

Research Article

A Novel Multiperson Game Approach for Linguistic Multicriteria Decision Making Problems

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Received 1 September 2013; Revised 2 November 2013; Accepted 24 November 2013; Published 2 February 2014

Academic Editor: Ching-Ter Chang

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Game theory is considered as an efficient framework in dealing with decision making problems for two players in the competitive environment. In general, the evaluation values of payoffs matrix are expressed by crisp values in a game model. However, many uncertainties and vagueness should be considered due to the qualitative criteria and the subjective judgment of decision makers in the decision making process. The aim of this study is to develop an effective methodology for solving the payoffs matrix with linguistic variables by multiple decision makers in a game model. Based on the linguistic variables, the decision makers can easily express their opinions with respect to criteria for each alternative. By using the linear programming method, we can find the optimal solution of a game matrix in accordance with the combination of strategies of each player effectively. In addition, the expected performance value (EPV) index is defined in this paper to compare the competition ability of each player based on the optimal probability of each strategy combination. And then, numerical example will be implemented to illustrate the computation process of the proposed model. The conclusion and future research are discussed at the end of this paper.

1. Introduction

In decision science field, game theory provides an effective way for handling the interactive optimization problems. Game theory started with the publication of “the theory of games and economics behavior” in 1944 by von Neumann and Morgenstern [1]. It is a special tool to analyze the interaction result among players and has been broadly applied in business, financial, politics, education, sports, and so forth [2–5].

There are three basic components in a game such as players, players’ strategies, and the performances (payoffs) with respect to the strategies of players. Strategy form and extensive form are two main ways to describe the interaction between players [6]. In strategy form, each player executes his/her strategy simultaneously and the payoff is decided based on the strategy combination of each player. In extensive

form, each player executes his/her strategy sequentially and the payoff is the final result based on the decision of each player. In general, the extensive form of a game can be transferred to the strategy form. The different classification types of game included cooperation or noncooperation games, zero-sum or non-zero-sum games, one round or multiround games, two-person or multiperson games.

Recently, the development trend of game theory is to integrate multicriteria decision making (MCDM) method to deal with the decision-making problems in real situations. There are some literatures that have been proposed by combining multicriteria decision method (MCDM) with game theory for coping with the decision making problems.

Campos [7] proposed a two-person zero sum fuzzy matrix game and applied fuzzy linear programming to calculate the mixed strategy probability of each player. Sakawa and

Nishizaki [8] applied the max-min concept to integrate fuzzy goals and fuzzy payoffs in a two-person zero sum game. Song and Kandel [6] applied fuzzy set to formulate the goals of players and the strategy probability of their competitors. The mixed strategy probability is calculated based on considering their goals and the probability of each strategy of competitors simultaneously. The drawback of Song and Kandel's model is that it is difficult to compute the game matrix with multiple persons. Wang [9] built a fuzzy linear programming model to deal with N -person multiattribute noncooperative game. Liao [10] applied fuzzy linear goal programming to solve a two-person zero sum game for analyzing the wireless market in Taiwan. Angelou and Economides [11] integrated analytic hierarchy process, game theory, and real options to analyze the business alternatives of information and communication technology (ICT). Reneke [12] used the vector function to evaluate long term investment alternatives for predicting oil prices and environmental degradation under the conditions of risk and uncertainty. Madani and Lund [13] used Monte-Carlo game theory (MCGT) technology to handle the uncertainty problem with the deterministic strategic games. Monroy and Fernández [14] extended the Shapley-Shubik index from conventional simple games to deal with the multi-criteria game problem. Barough et al. [15] used the traditional game approach to deal with two types of project construction conflict problem. Li and Hong [16] developed an effective methodology for handling the constrained matrix game with fuzzy payoffs. Monroy and Fernández [17] used voting systems to handle multi-criteria simple games in social-choice situation. The stable set and the core are the solution concept in the multi-criteria simple games. Different kinds of aggregation operators such as union, intersection, marginalization, and composition can be applied in their method. Lozan and Ungureanu [18] used graphs intersection method of the best response mappings to deal with the two-criterion games. Pusillo and Stef Tijs [19] used the improvement sets for developing the equilibrium condition for noncooperative multi-criteria games. Kawamura et al. [20] extended neutrally and evolutionarily stable strategies from single-criterion game to multi-criteria games. In entropy environment, Roy and Das [21] handled the multi-criteria bimatrix goal game problem by determining G-goal security strategies. They applied the real coded genetic algorithm to acquire the bounds of the objectives of the proposed game. The fuzzy programming technique is used to solve the formulated model.

