A BWM-TODIM based Integrated Decision Framework for Financial Technology Selection with Interval Type-2 Fuzzy Sets

Xiaomin Gong, Jingshu Zhang, Xuemei Zhao

Abstract—**In the context of the accelerated iteration of financial technology, the layout of financial technology in the banking industry is also accelerating and shifting gears. Actively cooperating with financial technology companies has become an important channel for banks to cope with challenges and achieve transformational development. Assessing and selecting the best financial technology company is one of the core issues that banks should address in establishing cooperative relationships. In this paper, an integrated decision-making framework based on the best-worst method (BWM) and TODIM (an acronym for interactive and multi-criteria decision making in Portuguese) is proposed for financial technology selection under the interval type-2 fuzzy (IT2F) environment. Within the proposed framework, the preference information of decision-makers for alternatives and pairwise comparison among criteria is captured by the interval type-2 fuzzy sets (IT2FSs), and the criteria weights are calculated by the IT2F-BWM method. Moreover, the IT2F-TODIM considering the psychological behavior state of decision-makers is introduced to determine the alternative ranking. The practicability and reliability of the proposed methodology are verified by a case study with sensitivity analysis and comparative analysis. This study contributes theoretically and practically to relevant literature by providing an effective framework capable of handling decision issues under uncertainty.**

***Index Terms*—interval type-2 fuzzy sets, best-worst method, TODIM method, financial technology selection**

I. Introduction

The deep integration of emerging technologies represented by big data, cloud computing, and artificial intelligence with the financial industry is driving the traditional financial industry into the fast lane of digital transformation and development. The fusion of finance and technology has not only stayed at the technical level, but also reflected the all-around integration of ideas, business models, and management models. In this context, banks need to explore new paths for technology-driven and collaborative innovation and development, and deepen the application of fintech in various business scenarios. Driven by financial technology (fintech for short), banks are opening a new chapter in financial innovation and development in terms of customer acquisition channels, financial products, and other management patterns and business processes. Therefore, it is a major development trend for banks to cooperate with technology companies to achieve transformation and enhance their competitiveness. At present, banks are vigorously developing consumer finance business, which is inseparable from the support of fintech. For example, banks are committed to applying big data risk control in multiple scenarios such as anti-fraud, mining potential customers, and risk event warning, and at the same time providing relevant data for pre-lending decision evaluation and post-lending risk control to reduce financial risks. Fintech companies can provide banks with the big data intelligent risk control decision-making engine to accurately anti-fraud and quickly identify fraud factors. For banks, it is particularly important to select a reliable technology company with competitive advantages [1].

In practice, the evaluation and selection of technology companies cannot rely only on a single standard but involve multiple aspects. This process belongs to the scope of decision-making under uncertainty. Therefore, in the face of complicated financial environments, technology company selection can be generalized as a multi-criteria decision-making (MCDM) issue and can be handled by constructing an effective decision-making framework with the help of the MCDM approaches. The establishment of the framework typically involves three phases: the characterization of criteria information, the configuration of criteria weights, and the excellence-inferiority ordering of the evaluation objects.

Due to the finiteness of expert cognition, the ambiguity of human thinking and decision environment, and the urgency of time, attribute information often cannot be presented in quantitative and precise numerical values but in uncertain forms [2]. In the depiction of uncertain information of attributes, fuzzy set [3] is a popular means that has been adopted in various fields of the decision-making process. Fuzzy sets come in many forms, such as type-1 and type-2 fuzzy sets. As an extension of the type-1 fuzzy set, the type-2 fuzzy set is more applicable and reliable in capturing uncertainty [4]. However, the generalized interval type-2 fuzzy set is not adopted widely, mainly due to its complicated computational procedures. To this end, an interval type 2 fuzzy set (IT2FS) is developed, which is relatively simple in form and low in computational complexity [5]. Relying on

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the significant advantages, the IT2FSs have been of concern to many scholars. For example, Chen et al. [6] proposed an efficiency-based MCDM framework incorporating the data envelopment analysis method in the context of IT2Fs for addressing the makeshift hospital selection issue. Heidarzade et al. [7] developed a hierarchical clustering-based approach to select suppliers and determine the proximity of suppliers, in which the preference of decision-makers is characterized by IT2Fs. Chen et al. [8] extended the QUALIFLEX approach in the interval type-2 fuzzy (IT2F) environment, which provides a feasible framework for MCDM and alternative sorting. Qin et al. [9] proposed a novel distance measure for IT2FSs based on the fuzzy logic and α-cuts, which is combined with the TODIM (an acronym in Portuguese of interactive and multi-criteria decision making) approach for selecting the optimal green supplier. Following the train of thought in the above research and considering the high uncertainty of technology selection in the fintech context, the IT2FS is adopted in this paper to capture and process attribute information.

The second phase is to identify the weight of criteria, which holds a very important status in the decision-making process that contains various contradictory attributes. In this regard, Rezaei [10] developed a robust MCDM method based on pairwise preference comparisons among attributes, called the Best-Worst Method (BWM). Compared with the generally considered tools such as the Analytical Hierarchy Process (AHP) and the Decision Making Trial and Evaluation Laboratory (DEMATEL), BWM significantly simplifies the gathering and processing of data and achieves well-consistent and reliable computational results through smaller pairwise comparisons [11]. To deal with decision-making issues with high uncertainty and adapt to complex situations, pairwise preference comparisons are further replaced by fuzzy preference comparisons, and various corresponding BWM with fuzzy forms are proposed. BWM, especially the fuzzy BWM with higher applicability, has been continuously explored and applied in various studies to determine the relative importance of each indicator [12]. For example, Zhang et al. [13] used the fuzzy BWM method to determine the weights of indicators related to urban economic development and air quality. Gul and Yucesan [14] conducted the performance assessment of Turkish Universities using the Bayesian BWM-TOPSIS framework. Ahmad et al. [15] identified the strategies provided by multiple stakeholder groups to respond to the COVID-19 outbreak based on a group BWM method. Pamučar et al. [16] utilized the BWM technique in combination with the MABAC method under the D number environment to deal with the healthcare waste management facility selection issue. By weighting the functions of supply chain management, Gunduz et al. [17] suggested a hybrid decision-making framework based on the BWM and Quality Function Deployment approaches to evaluate supply chain smartness and sustainability. Besides, the IT2FSs-based BWM that fully integrates the traditional advantages of IT2FSs and BWM has also been studied, see Gong et al. [18] and Celik and Gul [19] for details.

The third phase aims to gather the performance of each alternative (in this study, the technology company planning to cooperate with the bank) under all attributes to derive the comprehensive assessment result and make the final decision. The TODIM approach (an acronym in Portuguese of interactive and multiple attribute decision making) pioneered by Gomes and Lima [20] is a typical behavioral decision-making technology, which supplied a theoretical analysis frame for characterizing the psychological behavior characteristics of decision-makers and a feasible path for dealing with practical problems by means of MCDM [21]. In various environments and contexts, the TODIM can identify the overall dominance degree (also known as the global prospect value) of the alternatives under a pre-set loss attenuation parameter value, thus further determining the ranking sequence of alternatives. In recent years, the cross-integration and successful application of the TODIM in various fields have been increasing, such as in group emergency decision making [22], healthcare device selection [23], technology selection for energy conservation and emission reduction [24], portfolio allocation [25], and commercialization potential evaluation [26]. Moreover, Qin et al. [27] found that TODIM was less popularized in highly ambiguous environments, and for this, they proposed an extended IT2F TODIM method to improve its applicability. Subsequently, considering the uncertainty of information and the psychological state of decision-makers, Hong et al. [28] presented a failure mode and effect analysis framework based on the IT2F-TODIM for recycling channel selection. Inspired by Hong et al. [29], this paper introduces the IT2FSs-based TODIM into the decision-making framework of technology company selection in the context of fintech.

Based on the above analysis, this study focuses on how banks choose a reliable technology company to participate in financial innovation cooperation in the context of fintech. For this purpose, an integrated new decision-making framework based on BWM and TODIM with IT2FSs is proposed, which sufficiently considers the uncertainty of information and the behavior characteristics of decision-makers. The main contributions and innovations of this work are as follows: (1) Given the pronounced advantages of IT2FSs in expressing and manipulating uncertain information, IT2FSs are innovatively adopted to describe the criteria performance and the pairwise preference comparison among criteria, thus significantly improving the reliability of the evaluation data. (2) The IT2F-BWM is introduced to effectively configure criteria weights related to technology selection, which not only reduces the comparison among criteria distinctly but also restores the fuzzy nature of weight information. (3) Taking into account the psychological behavior of decision-makers in technology evaluation and selection, the extended IT2F-TODIM is suggested to identify the dominance degrees of alternatives in fintech and determine the final ranking. Of note, technology selection in the context of fintech is a new and promising research direction, and to our best knowledge, the fusion of BWM and TODIM in the IT2F environment is the first time. Therefore, this study serves as a valid complement both from theoretical and practical points of view.

The remainder of the paper is structured as follows. Section 2 reviews the interval type-2 fuzzy set. Section 3 illustrates the proposed framework integrating IT2F-BWM and IT2F-TODIM technologies. Section 4 verifies the applicability and effectiveness of the developed methodology through a case study. The final section concludes the paper.

II. Preliminaries

A. Definition of interval type-2 fuzzy set

Definition 1 [29]**.** A type-2 fuzzy set $\tilde{\tilde{\psi}}$ in the universe of discourse X can be defined by the type-2 membership function $\mu_{\tilde{\tilde{\psi}}}$ as follows:

$$\tilde{\tilde{\psi}} = \left\{((x,u), \mu_{\tilde{\tilde{\psi}}}(x,u)) \mid \forall x \in X, \forall u \in J_x \subseteq [0,1], 0 \le \mu_{\tilde{\tilde{\psi}}}(x,u) \le 1\right\} \quad (1)$$

where J_x represents an interval in [0,1]. $\tilde{\tilde{\psi}}$ can also be stated as:

$$\tilde{\tilde{\psi}} = \int_{x\in X}\int_{u\in J_x} \mu_{\tilde{\tilde{\psi}}}(x,u)\big/(x,u) \quad (2)$$

where x indicates the primary variable, $J_x \subseteq [0,1]$ is the primary membership of x, $u \in [0,1]$ is the secondary variable.

