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Evaluating the Green Innovation Ability of Engineering Teams in a Hesitation Fuzzy Environment

Yuhan Nie

International College, Krirk University, Bangkok 10220, Thailand

nathan694@yeah.net

Jiafu Su*

International College, Krirk University, Bangkok 10220, Thailand

jiafu.su@hotmail.com

*Corresponding author: jiafu.su@hotmail.com

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Abstract

Purpose: In this paper, the hesitant fuzzy multi-attribute decision-making method is used to present a green innovation ability (GIA) assessment technique for engineering teams.

Design/methodology/approach: In the evaluation method, we propose four evaluation indicators for GI input, GI implementation ability, GI development ability, and GI resource integration ability based on the evaluation indicators of GIA proposed by previous scholars, and use hesitant fuzzy sets as the expression tool for evaluation information. Thereafter, by improving the method proposed by Su et al. (2023) for positive and negative ideal points, this paper proposes a new evaluation method.

Findings: Through the use of this method, we found that it can fully consider the fuzziness and hesitancy of evaluators in uncertain environments, and express them in the form of fuzzy numbers. This shows that the method is viable, reasonable, and applicable to genuine evaluation procedures. Furthermore, this study provides a theoretical reference for the evaluation of engineering teams and other fields.

Originality/value: In this research, a decision-making reference point for the ideal point is proposed using the three-point estimate method, an integrated time estimation approach in the program evaluation and review technique (PERT). The research applies the hesitant fuzzy multi-attribute decision-making method to evaluate the green innovation capability of engineering teams by improving it. Further, the decision-making method is extended and applied to make some contributions to decision science.

Keywords: hesitant fuzzy set; multi-attribute decision-making; engineering team; green innovation ability; evaluation method.

JEL classification: C51, C52

1. Introduction

Given a lack of resources and the constrained capacity of the environment, environmental degradation and resource shortages have grown more prevalent (Su et al., 2022; L. Yang et al., 2021). Green development has become an important path leading overall development in recent years (Chen, 2023; Hou & Zhu,2022; Kuzu & Arslan,2023). As a member of the business environment, the impact of green development on engineering teams is becoming increasingly apparent. Firstly, there is a need for improvement in technology and design requirements. In the process of implementing green development strategies, engineering teams need to upgrade and improve their technical and design aspects to meet environmental protection, energy conservation, and other requirements. This includes the use of renewable energy, reducing waste production, and promoting green buildings. This requires engineering teams to continuously update their technology and knowledge and improve their skill levels. Secondly, there is an increased focus on environmental protection and safety requirements. The implementation of green development strategies requires a stronger focus on environmental and safety protection. For engineering teams, this means paying more attention to issues such as environmental pollution, ecological protection, and safe production. This requires engineering teams to follow relevant regulations and take appropriate measures to ensure environmental protection and safety during project implementation. Thirdly, the importance of teamwork is enhanced. In the process of implementing green development strategies, engineering teams from different disciplines need to work closely together to jointly address issues such as environmental protection and energy conservation and achieve sustainable development goals. It needs team members to enhance communication and collaboration, form a joint force, and work together to complete projects. Finally, sustainability thinking and concepts are crucial. Green development strategies emphasize the coordinated development of the economy, society, and environment, requiring engineering teams to possess sustainability thinking and concepts, focusing on long-term benefits and social responsibility, and better promoting the process of sustainable development (Song et al., 2023). In summary, the implementation of green development strategies requires engineering teams to possess advanced technology and design capabilities, strengthen environmental protection and safety awareness, and enhance teamwork and sustainability thinking to adapt and promote the sustainable development process of the new era. Therefore, their green innovation capabilities should also be paid attention to and valued.

The GI has also become an important part of green development in the context of green development (Yang et al., 2019). Currently, Environmental laws are being created in nations all over the world, which provide a stronger impetus for corporate green innovation (Huang et al., 2020; Riaz & Farid,2023). Therefore, how to translate green innovation into concrete practices while enhancing competitiveness is an urgent issue that companies are facing (Tu & Wu, 2021; Puška& Stojanović, 2022). Despite scholars having conducted a lot of research on teams over the past decade, such as, Costa et al. (2014) proposing a model of teamwork engagement, Ivanova-Stenzel and Kübler (2011) studying whether gender performance differences are affected by team gender composition, Wi et al. (2009) proposing a framework for analyzing the knowledge of new team managers and team member candidates, and Gomez et al. (2010) finding that motivation affects the relationship between team interaction and perceived learning. But, these studies mainly focus on team management and generalize to teams, without being specific to a particular type of team. With the development of organizations, the nature of teamwork is also constantly changing. In the past few decades, the product development of engineering organizations has increasingly been undertaken by interdisciplinary integrated product teams (Crowder et al., 2012). This means that research on engineering teams is particularly important. Moreover, in the current development, green innovation capabilities, as a new type of competitive advantage for organizations, are receiving increasing attention. This poses certain challenges for the development of engineering teams, but also provides some chances. Therefore, evaluating engineering teams from the perspective of green innovation capabilities can help them formulate development strategies and improve their competitiveness in the current business environment.

