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Evaluation of key criteria affecting the adoption of digital marketing by SMEs using an interval Valued Pythagorean fuzzy AHP technique

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Abstract

This study aims to identify the various criteria that affect the adoption of digital marketing by small and medium-sized enterprises. Five key criteria are identified through extensive literature review and expert opinion and evaluated using the interval-valued Pythagorean fuzzy analytical hierarchy technique. For the collection of responses, 30 experts are approached. Using the case of SMEs of Delhi NCR, the criteria priority weights are computed, and the results showed organizational structure as the most influential criterion and organizational environment as the least influential criterion for SMEs' adoption of digital marketing. SMEs' strategies and decision-makers can use these results to enhance their strategies and decision-making.

Keywords: Digital marketing; Pythagorean fuzzy sets; AHP; SMEs; Decision-making

1. Introduction

Over the last few decades, the Small and Medium-Sized Enterprises (SME) sector has played a vital role in developing the Indian economy. The SME sector makes significant contributions to the nation's employment and manufacturing sectors and is credited with generating the most substantial employment growth while accounting for a significant part of industrial production and exports in the country. When compared to other sectors and industries, they offer distinct advantages due to their size, low capital intensity, smaller, segmented markets to focus on, lower investment requirements, and generally more modest business sectors; they work with a compelling preparation of assets of capital and abilities that may, in any case, go unutilized. The SME sector in India is highly diverse in terms of the size of the enterprises, the variety of products and administrations offered, and the amount of innovation. It serves as a subordinate unit to large corporations and makes a significant contribution to the overall economic development of the country, as well.

The SME sector is a significant mainstay of the Indian economy, as it contributes enormously to the development of the Indian economy with a considerable portion of around 30 million units, creating work for around 70 million people, contributing approximately 45 per cent to assembling yield and approximately 40 per cent to products, and manufacturing more than 6000 items, both directly and circularly. As the government proceeds toward a more rapid and comprehensive growth strategy, this sector's importance becomes even more prominent. The

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SME sector can also assist in comprehending the proposed National Manufacturing Policy's goal of increasing the proportion of manufacturing units in the GDP from 16 per cent to 25 per cent by the end of 2022.

The growing need for mobile digital marketing provides a substantial opportunity for SMEs to promote and expand their enterprises, particularly in developing countries. In the words of Scharl et al. (2005), digital marketing provides a business with the option to communicate with customers frequently. This has altered how prospective and present customers communicate via devices like phones (Arghya et al., 2020; Hosseini et al., 2016). Business owners, large and small, can use these devices to market on the internet from any location (Agostini and Nosella, 2020). Digital marketing creation help to improve the company's assist advertisers in continuously reaching out to potential customers and digital image, and it is possible to achieve success in digital marketing (Arghya et al., 2020; Smutkupt et al., 2010). Persaud and Azhar (2012) also emphasized that organizations should concentrate on policies encouraging emotional connections with their customers and employees. SMEs that incorporate digital marketing into their strategic marketing plans must concentrate on building tactics that will raise awareness, encourage debate, and earn the trust of their target clients. However, digital marketing specialists have been unable to develop such partnerships due to the uncertainty around the usage and outcome of the technology (Eze et al., 2019).

Digitalization is challenging to incorporate into SME strategic plans (Leppänen and colleagues, 2004); these applications allow organizations to interact with clients more efficiently (Eze et al., 2014; Shankar et al., 2010). The distinctive characteristics of digital marketing are the ability to personalize communications, the ability to secure business transactions, and the ability to communicate smoothly and efficiently between organizations and customers. As a result, digital platforms enable businesses to achieve their goals, including accessing target markets, interacting with target audiences, understanding customer needs, and concluding deals. These systems facilitate the users at any time of day or night and ensure flawless interactions, allowing consumers to provide feedback using voice notes, messages, and other means, among others. According to Eze et al. (2019), business owners see these applications as a natural extension of their daily routines because they are accessible to their customers regardless of distance and location. This is critical to their success because online transactions are made available to customers regardless of distance and location. For SMEs, digital marketing is a good strategy since it encourages client patronage, increases awareness, and supports the expansion and popularity of the company (Eze et al., 2019; Franco and Garcia, 2018).