Although many literatures have been proposed by applying game theory to make a decision, few of them can integrate MCDM and game theory to handle the multiperson multi-criteria game in a fuzzy environment. In real environment, each player will compete with other players. A good player not only should consider his/her strategy for approaching his/her goal but also need to forecast the behaviors of competitors. There is usually more than one influenced factor that should be considered by each player in a game model. In addition, the uncertainty and fuzziness will happen in the real competitive environment because it is not easy to collect the decision information completely and the decision time is limited for making a decision. A good model must provide

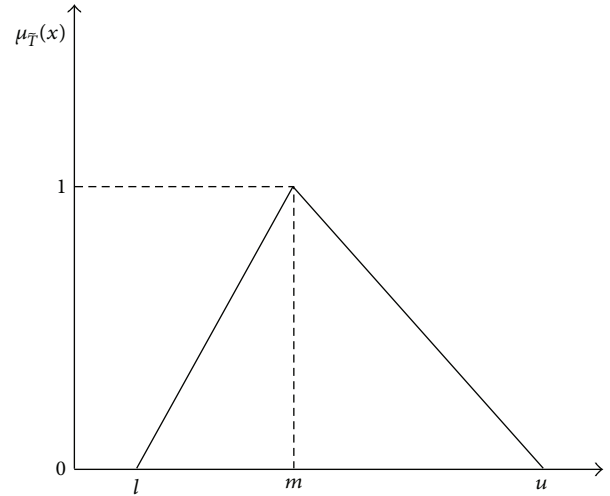


FIGURE 1: Triangular fuzzy number \tilde{T} .

a mechanism such as linguistic value or fuzzy number for experts to express their opinions flexibly.

However, the original game model usually considers one dimension or criterion to make a decision and the crisp values are used to evaluate the performance with respect to the dimension by single decision maker. In order to overcome the drawbacks of original game model, the main purpose of this study is to develop a new decision making method, linguistic multiperson multi-criteria game (LMPMCG) model, for dealing with the game problems under multiperson and multi-criteria environment. According to the linguistic variable, the decision makers can easily express their opinions with respect to each criterion for each alternative (strategy combination). By using the linear programming method, we can find the optimal solution of a game matrix effectively.

The reminder of this study is organized as follows. In Section 2, the definitions of linguistic variables and fuzzy numbers will be introduced. After that, the linguistic multiperson multi-criteria game model is presented at Section 3. And then, an example is implemented for the new mobile phone development project selection problem. Finally, conclusion and future research are discussed at the end of this paper.

2. Fuzzy Set and Linguistic Variable

Fuzzy set theory is first introduced by Zadeh in 1965 [22]. Fuzzy set theory is a very feasible method to handle the imprecise and uncertain information in a real world [23, 24]. Especially, it is more suitable for experts to express their subjective judgments and qualitative assessments in the decision making processes [25–27].

A positive triangular fuzzy number (PTFN) \tilde{T} can be defined as $\tilde{T} = (l, m, u)$, where $l \leq m \leq u$ and $l > 0$ (shown in Figure 1). The membership function $\mu_{\tilde{T}}(x)$ of positive triangular fuzzy number (PTFN) \tilde{T} is defined as [28, 29]

TABLE 1: Linguistic variables.