Definition 2 [29]**.** Let $\tilde{\tilde{\psi}}$ be a type-2 fuzzy set in the universe of discourse X with the type-2 membership function $\mu_{\tilde{\tilde{\psi}}}$. If all $\mu_{\tilde{\tilde{\psi}}}(x,u) = 1$, then $\tilde{\tilde{\psi}}$ is termed as an interval type-2 fuzzy set (IT2FS) and can be expressed as:

$$\tilde{\tilde{\psi}} = \int_{x\in X}\int_{u\in J_x} 1/(x,u) \quad (3)$$

Definition 3 [30]**.** Let $\tilde{\tilde{\psi}}$ be an IT2FS, $\mu^U_{\tilde{\tilde{\psi}}}(x)$ and $\mu^L_{\tilde{\tilde{\psi}}}(x)$ be the upper and lower membership functions (UMF and LMF) represented by the type-1 possibility distribution, then the footprint uncertainty of $\tilde{\tilde{\psi}}$ ($FOU(\tilde{\tilde{\psi}})$) can be defined as:

$$FOU(\tilde{\tilde{\psi}}) = \bigcup_{x\in X} J_x = \{(x,u) : u \in J_x = [\mu^L_{\tilde{\tilde{\psi}}}(x), \mu^U_{\tilde{\tilde{\psi}}}(x)]\} \quad (4)$$

IT2FS is usually simplified to reduce the computational complexity, and the trapezoidal interval type-2 fuzzy set (TrIT2FS) is one of the expressions, which is defined in the following form:

$$\begin{aligned}\tilde{\tilde{\psi}} &= (\tilde{\tilde{\psi}}^L, \tilde{\tilde{\psi}}^U) \\ &= \left[(\psi_1^L,\psi_2^L,\psi_3^L,\psi_4^L; h^L_{\tilde{\tilde{\psi}}}), (\psi_1^U,\psi_2^U,\psi_3^U,\psi_4^U; h^U_{\tilde{\tilde{\psi}}})\right]\end{aligned} \quad (5)$$

where $\psi_1^L \le \psi_2^L \le \psi_3^L \le \psi_4^L$, $\psi_1^U \le \psi_2^U \le \psi_3^U \le \psi_4^U$, and $0 \le h^L_{\tilde{\tilde{\psi}}} \le h^U_{\tilde{\tilde{\psi}}} \le 1$.

The UMF and LMF of the TrIT2FS are defined as:

$$\mu^U_{\tilde{\tilde{\psi}}}(x) = \begin{cases} \dfrac{(x-\psi_1^U)h^U_{\tilde{\tilde{\psi}}}}{\psi_2^U - \psi_1^U} & \psi_1^U \le x \le \psi_2^U \\ h^U_{\tilde{\tilde{\psi}}} & \psi_2^U \le x \le \psi_3^U \\ \dfrac{(\psi_4^U - x)h^U_{\tilde{\tilde{\psi}}}}{\psi_4^U - \psi_3^U} & \psi_3^U \le x \le \psi_4^U \\ 0 & otherwise \end{cases} \quad (6)$$

$$\mu^L_{\tilde{\tilde{\psi}}}(x) = \begin{cases} \dfrac{(x-\psi_1^L)h^L_{\tilde{\tilde{\psi}}}}{\psi_2^U - \psi_1^U} & \psi_1^L \le x \le \psi_2^L \\ h^L_{\tilde{\tilde{\psi}}} & \psi_2^L \le x \le \psi_3^L \\ \dfrac{(\psi_4^L - x)h^{LU}_{\tilde{\tilde{\psi}}}}{\psi_4^L - \psi_3^L} & \psi_3^L \le x \le \psi_4^L \\ 0 & otherwise \end{cases} \quad (7)$$

B. Operations of interval type-2 fuzzy sets

Definition 4 [31]**.** Let $\tilde{\tilde{\psi}} = (\tilde{\tilde{\psi}}^L, \tilde{\tilde{\psi}}^U) = ((\psi_1^L,\psi_2^L,\psi_3^L,\psi_4^L; h^L_{\tilde{\tilde{\psi}}}), (\psi_1^U,\psi_2^U,\psi_3^U,\psi_4^U; h^U_{\tilde{\tilde{\psi}}}))$ and $\tilde{\tilde{\chi}} = (\tilde{\tilde{\chi}}^L, \tilde{\tilde{\chi}}^U) = ((\chi_1^L,\chi_2^L,\chi_3^L,\chi_4^L; h^L_{\tilde{\tilde{\chi}}}), (\chi_1^U,\chi_2^U,\chi_3^U,\chi_4^U; h^U_{\tilde{\tilde{\chi}}}))$ be two TrIT2FSs, the laws of calculations are stated as follows:

$$\begin{aligned}\tilde{\tilde{\psi}} \oplus \tilde{\tilde{\chi}} = \Big(&(\psi_1^L+\chi_1^L, \psi_2^L+\chi_2^L, \psi_3^L+\chi_3^L, \psi_4^L+\chi_4^L; \min(h^L_{\tilde{\tilde{\psi}}}, h^L_{\tilde{\tilde{\chi}}})), \\ &(\psi_1^U+\chi_1^U, \psi_2^U+\chi_2^U, \psi_3^U+\chi_3^U, \psi_4^U+\chi_4^U; \min(h^U_{\tilde{\tilde{\psi}}}, h^U_{\tilde{\tilde{\chi}}}))\Big)\end{aligned} \quad (8)$$

$$\begin{aligned}\tilde{\tilde{\psi}} \ominus \tilde{\tilde{\chi}} = \Big(&(\psi_1^L-\chi_4^L, \psi_2^L-\chi_3^L, \psi_3^L-\chi_2^L, \psi_4^L-\chi_1^L; \min(h^L_{\tilde{\tilde{\psi}}}, h^L_{\tilde{\tilde{\chi}}})), \\ &(\psi_1^U-\chi_4^U, \psi_2^U-\chi_3^U, \psi_3^U-\chi_2^U, \psi_4^U-\chi_1^U; \min(h^U_{\tilde{\tilde{\psi}}}, h^U_{\tilde{\tilde{\chi}}}))\Big)\end{aligned} \quad (9)$$

$$\begin{aligned}\tilde{\tilde{\psi}} \otimes \tilde{\tilde{\chi}} = \Big(&(\psi_1^L\times\chi_1^L, \psi_2^L\times\chi_2^L, \psi_3^L\times\chi_3^L, \psi_4^L\times\chi_4^L; \min(h^L_{\tilde{\tilde{\psi}}}, h^L_{\tilde{\tilde{\chi}}})), \\ &(\psi_1^U\times\chi_1^U, \psi_2^U\times\chi_2^U, \psi_3^U\times\chi_3^U, \psi_4^U\times\chi_4^U; \min(h^U_{\tilde{\tilde{\psi}}}, h^U_{\tilde{\tilde{\chi}}}))\Big)\end{aligned} \quad (10)$$

$$\tilde{\tilde{\psi}} \oslash \tilde{\tilde{\chi}} = \left(\begin{aligned}&\left(\frac{\psi_1^L}{\chi_4^L}, \frac{\psi_2^L}{\chi_3^L}, \frac{\psi_3^L}{\chi_2^L}, \frac{\psi_4^L}{\chi_1^L}; \min(h^L_{\tilde{\tilde{\psi}}}, h^L_{\tilde{\tilde{\chi}}})\right), \\ &\left(\frac{\psi_1^U}{\chi_4^U}, \frac{\psi_2^U}{\chi_3^U}, \frac{\psi_3^U}{\chi_2^U}, \frac{\psi_4^U}{\chi_1^U}; \min(h^U_{\tilde{\tilde{\psi}}}, h^U_{\tilde{\tilde{\chi}}})\right)\end{aligned}\right) \quad (11)$$

$$k \times \tilde{\tilde{\psi}} = \begin{cases} \left(\begin{aligned}&(k\times\psi_1^L, k\times\psi_2^L, k\times\psi_3^L, k\times\psi_4^L; h^L_{\tilde{\tilde{\psi}}}), \\ &(k\times\psi_1^U, k\times\psi_2^U, k\times\psi_3^U, k\times\psi_4^U; h^U_{\tilde{\tilde{\psi}}})\end{aligned}\right), & k \ge 0 \\ \left(\begin{aligned}&(k\times\psi_4^L, k\times\psi_3^L, k\times\psi_2^L, k\times\psi_1^L; h^L_{\tilde{\tilde{\psi}}}), \\ &(k\times\psi_4^U, k\times\psi_3^U, k\times\psi_2^U, k\times\psi_1^U; h^U_{\tilde{\tilde{\psi}}})\end{aligned}\right), & k \le 0 \end{cases} \quad (12)$$

Definition 5 [7]**.** Let $\tilde{\tilde{\psi}} = (\tilde{\tilde{\psi}}^L, \tilde{\tilde{\psi}}^U) = ((\psi_1^L,\psi_2^L,\psi_3^L,\psi_4^L; h^L_{\tilde{\tilde{\psi}}}), (\psi_1^U,\psi_2^U,\psi_3^U,\psi_4^U; h^U_{\tilde{\tilde{\psi}}}))$ and $\tilde{\tilde{\chi}} = (\tilde{\tilde{\chi}}^L, \tilde{\tilde{\chi}}^U) = ((\chi_1^L,\chi_2^L,\chi_3^L,\chi_4^L; h^L_{\tilde{\tilde{\chi}}}), (\chi_1^U,\chi_2^U,\chi_3^U,\chi_4^U; h^U_{\tilde{\tilde{\chi}}}))$ be two TrIT2FSs in the universe of discourse X=[0, 1], $0 < \psi_1^L \le \psi_2^L \le \psi_3^L \le \psi_4^L \le 1$, $0 < \psi_1^U \le \psi_2^U \le \psi_3^U \le \psi_4^U \le 1$, $0 < \chi_1^L \le \chi_2^L \le \chi_3^L \le \chi_4^L \le 1$, $0 < \chi_1^U \le \chi_2^U \le \chi_3^U \le \chi_4^U \le 1$. Then, the distance between $\tilde{\tilde{\psi}}$ and $\tilde{\tilde{\chi}}$ is defined as follows:

$$d_{SD}(\tilde{\tilde{\psi}}, \tilde{\tilde{\chi}}) = \left| d_{SD}(\tilde{\tilde{\psi}}, \tilde{\tilde{1}}) - d_{SD}(\tilde{\tilde{\chi}}, \tilde{\tilde{1}}) \right| \quad (13)$$

where $\tilde{\tilde{1}}$ =((1,1,1,1;1), (1,1,1,1;1)), $d_{SD}(\tilde{\tilde{\psi}}, \tilde{\tilde{1}})$ and $d_{SD}(\tilde{\tilde{\chi}}, \tilde{\tilde{1}})$ are the signed distances of $\tilde{\tilde{\psi}}$ and $\tilde{\tilde{\chi}}$ from $\tilde{\tilde{1}}$, respectively. $d_{SD}(\tilde{\tilde{\psi}}, \tilde{\tilde{1}})$ and $d_{SD}(\tilde{\tilde{\chi}}, \tilde{\tilde{1}})$ are calculated as follows [32]:

$$\begin{aligned}d_{SD}(\tilde{\tilde{\psi}}, \tilde{\tilde{1}}) = \frac{1}{8}(&\psi_1^L + \psi_2^L + \psi_3^L + \psi_4^L + 4\psi_1^U + 2\psi_2^U + \\ &2\psi_3^U + 4\psi_4^U + 3(\psi_2^U + \psi_3^U - \psi_1^U - \psi_4^U)\frac{h^L_{\tilde{\tilde{\psi}}}}{h^U_{\tilde{\tilde{\psi}}}} - 16)\end{aligned} \quad (14)$$

$$\begin{aligned}d_{SD}(\tilde{\tilde{\chi}}, \tilde{\tilde{1}}) = \frac{1}{8}(&\chi_1^L + \chi_2^L + \chi_3^L + \chi_4^L + 4\chi_1^U + 2\chi_2^U + \\ &2\chi_3^U + 4\chi_4^U + 3(\chi_2^U + \chi_3^U - \chi_1^U - \chi_4^U)\frac{h^L_{\tilde{\tilde{\chi}}}}{h^U_{\tilde{\tilde{\chi}}}} - 16)\end{aligned} \quad (15)$$