Currently, the GIA has become a focus of scholars' attention. Frempong et al. (2021) attempted to examine the impact of sustainability-oriented supplier partnerships and GIA on corporate performance, to investigate the impact of corporate sustainability on performance. Yuan and Cao (2022) introduced corporate social responsibility and green dynamic ability based on stakeholder theory, resource view, and dynamic ability theory to study the driving mechanism of green innovation in enterprises. Abbas and Sağsan (2019) explored the role of knowledge management in GI and sustainable development activities of enterprises. Lin et al. (2021) studied the moderating effect of marketing ability and research and development intensity on the impact of GI strategy on brand value by integrating brand value literature and resource-based views. Although scholars have conducted a lot of research based on GIA, there are not many studies on the evaluation of GIA, and even fewer studies on the evaluation of GIA of engineering teams. Evaluating GIA is a complex process, which not only requires the construction of a scientific and reasonable evaluation index system but also effective evaluation information expression tools and evaluation methods. To assess the GIA of manufacturing companies precisely and objectively, Sun and Xu (2021) developed an evaluation index method. They then utilized cloud model tools to build a multi-level comprehensive evaluation model based on the principle of relative entropy and combined the analytic hierarchy process, entropy weight technique, and coefficient of variation method to calculate the comprehensive weight of each index. By analyzing the credit risk of core enterprises in supply chain finance, Mou et al. (2018) construct a credit risk evaluation system for supply chain finance by means of the "Fuzzy Analytic Hierarchy Process" (FAHP), and makes a quantitative measurement and evaluation of the credit risk of core enterprises. Su et al. (2023) evaluated the GIA of members in a green supply chain by constructing evaluation indicators in a hesitant fuzzy environment and selecting partners for green manufacturers after evaluation. Alibeigi et al. (2021) used a fuzzy multi-criteria decision-making approach to assess and rank the ECA of ASEAN countries. Xu and Zhai (2020) objectively evaluated the GIA of manufacturing enterprises in the innovation network and considered the interrelationships and information randomness among various evaluation indicators. Leung and Wong (2006) developed the multiple Sharpe ratio test statistic using the technique of repeated measures design. This provides investors with a tool to evaluate the performance of their portfolios, enabling them to make more informed decisions in their investments. They constructed an evaluation index system based on innovation environment, input, and output and used the cloud model method to express evaluation information. Zhang and Su (2018) propose an integrated QFD and 2-type linguistic approach for the evaluation and selection of innovation tasks in a crowdsourcing context. Inspired by the above research, this paper proposes an engineering team green innovation ability evaluation method based on the HF-MADM method by improving the method proposed by Su et al. (2023). In this method, we have improved the shortcomings of the previous methods in determining the ideal point. From the data collected by the Bank of Vietnam from 2014-2017, Alibeigi et al. (2021) use the DEA method to evaluate the technical efficiency, resource analysis, and operational efficiency issues of the Bank of Vietnam.

The motivation of this paper is to evaluate the green innovation capability of engineering teams based on a hesitant fuzzy environment, considering the uncertainty of evaluation in the current complex environment. Based on this motive, we propose some green innovation capability evaluation indexes. Moreover, we use the three-point estimation method to improve the hesitant fuzzy decision method of previous scholars to make it compound the evaluation environment of this paper. The research has the following contributions. First, this work improved the shortcomings of previous scholars in determining decision reference points and proposed an engineering team's GIA evaluation method based on the HF-MADM method. Second, this paper provided a theoretical reference for the evaluation of engineering teams and GIAs. The research applies the hesitant fuzzy multi-attribute decision-making method to evaluate the green innovation capability of engineering teams by improving it. Further, the decision-making method is extended and applied to make some contributions to decision science.

The rest of the paper is as follows: Section 2 gives the basic concepts of HFSs, determines the evaluation indicators of this paper, and proposes the evaluation method. Section 3 verifies the method proposed through examples. Section 4 presents the research conclusions and future research directions.

2. Methodology

2.1Hesitant Fuzzy Sets

We first state the concept of HFS. Let *W* be a fixed set, then a hesitant set is a function that maps each element of *W* to a subset. The mathematical expression (Xu & Xia, 2011a) is:

$$E = \left\{ < \mu, U_E\left(\mu\right) > | \ \mu \in W \right\},$$

where $U_E\left(\mu\right)$ represents the set of possible membership degrees of element μ in the set *E*, $U_E\left(\mu\right)$ is a collection of numbers in [0, 1], and $U = U_E\left(\mu\right)$ is called the hesitant fuzzy element (HFE).

We then discuss the basic operations of HFSs. Let the score and variance functions of $U_a\left(\mu\right)$ and $U_b\left(\mu\right)$ be $s\left(U_a\right)$, $v\left(U_a\right)$, $s\left(U_b\right)$, and $v\left(U_b\right)$, respectively. Then, according to Torra & Narukawa (2009), we have

1) If $s\left(U_a\right) < s\left(U_b\right)$, then $U_a < U_b$.