Performance		Weight		PTFN
Linguistic variables	Abbr.	Linguistic variables	Abbr.	
Extremely poor	EP	Extremely low	EL	(0.000, 0.000, 0.125)
Very poor	VP	Very low	VL	(0.000, 0.125, 0.250)
Poor	P	Low	L	(0.125, 0.250, 0.375)
Medium poor	MP	Medium low	ML	(0.250, 0.375, 0.500)
Fair	F	Fair	F	(0.375, 0.500, 0.625)
Medium good	MG	Medium high	MH	(0.500, 0.625, 0.750)
Good	G	High	H	(0.625, 0.750, 0.875)
Very good	VG	Very high	VH	(0.750, 0.875, 1.000)
Extremely good	EG	Extremely high	EH	(0.875, 1.000, 1.000)

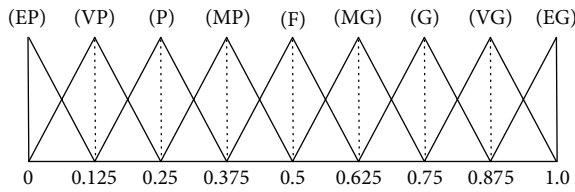


FIGURE 2: Membership functions of linguistic variables.

$$\mu_{\tilde{T}}(x) = \begin{cases} \frac{x-l}{m-l}, & l < x < m \\ \frac{u-x}{u-m}, & m < x < u \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

A linguistic variable is a variable whose values are expressed in linguistic terms, in other words, variable whose values are not numbers but words or sentences in a nature or artificial language [30–32]. For example, “weight” is a linguistic variable whose values can be very low, low, medium, high, very high, and so forth. These linguistic values can also be represented by fuzzy numbers. There are two advantages for using triangular fuzzy number to express linguistic variable [33, 34]. First, it is a rational and simple method to use triangular fuzzy number to express the opinions of experts. Second, it is easy to make the arithmetic operations between fuzzy numbers when using triangular fuzzy numbers to express the linguistic variables. It is suitable to represent the degree of subjective judgment in qualitative aspect than crisp value. Some linguistic variables and their membership functions can be illustrated as Table 1 and Figure 2.

Let $\tilde{T}_1 = (L_1, M_1, U_1)$ and $\tilde{T}_2 = (L_2, M_2, U_2)$ be two PTFNs. The additive operation of PTFNs can be calculated as [28, 33]

$$\tilde{T}_1 \oplus \tilde{T}_2 = (L_1 + L_2, M_1 + M_2, U_1 + U_2). \quad (2)$$

Many ranking methods have been developed to transform fuzzy number into crisp value. Lee and Li [35] presented the generalized mean value method to rank fuzzy numbers. It is very easy to compare fuzzy numbers by this method. This method has been applied in decision science, personnel selection, weapon selection and supplier selection fields, and

so forth [36–39]. Suppose that $\tilde{T} = (l, m, u)$ is a PTFN, the defuzzified value is easily computed as [35, 36]

$$G(\tilde{T}) = \frac{(l + m + u)}{3}. \quad (3)$$

If $G(\tilde{T}_1) > G(\tilde{T}_2)$, then $\tilde{T}_1 > \tilde{T}_2$.

3. Linguistic Multiperson Multicriteria Game (LMPMCG) Model

In real environment, each player must compete with other players to determine the actions. A good player not only must consider the own strategies for approaching the goals but also need to forecast the behaviors of their competitors to select the best reaction. Under this situation, many influenced criteria should be considered by each player to make a strategy decision in a game system. Because the different strategies of players will influence the performance of each other, we need to consider the strategies of each player based on a strategy combination. A strategy combination means combination of strategies of players in a specific situation. From this viewpoint, a new game model with linguistic variables for the multiperson multi-criteria problem is proposed in this study.