While digital marketing can be highly beneficial to SMEs, most studies on this subject are restricted to developed countries and theoretical frameworks. As a result, this study was compelled by a scarcity of research into and evaluation of the elements that influence SMEs' adoption of digital marketing. Aside from that, despite the advancements in digital marketing made by SMEs in various countries, the adoption rate of digital marketing by SMEs in many countries is still low (Hong et al., 2018, Algumzi, 2022, Bhagat, 2021).

If we compare SMEs in developing countries to SMEs in developed countries, we find that they have a slow-paced adoption of such digital marketing practices in contrast to SMEs in developed countries. Since limited knowledge of such new practices may be the reason for this difference, this research will help small businesses overcome this drawback (Agostini and Nosella, 2020; Hong et al., 2018). As a result, this paper aims to investigate the critical criteria



influencing SMEs' adoption of digital marketing to develop an integrated framework that can be used to guide small businesses and academics in their efforts to understand and successfully implement digital marketing in India.

SMEs can benefit from using the Pythagorean fuzzy analytical hierarchy process (PFAHP) to examine the elements that influence their adoption of digital marketing for more successful working. Pythagorean fuzzy sets (PFS) are an extension of intuitionistic fuzzy sets, which are themselves an extension of intuitionistic fuzzy sets (IFS). They give decision-makers greater latitude in communicating their opinions concerning the vagueness and uncertainty of the MCDM situation, increasing their autonomy. PFSs accomplish this objective because DMs do not have to issue association and non-association degrees whose sum is no greater than one; as an alternative, they can allocate degrees whose sum is at most one (Ilbahar et al. 2018). The total of squares of these degrees, on the other hand, must be no more than 1. Using the PFAHP technique, the weights of five digital marketing adoption criteria are determined.

The remainder of this paper is organized as follows: Section 2 discusses the characteristics that influence digital marketing adoption that has been uncovered through research. PFS, linguistic variables parameterized by Pythagorean fuzzy numbers, and the steps of the PFAHP are discussed in Section 3. Section 4 presents the case analysis, followed by a discussion of results and conclusion in section 5, along with limitations and future scope.

2. Criteria influencing the adoption of digital marketing

The author conducted a survey of the literature to guide the selection of a related domain for the literature search.

2.1 Worker's Attitude

According to the research, the Worker's attitude significantly impacts the technology adoption process in SMEs. According to an article by Bruque and Moyano (2007), workers' attitudes toward technological change will be modified if a training system is implemented in SMEs. According to Stockdale and Standing (2006), this will allow the transfer of knowledge necessary to use new tools while also changing the workers' attitudes toward technological change. SMEs continue to face significant challenges due to a lack of financial resources and technological expertise, as well as a lack of understanding of the benefits of e-commerce. Others, such as technical constraints on a specific topic, exist but can be solved by engaging a qualified technical professional (Gilmore et al., 2007). El-Gohary (2012) discovered that the utility and convenience of use of E-Marketing have a fair, positive direct impact on the adoption of E-Marketing by small tourism firms in Egypt.

2.2 Top Management's Attitude

In the new structure, management will simplify and rationalize the exchange of information by facilitating and rationalizing it (Bruque and Moyano, 2007). As a result of top management's influence on resource allocation decisions, new e-commerce projects can be initiated and completed with sufficient money, time, and human talent available (Tarafdar and Vaidya, 2006). These organizational criteria determine the amount to which EC is implemented. Among other things, managers' enthusiasm about developing technologies, their comfort with their use, and the existence of related experimentation and innovation all favour adopting new technologies (Tarafdar and Vaidya, 2006).