Definition 6 [5]. Let $\tilde{\tilde{\psi}} = (\tilde{\psi}^L, \tilde{\psi}^U) = ((\psi_1^L, \psi_2^L, \psi_3^L, \psi_4^L; h_{\tilde{\tilde{\psi}}}^L), h_{\tilde{\tilde{\psi}}}^L), (\psi_1^U, \psi_2^U, \psi_3^U, \psi_4^U; h_{\tilde{\tilde{\psi}}}^U))$ be a TrIT2FS. The defuzzified value of $\tilde{\tilde{\psi}}$ is calculated as follows:

$$Def(\tilde{\tilde{\psi}}) = \frac{1}{2}\left\{\frac{(\psi_4^U - \psi_1^U) + (h_{\tilde{\tilde{\psi}}}^U \cdot \psi_2^U - \psi_1^U) + (h_{\tilde{\tilde{\psi}}}^U \cdot \psi_3^U - \psi_1^U)}{4} + \psi_1^U + \frac{(\psi_4^L - \psi_1^L) + (h_{\tilde{\tilde{\psi}}}^L \cdot \psi_2^L - \psi_1^L) + (h_{\tilde{\tilde{\psi}}}^L \cdot \psi_3^L - \psi_1^L)}{4} + \psi_1^L\right\} \tag{16}$$

III. The Framework Based on IT2F-BWM and IT2F-TODIM

A. Description of the financial technology selection

Suppose that there is a financial technology selection problem with Q evaluation experts (decision-makers) as $Ex = \{Ex_1, Ex_2, \ldots, Ex_Q\}$, m alternative financial technologies as $FT = \{FT_1, FT_2, \ldots, FT_m\}$, and n evaluation criteria as $Cr = \{Cr_1, Cr_2, \ldots, Cr_n\}$. The notations $Ex_q\,(q = 1, 2, \ldots, Q)$, $FT_i\,(i = 1, 2, \ldots, m)$, and $Cr_j\,(j = 1, 2, \ldots, n)$ means the qth expert, the ith alternative financial technology, and the jth criterion, respectively. In the financial technology evaluation process, each expert Ex_q is assigned a weight $\varpi_q \geq 0$ that satisfies $\sum_{q=1}^{Q} \varpi_q = 1$. All experts are invited to evaluate the criteria related to each financial technology based on the linguistic terms shown in Table I. Fig. 1 depicts the membership functions of the TrIT2FSs corresponding to these linguistic terms.

TABLE I
Linguistic Terms for Evaluating Alternatives and the Corresponding TrIT2FSs

Linguistic terms	TrIT2FSs
Very low (VL)	((0,0,0,0.5;0.9), (0,0,0,1;1))
Low (L)	((0.5,1,1.5,2;0.9), (0,1,2,3;1))
Medium Low (ML)	((2,3,3.5,4;0.9), (1,3,4,5;1))
Medium (M)	((4,5,5.5,6;0.9), (3,5,6,7;1))
Medium high (MH)	((6,7,7.5,8;0.9), (5,7,8,9;1))
High (H)	((8,8.5,9,9.5;0.9), (7,8.5,9.5,10;1))
Very High (VH)	((9.5,10,10,10;0.9), (9,10,10,10;1))

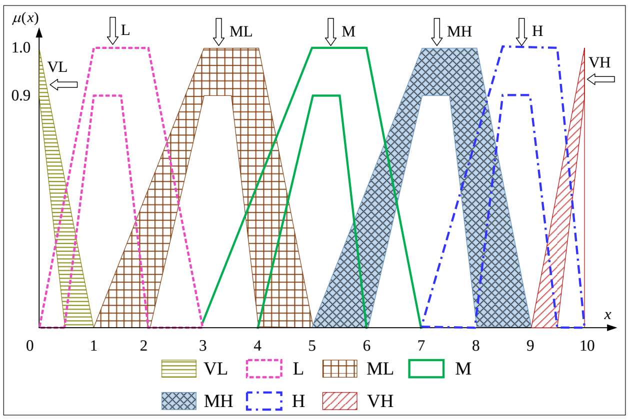

Fig. 1. Membership functions of TrIT2FS linguistic terms.

According to the mapping relationship between linguistic terms and the TrIT2FSs, the linguistic evaluation information will be further converted into TrIT2F numbers. For example, the TrIT2F number $\tilde{\tilde{x}}_{ij}^{(q)} = ((x_{ij1}^{q,L}, x_{ij2}^{q,L}, x_{ij3}^{q,L}, x_{ij4}^{q,L}; h_{ij}^{q,L}), (x_{ij1}^{q,U}, x_{ij2}^{q,U}, x_{ij3}^{q,U}, x_{ij4}^{q,U}; h_{ij}^{q,U}))$ is utilized to represent the evaluation of Ex_q for the financial technology FT_i with respect to the criterion Cr_j. Thus, for Ex_q (q=1,2,…,Q), the evaluation information can be expressed as a decision matrix $\tilde{\tilde{X}}^{(q)}$ with the TrIT2F form:

$$\tilde{\tilde{X}}^{(q)} = \left[\tilde{\tilde{x}}_{ij}^{(q)}\right]_{m\times n} = \begin{bmatrix} \tilde{\tilde{x}}_{11}^{(q)} & \tilde{\tilde{x}}_{12}^{(q)} & \cdots & \tilde{\tilde{x}}_{1n}^{(q)} \\ \tilde{\tilde{x}}_{21}^{(q)} & \tilde{\tilde{x}}_{11}^{(q)} & \cdots & \tilde{\tilde{x}}_{11}^{(q)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{x}}_{m1}^{(q)} & \tilde{\tilde{x}}_{11}^{(q)} & \cdots & \tilde{\tilde{x}}_{mn}^{(q)} \end{bmatrix} \tag{17}$$

The flow chart of the research methodology is presented in Fig. 2.

B. Determine the weight of criteria

In this paper, the weight of criteria is identified by the BWM method under the IT2FS environment. Specifically, the following steps are mainly included:

Step 1. Determine the best and the worst criteria.

Generally, the best and the worst criteria refer to the relatively most and least important criteria. For the criteria set $Cr = \{Cr_1, Cr_2, \ldots, Cr_n\}$, the expert group is invited to identify the best attribute and the worst criteria. The best and worst criteria given by the expert Ex_q (q=1,2,…,Q) are labeled as Cr_B^q and Cr_W^q, respectively.

Step 2. Determine preference comparison vectors.

The preference comparison vectors involve pairwise comparison between Cr_B^q and other attributes, and pairwise comparison between other attributes and Cr_W^q. Experts can determine linguistic preference comparisons according to the linguistic terms provided in Table II, and these linguistic preference comparisons can be transformed into TrIT2FSs.

TABLE II
Linguistic Terms for Rating the Importance of Criteria and the Corresponding TrIT2FSs

Linguistic terms	TrIT2FSs
Equally important (EI)	((1,1,1,1;0.9),(1,1,1,1;1))
Weakly important (WI)	((1.5,2,2,2.5;0.9),(1,2,2,3;1))
Moderate important (MI)	((2.5,3,3,3.5;0.9),(2,3,3,4;1))
Moderate plus important (MP)	((3.5,4,4,4.5;0.9),(3,4,4,5;1))
Strong important (SI)	((4.5,5,5,5.5;0.9),(4,5,5,6;1))
Strong plus important (SP)	((5.5,6,6,6.5;0.9),(5,6,6,7;1))
Very strong important (VS)	((6.5,7,7,7.5;0.9), (6,7,7,8;1)
Very, very strong important (VVS)	((7.5,8,8,8.5;0.9), (7,8,8,9;1)
Extreme important (EX)	((8.5,9,9,9.5;0.9),(8,9,9,10;1)

For expert Ex_q, the Best-to-Others vector and the Others-to-Worst vector under the IT2FS environment are:

$$\tilde{\tilde{U}}_{BO}^q = (\tilde{\tilde{U}}_{B1}^q, \ldots, \tilde{\tilde{U}}_{Bj}^q, \ldots, \tilde{\tilde{U}}_{Bn}^q) \tag{18}$$

$$\tilde{\tilde{U}}_{OW}^q = (\tilde{\tilde{U}}_{1W}^q, \ldots, \tilde{\tilde{U}}_{jW}^q, \ldots, \tilde{\tilde{U}}_{nW}^q) \tag{19}$$

where $\tilde{\tilde{U}}^q_{Bj}$ (j=1,2,…,n) denotes the preference of the criterion Cr^q_B over C_j, and $\tilde{\tilde{U}}^q_{jW}$ indicates the preference of criterion C_j over Cr^q_W. $\tilde{\tilde{U}}^q_{BB} = \tilde{\tilde{U}}^q_{WW} =$ ((1,1,1,1;0.9), (1,1,1,1; 1)).

Step 3. Determine the optimal weight of criteria for Ex_q.

The optimal weight for the criterion is the one where, for $\tilde{\tilde{w}}^q_B / \tilde{\tilde{w}}^q_j$ and $\tilde{\tilde{w}}^q_j / \tilde{\tilde{w}}^q_W$, it should satisfy $\tilde{\tilde{w}}^q_B / \tilde{\tilde{w}}^q_j = \tilde{\tilde{U}}^q_{Bj}$ and $\tilde{\tilde{w}}^q_j / \tilde{\tilde{w}}^q_W = \tilde{\tilde{U}}^q_{jW}$. To this end, the maximum value of $| \tilde{\tilde{w}}^q_B / \tilde{\tilde{w}}^q_j - \tilde{\tilde{U}}^q_{Bj} |$ and $| \tilde{\tilde{w}}^q_j / \tilde{\tilde{w}}^q_W - \tilde{\tilde{U}}^q_{jW} |$ should be minimized, and the corresponding optimization model can be stated as:

$$Min\ \underset{j}{Max} \left\{ \left| \tilde{\tilde{w}}^q_B / \tilde{\tilde{w}}^q_j - \tilde{\tilde{U}}^q_{Bj} \right|, \left| \tilde{\tilde{w}}^q_j / \tilde{\tilde{w}}^q_W - \tilde{\tilde{U}}^q_{jW} \right| \right\}$$
$$s.t. \begin{cases} \sum_{j=1}^{n} Def\left(\tilde{\tilde{w}}^q_j\right) = 1 \\ w^{q,L}_{j1} \le w^{q,L}_{j2} \le w^{q,L}_{j3} \le w^{q,L}_{j4} \\ w^{q,U}_{j1} \le w^{q,U}_{j2} \le w^{q,U}_{j3} \le w^{q,U}_{j4} \\ w^{q,U}_{j1} \le w^{q,L}_{j1} \\ w^{q,L}_{j4} \le w^{q,U}_{j4} \\ w^{q,U}_{j1} \ge 0,\ j = 1,2,...,n \end{cases} \tag{20}$$

where:

$\tilde{\tilde{w}}^q_B = [(w^{q,L}_{B1}, w^{q,L}_{B2}, w^{q,L}_{B3}, w^{q,L}_{B4}; h^{q,L}_{\tilde{\tilde{w}}_B}), (w^{q,U}_{B1}, w^{q,U}_{B2}, w^{q,U}_{B3}, w^{q,U}_{B4}; h^{q,U}_{\tilde{\tilde{w}}_B})]$;