3.1. Basic Notation of LMPMCG Model. Generally speaking, the contents of linguistic multiperson multi-criteria game (LMPMCG) model can be illustrated as follows.

- (1) A set of players is called $P = \{P^1, P^2, \dots, P^v\}$, where v represents the number of players.
- (2) A set of strategies of each player is called $S = \{S^1, S^2, \dots, S^v\}$, where $S^1 = \{s_1^1, s_2^1, \dots, s_{m_1}^1\}$, $S^2 = \{s_1^2, s_2^2, \dots, s_{m_2}^2\}$, ..., $S^v = \{s_1^v, s_2^v, \dots, s_{m_v}^v\}$. The m_1, m_2, \dots, m_v is the number of strategies for player 1, player 2, ..., and player v . The s_{π}^{δ} represents the π th strategy of player δ .
- (3) A set of strategies combination is $SC = [s_i^1, s_j^2, \dots, s_k^v]_{m_1 * m_2 * \dots * m_v}$. A strategy combination means a combination of the strategy of each player in a specific situation.

- (4) A set of criteria with respect to each strategy combination of each player is $C = \{C^1, C^2, \dots, C^v\}$, where $C^1 = \{c_1^1, c_2^1, \dots, c_{n_1}^1\}$, $C^2 = \{c_1^2, c_2^2, \dots, c_{n_2}^2\}$, ..., $C^v = \{c_1^v, c_2^v, \dots, c_{n_v}^v\}$. The n_1, n_2, \dots, n_v is the number of the criteria for player 1, player 2, ..., and player v . The c_π^δ represents the π th strategy criteria of player δ .
- (5) A set of strategies combination evaluation matrix of each player is $E = \{E^1, E^2, \dots, E^v\}$, where $E^i = [\tilde{x}_{(s_1^1, s_2^2, \dots, s_k^v), c_\pi^i}]_{(n_1 * n_2 * \dots * n_v) * n_i}$, $i = 1, 2, \dots, v$, and $\tilde{x}_{(s_1^1, s_2^2, \dots, s_k^v), c_\pi^i}$ represents the strategy performance of player i with respect to criterion c_π^i under strategy combination $(s_1^1, s_2^2, \dots, s_k^v)$.
- (6) A set of decision makers or experts is $D = \{D_1, D_2, \dots, D_r\}$, where r represents the number of decision makers.

3.2. Aggregation Process. In a game model, decision makers should express their opinions for the performance of each strategy combination with respect to each criterion based on the standpoint of each player. In general, the linguistic variables are suitable for decision makers used to express their subjective judgment. For a strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$, the performance evaluation of decision maker d with respect to criterion c_π^δ can be represented as a linguistic variable $\tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^d$. This linguistic variable can be formulated as a PTFN $= (a, b, c)$ where $a = {}^L x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^d$, $b = {}^M x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^d$, and $c = {}^U x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^d$ (refer to Table 1).

For a strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$, the aggregated performance evaluation of decision makers with respect to criterion c_π^δ can be computed as

$$\begin{aligned} & \tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} \\ &= \frac{1}{r} * \left(\tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^1 \oplus \tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^2 \right. \\ & \quad \left. \oplus \dots \oplus \tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}^r \right), \end{aligned} \quad (4)$$

where $\tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}$ represents the aggregated performance with respect to criterion c_π^δ under a strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$ based on the opinions of decision makers.

The aggregated performance evaluation of decision makers with respect to criterion c_π^δ under the strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$ can be defuzzified as

$$x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} = G\left(\tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}\right), \quad (5)$$

where $G(\tilde{x}_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}) = ({}^L x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} + {}^M x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} + {}^U x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta})/3$.

The weight of criterion c_π^δ of decision maker d can be represented as a linguistic variable $\tilde{w}_{c_\pi^\delta}^d$. It can be formulated as a PTFN $= (a, b, c)$ where $a = {}^L w_{c_\pi^\delta}^d$, $b = {}^M w_{c_\pi^\delta}^d$, and $c = {}^U w_{c_\pi^\delta}^d$ (refer to Table 1).

