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Interval-Valued Pythagorean Fuzzy Extension of DEMATEL for Prioritizing and Casualty Analysis of Environmental Criteria of Organizational Behaviour in Higher Education Sector

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Abstract. In this study, effect of the environmental factors on the organizational behaviour in higher education sector is analysed and these factors are prioritized. For this aim, first, the environmental criteria affecting the organizational behaviour of higher education sector are selected from the literature. Then, as a solution methodology, (i) some experts are asked to determine pairwise comparison of the criteria, (ii) the linguistic terms are converted to interval-valued Pythagorean fuzzy values, and (iii) an interval-valued Pythagorean fuzzy DEMATEL approach is developed and applied. According to the results, most of the economic, political, and professional domain criteria are of the cause category.

Key words: DEMATEL, interval-valued Pythagorean fuzzy sets and numbers, organizational behaviour, higher education sector, environmental criteria.

1. Introduction

In recent years, productivity and development of today's organizations have been dependent on some competitive opportunities that arise from competitive environments around the organizations. This is because today's organizations have changed from the point of view of organizational structure, organizational behaviour, and organizational relationship. An organization can get benefit from its competitive opportunities if its outside en-

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vironment is fully studied and analysed (Mwesigye and Muhangi, 2015). A typical organization, an educational organization like universities, research centres, higher education centres, etc., responds to the outside environment according to the information and recognition obtained about the outside environment. Higher education organizations of a country play significant roles in the country. Although these organizations may be affected by outside environment seriously, they are effective in national economical and cultural issues (Presmus *et al.*, 2003). Based on the literature, outside environment of the higher education sector (in terms of some environmental factors) can seriously influence organizational behaviour in this sector where output and productivity of the employees can be affected by these factors (Robbins and Judge, 2016). Generally, the variables and factors of outside environment of a university are important and the university should be managed and developed according to such environment for achieving the predetermined goals and objectives (Torkzadeh *et al.*, 2019). Therefore, we can claim that the environmental factors of an organization, especially organizations from the higher education sector, are important and crucial in all aspects of the organization, specifically its organizational behaviour.

The literature contains numerous studies about the organizational behaviour of general organizations, academic and higher education institutes, and especially the environmental aspect of such behaviour. The studies of Rojas (2000) and Gita Kumari and Pradhan (2014) have stated that organizational effectiveness is important for the managers. Torkzadeh and Dehghan Harati (2015) have concluded that effectiveness is an important index for assessing performance of organizations. They performed the study on the employees of Shiraz University as case study. Ketkar and Sett (2009) also mentioned that effectiveness can be measured by the employees' behaviour, financial performance, and operational performance of an organization. Also the works of Nabatchi *et al.* (2007), Zhang and Lee (2010), and Gita Kumari and Pradhan (2014) studied the importance of organizational behaviour on productivity and effectiveness of an organization. Robbins and Judge (2016) studied the importance of organizational behaviour and described it as a set of equipment for understanding, analysing, describing, and managing the behaviour in organizations. According to the study of Kapoor and Jain (2017), organizational behaviour analyses the impact of people, groups, and structures on improvement and effectiveness of an organization. According to this study, the behaviour in an organization can be studied and analysed in three levels, such as individual, group, and organizational level. Investigating the environmental aspect of organizations and its impact on organizational behaviour is also an important topic which was considered in the studies of Gibson (2007), Burton and Obel (2015), and Makolov (2019). According to the study of Lutans *et al.* (2021), the environmental aspect of organizational behaviour has forced the managers of universities to change their traditional procedures and be more responsible to their inside and outside environments. The studies of Rizvi (2007) and Mwesigye and Muhangi (2015) stated that higher education institutes and universities, like other organizations, have been significantly affected by recent developments of the organizational behaviour. The study of Daigle and Cuocco (2002) is about general responsiveness in higher education. They studied various responsiveness methods in the universities of United States and claim that it is a challenging issue in those universities. Furthermore, Kreysing (2002) studied the responsiveness and organizational complexity of higher education sector. As a result, they claimed that in order to

be more responsive to environmental changes in such organizations, their decentralization level should be increased.

In this study, we focus on the organizational behaviour aspect of higher education sector. This aspect is important in any organization and can help an organization to be successful. The main aim of this study is to analyse the environmental factors which may affect the organizational behaviour in the higher education sector. In this analysis, the aspects, such as importance weights of the factors and their influential impact on each other could be some very important and challenging issues. Therefore, the environmental criteria affecting the organizational behaviour of higher education sector are selected from the literature. We aim to apply the selected criteria and perform a study to determine their effect on the organizational behaviour of higher education sector and prioritize them. This is a new aspect of this field that to the best of our knowledge has not been considered earlier in the literature and can enable the managers to make suitable strategies for managing the organizations. As a solution methodology, some experts from the higher education sector of Iran are selected and are asked to compare the importance of the criteria pair wisely using linguistic terms. Then, in order to respect the uncertain nature of such evaluations, the linguistic terms are converted to interval-valued Pythagorean fuzzy values. Interval-valued Pythagorean fuzzy numbers are used as they keep more information and uncertainty compared to classical fuzzy numbers (see Das and Granados, 2022; Narang *et al.*, 2022; Dinçer *et al.*, 2023; Younis Al-Zibaree and Konur, 2023; Jafarzadeh Ghoushchi and Sarvi, 2023; Rezazadeh *et al.*, 2023). As DEMATEL approach can simultaneously determine importance weight values of the criteria and their influential impact on each other, an interval-valued Pythagorean fuzzy DEMATEL approach is developed for the first time for prioritizing the criteria and performing the causality analysis on them. Finally, the obtained results are interpreted, and some managerial insights are given. In addition, a sensitivity analysis of the proposed approach is performed, and the results are compared to the results obtained by the existing methods of the literature.

The contributions of this study to the literature of the field can be summarized as below:

- A real case study is considered and solved.
- For the first time, the impact of environmental criteria on organizational behaviour of the higher education sector is studied.
- In order to respect the uncertain nature of the problem, opinions of the experts of the field as linguistic terms are converted to interval-valued Pythagorean fuzzy values.
- For the first time, interval-valued Pythagorean fuzzy group DEMATEL approach is developed.

The rest of this paper is organized in five sections. In Section 2, some basic concepts of fuzzy sets and numbers are presented. The criteria affecting organizational behaviour of the higher education sector is described in Section 3. As solution approach, an interval-valued Pythagorean fuzzy group DEMATEL approach is developed in Section 4. In continuation, a case study is considered to evaluate the criteria of Section 2, and the numerical results and some remarks about the case study are reported in Section 5. Finally, the conclusions are given in Section 6.

2. Basic Concepts

Zadeh (1965) introduced fuzzy set theory for the first time. This is a useful theory in order to reflect the uncertain nature of real life systems while modelling them. Therefore, many real life problems are modelled and optimized in a fuzzy based uncertain environment. As the classical fuzzy sets and numbers may have some shortcomings and may not be able to reflect some high degrees of uncertainty, this theory has been developed and modified in the literature (Ali *et al.*, 2023; Naseem *et al.*, 2023; Mahmoodirad and Niroomand, 2023). For this aim, some newer types of fuzzy sets, such as type-2 fuzzy sets, intuitionistic fuzzy sets, Pythagorean fuzzy sets, etc., have been introduced in the literature (Wang *et al.*, 2023; Mishra *et al.*, 2023). These newer types of fuzzy sets and numbers reflect more uncertainty of events and parameters.

Pythagorean fuzzy sets and numbers were introduced by Yager (2013). This type of fuzzy numbers is more flexible and capable to reflect the uncertain nature of an uncertain event. Because of this flexibility and capability, this type of fuzzy numbers are widely used in optimization problems.

Some basic definitions and concepts of Pythagorean fuzzy sets and numbers are given in the rest of this section. These definitions later will be used to construct the solution methodology of this study.