$\tilde{\tilde{w}}^q_W = [(w^{q,L}_{W1}, w^{q,L}_{W2}, w^{q,L}_{W3}, w^{q,L}_{W4}; h^{q,L}_{\tilde{\tilde{w}}_W}), (w^{q,U}_{W1}, w^{q,U}_{W2}, w^{q,U}_{W3}, w^{q,U}_{W4}; h^{q,U}_{\tilde{\tilde{w}}_W})]$;

$\tilde{\tilde{w}}^q_j = [(w^{q,L}_{j1}, w^{q,L}_{j2}, w^{q,L}_{j3}, w^{q,L}_{j4}; h^{q,L}_{\tilde{\tilde{w}}_j}), (w^{q,U}_{j1}, w^{q,U}_{j2}, w^{q,U}_{j3}, w^{q,U}_{j4}; h^{q,U}_{\tilde{\tilde{w}}_j})]$;

Let $\tilde{\tilde{\theta}}^{q*}$ denotes the maximum absolute gap between $| \tilde{\tilde{w}}^q_B / \tilde{\tilde{w}}^q_j - \tilde{\tilde{U}}^q_{Bj} |$ and $| \tilde{\tilde{w}}^q_j / \tilde{\tilde{w}}^q_W - \tilde{\tilde{U}}^q_{jW} |$, and $\tilde{\tilde{\lambda}}^{q*} = [(\lambda^{q*}, \lambda^{q*}, \lambda^{q*}, \lambda^{q*}; 0.9), (\lambda^{q*}, \lambda^{q*}, \lambda^{q*}, \lambda^{q*}; 1)]$, we can obtain:

$$Min\ \lambda^{q*}$$
$$s.t. \begin{cases} \left| w^{q,L}_{B1} - w^{q,L}_{j1} w^{q,L}_{Bj1} \right| \le \lambda^{q*}, \left| w^{q,L}_{B2} - w^{q,L}_{j2} w^{q,L}_{Bj2} \right| \le \lambda^{q*}, \\ \left| w^{q,L}_{B3} - w^{q,L}_{j3} w^{q,L}_{Bj3} \right| \le \lambda^{q*}, \left| w^{q,L}_{B4} - w^{q,L}_{j4} w^{q,L}_{Bj4} \right| \le \lambda^{q*}, \\ \left| w^{q,U}_{B1} - w^{q,U}_{j1} w^{q,U}_{Bj1} \right| \le \lambda^{q*}, \left| w^{q,U}_{B2} - w^{q,U}_{j2} w^{q,U}_{Bj2} \right| \le \lambda^{q*}, \\ \left| w^{q,U}_{B3} - w^{q,U}_{j3} w^{q,U}_{Bj3} \right| \le \lambda^{q*}, \left| w^{q,U}_{B4} - w^{q,U}_{j4} w^{q,U}_{Bj4} \right| \le \lambda^{q*}, \\ \left| w^{q,L}_{j1} - w^{q,L}_{W1} w^{q,L}_{jW1} \right| \le \lambda^{q*}, \left| w^{q,L}_{j2} - w^{q,L}_{W2} w^{q,L}_{jW2} \right| \le \lambda^{q*}, \\ \left| w^{q,L}_{j1} - w^{q,L}_{W1} w^{q,L}_{jW1} \right| \le \lambda^{q*}, \left| w^{q,L}_{j2} - w^{q,L}_{W2} w^{q,L}_{jW2} \right| \le \lambda^{q*}, \\ \left| w^{q,L}_{j3} - w^{q,L}_{W3} w^{q,L}_{jW3} \right| \le \lambda^{q*}, \left| w^{q,L}_{j4} - w^{q,L}_{W4} w^{q,L}_{jW4} \right| \le \lambda^{q*}, \\ \left| w^{q,U}_{j1} - w^{q,U}_{W1} w^{q,U}_{jW1} \right| \le \lambda^{q*}, \left| w^{q,U}_{j2} - w^{q,U}_{W2} w^{q,U}_{jW2} \right| \le \lambda^{q*}, \\ \left| w^{q,U}_{j3} - w^{q,U}_{W3} w^{q,U}_{jW3} \right| \le \lambda^{q*}, \left| w^{q,U}_{j4} - w^{q,U}_{W4} w^{q,U}_{jW4} \right| \le \lambda^{q*}, \\ \sum_{j=1}^{n} Def\left(\tilde{\tilde{w}}^q_j\right) = 1 \\ w^{q,L}_{j1} \le w^{q,L}_{j2} \le w^{q,L}_{j3} \le w^{q,L}_{j4} \\ w^{q,U}_{j1} \le w^{q,U}_{j2} \le w^{q,U}_{j3} \le w^{q,U}_{j4} \\ w^{q,U}_{j1} \le w^{q,L}_{j1} \\ w^{q,L}_{j4} \le w^{q,U}_{j4} \\ w^{q,U}_{j1} \ge 0,\ j = 1,2,...,n \end{cases} \tag{21}$$

By Eq. (21), the optimal weight of criteria for Ex_q can be identified.

Step 4. Consistency check.

The consistency ratio is utilized to conduct the consistency check. For expert Ex_q, the consistency ratio $CR^{(q)}$ can be calculated by:

$$CR^{(q)} = \frac{\lambda^{q*}}{CI} \tag{22}$$

where $CR^{(q)} \in [0,1]$, the consistency index (CI) is the maximum possible values λ regarding different linguistic terms (see Table III), which is calculated by Eq. (22):

$$\lambda^2 - \left(1 + 2Def(\tilde{\tilde{U}}^q_{BW})\right)\lambda + \left(\left[Def(\tilde{\tilde{U}}^q_{BW})\right]^2 - Def(\tilde{\tilde{U}}^q_{BW})\right) = 0 \tag{23}$$

where $Def(\tilde{\tilde{U}}^q_{BW})$ is the defuzzified value of $\tilde{\tilde{U}}^q_{BW}$ based on Eq. (16). For the specific derivation of CI and the detailed analysis of the consistency check, see Wu et al. [33].

During the consistency check, the smaller the value of $CR^{(q)}$, the greater the consistency [34].

TABLE III
CONSISTENCY INDEX

	Defuzzified Value	Consistency Index
EI	0.975	2.9582
WI	1.95	4.4872
MI	2.925	5.8948
MP	3.9	7.2373
SI	4.875	8.5373
SP	5.85	9.8069
VS	6.825	11.0533
VVS	7.8	12.2812
EX	8.775	13.494

Step 5. Derive the optimal weight of criteria after aggregation.

$$\begin{aligned} \tilde{\tilde{w}}^*_j &= ((w^L_{j1}, w^L_{j2}, w^L_{j3}, w^L_{j4};\ h^L_{\tilde{\tilde{w}}_j}), (w^U_{j1}, w^U_{j2}, w^U_{j2}, w^U_{j2};\ h^U_{\tilde{\tilde{w}}_j})] \\ &= \bigoplus_{q=1}^{Q} (\varpi_q \times \tilde{\tilde{w}}^{q*}_j) \end{aligned} \tag{24}$$

where $\tilde{\tilde{w}}^{q*}_j$ represents the optimal weight of C_j for Ex_q obtained by Eq. (21), and $\tilde{\tilde{w}}^*_j$ is the optimal weight of criteria after aggregation.

C. The interval type-2 fuzzy TODIM technique

In this subsection, the TODIM method in the context of IT2FSs is employed to solve the financial technology selection problem, in which the bounded rational behavior of decision-makers can be fully reflected. The interval type-2 fuzzy TODIM technique can be summarized in the following steps:

Step 1. Aggregate the individual decision matrices into a group decision matrix.

By aggregating the evaluation values $\tilde{\tilde{X}}^{(q)} = [\tilde{\tilde{x}}_{ij}^{(q)}]_{m \times n}$ provided by all experts using Eq. (25), the group decision matrix $\tilde{\tilde{X}} = [\tilde{\tilde{x}}_{ij}]_{m \times n}$ can be obtained:

$$\begin{aligned}\tilde{\tilde{x}}_{ij} &= ((x_{ij1}^L, x_{ij2}^L, x_{ij3}^L, x_{ij4}^L; h_{ij}^L), (x_{ij1}^U, x_{ij2}^U, x_{ij3}^U, x_{ij4}^U; h_{ij}^U)) \\ &= \bigoplus_{q=1}^{Q} (\varpi_q \times \tilde{\tilde{x}}_{ij}^{(q)}) \\ &= ((\sum_{q=1}^{Q} \varpi_q x_{ij1}^{q,L}, \sum_{q=1}^{Q} \varpi_q x_{ij2}^{q,L}, \sum_{q=1}^{Q} \varpi_q x_{ij3}^{q,L}, \sum_{q=1}^{Q} \varpi_q x_{ij4}^{q,L}; \min_q\{h_{ij}^{q,L}\}), \\ &\quad (\sum_{q=1}^{Q} \varpi_q x_{ij1}^{q,U}, \sum_{q=1}^{Q} \varpi_q x_{ij2}^{q,U}, \sum_{q=1}^{Q} \varpi_q x_{ij3}^{q,U}, \sum_{q=1}^{Q} \varpi_q x_{ij4}^{q,U}; \min_q\{h_{ij}^{q,U}\}))\end{aligned} \tag{25}$$

where $\varpi_q \geq 0$ is the weight of expert Ex_q.

Step 2. Normalize the group TrIT2FS decision matrix.

Given the principle of criteria category, it is necessary to normalize the matrix $\tilde{\tilde{X}} = [\tilde{\tilde{x}}_{ij}]_{m\times n}$. Let $\tilde{\tilde{R}} = [\tilde{\tilde{r}}_{ij}]_{m\times n}$ be the normalized group decision matrix, $\tilde{\tilde{r}}_{ij}$ can be calculated as:

$$\tilde{\tilde{r}}_{ij} = ((r_{ij1}^L, r_{ij2}^L, r_{ij3}^L, r_{ij4}^L; h_{ij}^L), (r_{ij1}^U, r_{ij2}^U, r_{ij3}^U, r_{ij4}^U; h_{ij}^U)) = \begin{cases} \left((\frac{x_{ij1}^L}{x_{ij}^*}, \frac{x_{ij2}^L}{x_{ij}^*}, \frac{x_{ij3}^L}{x_{ij}^*}, \frac{x_{ij4}^L}{x_{ij}^*}; h_{ij}^L), (\frac{x_{ij1}^U}{x_{ij}^*}, \frac{x_{ij2}^U}{x_{ij}^*}, \frac{x_{ij3}^U}{x_{ij}^*}, \frac{x_{ij4}^U}{x_{ij}^*}; h_{ij}^U) \right), & j \in \Omega_B \\ \left((\frac{x_{ij}^-}{x_{ij4}^L}, \frac{x_{ij}^-}{x_{ij3}^L}, \frac{x_{ij}^-}{x_{ij2}^L}, \frac{x_{ij}^-}{x_{ij1}^L}; h_{ij}^L), (\frac{x_{ij}^-}{x_{ij4}^U}, \frac{x_{ij}^-}{x_{ij3}^U}, \frac{x_{ij}^-}{x_{ij2}^U}, \frac{x_{ij}^-}{x_{ij1}^U}; h_{ij}^U) \right), & j \in \Omega_C \end{cases} \tag{26}$$

where Ω_B and Ω_C represents the sets of benefit and cost criteria, and $x_{ij}^* = \max_i x_{ij4}^U$, $x_{ij}^- = \min_i x_{ij1}^U$.