The aggregated weight of criterion c_π^δ can be computed as

$$\tilde{w}_{c_\pi^\delta} = \frac{1}{r} * \left(\tilde{w}_{c_\pi^\delta}^1 \oplus \tilde{w}_{c_\pi^\delta}^2 \oplus \dots \oplus \tilde{w}_{c_\pi^\delta}^r \right), \quad (6)$$

where $\tilde{w}_{c_\pi^\delta}$ represents the aggregated weight with respect to criterion c_π^δ based on the opinions of decision makers.

The aggregated weight of criterion c_π^δ can be defuzzified as

$$w_{c_\pi^\delta} = G(\tilde{w}_{c_\pi^\delta}), \quad (7)$$

where $G(\tilde{w}_{c_\pi^\delta}) = ({}^L w_{c_\pi^\delta} + {}^M w_{c_\pi^\delta} + {}^U w_{c_\pi^\delta})/3$.

3.3. Decision Process. For the strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$, the weighted performance of strategy s_θ^δ for player δ with respect to criterion c_π^δ ($\pi = 1, 2, \dots, n_\delta$) can be calculated as

$$p_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} = x_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta} * \left(\frac{w_{c_\pi^\delta}}{\sum_{i=1}^{n_\delta} w_{c_i^\delta}} \right), \quad (8)$$

where $p_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_\pi^\delta}$ represents the weighted performance of strategy s_θ^δ for player δ with respect to criterion c_π^δ under strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$ and $(w_{c_\pi^\delta} / (\sum_{i=1}^{n_\delta} w_{c_i^\delta}))$ represents the normalized weight of criterion c_π^δ .

For the strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$, the integrated performance of player δ with respect to all criteria can be calculated as

$$\Psi_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)} = \sum_{i=1}^{n_\delta} p_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v), c_i^\delta}, \quad (9)$$

where $\Psi_{(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)}$ represents the integrated performance of player δ with respect to all criteria under the strategy combination $(s_1^1, s_2^2, \dots, s_\theta^\delta, \dots, s_k^v)$. It means the overall performance for player δ when player 1 chooses strategy s_1^1 , player 2 chooses strategy s_2^2 , ..., player δ chooses strategy s_θ^δ , ..., and player v chooses strategy s_k^v .

The optimal probability of each strategy for player δ can be computed by considering all strategy combinations of all players. Under this situation, player δ will maximize the expected performance by calculating the optimal probability of each strategy. Therefore, the problem of optimal probability

TABLE 2: The strategies and evaluation criteria of each enterprise.

	Strategy	Criteria
P^1	s_1^1 : Develop new high level mobile phone,	c_1^1 : Mobile margin profit
	s_2^1 : Develop new middle level mobile phone	c_2^1 : Market share rate
	s_3^1 : Develop new low level mobile phone	c_3^1 : Research cost
		c_4^1 : Research time
P^2	s_1^2 : Develop new high level mobile phone	c_1^2 : Market share rate
	s_2^2 : Develop new low level mobile phone	c_2^2 : Enterprise's total cost
	s_3^2 : Promote and manufacture old mobile phone	c_3^2 : Enterprise's net profit
P^3		c_1^3 : Enterprise's net profit
	s_1^3 : Develop new middle level mobile phone	c_2^3 : Mobile margin profit
	s_2^3 : Develop new low level mobile phone	c_3^3 : Research cost
		c_4^3 : Research time

TABLE 3: The linguistic performance of enterprise P^1 with respect to criteria for each strategy combination.