Definition 1 (Otay and Jaller, 2020). The Pythagorean fuzzy set $\tilde{P}$ with membership function $\mu_{\tilde{P}}(x) : X \to [0, 1]$ and non-membership function $\nu_{\tilde{P}}(x) : X \to [0, 1]$ with the condition $0 \leqslant \mu_{\tilde{P}}(x)^2 + \nu_{\tilde{P}}(x)^2 \leqslant 1$ on set X is defined as below:

$$\tilde{P} \cong \left\{\left\langle x, \mu_{\tilde{P}}(x), \nu_{\tilde{P}}(x)\right\rangle : x \in X\right\}. \tag{1}$$

Definition 2 (Otay and Jaller, 2020). The hesitancy degree of the Pythagorean set $\tilde{P}$ is defined as below:

$$\pi_{\tilde{P}}(x) = \sqrt{1 - \mu_{\tilde{P}}(x)^2 - \nu_{\tilde{P}}(x)^2}. \tag{2}$$

Definition 3 (Otay and Jaller, 2020). Considering the Pythagorean fuzzy numbers (PFNs) $\tilde{X} = \langle \mu_1, \nu_1 \rangle$ and $\tilde{Y} = \langle \mu_2, \nu_2 \rangle$, and $\lambda > 0$, the following operations can be defined:

$$\tilde{X} \oplus \tilde{Y} = \left\langle \sqrt{\mu_1^2 + \mu_2^2 - \mu_1^2\mu_2^2}, \nu_1\nu_2 \right\rangle, \tag{3}$$

$$\tilde{X} \otimes \tilde{Y} = \left\langle \mu_1\mu_2, \sqrt{\nu_1^2 + \nu_2^2 - \nu_1^2\nu_2^2} \right\rangle, \tag{4}$$

$$\lambda\tilde{X} = \left\langle \sqrt{1 - \left(1 - \mu_1^2\right)^{\lambda}}, \nu_1^{\lambda} \right\rangle, \tag{5}$$

$$\tilde{X}^{\lambda} = \left\langle \mu_1^{\lambda}, \sqrt{1 - \left(1 - \nu_1^2\right)^{\lambda}} \right\rangle. \tag{6}$$

Definition 4 (Zhang and Xu, 2014). Considering the PFNs $\tilde{X} = \langle \mu_1, \nu_1, \pi_{\tilde{X}} \rangle$ and $\tilde{Y} = \langle \mu_2, \nu_2, \pi_{\tilde{Y}} \rangle$, the Euclidean distance of the PFNs is defined as below:

$$d(\tilde{X}, \tilde{Y}) = \frac{1}{2}\left(\left|\mu_1^2 - \mu_2^2\right| + \left|\nu_1^2 - \nu_2^2\right| + \left|\pi_{\tilde{X}}^2 - \pi_{\tilde{Y}}^2\right|\right), \tag{7}$$

where $\pi_{\tilde{X}}^2 = 1 - \mu_1^2 - \nu_1^2$ is the hesitancy degree of the PFN $\tilde{X}$.

Definition 5 (Otay and Jaller, 2020). Considering the interval-valued PFN (IVPFN) $\tilde{X} = \langle [\mu_L, \mu_U], [\nu_L, \nu_U] \rangle$, the hesitancy degrees of its lower and upper points are defined as below, respectively:

$$\pi_L = \sqrt{1 - \mu_U^2 - \nu_U^2}, \tag{8}$$

$$\pi_U = \sqrt{1 - \mu_L^2 - \nu_L^2}. \tag{9}$$

Definition 6 (Otay and Jaller, 2020). Considering the IVPFN $\tilde{X}_j = \langle [\mu_{j,L}, \mu_{j,U}], [\nu_{j,L}, \nu_{j,U}] \rangle$, where $j = 1, 2, \ldots, n$, and the importance weight of w_j, where $\sum_{j=1}^{n} w_j = 1$, interval-valued Pythagorean fuzzy weighted average (IVPFWA) operator and interval-valued Pythagorean fuzzy weighted geometric (IVPFWG) operator of a set of IVPFNs are defined as below:

$$IVPFWA(\tilde{X}_1, \ldots, \tilde{X}_n) = \left\langle \left[\left(1 - \prod_{j=1}^{n} \left(1 - \mu_{j,L}^2\right)^{w_j}\right)^{\frac{1}{2}}, \left(1 - \prod_{j=1}^{n} \left(1 - \mu_{J,U}^2\right)^{w_j}\right)^{\frac{1}{2}} \right], \left[\prod_{j=1}^{n} \nu_{J,L}^{w_j}, \prod_{j=1}^{n} \nu_{J,U}^{w_j} \right] \right\rangle, \tag{10}$$

$$IVPFWG(\tilde{X}_1, \ldots, \tilde{X}_n) = \left\langle \left[\prod_{j=1}^{n} \mu_{j,L}^{w_j}, \prod_{j=1}^{n} \mu_{j,U}^{w_j} \right], \left[\left(1 - \prod_{j=1}^{n} \left(1 - \nu_{j,L}^2\right)^{w_j}\right)^{\frac{1}{2}}, \left(1 - \prod_{j=1}^{n} \left(1 - \nu_{j,U}^2\right)^{w_j}\right)^{\frac{1}{2}} \right] \right\rangle. \tag{11}$$

Definition 7 (Otay and Jaller, 2020). The equivalent crisp value (*CR*) of the interval-valued PFN (IVPFN) $\tilde{X} = \langle [\mu_L, \mu_U], [\nu_L, \nu_U] \rangle$ is obtained by below formulation.

$$CR(\tilde{X}) = \frac{1}{6}\left(\mu_L^2 + \mu_U^2 + \left(1 - \pi_L^4 - \nu_L^2\right) + \left(1 - \pi_U^4 - \nu_U^2\right) + \mu_L \mu_U + \left(\left(1 - \pi_L^4 - \nu_L^2\right)\left(1 - \pi_U^4 - \nu_U^2\right)\right)^{\frac{1}{4}}\right). \tag{12}$$

3. Environmental Criteria Affecting Organizational Behaviour in Higher Education Sector

The environmental aspect of organizational behaviour is an important issue for controlling and effective guidance of the behaviour of members of academic organizations. The managers of academic organizations can recognize and understand the internal behaviour of their organization by focusing on the environmental factors. Assessment of influence of the environmental criteria on the organizational behaviour of academic organizations can be helpful from different points of view, e.g. recognition of the internal behavioural processes of the universities, reaching the goals of universities in organizational behaviour, determining the future goals of universities in organizational behaviour, etc. This might be important to understand the effects of environmental criteria on organizational behaviour in the higher education sector. Therefore, for this aim, the problem of prioritizing and causality analysis of such criteria should be considered. According to the literature of organizational behaviour in higher education sector, the important criteria affecting such organizational behaviour are economic, social, technological, environmental, and professional domain criteria (Torkzadeh *et al.*, 2019), where each of these criteria can be divided into several criteria. Based on the literature, Table 1 represents 36 criteria affecting organizational behaviour of the higher education sector.

As mentioned earlier, it is an important study to evaluate the effect of the environmental criteria (as mentioned by Table 1) on organizational behaviour of the higher education sector. For this aim, a method for evaluating, prioritizing, and causality analysis of these criteria is needed. For this aim, an interval-valued Pythagorean group DEMATEL approach is developed for the first time in the next section, which performs prioritizing and causality analysis of the criteria of Table 1 on organizational behaviour of higher education sector.

4. Interval-Valued Pythagorean Fuzzy DEMATEL (IVPF-DEMATEL)

In this section, the proposed criteria of Table 1 are analysed and their importance weight values are calculated. There are several methods in the literature that can be used for weight determination of the criteria in MCDM problems (Sahoo and Goswami, 2023). The BWM is a method that determines the criteria weights by comparing the criteria with the best and the worst criteria and then determines all weight values by applying a mathematical model (Rezaei, 2015). The FUCUM (Pamučar *et al.*, 2018) is a subjective method of weight determination in MCDM where the relation between consistency and the required number of the comparisons of the criteria are considered. Žižović and Pamucar (2019) proposed the LBWA method for weight determination purposes. This approach enables the involvement of experts from different fields with the purpose of defining the relations between criteria and providing rational decision making. The DIBR method is another method based on defining the relationship between ranked criteria, i.e. it considers the relationship between adjacent criteria (Pamucar *et al.*, 2021).

Here, a solution methodology is proposed in order to evaluate the effect of the environmental criteria on organizational behaviour of the higher education sector as described

Table 1
Important criteria selected from the literature for the organizational behaviour assessment problem in academic organizations.

Criteria index	Criteria	Criteria category	Related references
C-1	General situation of economy	Economic criteria	Voiculet *et al.* (2010)
C-2	General life quality	Economic criteria	Alcaine (2016)
C-3	Economic indexes (employment, economic growth, etc.)	Economic criteria	Dananjaya and Kuswanto (2015)
C-4	Income and budget level of country	Economic criteria	Voiculet *et al.* (2010)
C-5	Economic crises	Economic criteria	Alcaine (2016)
C-6	Governmental (centralized) economy	Economic criteria	Alcaine (2016)
C-7	Internal and foreign investments	Economic criteria	Alcaine (2016)
C-8	Population	Social criteria	Voiculet *et al.* (2010)
C-9	Social crises	Social criteria	Alcaine (2016)
C-10	Social compatibility	Social criteria	Munizu (2010)
C-11	Social networks	Social criteria	O'Brien (2011)
C-12	Social life style	Social criteria	Alcaine (2016)
C-13	Social solidarity	Social criteria	Voiculet *et al.* (2010)
C-14	Social behaviour	Social criteria	Voiculet *et al.* (2010)
C-15	General knowledge of society	Social criteria	Voiculet *et al.* (2010)
C-16	Social organizations	Social criteria	Alcaine (2016)
C-17	Rules and regulations of the country	Political criteria	Voiculet *et al.* (2010)
C-18	Political changes	Political criteria	Alcaine (2016)
C-19	International relationships	Political criteria	Munizu (2010)
C-20	Governmental politics	Political criteria	Munizu (2010)
C-21	Political parties	Political criteria	Voiculet *et al.* (2010)
C-22	General politics of the country	Political criteria	Voiculet *et al.* (2010)
C-23	IT and ITC developments	Technological criteria	Mwesigye and Muhangi (2015)
C-24	Internet	Technological criteria	Beketova (2016)
C-25	Mobile phone developments	Technological criteria	Kirschner and Karpinski (2010)
C-26	Distance education	Technological criteria	Beketova (2016)
C-27	Science and technology developments	Technological criteria	Srikanthan and Dalrymple (2003)
C-28	Clean technology developments	Environmental criteria	Ar (2012)
C-29	Nature protection	Environmental criteria	Ar (2012)
C-30	Energy efficiency	Environmental criteria	Ar (2012)
C-31	Environmental pollutions	Environmental criteria	Ar (2012)
C-32	Major politics in education	Professional domain criteria	Torkzadeh *et al.* (2019)
C-33	Relationship with industries	Professional domain criteria	Torkzadeh *et al.* (2019)
C-34	Competitiveness	Professional domain criteria	Voiculet *et al.* (2010)
C-35	Innovation and development	Professional domain criteria	Voiculet *et al.* (2010)
C-36	Essence of higher education	Professional domain criteria	Srikanthan and Dalrymple (2003)

in Section 3. For this aim, a solution methodology should be applied with the following properties:

- to apply the opinions of the experts,
- to determine the weight of each criterion,
- to assess the impact of given criteria on organizational behaviour of the academic organizations.