Step 3. Determine the relative weight $\widehat{w}_{jf}$ of the criterion Cr_j to the reference criterion Cr_f:

$$\widehat{w}_{jf} = \frac{Def(\tilde{\tilde{w}}_j^*)}{Def(\tilde{\tilde{w}}_f^*)} \quad (j = 1, 2, ..., n) \tag{27}$$

where $Def(\tilde{\tilde{w}}_j^*)$ is the defuzzified value of the optimal interval type-2 fuzzy criteria weight $\tilde{\tilde{w}}_j^*$ obtained by Eq. (24), and $Def(\tilde{\tilde{w}}_f^*) = \max_j\{Def(\tilde{\tilde{w}}_j^*)\}$.

Step 4. Derive the dominance degree $\psi^{(Cr_j)}(FT_i, FT_g)$ of alternative financial technology FT_i over FT_g with respect to the criterion Cr_j by Eq. (28):

$$\psi^{(Cr_j)}(FT_i, FT_g) = \begin{cases} \sqrt{\dfrac{\widehat{w}_{jf} d_{SD}(\tilde{\tilde{r}}_{ij}, \tilde{\tilde{r}}_{gj})}{\sum_{j=1}^{n} \widehat{w}_{jf}}}, & if\ Def(\tilde{\tilde{r}}_{ij}) > Def(\tilde{\tilde{r}}_{gj}) \\ 0, & if\ Def(\tilde{\tilde{r}}_{ij}) = Def(\tilde{\tilde{r}}_{gj}) \\ -\dfrac{1}{\vartheta}\sqrt{\dfrac{\sum_{j=1}^{n} \widehat{w}_{jf} d_{SD}(\tilde{\tilde{r}}_{ij}, \tilde{\tilde{r}}_{gj})}{\widehat{w}_{jf}}}, & if\ Def(\tilde{\tilde{r}}_{ij}) < Def(\tilde{\tilde{r}}_{gj}) \end{cases} \tag{28}$$

where $Def(\tilde{\tilde{r}}_{ij})$ and $Def(\tilde{\tilde{r}}_{gj})$ are the defuzzified values of TrIT2FS $\tilde{\tilde{r}}_{ij}$ and $\tilde{\tilde{r}}_{gj}$ obtained by Eq. (16), $d_{SD}(\tilde{\tilde{r}}_{ij}, \tilde{\tilde{r}}_{gj})$ is the distance between $\tilde{\tilde{r}}_{ij}$ and $\tilde{\tilde{r}}_{gj}$ calculated by Eq. (13), and ϑ is the loss attenuation parameter. $\vartheta>1$ means the losses are attenuated and $0<\vartheta<1$ means the losses are amplified.

Step 5. Derive the overall dominance degree $\psi(FT_i, FT_g)$ of alternative financial technology FT_i over FT_g by Eq. (29):

$$\psi(FT_i, FT_g) = \sum_{j=1}^{n} \psi^{(Cr_j)}(FT_i, FT_g) \tag{29}$$

Step 6. Compute the global prospect value $T(FT_i)$ of the alternative financial technology FT_i:

$$T(FT_i) = \frac{\sum_{g=1}^{m} \psi(FT_i, FT_g) - \min_{1\leq i\leq m}\left\{\sum_{g=1}^{m} \psi(FT_i, FT_g)\right\}}{\max_{1\leq i\leq m}\left\{\sum_{g=1}^{m} \psi(FT_i, FT_g)\right\} - \min_{1\leq i\leq m}\left\{\sum_{g=1}^{m} \psi(FT_i, FT_g)\right\}} \tag{30}$$

Step 7. Rank all the financial technologies according to $T(FT_i)$, and the financial technology with a larger $T(FT_i)$ value is more acceptable.

IV. Case Study

This section provides an illustrative example is provided to illustrate the applicability of the developed method in Fintech selection.

A. Implementation and computation

Fintech is technology-driven financial innovation that aims to innovate the products and services provided by the traditional financial industry through the use of various technological means. Fintech also brings new challenges to financial security. With the rapid development of fintech, it has become an inevitable trend for banks to select a suitable technology company and create a partnership, which is of great significance.

Bank M is ready to select a fintech company to improve its management and service level and has initially identified five companies/alternatives $\{FT_i, i=1,2,3,4,5\}$. What needs to be solved on this basis is to choose the best one by considering the relevant evaluation criteria system. The identified criteria $\{Cr_j, j=1,2,3,4\}$ include artificial intelligence (Cr_1), blockchain (Cr_2), cloud computing (Cr_3) and big data (Cr_4), application scenario breakthrough capability (Cr_5), the proportion of online business (Cr_6). Four experts $\{Ex_q, q=1,2,3,4\}$ are empowered to assess the Best-to-Others and Others-to-Worst preference comparisons of criteria (BtO and OtW) based on linguistic information in Table II, and the results are shown in Table IV. These linguistic assessment data (in Table IV) are replaced by the TrIT2FSs accordingly.

TABLE IV
PREFERENCE COMPARISON IDENTIFIED BY EXPERTS

			Cr_1	Cr_2	Cr_3	Cr_4	Cr_5	Cr_6
Ex_1	Best (Cr_4)	BtO	MI	EX	SP	EI	VS	SI
	Worst (Cr_2)	OtW	SP	EI	SI	VVS	SI	MP
Ex_2	Best (Cr_4)	BtO	MP	SI	SI	EI	MI	EX
	Worst (Cr_6)	OtW	EX	MI	VS	VVS	SP	EI
Ex_3	Best (Cr_1)	BtO	EI	WI	MP	MI	VS	EX
	Worst (Cr_6)	OtW	VS	MP	SI	VS	VS	EI
Ex_4	Best (Cr_5)	BtO	MI	VVS	SI	MI	EI	VS
	Worst (Cr_2)	OtW	SP	EI	MP	VVS	SP	MI

Then, according to Eq. (21), the mathematical model for determining optimal criteria weight with respect to each expert is constructed. For instance, for expert Ex_1, the model with nonlinear constraints established based on the evaluation information can be expressed as (Model 1):

$$Min\ \lambda^{1*}$$

$$\text{s.t.}\ \begin{cases} \left|w_{41}^{1,L}-2.5w_{11}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-3w_{12}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-3w_{13}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-3.5w_{14}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-2w_{11}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-3w_{12}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-3w_{13}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-4w_{14}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.1}$$

$$\begin{cases} \left|w_{11}^{1,L}-5.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{12}^{1,L}-6w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{13}^{1,L}-6w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{14}^{1,L}-6.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{11}^{1,U}-5w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{12}^{1,U}-6w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{13}^{1,U}-6w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{14}^{1,U}-7w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.2}$$

$$\begin{cases} \left|w_{41}^{1,L}-8.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-9w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-9w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-9.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-8w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-9w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-9w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-10w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.3}$$

$$\begin{cases} \left|w_{21}^{1,L}-w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{22}^{1,L}-w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{23}^{1,L}-w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{24}^{1,L}-w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{21}^{1,U}-w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{22}^{1,U}-w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{23}^{1,U}-w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{24}^{1,U}-w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.4}$$

$$\begin{cases} \left|w_{41}^{1,L}-5.5w_{31}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-6w_{32}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-6w_{33}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-6.5w_{34}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-5w_{31}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-6w_{32}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-6w_{33}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-7w_{34}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.5}$$

$$\begin{cases} \left|w_{31}^{1,L}-4.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{32}^{1,L}-5w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{33}^{1,L}-5w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{34}^{1,L}-5.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{31}^{1,U}-4w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{32}^{1,U}-5w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{33}^{1,U}-5w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{34}^{1,U}-6w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.6}$$

$$\begin{cases} \left|w_{41}^{1,L}-w_{41}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-w_{42}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-w_{43}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-w_{44}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-w_{41}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-w_{42}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-w_{43}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-w_{44}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.7}$$

$$\begin{cases} \left|w_{41}^{1,L}-7.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-8w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-8w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-8.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-7w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-8w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-8w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-9w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.8}$$

$$\begin{cases} \left|w_{41}^{1,L}-6.5w_{51}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-7w_{52}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-7w_{53}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-7.5w_{54}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-6w_{51}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-7w_{52}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-7w_{53}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-8w_{54}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.9}$$

$$\begin{cases} \left|w_{51}^{1,L}-4.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{52}^{1,L}-5w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{53}^{1,L}-5w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{54}^{1,L}-5.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{51}^{1,U}-4w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{52}^{1,U}-5w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{53}^{1,U}-5w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{54}^{1,U}-6w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.10}$$

$$\begin{cases} \left|w_{41}^{1,L}-4.5w_{61}^{1,L}\right|\le\lambda^{1*}, \left|w_{42}^{1,L}-5w_{62}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,L}-5w_{63}^{1,L}\right|\le\lambda^{1*}, \left|w_{44}^{1,L}-5.5w_{64}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{41}^{1,U}-4w_{61}^{1,U}\right|\le\lambda^{1*}, \left|w_{42}^{1,U}-5w_{62}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{43}^{1,U}-5w_{63}^{1,U}\right|\le\lambda^{1*}, \left|w_{44}^{1,U}-6w_{64}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.11}$$

$$\begin{cases} \left|w_{61}^{1,L}-3.5w_{21}^{1,L}\right|\le\lambda^{1*}, \left|w_{62}^{1,L}-4w_{22}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{63}^{1,L}-4w_{23}^{1,L}\right|\le\lambda^{1*}, \left|w_{64}^{1,L}-4.5w_{24}^{1,L}\right|\le\lambda^{1*}, \\ \left|w_{61}^{1,U}-3w_{21}^{1,U}\right|\le\lambda^{1*}, \left|w_{62}^{1,U}-4w_{22}^{1,U}\right|\le\lambda^{1*}, \\ \left|w_{63}^{1,U}-4w_{23}^{1,U}\right|\le\lambda^{1*}, \left|w_{64}^{1,U}-5w_{24}^{1,U}\right|\le\lambda^{1*}, \end{cases} \tag{M1.12}$$

$$\sum_{j=1}^{6}\frac{1}{2}\left\{\frac{(w_{j4}^{1,U}-w_{j1}^{1,U})+(w_{j2}^{1,U}-w_{j1}^{1,U})+(w_{j3}^{1,U}-w_{j1}^{1,U})}{4}+w_{j1}^{1,U}+\frac{(w_{j4}^{1,L}-w_{j1}^{1,L})+(0.9w_{j2}^{1,L}-w_{j1}^{1,L})+(0.9w_{j3}^{1,L}-w_{j1}^{1,L})}{4}+w_{j1}^{1,L}\right\}=1 \tag{M1.13}$$

$$w_{j1}^{1,L}\le w_{j2}^{1,L}\le w_{j3}^{1,L}\le w_{j4}^{1,L},\ j=1,2,\ldots,6; \tag{M1.14}$$

$$w_{j1}^{1,U}\le w_{j2}^{1,U}\le w_{j3}^{1,U}\le w_{j4}^{1,U},\ j=1,2,\ldots,6; \tag{M1.15}$$

$$w_{j1}^{1,U}\le w_{j1}^{1,L},\ j=1,2,\ldots,6; \tag{M1.16}$$

$$w_{j4}^{1,L}\le w_{j4}^{1,U},\ j=1,2,\ldots,6; \tag{M1.17}$$

$$w_{j1}^{1,U}\ge 0,\ j=1,2,\ldots,6. \tag{M1.18}$$

On similar lines, the mathematical models for obtaining criteria weights for other experts are constructed. The resulting optimal weights $\tilde{\tilde{w}}_j^{q*}$ (j=1,2,…,6) of criteria in the form of TrIT2FS for four experts are shown in Table V.