Strategy combination	c_1^1			c_2^1			c_3^1			c_4^1		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
s_1^1, s_1^2, s_1^3	G	MG	VP	G	F	MP	G	G	F	P	EG	VP
s_2^1, s_1^2, s_1^3	F	EP	VG	P	G	MG	P	MP	MG	F	MG	VG
s_3^1, s_1^2, s_1^3	EG	MP	EP	G	MG	VG	EP	P	VP	P	P	MG
s_1^1, s_2^2, s_1^3	EG	F	G	EG	MG	VP	VG	G	MP	F	F	EG
s_2^1, s_2^2, s_1^3	EP	MP	VP	G	EG	MP	P	F	VG	G	EG	MP
s_3^1, s_2^2, s_1^3	EG	MG	MG	P	P	G	G	EP	VP	P	MP	VP
s_1^1, s_2^2, s_3^1	G	EG	MG	EG	MP	F	F	P	G	G	EG	MG
s_2^1, s_2^2, s_3^1	P	EG	MG	EG	MG	VG	VP	MG	EP	G	EG	P
s_3^1, s_2^2, s_3^1	G	G	F	EP	F	EG	G	F	F	EP	P	VG
s_1^1, s_2^2, s_2^3	EG	F	VG	F	EG	VP	EG	MG	P	EG	G	MG
s_2^1, s_2^2, s_2^3	EG	MG	VP	G	G	MG	EG	F	VG	EG	F	VP
s_3^1, s_2^2, s_2^3	G	MP	MG	P	F	MG	G	MG	MG	P	MG	MP
s_1^1, s_2^2, s_2^3	EP	MG	MG	G	EP	G	G	MP	F	G	MG	EG
s_2^1, s_2^2, s_2^3	EP	MG	VG	G	MG	EP	EP	G	MG	MP	MG	VG
s_3^1, s_2^2, s_2^3	EG	F	VG	EP	EP	P	MP	G	MP	G	G	VG
s_1^1, s_2^2, s_3^2	G	EP	VP	G	F	G	VG	F	P	EG	EP	EG
s_2^1, s_2^2, s_3^2	G	G	MG	EG	P	MG	P	P	MP	EG	EG	EP
s_3^1, s_2^2, s_3^2	EP	MP	MP	G	MG	VG	F	EG	F	EP	EP	MG

of each strategy for player δ can be formulated as a linear programming model as follows:

$$\begin{aligned}
 & \text{Max } \nu^\delta \\
 & \text{subject to } \Psi_{(s_1^1, s_1^2, \dots, s_1^\delta, \dots, s_1^\nu)} * \Phi_1^\delta + \Psi_{(s_1^1, s_1^2, \dots, s_1^\delta, \dots, s_1^\nu)} * \Phi_2^\delta \\
 & \quad + \dots + \Psi_{(s_1^1, s_1^2, \dots, s_{m_\delta}^\delta, \dots, s_1^\nu)} * \Phi_{m_\delta}^\delta \geq \nu^\delta \\
 & \quad \Psi_{(s_1^1, s_1^2, \dots, s_1^\delta, \dots, s_2^\nu)} * \Phi_1^\delta + \Psi_{(s_1^1, s_1^2, \dots, s_1^\delta, \dots, s_2^\nu)} * \Phi_2^\delta \\
 & \quad + \dots + \Psi_{(s_1^1, s_1^2, \dots, s_{m_\delta}^\delta, \dots, s_2^\nu)} * \Phi_{m_\delta}^\delta \geq \nu^\delta
 \end{aligned}$$

$$\begin{aligned}
 & \vdots \\
 & \Psi_{(s_{m_1}^1, s_{m_2}^2, \dots, s_{m_\delta}^\delta, \dots, s_{m_\nu}^\nu)} * \Phi_1^\delta + \Psi_{(s_{m_1}^1, s_{m_2}^2, \dots, s_{m_\delta}^\delta, \dots, s_{m_\nu}^\nu)} * \Phi_2^\delta \\
 & \quad + \dots + \Psi_{(s_{m_1}^1, s_{m_2}^2, \dots, s_{m_\delta}^\delta, \dots, s_{m_\nu}^\nu)} * \Phi_{m_\delta}^\delta \geq \nu^\delta, \\
 & \Phi_1^\delta + \Phi_2^\delta + \dots + \Phi_{m_\delta}^\delta = 1, \\
 & \Phi_i^\delta \geq 0; \quad i = 1, 2, \dots, m_\delta,
 \end{aligned} \tag{10}$$

TABLE 4: The linguistic performance of enterprise P^2 with respect to criteria for each strategy combination.