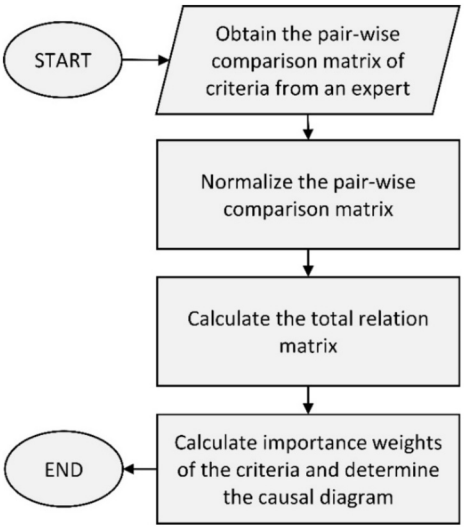

Fig. 1. Flowchart of the classical DEMATEL approach.

For this aim, the DEMATEL approach (see Alinezhad and Khalili, 2019; Nezhad *et al.*, 2023) is used. The classical form of the DEMATEL approach is represented by the flowchart of Fig. 1. As mentioned earlier, interval-valued Pythagorean fuzzy values represent more uncertain information compared to Pythagorean fuzzy values and some other types of fuzzy values. Therefore, in this section, the DEMATEL approach is extended to an interval-valued Pythagorean fuzzy form (we call it IVPF-DEMATEL) for evaluating the effect of the environmental criteria on organizational behaviour of higher education sector as described in Section 3.

In order to describe the steps of the proposed extended DEMATEL approach with interval-valued Pythagorean fuzzy information (IVPF-DEMATEL), some steps should be followed. These steps are detailed in the rest of this section and depicted in the flowchart of Fig. 2. The notations of this approach are detailed in Table 2 in advance.

Step 1. A set of criteria (each indexed by $j, k \in \{1, 2, \ldots, n\}$) and a set of experts of the field (each indexed by $e \in \{1, 2, \ldots, E\}$) are selected.

Step 2. Each expert is requested to complete the linguistic comparison matrix of the criteria (the linguistic terms are shown in the left column of Table 3). Based on the numerical values of Table 3, the linguistic comparison matrix is converted to an interval-valued Pythagorean fuzzy matrix such as $\tilde{A}_e = [\tilde{a}^e_{jk}]_{n\times n}$ for expert e, where $\tilde{a}^e_{jk} = \langle(\mu^e_{jk,L}, \mu^e_{jk,U}), (\nu^e_{jk,L}, \nu^e_{jk,U})\rangle$ is the equivalent interval-valued Pythagorean fuzzy value for comparing criterion j to k (importance or influence of j to k).

Step 3. The IVPF matrixes obtained from the experts are integrated into one matrix shown as $\tilde{A} = [\tilde{a}_{jk}]_{n\times n}$ (where $\tilde{a}_{jk} = \langle(\mu_{jk,L}, \mu_{jk,U}), (\nu_{jk,L}, \nu_{jk,U})\rangle$) using the IVPFWG

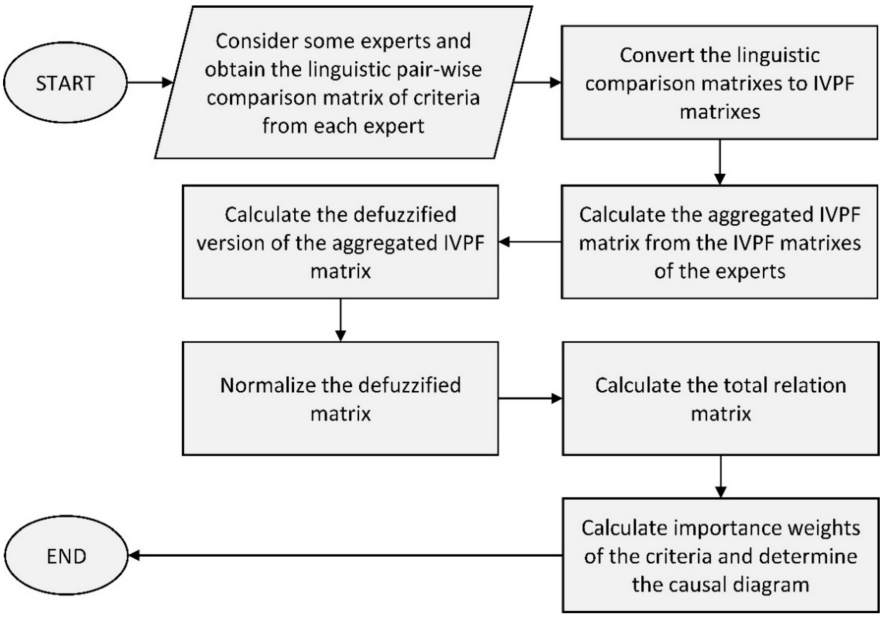

Fig. 2. General framework of the proposed interval-valued Pythagorean fuzzy DEMATEL (IVPF-DEMATEL).

Table 2
The notations used in the proposed solution methodology.

Notation	Description
n	Number of criteria
E	Number of experts
j, k	Indexes used for the criteria
e	Index used for the experts
w_e	Importance weight of expert e
$\tilde{a}^e_{jk} = \langle(\mu^e_{jk,L}, \mu^e_{jk,U}), (\nu^e_{jk,L}, \nu^e_{jk,U})\rangle$	Equivalent interval-valued Pythagorean fuzzy value for comparing criterion j to k by expert e
$\tilde{A}_e = [\tilde{a}^e_{jk}]_{n\times n}$	Interval-valued Pythagorean fuzzy matrix of pairwise comparisons of the criteria
$\tilde{a}_{jk} = \langle(\mu_{jk,L}, \mu_{jk,U}), (\nu_{jk,L}, \nu_{jk,U})\rangle$	Integrated interval-valued Pythagorean fuzzy value for comparing criterion j to k by expert e
$\tilde{A} = [\tilde{a}_{jk}]_{n\times n}$	Integrated interval-valued Pythagorean fuzzy matrix of pairwise comparisons of the criteria
$\pi^2_{jk} = (\pi^2_{jk,L}, \pi^2_{jk,U})$	Interval hesitancy degree of the interval-valued Pythagorean fuzzy value $\tilde{a}^e_{jk}$
$A = [a_{jk}]_{n\times n}$	The crisp matrix which is obtained instead of $\tilde{A} = [\tilde{a}_{jk}]_{n\times n}$
$N = [na_{jk}]_{n\times n}$	The normalized form of the crisp matrix $A = [a_{jk}]_{n\times n}$
$T = [t_{jk}]_{n\times n}$	Total-relation matrix
R_j	Sum of row values for criterion j in the total-relation matrix
C_j	Sum of column values for criterion j in the total-relation matrix
ω_j	The importance weight value of criterion j

Table 3
Linguistic terms for comparing the criteria in the proposed IVPF-DEMATEL (modified version of Otay and Jaller, 2020).