The consistency ratio results calculated by Eq. (22) are $CR^{(1)}$=0.0248, $CR^{(2)}$=0.0226, $CR^{(3)}$=0.0197, and $CR^{(4)}$= 0.0240, which reflect great consistency. Moreover, this paper assumes that the weights of the four experts are equal, thus, the optimal weights of criteria after aggregation are determined based on Eq. (24).

In addition, Table VI presents the evaluation results of the five alternatives provided by the experts based on the linguistic terms in Table I, which are also transformed into the form of TrIT2FS accordingly.

Then, the group TrIT2FS decision matrix $\tilde{\tilde{X}}=[\tilde{\tilde{x}}_{ij}]_{5\times 6}$ is calculated by aggregating the individual decision matrices based on Eq. (25), which is presented in Table VII. By classifying the six criteria as the benefit-type, the normalized group decision-making matrix $\tilde{\tilde{R}}$ = $[\tilde{\tilde{r}}_{ij}]_{5\times 6}$ is further obtained according to Eq. (26) and listed in Table VIII.

TABLE VI
PREFERENCE COMPARISON IDENTIFIED BY EXPERTS

		Cr_1	Cr_2	Cr_3	Cr_4	Cr_5	Cr_6
Ex_1	FT_1	VH	H	VH	H	H	L
	FT_2	H	H	VH	VH	VH	VH
	FT_3	MH	M	MH	MH	H	VH
	FT_4	ML	ML	MH	H	H	VH
	FT_5	L	L	MH	M	M	M
Ex_2	FT_1	MH	M	M	H	MH	H
	FT_2	M	MH	H	H	MH	H
	FT_3	ML	MH	MH	H	MH	H
	FT_4	L	L	M	M	M	H
	FT_5	VL	VL	L	L	L	MH
Ex_3	FT_1	M	M	M	M	MH	MH
	FT_2	MH	MH	MH	M	M	VH
	FT_3	MH	MH	MH	MH	MH	H
	FT_4	M	M	M	M	M	MH
	FT_5	ML	ML	ML	ML	ML	M
Ex_4	FT_1	MH	H	H	M	ML	M
	FT_2	H	H	MH	H	H	MH
	FT_3	MH	M	M	MH	ML	M
	FT_4	H	MH	MH	M	M	MH
	FT_5	M	MH	M	ML	ML	L

TABLE VII
GROUP TRIT2FS DECISION MATRIX

	Cr_1	Cr_2
FT_1	((6.38, 7.25, 7.63, 8; 0.9), (5.5, 7.25, 8, 8.75; 1.0))	((6, 6.75, 7.25, 7.75; 0.9), (5, 6.75, 7.75, 8.5; 1.0))
FT_2	((6.5, 7.25, 7.75, 8.25; 0.9), (5.5, 7.25, 8.25, 9, 1.0))	((7, 7.75, 8.25, 8.75; 0.9), (6, 7.75, 8.75, 9.5; 1.0))
FT_3	((5, 6, 6.5, 7; 0.9), (4, 6, 7, 8; 1.0))	((5, 6, 6.5, 7; 0.9), (4, 6, 7, 8; 1.0))
FT_4	((3.63, 4.38, 4.88, 5.38; 0.9), (2.75, 4.38, 5.38, 6.25; 1.0))	((3.125, 4, 4.5, 5; 0.9), (2.25, 4, 5, 6; 1.0))
FT_5	((1.63, 2.25, 2.63, 3.13; 0.9), (1, 2.25, 3, 4; 1.0))	((2.13, 2.75, 3.13, 3.63; 0.9), (1.5, 2.75, 3.5, 4.5; 1.0))

	Cr_3	Cr_4
FT_1	((6.38, 7.13, 7.5, 7.88; 0.9), (5.5, 7.13, 7.88, 8.5; 1.0))	((6, 6.75, 7.25, 7.75; 0.9), (5, 6.75, 7.75, 8.5; 1.0))
FT_2	((7.38, 8.13, 8.5, 8.88; 0.9), (6.5, 8.125, 8.88, 9.5))	((7.38, 8, 8.38, 8.75; 0.9), (6.5, 8, 8.75, 9.25; 1.0))
FT_3	((5.5, 6.5, 7, 7.5; 0.9), (4.5, 6.5, 7.5, 8.5; 1.0))	((6.5, 7.38, 7.88, 8.38; 0.9), (5.5, 7.38, 8.38, 9.25; 1.0))
FT_4	((5, 6, 6.5, 7; 0.9), (4, 6, 7, 8; 1.0))	((5, 5.88, 6.38, 6.88; 0.9), (4, 5.88, 6.88, 7.75; 1.0))
FT_5	((3.125, 4, 4.5, 5; 0.9), (2.25, 4, 5, 6; 1.0))	((2.125, 3, 3.5, 4; 0.9), (1.25, 3, 4, 5; 1.0))

	Cr_5	Cr_6
FT_1	((5.5, 6.38, 6.88, 7.38; 0.9), (4.5, 6.38, 7.38, 8.25; 1.0))	((4.63, 5.38, 5.88, 6.38; 0.9), (3.75, 5.38, 6.38, 7.25; 1.0))
FT_2	((6.88, 7.63, 8, 8.38; 0.9), (6, 7.63, 8.38, 9; 1.0))	((8.25, 8.88, 9.13, 9.38; 0.9), (7.5, 8.88, 9.38, 9.75; 1.0))
FT_3	((5.5, 6.38, 6.88, 7.38; 0.9), (4.5, 6.38, 7.38, 8.25; 1.0))	((7.38, 8, 8.38, 8.75; 0.9), (6.5, 8, 8.75, 9.25; 1.0))
FT_4	((5, 5.88, 6.38, 6.88; 0.9), (4, 5.88, 6.88, 7.75; 1.0))	((7.38, 8.13, 8.5, 8.88; 0.9), (6.5, 8.13, 8.88, 9.5; 1.0))
FT_5	((4, 5, 5.5, 6; 0.9), (3, 5, 6, 7; 1.0))	((6, 6.88, 7.38, 7.88; 0.9), (5, 6.88, 7.88, 8.75; 1.0))

According to Eq. (16), the defuzzified values of the optimal interval type-2 fuzzy criteria weights are calculated as: $Def(\tilde{\tilde{w}}_1^*)$ =0.2248, $Def(\tilde{\tilde{w}}_2^*)$ =0.1203, $Def(\tilde{\tilde{w}}_3^*)$ =0.1267, $Def(\tilde{\tilde{w}}_4^*)$ =0.2739, $Def(\tilde{\tilde{w}}_5^*)$ =0.1798, and $Def(\tilde{\tilde{w}}_6^*)$ =0.0744. Then, the criterion Cr_4 is recognized as the reference criterion Cr_f. By using Eq. (27), the relative weights $\hat{w}_{jf}$ (j=1,2,3,4) are obtained and are shown in Fig. 3.

Let the loss attenuation parameter ϑ=1, the dominance degree $\psi^{(Cr_j)}(FT_i, FT_g)$ of alternative FT_i over FT_g for each criterion can be calculated by Eq. (28), which is shown in Table IX. Further, the overall dominance degree of FT_i over FT_g is obtained based on Eq. (29) as:

$$\left[\psi(FT_i, FT_g)\right]_{5\times5} = \begin{bmatrix} 0 & -8.094 & -2.825 & -1.516 & -0.211 \\ 1.098 & 0 & 1.162 & 1.619 & 2.206 \\ -2.765 & -7.743 & 0 & 0.492 & 1.847 \\ -6.556 & -10.087 & -5.854 & 0 & 1.472 \\ -9.969 & -13.723 & -11.193 & -9.109 & 0 \end{bmatrix}$$

Finally, using Eq. (30), the global prospect value of FT_i can be determined as: $T(FT_1)$ =0.6260, $T(FT_2)$ =1, $T(FT_3)$=0.7154, $T(FT_4)$ =0.4587, and $T(FT_5)$=0. Thus, the ranking order is listed as $FT_2 \succ FT_3 \succ FT_1 \succ FT_4 \succ FT_5$, and the Fintech company FT_2 is regarded as the best one.

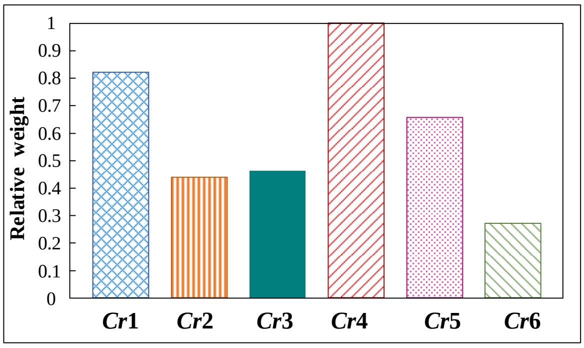

Fig. 3. Relative weights of criteria.

B. Sensitivity analysis of loss attenuation parameter

In the calculation of alternative dominance degree by the interval type-2 fuzzy TODIM method, the loss attenuation parameter ϑ is utilized to reflect the behavior characteristics of decision-makers. ϑ>1 means the losses are attenuated and 0< ϑ<1 means the losses are amplified. To examine the influence of parameter ϑ on financial technology selection results, this subsection conducts a sensitivity analysis of ϑ. To this end, different values of ϑ are chosen to derive the global prospect value of FT_i, including ϑ=0.5, ϑ=0.8, ϑ=2, and ϑ=4. The corresponding results are shown in Table X.

It can be seen from Table X that as the value of ϑ increases, the global prospect value of the alternatives FT_1, FT_3, and FT_4 become smaller, that is, the overall dominance degrees decrease. Moreover, compared with FT_1, FT_3 and FT_4 are more sensitive to changes in parameter ϑ. We provide the dominance degree results of FT_1 and FT_4 over other alternatives for ϑ=0.5 and ϑ=4, which are presented in Figs. 4 and 5.