2.3 Tech advancements

There are no sophisticated methods in place to measure the efficacy of e-marketing. Identifying sales resulting from technology is tough when determining the return on investment and the costs associated with the technology (Gilmore et al., 2007). A significant amount of research considers cost as a key aspect in determining the criterion that influences adoption (Gilmore et al., 2007; El-Gohary, 2012; Al-Qirim, 2007). Previous studies have shown that individuals have become more responsive to the internet, yet there are some expectations and worries regarding technology's credibility regarding the money being spent (Curtis et al., 2010; Stockdale and Standing, 2006). Regarding language and fundamental technical issues such as spamming, there are still certain impediments to SMEs (Kendall et al., 2001). Within businesses, technological innovation is also concerned with the technical compatibility with the rest of the business-related environment (Al-Qirim, 2007).

2.4 Organizational Structure

In SMEs, the adoption of electronic-based marketing is directly influenced by senior management, which is responsible for making all decisions ranging from day-to-day operations to long-term expenditures (Bruque and Moyano, 2007; Nguyen, 2009). An increased degree of engagement and participation among members and employees in their company, and as a result, a greater level of involvement in adopting new technology will result (Bruque and Moyano, 2007). Leaders who are well-versed in developing technologies can persuade other managers to consider them. Positively inclined leaders who support the implementation of e-commerce technologies encourage and support the developments (Tarafdar and Vaidya, 2006). Small businesses that use information technology are more likely to have CEOs with a positive attitude who are imaginative and informed about the technology they are implementing (Thong and Yap, 1995).

2.5 Organizational Environment

SMEs regarded technology as a tool for staying competitive. When competitors use technology to keep one step ahead, SMEs are more likely to leap on board and adopt the new technology (El-Gohary, 2012). Influence, legislation, and actions from the government have an impact on adoption. The availability of fundamental infrastructures, such as high-speed internet access, is critical to stimulating the use of technology (El-Gohary, 2012). Vendors and business partners are subject to the same restrictions (Al-Qirim, 2007; Ifinedo, 2011). External influences such as globalization, economic climates, and market trends all impact SMEs' decision-making (Stockdale and Standing, 2006; El-Gohary, 2012). A study by Pookulangara and Koesler (2011) investigated the role of culture as a mediating element in social media marketing adoption.

3. Materials and methods

The current study intends to uncover the elements that affect the adoption of digital marketing by SMEs and then rank the characteristics that have been found to impact digital marketing adoption. To accomplish this, a trustworthy and precise technique is required to evaluate and rank criteria. Therefore, in this study, the PFS and AHP technique is used to evaluate the criteria affecting SMEs' adoption of digital marketing. A significant area of management science is Multi-criteria decision-making (MCDM), which reveals multiple



conflicting criteria in decision-making (DM) environments. It comprises numerous types of procedures for DMs and practitioners. MCDM-based techniques significantly involve human involvement and assessments (Kubler et al. 2016).

Criteria weights are determined through the AHP process, and alternative ranking is defined. The process of DM starts with the alternative's comparison based on criteria. The assessment persists up to the 1st level criteria, and then a comparison with the goal occurs. AHP has various advantages over other methods, such as:

1. hierarchical structure definition,
2. problem demonstration in a structured way and
3. combination of all the decisions with structured connections.

After defining the hierarchy structure, experts used the linguistic scale for pairwise comparisons. Then, the linguistic scale is changed to quantitative values by employing FSS which can deal with ambiguity and imprecision of human judgements. Therefore, it can be said that having multiple criteria FAHP is quite helpful for uncertain problems.