Linguistic term	Equivalent interval-valued Pythagorean fuzzy number $\langle(\mu^e_{jk,L}, \mu^e_{jk,U}),\ (\nu^e_{jk,L}, \nu^e_{jk,U})\rangle$
Certainly low influence (CLI)	$\langle(0.00, 0.00), (0.90, 1.00)\rangle$
Very low influence (VLI)	$\langle(0.10, 0.20), (0.80, 0.90)\rangle$
Low influence (LI)	$\langle(0.20, 0.35), (0.65, 0.80)\rangle$
Below average influence (BAI)	$\langle(0.35, 0.45), (0.55, 0.65)\rangle$
Average influence (AI)	$\langle(0.45, 0.55), (0.45, 0.55)\rangle$
Above average influence (AAI)	$\langle(0.55, 0.65), (0.35, 0.45)\rangle$
High influence (HI)	$\langle(0.65, 0.80), (0.20, 0.35)\rangle$
Very high influence (VHI)	$\langle(0.80, 0.90), (0.10, 0.20)\rangle$
Certainly high influence (CHI)	$\langle(0.90, 1.00), (0.00, 0.00)\rangle$
No influence (NI)	$\langle(0.00, 0.00), (0.00, 0.00)\rangle$

operator described in Section 2 as below:

$$\mu_{jk,L} = \prod_{e=1}^{E} \left(\mu^e_{jk,L}\right)^{w_e}, \quad j,k \in \{1,2,\ldots,n\}, \tag{13}$$

$$\mu_{jk,U} = \prod_{e=1}^{E} \left(\mu^e_{jk,U}\right)^{w_e}, \quad j,k \in \{1,2,\ldots,n\}, \tag{14}$$

$$\nu_{jk,L} = \sqrt{1 - \prod_{e=1}^{E} \left(1 - \left(\nu^e_{jk,L}\right)^2\right)^{w_e}}, \quad j,k \in \{1,2,\ldots,n\}, \tag{15}$$

$$\nu_{jk,U} = \sqrt{1 - \prod_{e=1}^{E} \left(1 - \left(\nu^e_{jk,U}\right)^2\right)^{w_e}}, \quad j,k \in \{1,2,\ldots,n\}, \tag{16}$$

where w_e is the importance weight of expert e.

Step 4. The values of the fuzzy matrix $\tilde{A} = [\tilde{a}_{jk}]_{n\times n}$ are deffuzified using the below equation:

$$\begin{aligned} a_{jk} = \frac{1}{6}\big(&\mu^2_{jk,L} + \mu^2_{jk,U} + \left(1 - \pi^4_{jk,L} - \nu^2_{jk,L}\right) + \left(1 - \pi^4_{jk,U} - \nu^2_{jk,U}\right) \\ &+ \mu_{jk,L}\mu_{jk,U} + \left(\left(1 - \pi^4_{jk,L} - \nu^2_{jk,L}\right)\left(1 - \pi^4_{jk,U} - \nu^2_{jk,U}\right)\right)^{\frac{1}{4}}\big), \\ &j,k \in \{1,2,\ldots,n\}. \end{aligned} \tag{17}$$

Therefore, the crisp matrix $A = [a_{jk}]_{n\times n}$ is obtained instead of $\tilde{A} = [\tilde{a}_{jk}]_{n\times n}$.

Step 5. Each value of the crisp matrix $A = [a_{jk}]_{n\times n}$ is normalized by the below equation in order to obtain the normalized matrix $N = [na_{jk}]_{n\times n}$:

$$na_{jk} = \frac{a_{jk}}{\max_j \left\{\sum_{k=1}^{n} a_{jk}\right\}}, \quad j,k \in \{1,2,\ldots,n\}. \tag{18}$$

Step 6. The total-relation matrix ($T = [t_{jk}]_{n\times n}$) is obtained by below equation:

$$T = N(I - N)^{-1}. \tag{19}$$

In equation (19), I is the unit matrix, and $(I - N)^{-1}$ is the inverse form of matrix $I - N$.

Step 7. The causal diagram is constructed in this step. For this aim, for each criterion in the total-relation matrix the sum of row values (R_j) and the sum of column values (C_j) are calculated using below equations:

$$R_j = \sum_{k=1}^{n} t_{kj}, \quad j \in \{1, 2, \ldots, n\}, \tag{20}$$

$$C_j = \sum_{k=1}^{n} t_{jk}, \quad j \in \{1, 2, \ldots, n\}. \tag{21}$$

On the causal diagram, a point is depicted for each criterion. The horizontal axis of this diagram shows the importance weights of the criteria, and the vertical axis shows the degree of relation for the criteria. The coordinate of criterion j is obtained as $(R_j + C_j, R_j - C_j)$. For the case of $R_j - C_j > 0$, the criterion is effective and is categorized as cause class. For the case of $R_j - C_j < 0$, the criterion is susceptive and is categorized as effect class.

5. Computational Study

In this section, the solution methodology proposed by Section 4 is implemented to evaluate the environmental criteria influencing the organizational behaviour of academic sector described by Section 3 for the case of higher education sector of Iran. For this aim, the following issues are considered.

- Based on Section 3, number of the environmental criteria is $n = 36$, which are detailed in Table 1.
- In order to perform the proposed solution methodology, number of the experts is set to $E = 3$, therefore, $e = 1, 2, 3$. These experts are selected from the higher education sector of Iran and all of them have at least 5 years of managerial experience in this sector.
- Each expert is asked to evaluate the pairwise comparison of the criteria of Table 1 according to the linguistic terms of Table 3. Then each linguistic term of the pairwise comparisons is converted to its equivalent IVPFN using the rules of Table 3. Therefore, three 36×36 comparison matrixes are obtained, such as $A_e = [\tilde{a}^e_{jk}]_{36\times 36}$, where $e = 1, 2, 3$.

The proposed solution methodology of Section 4 is coded in MATLAB and is run for the case study on a PC with Core i7 and 2.8 GHz CPU and 16 GB RAM. In the rest of

this section, first the results obtained by the proposed solution methodology are presented and discussed, then a comparative study considering the approaches of the literature is performed and the obtained results are presented.

5.1. *Results Obtained by the Proposed IVPF-DEMATEL*

The proposed IVPF-DEMATEL is applied to evaluate the environmental criteria of the organizational behaviour of the higher education sector described in Section 3 (see Table 1). For this aim, the steps of the IVPF-DEMATEL described in Section 4 are implemented. As mentioned, three experts of the field are selected to evaluate the pairwise influences of the criteria according to the linguistic terms of Table 3. Then according to the conversion of Table 3, the linguistic terms are converted to IVPF values. Therefore, for each expert a comparison matrix of the criteria with IVPF values is obtained. After this step, the IVPF matrixes of the experts are integrated by the IVPFWG operator (using equations (13)–(16)), and the obtained integrated matrix is defuzzified by Eq. (17). It is worth to mention that in this step, the experts are weighted equally as $w_1 = w_2 = w_3 = \frac{1}{3}$. Then, the obtained crisp matrix is normalized by equation (18), and after that, the total relation matrix is obtained by Eq. (19). Finally, in the last step, for each criterion the values of R_j, C_j, $R_j + C_j$, and $R_j - C_j$ are obtained using equations (20)–(21). As mentioned earlier, the value of $R_j - C_j$ determines the cause or effect category of the criterion and $R_j + C_j$ shows the importance degree of the criterion. Therefore, the importance weight value of criterion j is shown by ω_j and is calculated by the below formulation as a normalized value.

$$\omega_j = \frac{R_j + C_j}{\sum_{k=1}^{n} R_k + C_k}, \quad j \in \{1, 2, \ldots, n\}. \tag{22}$$

Based on the above-mentioned procedure, the results of applying the proposed IVPF-DEMATEL for evaluating the impact of the criteria of Section 3 (Table 13) on the organizational behaviour of higher education sector, are obtained and represented by Table 4 and Fig. 3.

According to the results of Table 4, 21 criteria are placed in the cause category and 15 criteria are placed in the effect category. According to these results, the criteria such as general life quality (C-2), economic indexes (C-3), income and budget level of country (C-4), economic crises (C-5), population (C-8), social crises (C-9), general knowledge of society (C-15), rules and regulations of the country (C-17), political changes (C-18), international relationships (C-19), governmental politics (C-20), political parties (C-21), general politics of the country (C-22), IT and ITC developments (C-23), internet (C-24), science and technology developments (C-27), major politics in education (C-32), relationship with industries (C-33), competitiveness (C-34), innovation and development (C-35), and essence of higher education (C-36) are cause criteria where their influential effect is higher. On the other hand, the criteria such as general situation of economy (C-1), governmental (centralized) economy (C-6), internal and foreign investments (C-7), social compatibility (C-10), social networks (C-11), social life style (C-12), social solidarity

Table 4
The values of R_j, D_j, $R_j + C_j$, and $R_j - C_j$ obtained by applying the proposed IVPF-DEMATEL.