TABLE X
GLOBAL PROSPECT VALUE OF TFI WITH DIFFERENT VALUES OF Θ

	ϑ=0.5	ϑ=0.8	ϑ=1	ϑ=2	ϑ=4
FT_1	0.6302	0.6276	0.6260	0.6189	0.6085
FT_2	1.0000	1.0000	1.0000	1.0000	1.0000
FT_3	0.7271	0.7199	0.7154	0.6957	0.6667
FT_4	0.4709	0.4634	0.4587	0.4380	0.4075
FT_5	0.0000	0.0000	0.0000	0.0000	0.0000

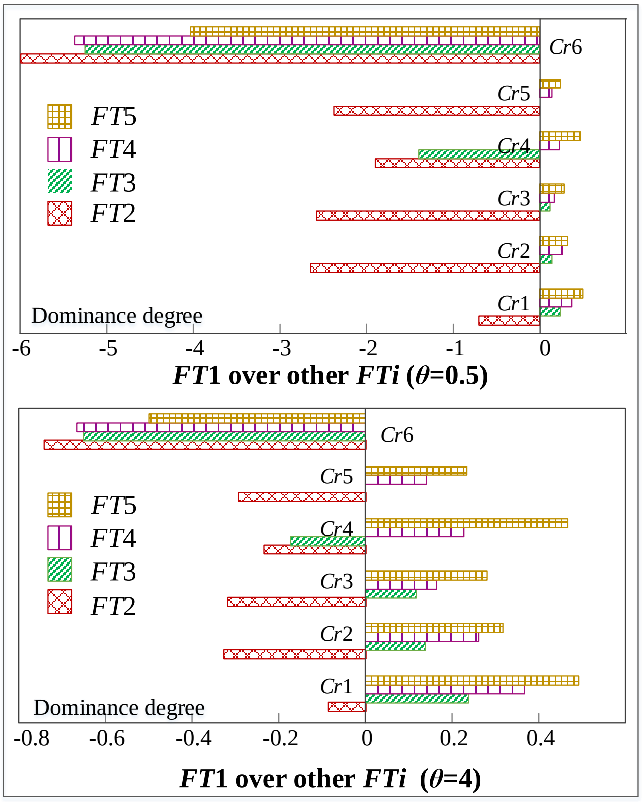

Fig. 4. The dominance degree of FT_1 over other FT_i with ϑ=0.5 and ϑ=4.

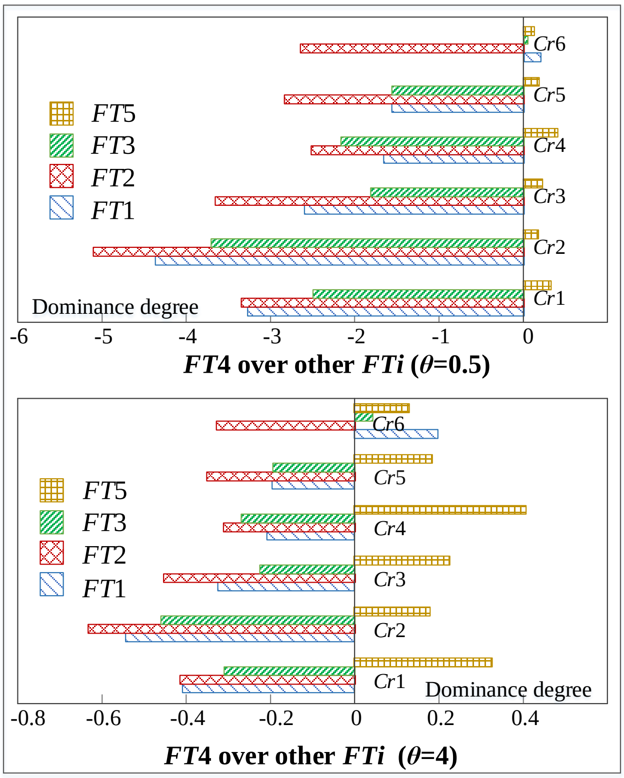

Fig. 5. The dominance degree of FT_4 over other FT_i with ϑ=0.5 and ϑ=4.

As shown in these two figures, the loss of FT_1 over other FT_i mainly exists in Cr_6, while FT_4 has significant losses in Cr_1, Cr_2, Cr_3, Cr_4, and Cr_5. When ϑ=0.5, the losses of FT_1 and FT_4 are amplified respectively, but the losses of FT_4 are significantly greater than that of FT_1, resulting in a higher overall dominance of FT_1; and when ϑ=4, although losses are attenuated, they cannot be compensated by the corresponding advantages. We also note that the fluctuation of parameter ϑ does not change the overall ranking result of the alternatives, i.e., $FT_2 \succ FT_3 \succ FT_1 \succ FT_4 \succ FT_5$.

This phenomenon suggests that despite the change in the level of risk aversion of decision-makers, they still regard FT_2 as the best option in financial technology. In some ways, the robustness of the proposed method is proved. We can also conclude that the sensitivity of the parameter ϑ is susceptible to the influence of the assessment information, more specifically, the smaller the difference in the assessment information, the more sensitive the sorting results are to the variation of the parameters.

C. Comparative analysis

To illustrate the effectiveness of the presented framework, a comparative analysis is performed in this section. The commonly used weight allocation method (entropy measure) and decision method (multi-attributive border approximation area comparison, MABAC) are adopted to implement the same case. The basic principle of the MABAC approach is to determine the values of the criteria functions of the alternatives ($S(FT_i)$) according to the distances between the alternatives and the boundary approximation area, and sort the alternatives based on $S(FT_i)$. To this end, the comparison consists of four models including Entropy-MABAC, BWM-MABAC, Entropy-TODIM, and BWM-TODIM. All models are implemented in the IT2F context.

The evaluation results obtained by the Entropy-MABAC model are: $S(FT_1)$=0.0638, $S(FT_2)$=0.1925, $S(FT_3)$=0.0715, $S(FT_4)$=-0.0193, and $S(FT_5)$=-0.1993; while the results based on the BWM-MABAC model are: $S(FT_1)$=0.1004, $S(FT_2)$= 0.1869, $S(FT_3)$=0.0696, $S(FT_4)$=-0.0513, $S(FT_5)$=-0.2522. The core of TODIM is to calculate the global prospect values of the alternatives to determine the priority of the alternatives. In view of this, the global prospect values of the fintech companies determined under Entropy-TODIM framework are: $T(FT_1)$=0.6733, $T(FT_2)$=1.0000, $T(FT_3)$=0.7181, $T(FT_4)$ = 0.4438, $T(FT_5)$=0.0000. From this, it can be concluded that the ranking obtained by the Entropy-MABAC and Entropy-TODIM models are completely consistent with that obtained by the BWM-TODIM in this paper, that is $FT_2 \succ FT_3 \succ FT_1 \succ FT_4 \succ FT_5$. The ranking by BWM-MABAC is $FT_2 \succ FT_1 \succ FT_3 \succ FT_4 \succ FT_5$, which is slightly different from that obtained by other models. In addition, Spearman's rank correlation coefficient test [35] is conducted to analyze differences in decision results. The correlation coefficient of the two ranking results is 0.9, which indicates that there is a significant relationship between the results of the BWM-MABAC and BWM-TODIM methods. Moreover, the four decision-making models constantly identify FT_2 as the best alternative, thus verifying the credibility and validity of the results based on the BWM-TODIM method.

V. CONCLUSIONS

At present, technological innovation is unprecedentedly active, and a new round of technological revolutions such as big data and artificial intelligence is reshaping the financial industry format and competition pattern. In the context of accelerated integration by fintech, banks are facing severe transformation challenges. Before cooperating with fintech companies, banks need to comprehensively evaluate technology companies and select the ones with appropriate and competitive advantages. This paper studies the selection problem of technology companies. To this end, a novel integrated decision-making framework is proposed, which fully considers the uncertainty of information and the psychological behavior state of decision-makers towards loss. The design of the model benefits from the synergistic use of BWM and TODIM approaches, both of which are implemented in the IT2F environment. Within the proposed model, the criteria weights are recognized by the IT2F-BWM method, and the ranking results of alternative technology companies are determined by the IT2F-TODIM method. Finally, the practicability and reliability of the introduced methodology are verified by a case study with sensitivity analysis and comparative analysis. The results obtained indicate that the proposed framework can effectively help the bank to select a satisfactory financial technology company.

It is worth noting that this is the first time that BWM and TODIM are fused in the context of IT2FSs, which provides a new perspective for decision-making. The proposed methodology is not specific to only financial technology selection; instead, it can be applied to any complex and uncertain MCDM problem because of its easily-to-implement uncertainty representation and decision modeling framework. In future, it would be interesting to develop a more well-rounded criteria system for financial technology selection; in addition, the expert preference information can be characterized by several different fuzzy types to adapt to more complicated assessment environments.

TABLE V
OPTIMAL TrIT2FS WEIGHTS OF CRITERIA FOR FOUR EXPERTS

	Cr_1	Cr_2	Cr_3
EX_1	((0.2025, 0.2362, 0.2362, 0.2834; 0.9), (0.1771, 0.2362, 0.2362, 0.3543; 1.0))	((0.0399, 0.0419, 0.0419, 0.0441; 0.9), (0.0382, 0.0419, 0.0419, 0.0467; 1.0))	((0.1090, 0.1181, 0.1181, 0.1288, 0.9), (0.1012, 0.1181, 0.1181, 0.1417; 1.0))
EX_2	((0.1430, 0.1609, 0.1609, 0.1839; 0.9), (0.1287, 0.1609, 0.1609, 0.2146; 1.0))	((0.1170, 0.1287, 0.1287, 0.1430; 0.9), (0.1073, 0.1287, 0.1287, 0.1609; 1.0))	((0.1170, 0.1287, 0.1287, 0.1430; 0.9), (0.1073, 0.1287, 0.1287, 0.1609; 1.0))
EX_3	((0.2954, 0.2954, 0.2954, 0.2954; 0.9), (0.2954, 0.2954, 0.2954, 0.2954; 1.0))	((0.2242, 0.2803, 0.2803, 0.3442; 0.9), (0.1869, 0.2803, 0.2803, 0.3558; 1.0))	((0.1246, 0.1401, 0.1401, 0.1602; 0.9), (0.1121, 0.1401, 0.1401, 0.1869; 1.0))
EX_4	((0.1790, 0.2088, 0.2088, 0.2506; 0.9), (0.1566, 0.2088, 0.2088, 0.3132; 1.0))	((0.0399, 0.0420, 0.0420, 0.0445; 0.9), (0.0380, 0.0420, 0.0420, 0.0475; 1.0))	((0.1139, 0.1253, 0.1253, 0.1392; 0.9), (0.1044, 0.1253, 0.1253, 0.1566; 1.0))
	Cr_4	Cr_5	Cr_6
EX_1	((0.3734, 0.3734, 0.3734, 0.3734, 0.9), (0.3734, 0.3734, 0.3734, 0.3734; 1.0))	((0.0945, 0.1012, 0.1012, 0.1090, 0.9), (0.0886, 0.1012, 0.1012, 0.1181; 1.0))	((0.1288, 0.1417, 0.1417, 0.1575, 0.9), (0.1181, 0.1417, 0.1417, 0.1771; 1.0))
EX_2	((0.3392, 0.3392, 0.3392, 0.3392; 0.9), (0.3392, 0.3392, 0.3392, 0.3392; 1.0))	((0.1839, 0.2146, 0.2146, 0.2575; 0.9), (0.1609, 0.2146, 0.2146, 0.3218; 1.0))	((0.0363, 0.0381, 0.0381, 0.0401; 0.9), (0.0347, 0.0381, 0.0381, 0.0424; 1.0))
EX_3	((0.1602, 0.1869, 0.1869, 0.2242; 0.9), (0.1401, 0.1869, 0.1869, 0.2803; 1.0))	((0.0747, 0.0801, 0.0801, 0.0862; 0.9), (0.0701, 0.0801, 0.0801, 0.0934; 1.0))	((0.0316, 0.0331, 0.0331, 0.0349; 0.9), (0.0302, 0.0331, 0.0331, 0.0369; 1.0))
EX_4	((0.1790, 0.2088, 0.2088, 0.2506; 0.9), (0.1566, 0.2088, 0.2088, 0.3132; 1.0))	((0.3322, 0.3322, 0.3322, 0.3322; 0.9), (0.3322, 0.3322, 0.3322, 0.3322; 1.0))	((0.0835, 0.0895, 0.0895, 0.0964; 0.9), (0.0783, 0.0895, 0.0895, 0.1044; 1.0))