2) Under the condition that $s\left(U_a\right) = s\left(U_b\right)$, if $v\left(U_a\right) > v\left(U_b\right)$, then $U_a < U_b$; if $v\left(U_a\right) = v\left(U_b\right)$, then $U_a = U_b$; and if $v\left(U_a\right) < v\left(U_b\right)$, then $U_a > U_b$;

in which $s\left(U\right) = \frac{1}{L_U} \sum_{v \in h} v$, $v\left(U\right) = \frac{1}{L_U} \left(\sum_{\chi_i, \chi_j \in U} (\chi_i - \chi_j)^2 \right)^{\frac{1}{2}}$, and L_U denotes the number of elements in *U*.

Thereafter, we discuss the distance between the two HFSs. The hesitant Euclidean distance between two HFEs is (Xu & Xia, 2011b):

$$d\left(U_i,U_j\right)=\left(\frac{1}{L}\sum_{k=1}^{L}\left|U_i^{\tau(k)}-U_j^{\tau(k)}\right|^2\right)^{\frac{1}{2}}.$$

2.2 The three-point estimation method

The three-point estimation method is a technique used in project management to estimate the time, cost, or other quantitative measures of tasks. It is based on the assumption that tasks may take longer or shorter than expected, and three estimates are better able to reflect this uncertainty. Specifically, the three-point estimation method requires estimators to provide three values: the time to optimize the performance of the task (TOPT), the time for worst scenario task completion (TWST), and the time most likely to complete the task (TMOST). These three values can be used to calculate the time estimate (TE) for the task, as follows (Premachandra, 2001):

$$TE=\frac{\left(TOPT+4TMOST+TWST\right)}{6}. \tag{1}$$

Here, $4TMOST$ represents four times the time required in the most likely scenario, because according to statistical knowledge, the completion time of a task often fluctuates within two times the range of the most likely scenario.

The three-point estimation method can be used to estimate any number of tasks, such as individual tasks in a project, the entire project, or a product development cycle, etc. The advantage of using the three-point estimation method is that it can provide more accurate time estimates while also reflecting the uncertainty and risk of task completion.

2.3 Evaluation indicators

The GIA refers to the ability and willingness of enterprises or individuals to promote environmental sustainability(Ye et al., 2023). It involves the use of sustainable methods in product design, production processes, resource utilization, and waste management to reduce negative impacts on the environment. Enterprises or individuals with GIA typically develop environmentally-friendly products and services, reduce energy and resource consumption, and improve ecological systems and community health, while enhancing their own competitiveness and market value. The evaluation of GIA can be considered from the following aspects. Firstly, technological innovation ability (TIA): one of the key factors of GIA is TIA. To evaluate the TIA of enterprises or individuals, one can consider aspects such as research and development investment, research and development results, and technological strength. Secondly, product innovation ability (PIA): the GIA also involves PIA, including research and development, design, manufacturing, and promotion of environmentally-friendly products. To evaluate the PIA of enterprises or individuals, one can consider aspects such as the quantity, quality, market share, and environmental benefits of product innovation. Next, system innovation ability (SIA): the GIA also requires the support of the SIA. To evaluate the SIA of enterprises or individuals, one can consider their ability and contribution in the construction, improvement, and optimization of environmental protection systems. Furthermore, service innovation ability (S-IA): the ability of enterprises or individuals to provide environmental services is also an important indicator of evaluating the GIA. To evaluate the S-IA of enterprises or individuals, one can consider aspects such as the types, quality, and impact of service innovation. Finally, management innovation ability (MIA): to evaluate the MIA of enterprises or individuals, one can consider their ability and achievements in formulating, implementing, and evaluating environmental management strategies. This includes the assistance provided by businesses or individuals in fields including developing environmental standards, building environmental management systems, and providing environmental training. Therefore, in order to ensure the scientific and reasonable evaluation results, we will combine the above and the GIA evaluation indexes proposed by scholars to determine the evaluation indexes of the GIA of engineering teams. Currently, Ma et al. (2022) constructed a comprehensive evaluation indicator system for regional green TIA from the perspective of multiple participating subjects, such as enterprises, research institutions, governments, and other market subjects. Chen (2023) selected the indicators system quantitatively based on the connotation of GIA in high-tech industries by using both R clustering and coefficient of variation methods and ultimately determined the evaluation indicator system for GIA in high-tech industries. Li and Zheng (2020) designed the evaluation indicator system for open innovation ability in nuclear power enterprises based on the connotation characteristics of open innovation ability in nuclear power enterprises from three aspects: innovation resource acquisition, innovation resource integration, and innovation diffusion. They combined the entropy weight method and numerical conversion to construct an improved mutation degree evaluation model. Peng et al. (2023) collected and organized the evaluation indicator system for enterprise GIA through expert consultation, investigation, and questionnaire survey based on the current development status of enterprise GIA, and combined its connotation characteristics such as sustainability, greenness, and technological upgrading. This article will integrate their proposed indicators and propose standards for GIA applicable to engineering teams. These standards contain four indicators and nine aspects. Specific indicators are shown in Table 1.