Criterion (j)	R_j	C_j	$R_j + C_j$	$R_j - C_j$	Cause/ effect	Criterion (j)	R_j	C_j	$R_j + C_j$	$R_j - C_j$	Cause/ effect
C-1	2.549	2.605	5.154	−0.056	Effect	C-19	3.234	2.295	5.529	0.939	Cause
C-2	2.741	2.311	5.052	0.430	Cause	C-20	3.395	1.984	5.379	1.411	Cause
C-3	3.085	2.386	5.471	0.699	Cause	C-21	2.965	2.321	5.286	0.644	Cause
C-4	3.162	2.350	5.512	0.812	Cause	C-22	3.343	2.086	5.429	1.257	Cause
C-5	3.048	2.190	5.238	0.858	Cause	C-23	2.772	2.526	5.298	0.246	Cause
C-6	2.445	2.828	5.273	−0.383	Effect	C-24	2.770	2.567	5.337	0.203	Cause
C-7	2.266	2.605	4.871	−0.339	Effect	C-25	1.701	2.822	4.523	−1.121	Effect
C-8	2.405	2.027	4.432	0.378	Cause	C-26	2.404	2.419	4.823	−0.015	Effect
C-9	2.583	2.027	4.610	0.556	Cause	C-27	2.527	2.486	5.013	0.041	Cause
C-10	1.739	2.707	4.446	−0.968	Effect	C-28	1.945	2.903	4.848	−0.958	Effect
C-11	2.115	2.575	4.690	−0.460	Effect	C-29	1.653	2.997	4.65	−1.344	Effect
C-12	1.742	2.699	4.441	−0.957	Effect	C-30	1.626	3.028	4.654	−1.402	Effect
C-13	2.212	2.738	4.950	−0.526	Effect	C-31	1.172	3.234	4.406	−2.062	Effect
C-14	2.397	2.765	5.162	−0.368	Effect	C-32	2.608	2.195	4.803	0.413	Cause
C-15	2.768	2.534	5.302	0.234	Cause	C-33	2.665	2.409	5.074	0.256	Cause
C-16	1.796	3.123	4.919	−1.327	Effect	C-34	2.608	2.533	5.141	0.075	Cause
C-17	2.892	2.038	4.930	0.854	Cause	C-35	2.574	2.539	5.113	0.035	Cause
C-18	3.434	2.068	5.502	1.366	Cause	C-36	2.964	2.383	5.347	0.581	Cause

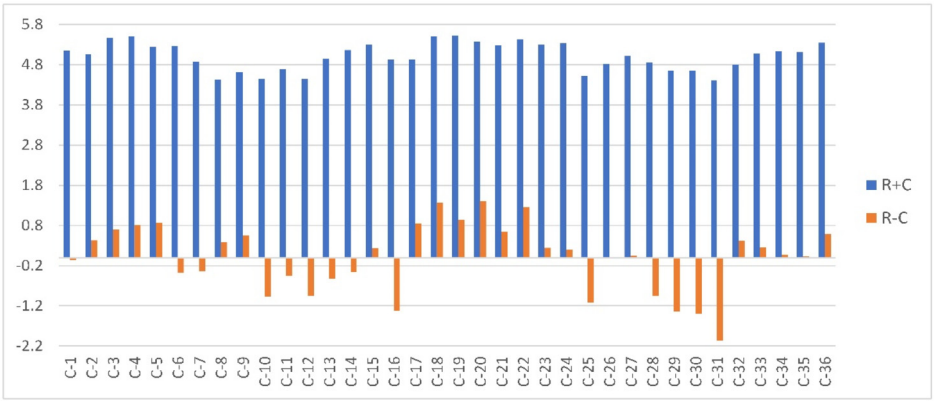

Fig. 3. Cause and effect diagram containing $R_j + C_j$ and $R_j - C_j$ values of Table 4.

(C-13), social behaviour (C-14), social organizations (C-16), mobile phone developments (C-25), distance education (C-26), clean technology developments (C-28), nature protection (C-29), energy efficiency (C-30), and environmental pollutions (C-31) are effect criteria where their influential effect is higher. The cause and effect diagram of the criteria is also depicted in Fig. 3. In this figure, the cause and effect categories of the criteria can be easily noted.

The obtained results can be interpreted in a summarized form. The criteria of the cause category are of the economic, political, and professional domain based criteria. This shows that the organizational behaviour of the higher education sector of Iran is mainly affected by these types of criteria.

Table 5
The importance weight values and the ranking of the criteria obtained by applying the proposed IVPF-DEMATEL.

Criterion (j)	$R_j + C_j$	ω_j	Ranking	Criterion (j)	$R_j + C_j$	ω_j	Ranking
C-1	5.154	0.02853	15	C-19	5.529	0.03061	1
C-2	5.052	0.02797	19	C-20	5.379	0.02978	6
C-3	5.471	0.03029	4	C-21	5.286	0.02926	11
C-4	5.512	0.03051	2	C-22	5.429	0.03005	5
C-5	5.238	0.02900	13	C-23	5.298	0.02933	10
C-6	5.273	0.02919	12	C-24	5.337	0.02955	8
C-7	4.871	0.02697	24	C-25	4.523	0.02504	32
C-8	4.432	0.02453	35	C-26	4.823	0.02670	26
C-9	4.610	0.02552	31	C-27	5.013	0.02775	20
C-10	4.446	0.02461	33	C-28	4.848	0.02684	25
C-11	4.690	0.02596	28	C-29	4.65	0.02574	30
C-12	4.441	0.02458	34	C-30	4.654	0.02576	29
C-13	4.950	0.02740	21	C-31	4.406	0.02439	36
C-14	5.162	0.02858	14	C-32	4.803	0.02659	27
C-15	5.302	0.02935	9	C-33	5.074	0.02809	18
C-16	4.919	0.02723	23	C-34	5.141	0.02846	16
C-17	4.930	0.02729	22	C-35	5.113	0.02830	17
C-18	5.502	0.03046	3	C-36	5.347	0.02960	7

Furthermore, the values obtained for $R_j + C_j$ show the importance of the criteria. As can be seen from Table 4 and Fig. 3, most of the criteria from the cause category have higher value of $R_j + C_j$ compared to the criteria of the effect category. In order to obtain the normalized importance of the criteria (ω_j), Eq. (22) is used and the obtained ω_j values are presented in Table 5. In this table, according to the values of ω_j, the criteria are ranked, and their ranking is reported as well. As can be seen, the first ranked criterion is C-19, which is of the cause category, and the last ranked criterion is C-31, which is of the effect category.

5.2. *Impact of the Results and Managerial Insights*

The results obtained from the proposed IVPF-DEMATEL and represented in Section 5.1 can be applied by managers of higher education sector in order to manage and improve organizational behaviour of that sector. The following managerial implications and insights can be considered from the obtained results.

- In general, managers should concentrate on the cause category of criteria (Fontela and Gabus, 1976).
- According to the obtained results, most of economic, political, and professional domain criteria are of the cause category. This means that these criteria should be taken into account more by the managers of the higher education sector of Iran for improving the organizational behaviour of that sector.
- The criteria with higher importance weight values like C-19 (international relationships), C-4 (income and budget level of country), C-18 (political changes), C-3 (economic indexes (employment, economic growth, etc.)), etc. are the most important cri-

teria to focus on for the managers in the higher education sector of Iran. This shows that the organizational behaviour of the higher education sector of Iran can be sensitive to international relationships, economic criteria, and political changes.

- According to the obtained results, the environmental criteria such as C-28 (clean technology developments), C-29 (nature protection), C-30 (energy efficiency), and C-31 (environmental pollutions) are in the effect category and also obtain least importance weight values. Actually, this class of criteria are out of control of the managers of the higher education sector of Iran and need to be managed by the government directly.

5.3. *Sensitivity Analysis*

In this section, a sensitivity analysis is performed in order to study the behaviour of the proposed IVPF-DEMATEL approach over some possible variations. Two types of variations can be made in the proposed approach that are explained below.

- As in Section 2, two integrating operators of interval-valued Pythagorean fuzzy numbers are defined, such as IVPFWG and IVPFWA, Step 3 of the proposed IVPF-DEMATEL approach can be performed by each of the IVPFWG and IVPFWA operators. Therefore, by applying the operators IVPFWG and IVPFWA, the proposed approach can be titled as IVPFWG-DEMATEL and IVPFWA-DEMATEL, respectively.
- Considering each of the IVPFWG-DEMATEL and IVPFWA-DEMATEL approaches, the importance weight values of the experts can be changed. For this aim four experiments of Table 6 are defined.

It is notable to mention that the IVPFWG-DEMATEL approach with the weight values of Experiment 1 has been performed in Section 5.1 and the obtained results have been analysed there. Therefore, in this section, the scenarios of Table 7 are considered for sensitivity analysis of the proposed IVPF-DEMATEL.

The results obtained for the scenarios of Table 7 are represented in Table 8, Table 9, and Fig. 4. These results can be analysed from two points of view, such as the difference between cause and effect results among the scenarios, and the difference between the importance weights or rankings of the criteria among the scenarios. According to the results of Table 8, when the IVPFWG-DEMATEL is used, the cause and effect results of scenarios 1 to 4 (changing in the importance weights of the experts) are compared. In this case, only the cause and effect results of 22.22% of the criteria are changed. For other criteria, these results among the scenarios remain unchanged. For the case of IVPFWA-DEMATEL and

Table 6
Different weight combinations of the experts for sensitivity analysis.

Experiment	Importance weight (w_e)		
	Expert 1 ($e = 1$)	Expert 2 ($e = 2$)	Expert 3 ($e = 3$)
1	0.33	0.33	0.33
2	0.60	0.30	0.10
3	0.10	0.60	0.30
4	0.30	0.1	0.60

Table 7
Different scenarios defined for sensitivity analysis of the proposed IVPF-DEMATEL.