TABLE VIII
NORMALIZED GROUP TrIT2FS DECISION MATRIX

	Cr_1	Cr_2	Cr_3
FT_1	((0.7083, 0.8056, 0.8472, 0.8889; 0.9), (0.6111, 0.8056, 0.8889, 0.9722; 1.0))	((0.6316, 0.7105, 0.7632, 0.8158; 0.9), (0.5263, 0.7105, 0.8158, 0.8947; 1.0))	((0.6711, 0.7500, 0.7895, 0.8289; 0.9), (0.5789, 0.7500, 0.8289, 0.8947; 1.0))
FT_2	((0.7222, 0.8056, 0.8611, 0.9167; 0.9), (0.6111, 0.8056, 0.9167, 1; 1.0))	((0.7368, 0.8158, 0.8684, 0.9211; 0.9), (0.6316, 0.8158, 0.9211, 1; 1.0))	((0.7763, 0.8553, 0.8947, 0.9342; 0.9), (0.6842, 0.8553, 0.9342, 1; 1.0))
FT_3	((0.5556, 0.6667, 0.7222, 0.7778; 0.9), (0.4444, 0.6667, 0.7778, 0.8889; 1.0))	((0.5263, 0.6316, 0.6842, 0.7368; 0.9), (0.4211, 0.6316, 0.7368, 0.8421; 1.0))	((0.5789, 0.6842, 0.7368, 0.7895; 0.9), (0.4737, 0.6842, 0.7895, 0.8947; 1.0))
FT_4	((0.4028, 0.4861, 0.5417, 0.5972; 0.9), (0.3056, 0.4861, 0.5972, 0.6944; 1.0))	((0.3289, 0.4211, 0.4737, 0.5263; 0.9), (0.2368, 0.4211, 0.5263, 0.6316; 1.0))	((0.5263, 0.6316, 0.6842, 0.7368; 0.9), (0.4211, 0.6316, 0.7368, 0.8421; 1.0))
FT_5	((0.1806, 0.2500, 0.2917, 0.3472; 0.9), (0.1111, 0.2500, 0.3333, 0.4444; 1.0))	((0.2237, 0.2895, 0.3289, 0.3816; 0.9), (0.1579, 0.2895, 0.3684, 0.4737; 1.0))	((0.3289, 0.4211, 0.4737, 0.5263; 0.9), (0.2368, 0.4211, 0.5263, 0.6316; 1.0))
	Cr_4	Cr_5	Cr_6
A_1	((0.6486, 0.7297, 0.7838, 0.8378; 0.9), (0.5405, 0.7297, 0.8378, 0.9189; 1.0))	((0.6111, 0.7083, 0.7639, 0.8194; 0.9), (0.5000, 0.7083, 0.8194, 0.9167; 1.0))	((0.4744, 0.5513, 0.6026, 0.6538; 0.9), (0.3846, 0.5513, 0.6538, 0.7436; 1.0))
A_2	((0.7973, 0.8649, 0.9054, 0.9459; 0.9), (0.7027, 0.8649, 0.9459, 1; 1.0))	((0.7639, 0.8472, 0.8889, 0.9306; 0.9), (0.6667, 0.8472, 0.9306, 1; 1.0))	((0.8462, 0.9103, 0.9359, 0.9615; 0.9), (0.7692, 0.9103, 0.9615, 1; 1.0))
A_3	((0.7027, 0.7973, 0.8514, 0.9054; 0.9), (0.5946, 0.7973, 0.9054, 1; 1.0))	((0.6111, 0.7083, 0.7639, 0.8194; 0.9), (0.5000, 0.7083, 0.8194, 0.9167; 1.0))	((0.7564, 0.8205, 0.8590, 0.8974; 0.9), (0.6667, 0.8205, 0.8974, 0.9487; 1.0))
A_4	((0.5405, 0.6351, 0.6892, 0.7432; 0.9), (0.4324, 0.6351, 0.7432, 0.8378; 1.0))	((0.5556, 0.6528, 0.7083, 0.7639; 0.9), (0.4444, 0.6528, 0.7639, 0.8611; 1.0))	((0.7564, 0.8333, 0.8718, 0.9103; 0.9), (0.6667, 0.8333, 0.9103, 0.9744; 1.0))
A_5	((0.2297, 0.3243, 0.3784, 0.4324; 0.9), (0.1351, 0.3243, 0.4324, 0.5405; 1.0))	((0.4444, 0.5556, 0.6111, 0.6667; 0.9), (0.3333, 0.5556, 0.6667, 0.7778; 1.0))	((0.6154, 0.7051, 0.7564, 0.8077; 0.9), (0.5128, 0.7051, 0.8077, 0.8974))

TABLE IX
DOMINANCE DEGREE OF *FTi* OVER *FTG* FOR EACH CRITERION

Cr_1	FT_1	FT_2	FT_3	FT_4	FT_5	Cr_2	FT_1	FT_2	FT_3	FT_4	FT_5
FT_1	0	-0.3515	0.2387	0.3693	0.4955	FT_1	0	-1.3226	0.1393	0.2634	0.3200
FT_2	0.0790	0	0.2514	0.3776	0.5018	FT_2	0.1592	0	0.2115	0.3077	0.3574
FT_3	-1.0619	-1.1185	0	0.2818	0.4343	FT_3	-1.1573	-1.7574	0	0.2235	0.2881
FT_4	-1.6427	-1.6799	-1.2533	0	0.3305	FT_4	-2.1883	-2.5569	-1.8572	0	0.1817
FT_5	-2.2044	-2.2322	-1.9317	-1.4700	0	FT_5	-2.6586	-2.9694	-2.3935	-1.5098	0
Cr_3	FT_1	FT_2	FT_3	FT_4	FT_5	Cr_4	FT_1	FT_2	FT_3	FT_4	FT_5
FT_1	0	-1.2892	0.1181	0.1652	0.2826	FT_1	0	-0.9488	-0.6979	0.2287	0.4705
FT_2	0.1633	0	0.2016	0.2323	0.3264	FT_2	0.2599	0	0.1761	0.3462	0.5375
FT_3	-0.9327	-1.5912	0	0.1155	0.2567	FT_3	0.1912	-0.6428	0	0.2981	0.5079
FT_4	-1.3042	-1.8338	-0.9116	0	0.2293	FT_4	-0.8347	-1.2637	-1.0881	0	0.4112
FT_5	-2.2312	-2.5768	-2.0269	-1.8103	0	FT_5	-1.7175	-1.9622	-1.8539	-1.5010	0
Cr_5	FT_1	FT_2	FT_3	FT_4	FT_5	Cr_6	FT_1	FT_2	FT_3	FT_4	FT_5
FT_1	0	-1.1872	0.0000	0.1414	0.2351	FT_1	0	-2.9949	-2.6230	-2.6839	-2.0145
FT_2	0.2135	0	0.2135	0.2561	0.3176	FT_2	0.2228	0	0.1075	0.0989	0.1649
FT_3	0.0000	-1.1872	0	0.1414	0.2351	FT_3	0.1951	-1.4455	0	-0.5684	0.1250
FT_4	-0.7860	-1.4239	-0.7860	0	0.1878	FT_4	0.1997	-1.3290	0.0423	0	0.1319
FT_5	-1.3072	-1.7659	-1.3072	-1.0445	0	FT_5	0.1499	-2.2161	-1.6798	-1.7734	0

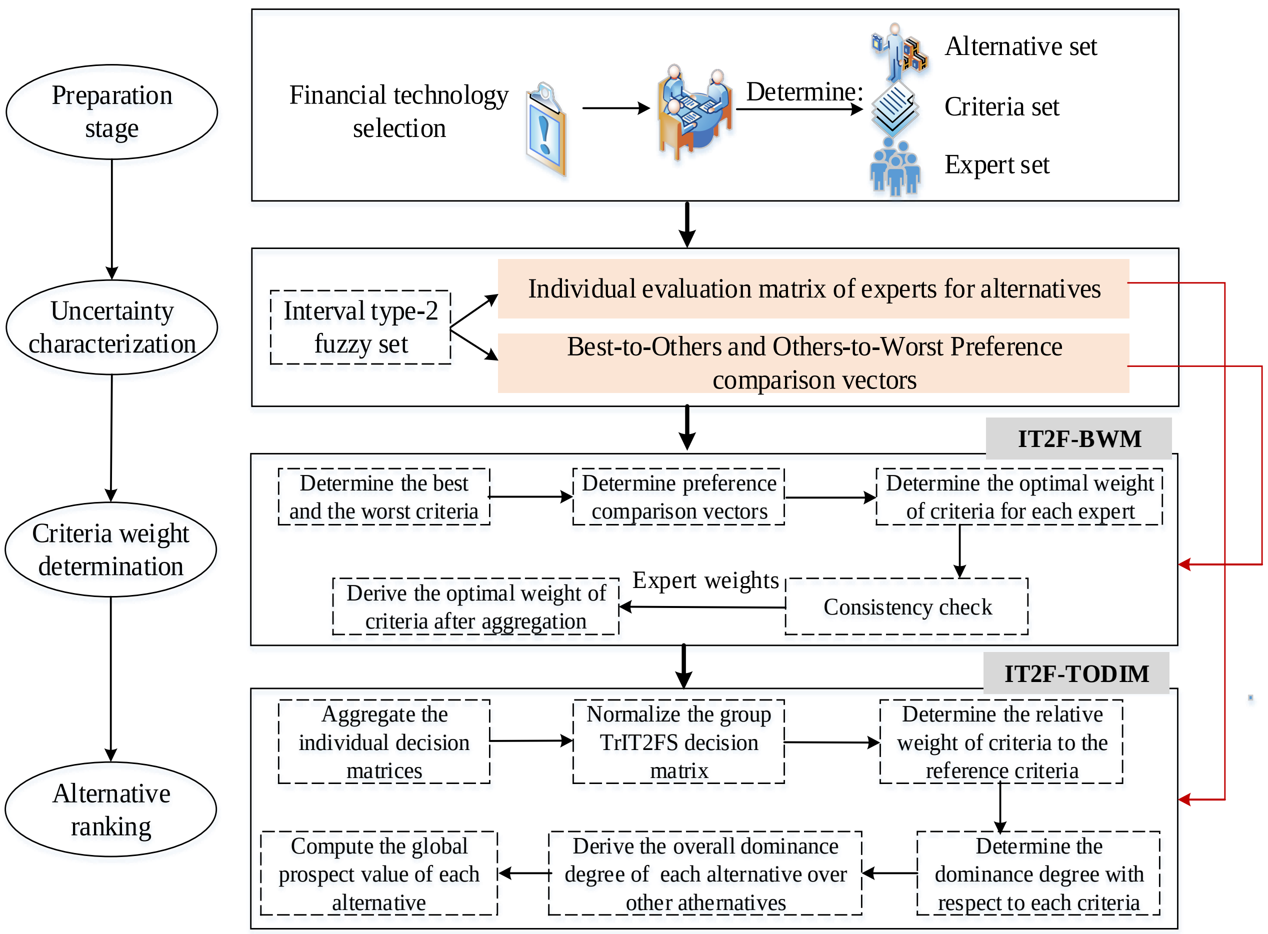

Fig. 2. Flow chart of the research framework.

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