Table 1. Evaluation indicators

indicators	Indicator Markers	Indicator content
Green Innovation Input (GII)	*GII*	Financial Costs (FC)
		Human Costs (HC)
Green innovation implementation ability (GIIA)	*GIIA*	Economic benefits (EcB)
		Environmental benefits (EnB)
		Social benefits (SoB)
Green innovation development ability (GIDA)	*GIDA*	Transformation of results (ToR)
		Technological Progress (TP)
Green innovation resource integration ability (GIRIA)	*GIRIA*	Awareness of the importance of innovation resource integration (AI-IRI)
		Government Support (GS)

2.4 Evaluation Methods and Steps

Multi-attribute decision-making (MADM) is a common task in human activities that solves the problem of making the best choice with the highest satisfaction from a set of alternative solutions characterized by their attributes (Pham et al., 2018; Xu & Zhang, 2013). HF-MADM is a type of MADM that uses HFSs (Torra, 2010) as the decision information representation tool. This type of decision inherits the characteristics of HFSs, so there can be multiple expert decision values (i.e., membership degrees) under an attribute, and it can solve the problem of inconsistent expert decision values under a certain attribute; For example, B. Li et al. (2019) constructed a two-sided matching model for complex product manufacturing tasks using double hesitant fuzzy sets.. In previous studies, Su et al. (2023) proposed an improved HF-MADM method that optimized the consideration of attribute weights based on the method researched by Liu et al. (2016). This method improved Liu et al. (2016)'s method to some extent, but there are still shortcomings in determining the positive and negative ideal points. Therefore, this paper will further improve the method proposed by Su et al. (2023) and apply the improved method to the evaluation of the GIA of an engineering team.

The selection of decision reference points is generally determined by decision-makers based on their risk preferences and psychological states. In traditional MADM, since no reference point is specified, most scholars use the median (Jiang, 2014), zero point (Gao et al., 2014), the expected values of decision-makers for each attribute (Yunzhi Liu & Fan, 2015), and positive and negative ideal points (Liu et al., 2013; Wang et al., 2009) as decision reference points. Additionally, the majority of researchers use both positive and negative ideal points as decision reference points (Wang et al., 2017). The so-called positive and negative ideal points refer to selecting the extreme values from all solutions as the ideal decision reference points for decision-making (Aksoy et al., 2022). However, such a selection of positive and negative ideal points has certain limitations. The extreme values may not necessarily be ideal values, and they contain only some extreme information. In order to incorporate all the information, we suggest a decision reference point for the ideal point using the three-point estimation approach, which is a time estimation method in the program evaluation and review technique (PERT). The specific model is as follows:

$$\hat{U}_j = \frac{\sum_{i=1}^{N} U_{ij}^{+} \Big/ N + 4\overline{U_{ij}} + \sum_{i=1}^{N} U_{ij}^{-} \Big/ N}{6}, \quad (2)$$

$$\begin{cases} U^{+} = \max\left\{\gamma_I \,\middle|\, I = 1, 2, \ldots, L_h\right\} \\ U^{-} = \min\left\{\gamma_I \,\middle|\, I = 1, 2, \ldots, L_h\right\} \end{cases}, \quad (3)$$

where, $\overline{U_{ij}}$ is the average of the remaining numbers after eliminating U_{ij}^{+} and U_{ij}^{-} for each HFE.

The evaluation steps for the optimization of positive and negative ideal points are as follows:

Step 1: The evaluator evaluates the engineering team's green innovation capabilities based on the evaluation indicators to form an evaluation matrix *D*. Then, the evaluator calculates the ideal solutions H^{e} using formulas (1) and (2).

Step 2: Using the information in the evaluation matrix *D*, the technique proposed by Su et al. (2023) is used to calculate α, β and γ. The calculation formulas are as follows:

$$\alpha' = \max_{1\le i\le n, 1\le j\le m} \frac{s(U_{ij})}{s(U_{ij}) + v(U_{ij})}, \tag{4}$$

$$\beta' = \max_{1\le j\le n, 1\le p,q\le m} d(U_{pj}, U_{qj}), \tag{5}$$

$$\gamma' = \max_{1\le j\le n, 1\le t\le n} (1 - u_{jt}), \tag{6}$$

where

$$d(U_{pj}, U_{qj}) = \left(\frac{1}{L} \sum_{k=1}^{L} \left| U_{pj}^{\tau(k)} - U_{qj}^{\tau(k)} \right|^2 \right)^2, \tag{7}$$

$$r_{jt} = \frac{\sum_{a=1}^{m} \left(\frac{1}{L_a} \sum_{k=1}^{L_a} U_{aj}^{\tau(k)} \cdot U_{at}^{\tau(k)} \right)}{\max\left\{ \sum_{a=1}^{m} \left(\frac{1}{L_a} \sum_{k=1}^{L_a} \left(U_{aj}^{\tau(k)} \right)^2 \right), \sum_{a=1}^{m} \left(\frac{1}{L_a} \sum_{k=1}^{L_a} \left(U_{at}^{\tau(k)} \right)^2 \right) \right\}}. \tag{8}$$