Scenario	Experiment	Operator	Note
1	1	IVPFWG	The proposed IVPF-DEMATEL
2	2		is titled as IVPFWG-DEMATEL
3	3		
4	4		
5	1	IVPFWA	The proposed IVPF-DEMATEL
6	2		is titled as IVPFWA-DEMATEL
7	3		
8	4		

scenarios 5 to 8, also the cause and effect results of 22.22% criteria are changed. Furthermore, any pair of the scenarios with similar experiment (similar set weight values of the experts) can be compared to investigate the impact of the operators IVPFWG and IVPFWA of the obtained cause and effect results. For this aim, the following results are obtained.

- Comparing the results obtained by experiment 1 for the IVPFWG-DEMATEL and the IVPFWA-DEMATEL (scenarios 1 and 5), the cause and effect results for only 2.77% of the criteria are changed.
- Comparing the results obtained by experiment 2 for the IVPFWG-DEMATEL and the IVPFWA-DEMATEL (scenarios 2 and 6), the cause and effect results for only 8.33% of the criteria are changed.
- Comparing the results obtained by experiment 3 for the IVPFWG-DEMATEL and the IVPFWA-DEMATEL (scenarios 3 and 7), the cause and effect results for only 11.11% of the criteria are changed.
- Comparing the results obtained by experiment 4 for the IVPFWG-DEMATEL and the IVPFWA-DEMATEL (scenarios 4 and 8), the cause and effect results for only 13.88% of the criteria are changed.

On the other hand, the results of the scenarios in terms of the ranking of the criteria can be compared to investigate the sensitivity of the proposed IVPF-DEMATEL approach. The importance weight of each criterion in each scenario is obtained by formula (22). The obtained weight values are used to rank the criteria in each scenario. The obtained importance weight values and associated ranking in each scenario are represented by Table 8. Here, the obtained rankings can be compared using the Jaccard similarity index (JSI) (see Niroomand *et al.*, 2019). Thus, for any pair of the rankings a JSI value which is between 0 (indicating no similarity) and 1 (indicating full similarity) is obtained. These values are reported in Table 10. According to these results, the highest JSI is 0.92 which means the rankings of Scenario 5 and Scenario 6 are the most similar rankings. This means that when applying the IVPFWA-DEMATEL approach for experiments 1 and 2, the obtained rankings are more similar than other pairs of scenarios. Also, the lowest JSI is 0.62 which means the rankings of Scenario 3 and Scenario 8 are the least similar rankings. This means that when applying the IVPFWG-DEMATEL approach for Experiment 3 and the

Table 8
The cause and effect results of the criteria obtained by the proposed IVPF-DEMATEL for all of the scenarios.

Criterion	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
C-1	Effect	Effect	Effect	Cause	Effect	Effect	Effect	Effect
C-2	Cause	Cause	Cause	Cause	Cause	Effect	Cause	Cause
C-3	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-4	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-5	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-6	Effect	Cause	Effect	Effect	Effect	Cause	Effect	Effect
C-7	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-8	Cause	Effect	Cause	Cause	Cause	Effect	Cause	Cause
C-9	Cause	Effect	Cause	Cause	Cause	Effect	Cause	Cause
C-10	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-11	Effect	Effect	Effect	Effect	Effect	Effect	Cause	Effect
C-12	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-13	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-14	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-15	Cause	Cause	Cause	Cause	Cause	Effect	Cause	Cause
C-16	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-17	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-18	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-19	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-20	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-21	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-22	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-23	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-24	Cause	Cause	Cause	Effect	Cause	Cause	Cause	Cause
C-25	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-26	Effect	Effect	Cause	Cause	Effect	Effect	Effect	Effect
C-27	Cause	Cause	Effect	Effect	Cause	Cause	Cause	Cause
C-28	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-29	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-30	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-31	Effect	Effect	Effect	Effect	Effect	Effect	Effect	Effect
C-32	Cause	Effect	Cause	Cause	Cause	Effect	Cause	Cause
C-33	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause
C-34	Cause	Cause	Cause	Cause	Cause	Cause	Effect	Cause
C-35	Cause	Cause	Effect	Cause	Effect	Effect	Effect	Effect
C-36	Cause	Cause	Cause	Cause	Cause	Cause	Cause	Cause

IVPFWA-DEMATEL approach for Experiment 4, the obtained rankings are less similar than other pairs of scenarios.

To summarizae this section, the proposed approach is sensitive to the importance weight of each expert. Furthermore, this approach is sensitive to the aggregating operator that is used for integrating the pairwise comparison matrixes of the experts.

5.4. *Comparative Study*

In this section, the results obtained by the proposed IVPF-DEMATEL in Section 5.1 and Section 5.3 are compared to the approaches of the literature. Otay and Jaller (2020) proposed an interval-valued Pythagorean fuzzy AHP (IVPF-AHP) which is used in this sec-

Table 9
The importance weights and ranking of the criteria obtained by the proposed IVPF-DEMATEL for all of the scenarios.

Criterion (j)	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8	
	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking
C-1	0.02853	15	0.02905	13	0.02829	14	0.02813	17	0.02745	17	0.02789	18	0.02728	23	0.02741	20
C-2	0.02797	19	0.02803	20	0.02777	19	0.02791	18	0.02740	19	0.02750	19	0.02737	21	0.02746	18
C-3	0.03029	4	0.03145	4	0.02979	3	0.02938	6	0.02988	7	0.03098	7	0.02922	6	0.02937	10
C-4	0.03051	2	0.03188	3	0.02977	4	0.02965	3	0.03071	5	0.03183	5	0.03000	4	0.03009	5
C-5	0.02900	13	0.02954	12	0.02799	16	0.02916	7	0.02968	8	0.03031	9	0.02914	8	0.02964	8
C-6	0.02919	12	0.02963	10	0.02938	8	0.02840	12	0.02803	15	0.02845	15	0.02816	16	0.02768	16
C-7	0.02697	24	0.02597	27	0.02758	23	0.02691	27	0.02505	33	0.02458	32	0.02572	32	0.02524	33
C-8	0.02453	35	0.02351	33	0.02554	33	0.02512	34	0.02542	31	0.02399	34	0.02592	31	0.02630	29
C-9	0.02552	31	0.02447	31	0.02703	26	0.02561	33	0.02685	24	0.02525	27	0.02783	18	0.02742	19
C-10	0.02461	33	0.02283	34	0.02614	31	0.02511	35	0.02398	36	0.02272	36	0.02525	35	0.02414	36
C-11	0.02596	28	0.02455	30	0.02771	20	0.02583	32	0.02520	32	0.02433	33	0.02661	28	0.02479	34
C-12	0.02458	34	0.02218	36	0.02766	22	0.02465	36	0.02491	34	0.02325	35	0.02731	22	0.02418	35
C-13	0.02740	21	0.02714	23	0.02770	21	0.02730	23	0.02646	26	0.02635	24	0.02688	27	0.02632	28
C-14	0.02858	14	0.02834	19	0.02908	11	0.02786	19	0.02668	25	0.02675	23	0.02727	24	0.02630	30
C-15	0.02935	9	0.02900	14	0.03038	1	0.02820	16	0.02738	20	0.02745	20	0.02840	15	0.02658	23
C-16	0.02723	23	0.02654	25	0.02798	17	0.02753	22	0.02768	16	0.02693	22	0.02874	12	0.02747	17
C-17	0.02729	22	0.02876	17	0.02479	34	0.02914	8	0.03089	4	0.03194	4	0.02894	10	0.03115	3
C-18	0.03046	3	0.03190	2	0.02908	10	0.03009	1	0.03162	2	0.03258	2	0.03044	2	0.03157	2
C-19	0.03061	1	0.03209	1	0.02991	2	0.02950	4	0.03111	3	0.03210	3	0.03003	3	0.03088	4
C-20	0.02978	6	0.03118	5	0.02795	18	0.03001	2	0.03180	1	0.03276	1	0.03051	1	0.03177	1
C-21	0.02926	11	0.03013	8	0.02864	12	0.02884	10	0.02949	9	0.03039	8	0.02848	14	0.02933	11
C-22	0.03005	5	0.03111	6	0.02920	9	0.02949	5	0.03008	6	0.03101	6	0.02916	7	0.02987	6
C-23	0.02933	10	0.02957	11	0.02946	7	0.02863	11	0.02866	14	0.02880	14	0.02883	11	0.02842	13
C-24	0.02955	8	0.03027	7	0.02973	5	0.02839	13	0.02918	11	0.02950	11	0.02905	9	0.02887	12
C-25	0.02504	32	0.02447	32	0.02428	36	0.02645	31	0.02486	35	0.02472	30	0.02390	36	0.02602	32
C-26	0.02670	26	0.02654	24	0.02670	28	0.02671	29	0.02599	27	0.02608	25	0.02569	34	0.02633	27
C-27	0.02775	20	0.02862	18	0.02704	25	0.02773	21	0.02905	12	0.02950	10	0.02803	17	0.02943	9
C-28	0.02684	25	0.02760	22	0.02694	27	0.02724	24	0.02941	10	0.02892	13	0.02944	5	0.02971	7
C-29	0.02574	30	0.02457	29	0.02616	30	0.02676	28	0.02588	28	0.02461	31	0.02695	25	0.02624	31
C-30	0.02576	29	0.02465	28	0.02597	32	0.02697	26	0.02588	29	0.02486	29	0.02652	29	0.02639	25
C-31	0.02439	36	0.02252	35	0.02442	35	0.02665	30	0.02693	23	0.02516	28	0.02774	19	0.02799	15
C-32	0.02659	27	0.02634	26	0.02624	29	0.02715	25	0.02584	30	0.02557	26	0.02572	33	0.02636	26
C-33	0.02809	18	0.02766	21	0.02857	13	0.02782	20	0.02707	22	0.02719	21	0.02755	20	0.02642	24
C-34	0.02846	16	0.02888	15	0.02800	15	0.02826	15	0.02743	18	0.02823	16	0.02692	26	0.02712	22
C-35	0.02830	17	0.02880	16	0.02741	24	0.02837	14	0.02721	21	0.02811	17	0.02622	30	0.02730	21
C-36	0.02960	7	0.03007	9	0.02956	6	0.02888	9	0.02866	13	0.02920	12	0.02861	13	0.02826	14