3.1 Preliminary Pythagorean fuzzy sets

Atanassov (1986) was the first to propose IFS and has been used by numerous researchers in various disciplines to deal with ambiguity since then. These sets can be articulated in terms of association function, non-association function and uncertainty degree. However, in some cases, it fails to fulfil the requirement when the degree of association and non-association is more than 1. IFSs are impotent to describe the condition. Therefore, Yager (2014) developed PFS. These sets simplify the IFS as, in some situations, IFS can not deal with the uncertainty. This achievement makes PFS extra effective and adaptable to resolve problems, including uncertainty (Mohd and Abdullah 2017; Ilbahar et al. 2018).

In PFS, unlike the IFS, the sum of association and non-association degrees can exceed 1, but the sum of squares cannot (Ilbahar et al., 2018; Zeng et al., 2016; Zhang and Xu, 2014). This situation is shown below in Definition 1.

Definition 1: The set X denotes a universe of discourse in the first definition. According to Zhang and Xu (2014), the following is the definition of a Pythagorean fuzzy set $P:Q = \{ \langle y, Q(\alpha_Q(y), \beta_Q(y)) \rangle \mid y \in Y \}$ (1)

where $\alpha_Q(y): Y \rightarrow [0, 1]$ defines the degree of membership and $\beta_Q(y): Y \rightarrow [0, 1]$ defines the degree of non-membership of the element $y \in Y$ to Q , respectively, and for every $y \in Y$, it holds:

$$0 \leq \alpha_Q(y)^2 + \beta_Q(y)^2 \leq 1 \quad (2)$$

For any PFS Q and $y \in Y$, $\mu_Q(y) = \sqrt{1 - \alpha_Q^2(y) - \beta_Q^2(y)}$ is known as the degree of indeterminacy of y to Q .

Definition 2: Let $\pi_1 = Q(\alpha_{\pi_1}, \beta_{\pi_1})$ and $\pi_2 = Q(\alpha_{\pi_2}, \beta_{\pi_2})$ be two PFNs, and $\gamma > 0$, then the processes on these two PFNs are defined as follows (Zeng et al. 2016; Zhang and Xu 2014):

$$\pi_1 \oplus \pi_2 = Q\left(\sqrt{\alpha_{\pi_1}^2 + \alpha_{\pi_2}^2 - \alpha_{\pi_1}^2 \alpha_{\pi_2}^2}, \beta_{\pi_1} \beta_{\pi_2}\right) \quad (3)$$

$$\pi_1 \otimes \pi_2 = Q\left(\alpha_{\pi_1} \alpha_{\pi_2}, \sqrt{\beta_{\pi_1}^2 + \beta_{\pi_2}^2 - \beta_{\pi_1}^2 \beta_{\pi_2}^2}\right) \quad (4)$$

$$\gamma \pi_1 = Q\left(\sqrt{1 - (1 - \alpha_{\pi_1}^2)^\gamma}, (\beta_{\pi_1})^\gamma\right), \gamma > 0 \quad (5)$$

$$\pi_1^\gamma = Q\left((\alpha_{\pi_1})^\gamma, \sqrt{1 - (1 - \beta_{\pi_1}^2)^\gamma}\right), \gamma > 0 \quad (6)$$

Definition 3: Let $\pi_1 = Q(\alpha_{\pi_1}, \beta_{\pi_1})$ and $\pi_2 = Q(\alpha_{\pi_2}, \beta_{\pi_2})$ be two PFNs, a nature quasi-ordering on the PFNs is defined as follows (Zhang and Xu 2014):

$\pi_1 \geq \pi_2$ if and only if $\alpha_{\pi_1} \geq \alpha_{\pi_2}$ and $\beta_{\pi_1} \leq \beta_{\pi_2}$

A score function is proposed to compute two PFNs by (Zhang and Xu 2014) as follows:

$$s(\pi_1) = (\alpha_{\pi_1})^2 - (\beta_{\pi_1})^2 \quad (7)$$

$$s(\pi_2) = (\alpha_{\pi_2})^2 - (\beta_{\pi_2})^2 \quad (8)$$

Definition 4: To compare the two PFNs, the given below laws are defined based on the score functions proposed above (Zhang and Xu 2014):