If $\alpha' + \beta' + \gamma' > 1$, then, we have

$$\begin{cases} \alpha = \alpha' - \dfrac{(\alpha' + \beta' + \gamma') - 1}{3} \\ \beta = \beta' - \dfrac{(\alpha' + \beta' + \gamma') - 1}{3} \\ \gamma = \gamma' - \dfrac{(\alpha' + \beta' + \gamma') - 1}{3} \end{cases}. \tag{9}$$

On the other hand, if $\alpha' + \beta' + \gamma' < 1$, then, we have

$$\begin{cases} \alpha = \alpha' + \dfrac{1 - (\alpha' + \beta' + \gamma')}{3} \\ \beta = \beta' + \dfrac{1 - (\alpha' + \beta' + \gamma')}{3} \\ \gamma = \gamma' + \dfrac{1 - (\alpha' + \beta' + \gamma')}{3} \end{cases}. \tag{10}$$

Also, if $\alpha' + \beta' + \gamma' = 1$, then, we have

$$\begin{cases} \alpha = \alpha' \\ \beta = \beta' \\ \gamma = \gamma' \end{cases}. \tag{11}$$

Step3: Based on the calculation results of α , β and γ, the weights of each indicator are found. The calculation formula is as follows (Liu et al., 2016):

$$\omega_j^* = \frac{\alpha \sum_{i=1}^{n} \frac{s(U_{ij})}{s(U_{ij}) + v(U_{ij})} + \beta \frac{1}{n} \sqrt{\sum_{1 \le p,q \le n} d^2(U_{pj}, U_{qj})} + \gamma \sum_{t=1}^{m} (1 - r_{jt})}{\sum_{j=1}^{n} \left(\alpha \sum_{i=1}^{n} \frac{s(U_{ij})}{s(U_{ij}) + v(U_{ij})} + \beta \frac{1}{n} \sqrt{\sum_{1 \le p,q \le n} d^2(U_{pj}, U_{qj})} + \gamma \sum_{t=1}^{m} (1 - r_{jt}) \right)} . \tag{12}$$

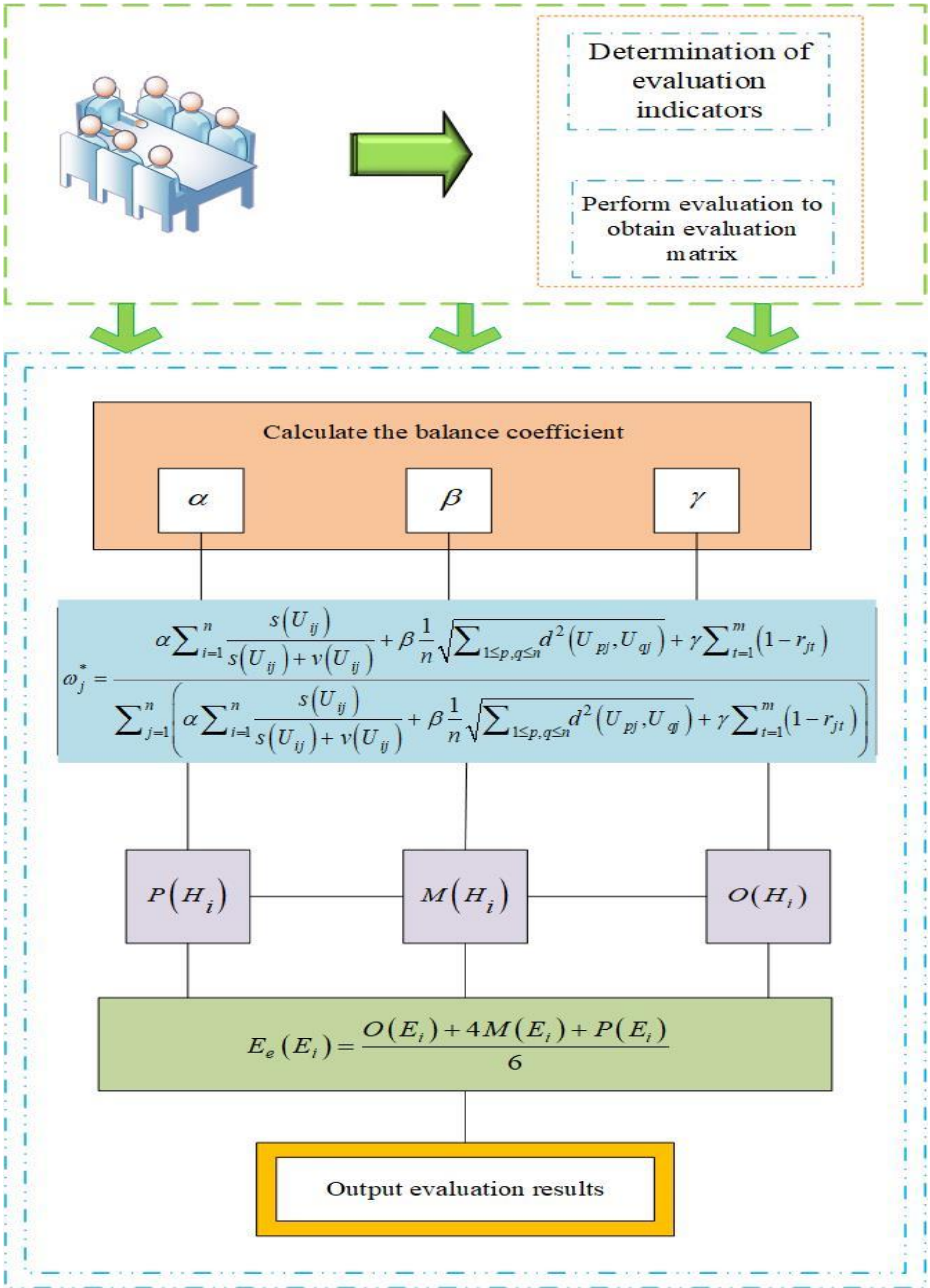
Step 4: Calculate the pessimistic similarity $S_p(H_i)$, the most likely similarity $S_m(H_i)$, and the optimistic similarity $S_O(H_i)$ for each engineering team to be evaluated with the following formula (Su et al., 2023):

