Decision Making for Organic Food Selection. *Yugoslav Journal of Operations Research*. <https://doi.org/10.2298/YJOR240315022S>
- [58] Biswas, S., Pamucar, D., Dey, P., Chatterjee, S., & Majumder, S. (2023). A q-ROF Based Intelligent Framework for Exploring the Interface Among the Variables of Culture Shock and Adoption Toward Organizational Effectiveness. In *Computational Intelligence for Modern Business Systems: Emerging Applications and Strategies* (pp. 255-293). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-5354-7_14
- [59] Bączek, M., Zagańczyk-Bączek, M., Szpringer, M., Jaroszyński, A., & Woźakowska-Kapłon, B. (2021). Students' perception of online learning during the COVID-19 pandemic: a survey study of Polish medical students. *Medicine*, 100(7), e24821. <http://dx.doi.org/10.1097/MD.00000000000024821>
- [60] Pei, L., & Wu, H. (2019). Does online learning work better than offline learning in undergraduate medical education? A systematic review and meta-analysis. *Medical education online*, 24(1), 1666538. <https://doi.org/10.1080/10872981.2019.1666538>
- [61] Yuhanna, I., Alexander, A., & Kachik, A. (2020). Advantages and disadvantages of Online Learning. *Journal Educational Verkenning*, 1(2), 13-19. <https://doi.org/10.48173/jev.v1i2.54>
- [62] Mukhtar, K., Javed, K., Arooj, M., & Sethi, A. (2020). Advantages, Limitations and Recommendations for online learning during COVID-19 pandemic era. *Pakistan journal of medical sciences*, 36(COVID19-S4), S27. <https://doi.org/10.12669/pjms.36.COVID19-S4.2785>
- [63] Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching: Opportunities and challenges in emergency situations. *Societies*, 10(4), 86. <https://doi.org/10.3390/soc10040086>
- [64] Fatonia, N. A., Nurkhyatic, E., Nurdawati, E., Fidziah, G. P., Adhag, S., Irawanh, A. P., Julyanto, O., & Azizi, E. (2020). University students online learning system during Covid-19 pandemic: Advantages, constraints and solutions. *Systematic reviews in pharmacy*, 11(7), 570-576.
- [65] Firmansyah, R., Putri, D., Wicaksono, M., Putri, S., Widiyanto, A., & Palil, M. (2021). Educational transformation: An evaluation of online learning due to COVID-19. *International Journal of Emerging Technologies in Learning (IJET)*, 16(7), 61-76. <https://doi.org/10.3991/ijet.v16i07.21201>
- [66] Pandit, D., & Agrawal, S. (2022). Exploring challenges of online education in COVID times. *FIIB Business Review*, 11(3), 263-270. <https://doi.org/10.1177/2319714520986254>
- [67] Deveci, M., Gokasar, I., Pamucar, D., Biswas, S., & Simic, V. (2022). An Integrated Proximity Indexed Value and q-Rung Orthopair Fuzzy Decision-Making Model for Prioritization of Green Campus Transportation. In *q-Rung Orthopair Fuzzy Sets* (pp. 303-332). Springer, Singapore. https://doi.org/10.1007/978-981-19-1449-2_12

- [68] Biswas, S., Majumder, S., Pamucar, D., & Dawn, S. K. (2021). An extended LBWA framework in picture fuzzy environment using actual score measures application in social enterprise systems. *International Journal of Enterprise Information Systems (IJEIS)*, 17(4), 37-68. <https://doi.org/10.4018/IJEIS.2021100103>
- [69] Pamucar, D., Žižović, M., Biswas, S., & Božanić, D. (2021). A new logarithm methodology of additive weights (LMAW) for multi-criteria decision-making: Application in logistics. *Facta Universitatis, Series: Mechanical Engineering*, 19(3), 361-380. <https://doi.org/10.22190/FUME210214031P>