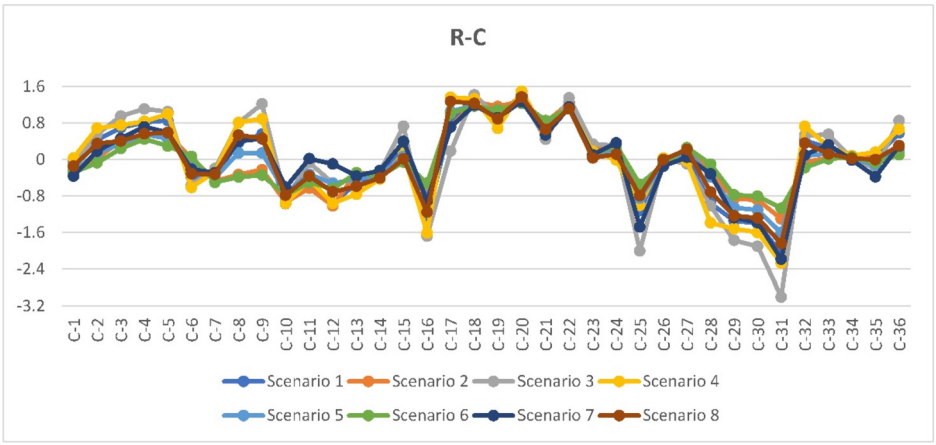

Fig. 4. The graph of $R_j - C_j$ values of the criteria obtained by the proposed IVPF-DEMATEL for all of the scenarios.

Table 10
The Jaccard similarity indexes of pair-wise comparison of the criteria rankings obtained by the proposed IVPF-DEMATEL for all of the scenarios.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Scenario 1	–	0.91	0.81	0.86	0.76	0.80	0.72	0.71
Scenario 2	–	–	0.76	0.89	0.80	0.84	0.74	0.74
Scenario 3	–	–	–	0.72	0.68	0.67	0.67	0.62
Scenario 4	–	–	–	–	0.83	0.87	0.76	0.78
Scenario 5	–	–	–	–	–	0.92	0.84	0.90
Scenario 6	–	–	–	–	–	–	0.79	0.87
Scenario 7	–	–	–	–	–	–	–	0.81
Scenario 8	–	–	–	–	–	–	–	–

Table 11
Different scenarios defined for the IVPF-AHP approach.

Scenario	Experiment	Operator	Note
1	1	IVPFWG	The proposed IVPF-AHP is titled as IVPFWG-AHP
2	2		
3	3		
4	4		
5	1	IVPFWA	The proposed IVPF-AHP is titled as IVPFWA-AHP
6	2		
7	3		
8	4		

tion for comparison purposes. As the IVPF-AHP approach is sensitive to the IVPFWG and IVPFWA operators, the similar experiments and scenarios as Table 6 and Table 7 are defined for this approach. Therefore, the scenarios of Table 11 are considered.

Table 12
The weights and ranking of the criteria obtained by the IVPF-AHP for all of the scenarios.

Criterion (j)	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8	
	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking	ω_j	Ranking
C-1	0.0313	14	0.0251	19	0.0322	14	0.0322	12	0.0199	20	0.0165	21	0.0225	22	0.022	18
C-2	0.033	10	0.026	18	0.0314	16	0.0402	9	0.0277	14	0.0214	18	0.0292	14	0.0343	11
C-3	0.0463	6	0.0461	7	0.0416	6	0.0492	7	0.0382	9	0.0386	10	0.0362	9	0.0392	9
C-4	0.0481	5	0.0507	5	0.0427	4	0.0516	6	0.0476	7	0.0492	7	0.0438	6	0.0481	7
C-5	0.046	7	0.0429	8	0.0365	9	0.0619	3	0.0521	6	0.0463	8	0.0492	5	0.0585	5
C-6	0.023	22	0.029	14	0.0247	20	0.0154	25	0.0223	16	0.0267	15	0.0228	20	0.0171	23
C-7	0.0169	26	0.0119	26	0.0222	27	0.015	26	0.0104	29	0.0076	29	0.0148	30	0.0104	27
C-8	0.0185	25	0.0093	29	0.0245	21	0.0246	20	0.0198	21	0.0085	28	0.0253	18	0.0307	13
C-9	0.0235	21	0.0118	27	0.0336	12	0.0285	15	0.0226	15	0.0107	26	0.0309	12	0.0319	12
C-10	0.0085	31	0.0058	34	0.0147	30	0.0069	31	0.0068	32	0.0046	34	0.0124	32	0.0059	32
C-11	0.013	28	0.0086	30	0.0224	26	0.0109	28	0.0107	28	0.0066	31	0.0192	24	0.0101	28
C-12	0.0076	32	0.0042	35	0.0181	28	0.0058	32	0.008	31	0.0046	35	0.0181	28	0.006	31
C-13	0.0164	27	0.0156	25	0.0233	23	0.0119	27	0.0125	27	0.0116	25	0.0187	27	0.0097	29
C-14	0.0214	24	0.0183	22	0.0267	18	0.0169	24	0.0135	26	0.0119	24	0.0188	26	0.0113	26
C-15	0.0306	16	0.0264	17	0.0407	7	0.0229	22	0.0198	22	0.0171	20	0.0284	16	0.0164	24
C-16	0.0096	30	0.0109	28	0.0142	32	0.0057	33	0.0091	30	0.0098	27	0.0147	31	0.0051	34
C-17	0.0321	13	0.0355	11	0.0181	29	0.0526	5	0.0648	3	0.0703	4	0.0436	7	0.0731	3
C-18	0.0648	1	0.0719	1	0.0499	1	0.0651	2	0.0743	2	0.0811	2	0.0602	2	0.0735	2
C-19	0.0505	4	0.0677	2	0.0426	5	0.0399	10	0.06	5	0.0711	3	0.0495	4	0.0532	6
C-20	0.0564	3	0.0646	4	0.0388	8	0.0672	1	0.0817	1	0.0862	1	0.0652	1	0.0848	1
C-21	0.0378	9	0.0478	6	0.0347	11	0.0329	11	0.0458	8	0.0545	6	0.0392	8	0.0409	8
C-22	0.0576	2	0.0653	3	0.0463	3	0.0567	4	0.0622	4	0.0677	5	0.0527	3	0.0607	4
C-23	0.0326	11	0.0326	12	0.032	15	0.0318	13	0.028	13	0.0287	12	0.0274	17	0.0274	16
C-24	0.0324	12	0.0408	9	0.0331	13	0.0241	21	0.0357	10	0.0409	9	0.0344	10	0.0302	14
C-25	0.0075	33	0.0077	31	0.0066	35	0.0081	29	0.0062	34	0.0073	30	0.0052	36	0.0065	30
C-26	0.0221	23	0.0194	21	0.0231	24	0.0223	23	0.0179	24	0.0155	22	0.0193	23	0.02	21
C-27	0.0247	20	0.0273	16	0.0229	25	0.0249	19	0.035	11	0.0379	11	0.0294	13	0.0348	10
C-28	0.0107	29	0.0178	24	0.0145	31	0.0072	30	0.0222	17	0.0274	14	0.0242	19	0.0157	25
C-29	0.0074	34	0.0074	32	0.0096	33	0.0056	34	0.0063	33	0.0057	33	0.0099	33	0.0052	33
C-30	0.0072	35	0.0074	33	0.0094	34	0.0053	35	0.0061	35	0.0058	32	0.0091	34	0.0048	35
C-31	0.0037	36	0.0042	36	0.0047	36	0.0024	36	0.0039	36	0.0044	36	0.006	35	0.0022	36
C-32	0.0261	19	0.0182	23	0.0261	19	0.0317	14	0.0174	25	0.0123	23	0.019	25	0.0228	17
C-33	0.0297	17	0.0239	20	0.0358	10	0.027	18	0.0208	19	0.0183	19	0.029	15	0.0188	22
C-34	0.0309	15	0.0297	13	0.0314	17	0.0279	16	0.0216	18	0.0227	16	0.0227	21	0.0202	19
C-35	0.0273	18	0.0276	15	0.0235	22	0.0272	17	0.0197	23	0.0222	17	0.0164	29	0.0202	20
C-36	0.0449	8	0.0407	10	0.0473	2	0.0404	8	0.0295	12	0.0287	13	0.0325	11	0.0282	15