$$\begin{cases} E(E_i) = \left[1 - d_w(H_i,\ H^e)\right] \\ d_\lambda(E_i,\ E^+) = \sum_{j}^{m} \omega_j \sqrt{\frac{1}{l_j} \sum_{k=1}^{l_j} \left| U_{ij}^{\tau(k)} - (U_j)^{\tau(k)} \right|^2} \end{cases} . \tag{13}$$

Step5: Based on the three calculated similarities, calculate the expected similarity $E(H_i)$. The formula is as follows (Su et al., 2023):

$$E_e(E_i) = \frac{O(E_i) + 4M(E_i) + P(E_i)}{6} . \tag{14}$$

The evaluation process is shown in the following figure:



$$\omega_j^* = \frac{\alpha \sum_{i=1}^{n} \frac{s(U_{ij})}{s(U_{ij})+v(U_{ij})} + \beta \frac{1}{n} \sqrt{\sum_{1\le p,q\le n} d^2(U_{pj},U_{qj})} + \gamma \sum_{t=1}^{m} (1-r_{jt})}{\sum_{j=1}^{n} \left(\alpha \sum_{i=1}^{n} \frac{s(U_{ij})}{s(U_{ij})+v(U_{ij})} + \beta \frac{1}{n} \sqrt{\sum_{1\le p,q\le n} d^2(U_{pj},U_{qj})} + \gamma \sum_{t=1}^{m} (1-r_{jt}) \right)}$$

$$E_e(E_i) = \frac{O(E_i)+4M(E_i)+P(E_i)}{6}$$

Figure 1. The evaluation process of green innovation ability

3. Case studies

Province *A* is an area rich in ecological resources but also relatively fragile. Taking green as the foundation and innovation as the driving force, promoting high-quality leapfrog development is the only way for the province's green transformation and upgrading. This article investigates excellent green innovative teams in Province *A* and ultimately selects four strong green innovation teams GIT_1, GIT_2, GIT_3 and GIT_4, for evaluation. The GIT_1 is a solar energy technology engineering research team dedicated to providing green energy, The GIT_2 is a new material engineering technology team characterized by the research and development of green building materials, the GIT_3 mainly researches and provides clean energy and green products, and the GIT_4 is a new energy vehicle engineering research and development team dedicated to promoting green sustainable development. These engineering teams promote the sustainable development of the green, low-carbon circular economy through technological innovation and become advocates, promoters, and practitioners of green innovation development. To ensure the credibility and effectiveness of the optimal solution selection, the government of Province *A* took the lead and organized a decision-making group composed of representatives from higher education institutions, scientific research institutes, and science and technology innovation associations engaged in engineering team innovation and development, green innovation, and environmental management. After conducting a detailed investigation of the relevant information of the four engineering teams, the indicators proposed in Section 2.3 were evaluated. Here, $U_{11} = \{0.556, 0.7, 0.738, 0.742\}$ indicates that there are four different views of the decision group on GII, i.e., 0.556, 0.7, 0.738, and 0.742 for the extent to which option GIT_1 satisfies attribute GII, which means that the members in the decision group have different views. The assessment outcomes are displayed in Table 2. (Adapted from (Peng et al., 2023))