If $s(\pi_1) < s(\pi_2)$, then $\pi_1 < \pi_2$

If $s(\pi_1) > s(\pi_2)$, then $\pi_1 > \pi_2$

If $s(\pi_1) = s(\pi_2)$, then $\pi_1 \sim \pi_2$

3.2 Pythagorean fuzzy AHP technique

AHP is the MCDM technique for determining the priority weights of the criteria. But human judgements are vague, and standard AHP is not appropriate to evaluate in such a situation. Therefore, PFAHP is utilized to determine the priority weights of the key criteria affecting SMEs' implementation of digital marketing in India. A detailed procedure of PFAHP techniques is given in Annexure 1.



4. Case study and analysis

The region of Delhi NCR has been selected to demonstrate the application of PFAHP in SMEs' digital marketing adoption problem. 30 experts from 15 SMEs of Delhi NCR are selected through purposive sampling and approached for data collection. A web-based questionnaire has been distributed among the selected 30 experts using platforms like Facebook, Instagram, and WhatsApp to determine priority weights of digital marketing adoption criteria using a pairwise comparison of the PFAHP technique. Their responses have been collected on the linguistic scale (see Table 2) and analyzed. The evaluation process takes place from the mid of February to end of the end of March 2022. The team of experts includes the owner, sales managers, and sales associates of the SMEs with an experience of 8-15 years.

Five key criteria namely, Worker's attitude (F1), Top management attitude (F2), Tech advancements (F3), Organizational structure (F4), and Organizational environment (F5), are identified from the literature, finalized after discussion with the experts and considered in this study for evaluation of digital marketing adoption by SMEs. Thirty experts are requested to express their opinion on comparisons of criteria pairs in matrix form about the priority weight of each criterion by using the linguistic variables defined in annexure 1-Table 1. After collecting the responses on the linguistic scale, Linguistic variables become interval-valued Pythagorean fuzzy numbers. Since the experts' opinions differ, a pairwise comparison matrix must be compromised. The pairwise comparison matrix for the criteria is shown in Table 2.

Table 2. Aggregated pairwise decision matrix

Criteria	F1	F2	F3	F4	F5
F1	$\{(0.20, 0.20), (0.20, 0.20)\}$	$\{(0.61, 0.71), (0.29, 0.36)\}$	$\{(0.46, 0.56), (0.43, 0.53)\}$	$\{(0.29, 0.38), (0.60, 0.71)\}$	$\{(0.62, 0.72), (0.28, 0.37)\}$
F2	$\{(0.29, 0.36), (0.61, 0.71)\}$	$\{(0.20, 0.20), (0.20, 0.20)\}$	$\{(0.43, 0.53), (0.47, 0.57)\}$	$\{(0.26, 0.36), (0.62, 0.74)\}$	$\{(0.51, 0.62), (0.38, 0.48)\}$
F3	$\{(0.43, 0.53), (0.46, 0.56)\}$	$\{(0.47, 0.57), (0.43, 0.53)\}$	$\{(0.20, 0.20), (0.20, 0.20)\}$	$\{(0.34, 0.43), (0.56, 0.66)\}$	$\{(0.59, 0.70), (0.30, 0.40)\}$
F4	$\{(0.60, 0.71), (0.29, 0.38)\}$	$\{(0.62, 0.74), (0.26, 0.36)\}$	$\{(0.56, 0.66), (0.34, 0.43)\}$	$\{(0.20, 0.20), (0.20, 0.20)\}$	$\{(0.67, 0.81), (0.19, 0.27)\}$
F5	$\{(0.28, 0.37), (0.62, 0.72)\}$	$\{(0.38, 0.48), (0.51, 0.62)\}$	$\{(0.30, 0.40), (0.59, 0.70)\}$	$\{(0.19, 0.27), (0.67, 0.81)\}$	$\{(0.20, 0.20), (0.20, 0.20)\}$

Using Eqs. (9)- (12) are given in appendix I, the matrix D(difference matrix) and matrix S (Interval multiplicative matrix) are computed as given in Tables 3 and 4, respectively.