Strategy combination	c_1^2			c_2^2			c_3^2		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
s_1^1, s_1^2, s_1^3	G	MP	VG	G	F	VG	F	EG	VG
s_2^1, s_1^2, s_1^3	P	EP	P	P	F	F	P	MG	F
s_3^1, s_1^2, s_1^3	G	G	F	EP	MP	P	EP	MP	MG
s_1^1, s_2^2, s_1^3	P	F	MP	F	MP	MP	G	MG	MP
s_2^1, s_2^2, s_1^3	EP	P	VG	G	MG	VG	G	EG	VP
s_3^1, s_2^2, s_1^3	EG	MP	F	MP	G	VP	EG	MG	EG
s_1^1, s_3^2, s_1^3	EP	EP	P	F	F	MG	G	EG	F
s_2^1, s_3^2, s_1^3	EG	G	G	P	G	P	EG	G	MP
s_3^1, s_3^2, s_1^3	G	P	VG	G	MP	VG	P	MG	VG
s_1^1, s_1^2, s_2^3	P	F	P	MP	MG	VP	P	EP	MG
s_2^1, s_1^2, s_2^3	G	MP	VG	F	MG	G	F	MP	VG
s_3^1, s_1^2, s_2^3	EG	G	MG	G	P	MG	G	MG	VP
s_1^1, s_2^2, s_2^3	EG	F	EP	MP	EG	MP	P	G	EG
s_2^1, s_2^2, s_2^3	EG	MG	VP	EP	G	VG	P	MP	MP
s_3^1, s_2^2, s_2^3	P	MP	VP	G	EP	G	F	P	EP
s_1^1, s_3^2, s_2^3	EP	MG	G	P	F	MP	G	G	P
s_2^1, s_3^2, s_2^3	G	MG	G	P	MG	VG	G	MG	MG
s_3^1, s_3^2, s_2^3	EP	MP	VG	MP	EG	MG	EG	MP	VG

where v^δ represents the expected performance of player δ and Φ_π^δ is the probability of the strategy s_π^δ .

4. Numerical Example

Suppose that there are three enterprises (players) P^1 , P^2 , and P^3 who can produce high technology mobile phone in the market. Each enterprise possesses its strong point and weakness. The product development strategy and manufacture strategy of each enterprise will influence the competitive performance of other enterprises in the different dimensions. Based on R&D ability and the brand impressions of each enterprise, the strategy of each enterprise will be limited to develop a new product. Enterprise P^1 invites three experts to analyze and select a suitable strategy for developing a new mobile phone. The first expert is a marketing director who comes from the marketing department in the enterprise. The second expert is an R&D manager who is the project leader of the research and development department in the enterprise. The third expert is a strategy professor who is invited from the university. Enterprise P^1 has three development strategies and also knows that competitor P^2 has three strategies and competitor P^3 has two strategies for developing a new mobile phone. Enterprise P^1 considers four criteria to make a decision. Enterprise P^1 also knows that competitor P^2 considers three criteria for making decision and competitor P^3 considers four criteria for making decision. The strategies and evaluation criteria of enterprises are shown in Table 2.

According to the computational process of linguistic multiperson multi-criteria game (LMPMCG) model, the problem can be solved as follows.

4.1. Aggregating the Evaluations of Experts

Step 1. Each expert uses the linguistic variables to evaluate the performance of each enterprise with respect to each criterion based on different strategy combinations as Tables 3, 4, and 5.