Table 2. Information of green innovation ability evaluation of engineering team

	GII	$GIIA$	$GIDA$	$GIRIA$
GIT_1	[0.556, 0.7, 0.738, 0.742]	[0.555, 0.621, 0.759, 0.79, 0.897]	[0.603, 0.665, 0.782, 0.787]	[0.66, 0.678, 0.708, 0.71, 0.786]
GIT_2	[0.585, 0.601, 0.645, 0.81]	[0.549, 0.573, 0.671]	[0.554, 0.802, 0.882]	[0.68, 0.688, 0.772, 0.793, 0.888]
GIT_3	[0.726, 0.776, 0.874]	[0.531, 0.816, 0.818]	[0.646, 0.657, 0.838, 0.883]	[0.536, 0.638, 0.81]

GIT_4	[0.587, 0.763, 0.849]	[0.538, 0.579, 0.691, 0.789]	[0.594, 0.697, 0.822]	[0.737, 0.779, 0.79, 0.838]

Step 1: Calculate the ideal point according to Equations (1) and (2):

$$H^e = [0.7079, 0.6827, 0.7339, 0.7329]$$

Step 2: Calculate α , β and γ according to Equations (3)-(10):

$$\alpha' = 0.9092 \text{ , } \beta' = 0.1712 \text{ , } \gamma' = 0.0707$$

Since $\alpha' + \beta' + \gamma' > 1$, according to Equation (8), we get $\alpha = 8588$, $\beta = 0.1208$, $\gamma = 0.0203$

Step 3: Calculate the weights of each indicator according to Equation (11):

$$\lambda = \{0.2, 0.2, 0.3, 0.3\}$$

Step 4: Calculate the pessimistic similarity $P(H_i)$, the most likely similarity $M(H_i)$, and the optimistic similarity $O(H_i)$ according to Equation (12). Table 3 displays the outcomes.

Table 3. Similarity calculation results

	$P(H_i)$	$M(H_i)$	$O(H_i)$
GIT_1	0.7615	0.7793	0.7629
GIT_2	0.7452	0.7565	0.7318
GIT_3	0.69	0.6915	0.6731
GIT_4	0.6421	0.6748	0.6757

Step 4: Calculate the expected similarity according to Equation (13).

$$GIT_1 = 0.7736 \text{，} GIT_2 = 0.7505 \text{，} GIT_3 = 0.6881 \text{，} GIT_4 = 0.6695$$

The final evaluation result is $GIT_1 \succ GIT_2 \succ GIT_3 \succ GIT_4$; that is, the GIT_1 is the best GIA among these four engineering teams.

4. Comparative Analysis

Liu, et al. (2016) suggested a technique for the HF-MADM problem with unknown attribute weights that takes attribute weight optimization into account. This method largely quantifies the subjective weight determination methods used previously and comprehensively considers the score values of the alternatives under each attribute, as well as the dispersion degree (i.e., variance) of decision information and the correlation between attributes to determine attribute weights. However, this method tends to be subjectively biased when determining the balancing coefficient. In this method, the balancing coefficient directly affects the weights of the attribute and ultimately directly impacts the decision results. The approach could cause decision-makers to make biased decisions as a result of their incorrect estimation of the balancing coefficient and the loss of advantages in other risky scenarios as a result of just taking risk preferences into account. Su et al. (2023) updated the method in order to address the method's drawbacks, which can help prevent these problems. By quantifying and modifying the balancing coefficient, this method makes it more objective and avoids the impact of subjective negligence on the decision results. In addition, Su et al. (2023) bring the PERT into the ranking of decision results. This method systematically takes into account the influence of various risk preferences and unifies the decision outcomes, making it easier for decision-makers to select the best option. However, Su et al. (2023) and other methods still use Liu, et al. (2016)'s method when determining the decision reference points. In fact, there are some shortcomings in their selection of decision reference points, so this article makes improvements to their methods. In this section, we compare our method with Su et al. (2023) and Liu, et al. (2016) methods. The comparison results are shown in Table 4.

Table 4. Comparative Results

method	The proposed method	Su et al. (2023) method	Liu et al. (2016) method
ideal point	[0.7079,0.6827,0.7339,0.7329]	[0.556,0.897,0.883,0.888]	[0.556,0.897,0.883,0.888]
balance	$\alpha = 0.8588$,	$\alpha = 0.8588$,	$\alpha = 0.8588$,

coefficient **weight**	$\beta = 0.1208$, $\gamma = 0.0203$. $\lambda = \{0.2, 0.2, 0.3, 0.3\}$	$\beta = 0.1208$, $\gamma = 0.0203$. $\lambda = \{0.2, 0.2, 0.3, 0.3\}$	$\beta = 0.1208$, $\gamma = 0.0203$. $\lambda = \{0.2, 0.2, 0.3, 0.3\}$
Scheme scored	$GIT_1 = 0.7736$, $GIT_2 = 0.7505$, $GIT_3 = 0.6881$, $GIT_4 = 0.6695$	$GIT_1 = 0.651$, $GIT_2 = 0.6532$, $GIT_3 = 0.5311$, $GIT_4 = 0.506$	$GIT_1 = 0.5801$, $GIT_2 = 0.5532$, $GIT_3 = 0.4249$, $GIT_4 = 0.499$
Optimal solution	GIT_1	GIT_2	GIT_1