Table 3. Difference matrix

Criteria	F1		F2		F3		F4		F5	
F1	0.00	0.00	0.24	0.42	-0.07	0.12	-0.42	-0.22	0.24	0.45
F2	-0.42	-0.24	0.00	0.00	-0.15	0.07	-0.48	-0.26	0.03	0.24
F3	-0.12	0.07	-0.07	0.15	0.00	0.00	-0.33	-0.13	0.19	0.41
F4	0.22	0.42	0.26	0.48	0.13	0.33	0.00	0.00	0.38	0.62
F5	-0.45	-0.24	-0.24	-0.03	-0.41	-0.19	-0.62	-0.38	0.00	0.00

Table 4. Interval multiplicative matrix

Criteria	F1		F2		F3		F4		F5	
F1	1.00	1.00	2.28	4.33	0.79	1.54	0.24	0.47	2.31	4.66
F2	0.23	0.44	1.00	1.00	0.60	1.26	0.19	0.41	1.11	2.32
F3	0.65	1.27	0.79	1.66	1.00	1.00	0.32	0.64	1.92	4.06
F4	2.13	4.24	2.46	5.25	1.56	3.08	1.00	1.00	3.73	8.39
F5	0.21	0.43	0.43	0.90	0.25	0.52	0.12	0.27	1.00	1.00

The determinacy value and weights before normalization are in Tables 5 and 6, respectively.

Table 5. Determinacy value matrix

Criteria	F1	F2	F3	F4	F5
F1	1.00	0.81	0.81	0.80	0.80
F2	0.81	1.00	0.79	0.78	0.79
F3	0.81	0.79	1.00	0.80	0.78
F4	0.80	0.78	0.80	1.00	0.77
F5	0.80	0.79	0.78	0.77	1.00

Table 6. Weights matrix before normalization

Criteria	F1	F2	F3	F4	F5
F1	1.000	2.690	0.937	0.282	2.780
F2	0.273	1.000	0.732	0.233	1.348
F3	0.774	0.965	1.000	0.388	2.342
F4	2.552	3.009	1.860	1.000	4.641
F5	0.258	0.524	0.300	0.148	1.000

Lastly, the normalized priority weights of key criteria are calculated using Eq. (15), as given in Table 7.

Table 7. Normalized priority weights and rank

Criteria	Normalized Weight	Rank
F1	0.209	2
F2	0.091	4
F3	0.145	3
F4	0.331	1
F5	0.059	5

5. Discussion and conclusion

5.1 Discussion and implications

Adopting digital marketing allows SMEs to increase their profit, enhancing customer relations, reducing cost, allowing flexibility, and overall will help increase profitability. This study aims to identify the key criteria that affect SMEs' adoption of digital marketing. Five key criteria were identified through an extensive review of literature and experts' opinions and evaluated using the PFAHP technique. Table 7 provides the priority weights and ranks of each criterion evaluated by 30 experts. The results show that the order of five basic influencing criteria is Organizational structure> Worker's attitude>Tech advancements>Top management attitude>Organizational Environment. Organizational structure is the most influential criterion for the adoption of digital marketing by SMEs, as the management of the