Table 13
The Jaccard similarity indexes of pair-wise comparison of the criteria rankings obtained by the proposed IVPF-AHP for all of the scenarios.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Scenario 1	–	0.87	0.84	0.88	0.84	0.82	0.83	0.83
Scenario 2	–	–	0.77	0.80	0.83	0.91	0.80	0.80
Scenario 3	–	–	–	0.79	0.78	0.73	0.80	0.77
Scenario 4	–	–	–	–	0.84	0.79	0.80	0.87
Scenario 5	–	–	–	–	–	0.89	0.91	0.89
Scenario 6	–	–	–	–	–	–	0.82	0.82
Scenario 7	–	–	–	–	–	–	–	0.86
Scenario 8	–	–	–	–	–	–	–	–

The criteria of Table 1 in Section 3 are evaluated by the above-mentioned IVPF-AHP and the same experts of the field as invited for the proposed IVPF-DEMATEL. The main outputs of the IVPF-AHP are importance weights and ranking of the criteria. These values for all scenarios of Table 11 are obtained and reported in Table 12.

According to the results of Table 12, the importance weight values and ranking of the criteria are sensitive to the variations of the importance weights of the experts and the integrating operators. According to these results, some criteria show less sensitivity and some others show high sensitivity to these variations. The pairwise comparison of the obtained rankings of Table 12 is done in terms of Jaccard similarity index and the obtained JSI values are reported by Table 13. According to the obtained JSI values, the highest similarity is seen between the rankings of scenarios 5 and 6 (experiments 1 and 2 when applying the IVPFWG operator) and 5 and 7 (experiments 1 and 3 when applying the IVPFWA operator) with similar JSI values of 0.91.

The rankings obtained by the scenarios of the proposed IVPF-DEMATEL are compared to the rankings obtained by the above-mentioned IVPF-AHP. A schematic representation for comparing the obtained rankings is represented by Fig. 5. In this figure, based on Table 7 and Table 11, the scenarios are categorized based on the experiments in such a way that in each experiment four approaches are considered, such as the IVPF-DEMATEL with IVPFWG and IVPFWA operators (called IVPFWG-DEMATEL and IVPFWA-DEMATEL) and IVPF-AHP with IVPFWG and IVPFWA operators (called IVPFWG-AHP and IVPFWA-AHP). Figure 5 shows that the rankings of the mentioned four approaches in Experiment 2 (importance weight combination of $(w_1, w_2, w_3) = (0.60, 0.30, 0.10)$) have more stability than other experiments. On the other hand, the least stability of rankings appears in Experiment 3 and Experiment 4.

Finally, the rankings obtained by the proposed IVPF-DEMATEL and the IVPF-AHP approaches represented in Table 9 and Table 11 are compared. For this aim, for any pair of ranking from these two tables, the Jaccard similarity index (JSI) is calculated. All the JSI values are reported by Table 14. The similarities are higher than 0.63 which is between Scenario 3 of the IVPF-DEMATEL and Scenario 4 of the IVPF-AHP. The main and fair comparisons are done when the same scenario is considered for both approaches. In this case, the JSI values of the main diagonal of the table are considered. Therefore, when considering scenarios 1 to 8 for both approaches, the JSI values of 0.80, 0.88, 0.75, 0.75,

Table 14
The Jaccard similarity indexes of pair-wise comparison of the criteria rankings obtained by the proposed IVPF-DEMATEL and the IVPF-DEMATEL for all of the scenarios.

		IVPF-AHP							
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
IVPF-DEMATEL	Scenario 1	0.80	0.83	0.78	0.73	0.74	0.79	0.72	0.70
	Scenario 2	0.81	0.88	0.75	0.74	0.77	0.83	0.74	0.72
	Scenario 3	0.70	0.71	0.75	0.63	0.65	0.67	0.66	0.60
	Scenario 4	0.81	0.87	0.74	0.75	0.77	0.83	0.75	0.73
	Scenario 5	0.76	0.81	0.69	0.73	0.83	0.86	0.78	0.76
	Scenario 6	0.78	0.86	0.70	0.75	0.83	0.91	0.78	0.78
	Scenario 7	0.72	0.74	0.67	0.67	0.76	0.76	0.76	0.68
	Scenario 8	0.73	0.77	0.66	0.71	0.82	0.83	0.76	0.76

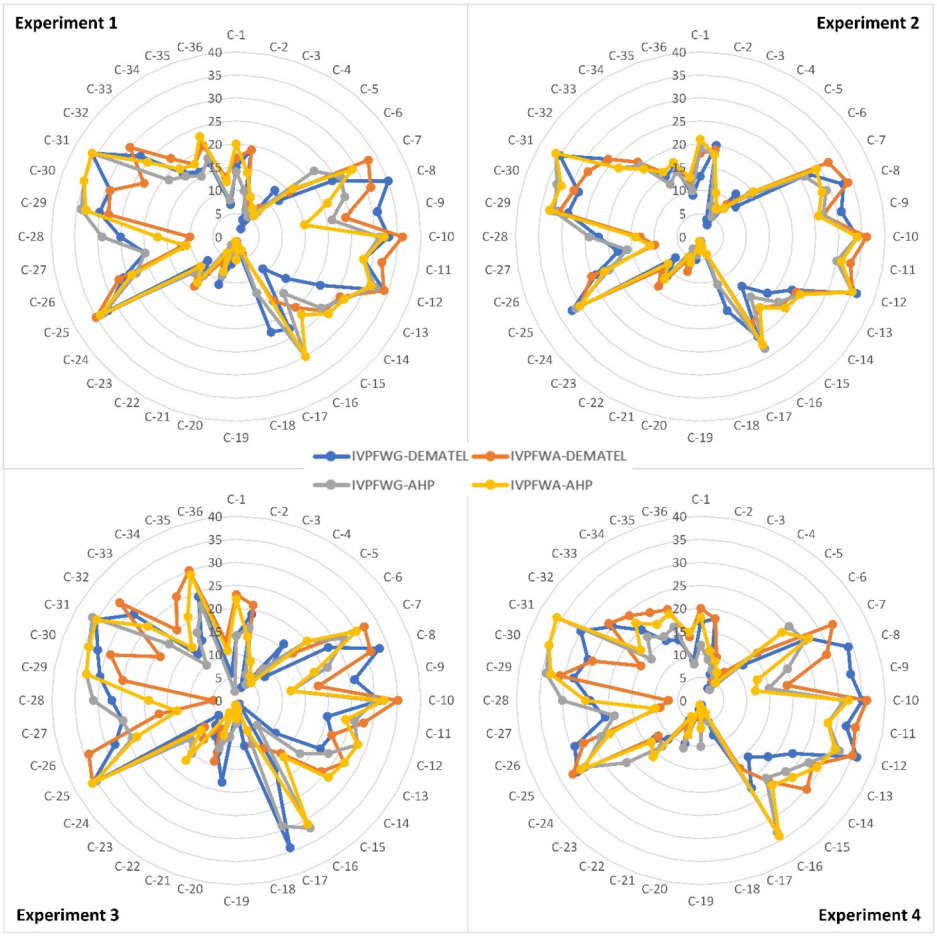

Fig. 5. Schematic representation of the criteria under all scenarios.

0.83, 0.91, 0.76, and 0.76 are obtained. According to these values, a fair and acceptable similarity exists between the proposed IVPF-DEMATEL and the IVPF-AHP approaches.

6. Conclusion

In this study, some environmental criteria affecting organizational behaviour of the higher education sector were considered. The aim of the study was to analyse and prioritize these factors for giving some insights to the managers. As a solution methodology, first some experts from the higher education sector of Iran were selected and asked to determine pairwise comparison of the criteria. Then, in order to respect the uncertain nature of the comparisons, the linguistic terms were converted to interval-valued Pythagorean fuzzy values. Interval-valued Pythagorean fuzzy numbers were used as they keep more information and uncertainty compared to classical fuzzy numbers. Then, an interval-valued Pythagorean fuzzy DEMATEL approach was developed for the first time for prioritizing the criteria and performing the causality analysis on them. Finally, the obtained results were interpreted, and some managerial insights were given. According to the obtained results, most of the economic, political, and professional domain criteria were selected to be of the cause category. According to the obtained results, the managers can improve the organizational behaviour of their organizations by focusing on the cause category of the criteria. On the other hand, there were some limitations for performing this study. A limitation is selecting suitable and experienced people for criteria comparison step. Another limitation was reflecting the uncertainty that may happen in comparing the criteria that was solved by linguistic terms and their equivalent fuzzy values.

This study can be extended by considering more range of criteria other than the environmental criteria. Also, other types fuzzy sets and numbers can be considered for reflecting the uncertain nature of the problem.

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