From the comparison results in Table 4, we can see that different evaluation methods lead to different outcomes. In comparison with the method proposed by Su et al. (2023), our proposed method results in inconsistent evaluation results due to the difference in the method of determining the ideal point. However, the evaluation scores obtained by Su et al. (2023) do not differ significantly, indicating that there is not much difference between choosing GIT_1 and GIT_2 . Therefore, it can be considered that the evaluation results of our method are consistent with Su et al.'s method. Since the decision-maker determines the balance coefficient for the technique put forth by Liu et al. (2016), we make the assumption that our suggested method's balance coefficient is equivalent to that of theirs. The evaluation results are consistent with our method and the difference between and are more pronounced. These results indicate that our method is reasonable and can be applied in practical evaluations. Moreover, our proposed method can more clearly distinguish the differences between different evaluation objects, making it easier for decision-makers to compare evaluation results and make decisions.

5. Conclusions

The GIA is crucial for engineering teams. As society's attention to environmental protection continues to increase, both companies and organizations need to adopt some sustainable methods to achieve their goals (Ibnou-Laaroussi et al., 2020). Therefore, engineering teams need to have GIAs to meet these demands and adopt environmentally friendly design, production, and management methods in engineering projects. Engineering teams with GIAs can design, develop, and produce more environmentally friendly products and services, reduce negative impacts on the environment, and improve the health of both ecosystems and communities. In addition, the GIA can also increase both the competitiveness and market value of engineering teams because more and more customers and investors are interested in environmental protection and sustainability and are willing to purchase and support these types of products and services. In engineering projects, the GIA can also help engineering teams comply with environmental laws and standards, reduce environmental accidents and risks, and improve the sustainability and long-term value of projects. Therefore, for any engineering team, possessing the GIA is essential, as it can help them better adapt to future environmental changes and challenges. And, as the development of products in engineering organizations becomes more diversified, the role played by engineering teams becomes increasingly important. In recent years, with the growing attention to green development, evaluating an organization or team's ability for green innovation has become a hot research topic. In order to achieve the objectives, in this paper, a multi-attribute engineering team green innovation capability evaluation method is proposed considering uncertainty scenarios. Its purpose is to help engineering teams to innovate themselves to meet the development of the times by evaluating the green innovation capability of engineering teams. Meanwhile, it also helps engineering teams to enhance their self-competitive advantage in the market. In addition, such a study provides methodological references for organizational evaluation, team evaluation, and formula evaluation. So, based on previous research, this article proposes indicators such as GII, GIIA, GIDA, and GIRIA for evaluating the GIA of engineering teams. In the evaluation process, to address the hesitancy and fuzziness of evaluators in uncertain environments, this article uses HFSs as the expression tool for evaluation information and applies an improved HF-MADM method proposed by Su et al. (2023) for the evaluation. Finally, we use the method proposed in this article to evaluate the GIA of four engineering teams. Through the application of this method, we found that the evaluation method for the GIA of engineering teams based on the HF-MADM method can effectively address the problems raised in this study. The research applies the hesitant fuzzy multi-attribute decision-making method to evaluate the green innovation capability of engineering teams by improving it. Further, the decision-making method is extended and applied to make some contributions to decision science.

The importance of the research can be summed up as follows: First off, by focusing on the evaluation of engineering teams' GIA, this research addresses some of the issues Su et al. (2023) had. It also offers a theoretical framework for resolving comparable evaluation issues in other domains. Second, to evaluate the scheme, this study defines the indicator characteristics from the standpoint of GIA and uses HFSs as an information expression tool to aggregate the decision information for each attribute, offering a research idea for the evaluation of engineering teams.

Finally, the research provides a reference for the determination of the ideal point in HFSs and makes a certain contribution to the application of HFSs. Through the use of case studies, it was discovered that the suggested method for assessing engineering teams in the HF-MADM environment has a wide range of applications and is more useful for making decisions. There are also some limitations in this study. The study of the green capabilities of engineering teams is not detailed enough because it is more biased towards studying a method that allows it to evaluate well the green innovation capabilities of engineering teams. And, in terms of information representation, this paper only uses hesitant fuzzy sets as an information expression tool, and more fuzzy sets can be used in future research. Meanwhile, this paper still refers to the traditional method of determining the balance coefficient, and we will try to expand on some new methods for balance coefficient determination in future research. In future research, we will apply the method to other evaluation issues, such as organizational performance evaluation, engineering team performance evaluation (Ramadan & Safavi, 2022), and selection of cooperative members in engineering teams, the safety of banks (Pho et al., 2021). We also plan to further improve the method, such as expanding the expression tools to interval hesitant fuzzy numbers, probability hesitant fuzzy numbers, and hesitant triangular fuzzy numbers.

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