firms takes all the decisions. For the growth of organizations, the management must be flexible, knowledgeable, and open to innovative strategies and ideas. Management should hire young employees with technical knowledge and focus on adopting new and innovative strategies. Worker's attitude stands at second rank, indicating the user of the service or product matters greatly in adopting technology and practices among SMEs (Bruque&Moyano, 2007). It is the need of the hour that the SMEs training system should change regarding knowledge transfer about new tools and modify the workers' attitude towards technological change. Tech advancement criterion is rank third as acceptance of technological innovations has a significant impact and concerns technology compatibility with other business-related environment within organizations (Al-Qirim, 2007). A fourth rank, top management attitude criterion also influence the SMEs to adopt digital marketing. The structure of the organization, managers and other decision-makers should be open to using technology in marketing their services. The organizational environment is at fifth rank, indicating the competition can influence the SMEs to adopt digital marketing. If the competitors start to use technology to stay ahead, SMEs tend to jump into the race and embrace the new technology (El-Gohary, 2012; Al-Qirim, 2007; Ifinedo, 2011; Grandon and Pearson, 2004).

5.2 Limitations and future scope

Although the findings of this study have significant implications for the growth of SMEs, some limitations are also there, such as the number of experts and geographical region being limited. Further studies can explore the adoption of digital marketing in other sectors. Also, the results can be compared for various geographical locations. In the future, other MCDM techniques can be used for analyzing the same problem, such as Fuzzy TOPSIS, Fuzzy VIKOR, Fuzzy ELECTRE, Fuzzy MOORE, etc., and some other fuzzy sets can be utilized.

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Annex I

Step 1: Pairwise comparison matrix

Using the linguistic scale (see Table 1) by Ilbahar et al. (2018) expert's opinions has been collected to prepare the compromise pairwise comparison matrix $A = (a_{ik})_{m \times m}$.

Table 1. Weighting scale for PFAHP (Ilbahar et al., 2018)

Linguistic term	Pythagorean fuzzy numbers			
	α_L	α_U	β_L	β_U
Certainly low important (CLI)	0.00	0.00	0.90	1.00
Very low important (VLI)	0.10	0.20	0.80	0.90
Low important (LI)	0.20	0.35	0.65	0.80
Below average important (BAI)	0.35	0.45	0.55	0.65
Average important (AI)	0.45	0.55	0.45	0.55
Above average important (AAI)	0.55	0.65	0.35	0.45
High important (HI)	0.65	0.80	0.20	0.35
Very high important (VHI)	0.80	0.90	0.10	0.20
Certainly high important (CHI)	0.90	1.00	0.00	0.00
Exactly equal (EE)	0.197	0.197	0.197	0.197

Step 2: Difference matrix

The difference matrix $D = (d_{ik})_{m \times m}$ between lower and upper values of the membership and non-membership functions are calculated using Eqs. (9) and (10).

$$d_{ik_L} = \alpha_{ik_L}^2 - \beta_{ik_U}^2 \quad (9)$$

$$d_{ik_U} = \alpha_{ik_U}^2 - \beta_{ik_L}^2 \quad (10)$$

Step 3: Interval multiplicative matrix

Interval multiplicative matrix $S = (s_{ik})_{m \times m}$ is computed using Eqs. (11) and (12).

$$s_{ik_L} = \sqrt{1000d_L} \quad (11)$$

$$s_{ik_U} = \sqrt{1000d_U} \quad (12)$$



Step 4: Determinacy value

The determinacy value $\tau = (\tau_{ik})_{m \times m}$ is calculated using Eq. (13).

$$\tau_{ik} = 1 - (\alpha_{ik_U}^2 - \alpha_{ik_L}^2) - (\beta_{ik_U}^2 - \beta_{ik_L}^2) \quad (13)$$

Step 5: Unnormalized weights matrix

The determinacy degrees are multiplied with interval multiplicative matrix for finding the matrix of weights, $T = (t_{ik})_{m \times m}$ before normalization using Eq. (14).

$$t_{ik} = \left(\frac{s_{ik_L} + s_{ik_U}}{2} \right) \tau_{ik} \quad (14)$$

Step 6: Normalized priority weights

The normalized priority weights w_i is computed by using Eq. (15).

$$w_i = \frac{\sum_{k=1}^m t_{ik}}{\sum_{i=1}^m \sum_{k=1}^m t_{ik}} \quad (15)$$