Step 2. Transform the linguistic evaluation of the performance of each enterprise with respect to each criterion into PTFN as Tables 6, 7, and 8. And then, the performance of each enterprise with respect to each criterion can be aggregated as Table 9.

Step 3. The aggregated performance of each enterprise with respect to each criterion can be defuzzied as Table 10.

Step 4. Each expert uses the linguistic variables to evaluate the weight of each criterion as Table 11.

Step 5. Transform the linguistic evaluation of the weight of each criterion into PTFN as Table 12. And then, the aggregated weight of each criterion can be computed as Table 12.

Step 6. The aggregated weight of each criterion can be defuzzied as Table 12.

4.2. Analysis of Mixed Strategy. After aggregating the evaluations of experts, the optimal strategy of each enterprise can be determined by considering all strategy combinations. At first, the weighted performance of each strategy combination based on the opinions of experts must be calculated. And then, the optimal probability of each strategy for each

TABLE 5: The linguistic performance of enterprise P^3 with respect to criteria for each strategy combination.

Strategy combination	c_1^3			c_2^3			c_3^3			c_4^3		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
s_1^1, s_1^2, s_1^3	P	MP	F	P	F	F	P	EP	MP	G	MP	P
s_2^1, s_1^2, s_1^3	G	MP	MP	G	G	VG	G	MP	VG	F	G	VG
s_3^1, s_1^2, s_1^3	EP	G	F	G	P	G	F	F	G	EG	MG	P
s_1^1, s_2^2, s_1^3	F	MG	MG	EG	MG	VP	G	F	VP	P	EG	VG
s_2^1, s_2^2, s_1^3	EG	P	P	F	MG	G	F	F	G	G	F	MP
s_1^1, s_2^2, s_1^3	F	P	VG	EG	EG	VG	EG	F	MG	F	G	VP
s_1^1, s_3^2, s_1^3	P	EG	VP	F	MG	MG	EG	MP	VP	P	P	P
s_2^1, s_3^2, s_1^3	G	MP	MP	P	F	P	P	MG	P	G	MG	G
s_3^1, s_3^2, s_1^3	EP	EG	G	G	P	MG	G	P	VG	G	G	MG
s_1^1, s_1^2, s_2^3	EG	G	MP	F	G	VG	F	MG	G	EG	F	VG
s_2^1, s_1^2, s_2^3	P	P	VP	G	EP	P	G	MP	MG	P	G	G
s_3^1, s_1^2, s_2^3	G	EP	P	G	F	G	EG	G	F	G	MG	VP
s_1^1, s_2^2, s_2^3	F	MG	VG	EG	MG	EG	P	F	MG	F	MP	P
s_2^1, s_2^2, s_2^3	P	F	P	F	EG	VP	G	EG	VP	EP	F	P
s_3^1, s_2^2, s_2^3	EG	MP	VP	EP	MG	MP	EP	P	EG	EG	EP	G
s_1^1, s_3^2, s_2^3	G	G	P	EG	G	MG	F	EP	MG	G	F	MG
s_2^1, s_3^2, s_2^3	G	G	MG	G	MG	EG	G	F	MP	EG	MP	VG
s_3^1, s_3^2, s_2^3	F	MP	VP	P	EP	VP	EG	MP	G	EP	P	F

enterprise can be formulated by a linear programming model. Finally, the occurrence probability of each strategy combination can be computed by solving the linear programming model. The computational steps can be illustrated as follows.

Step 1. For any strategy combination, the weighted performance of each enterprise with respect to each criterion can be calculated as Table 13.

Step 2. Calculate the aggregated performance of each enterprise with respect to all criteria for any strategy combination.

Step 3. The aggregated performance of each enterprise for the strategy combination can be arranged as a multiperson multi-criteria noncooperation game as Table 14. According to Table 14, the performance of enterprise P^1 is 0.5254 when enterprise P^1 chooses strategy s_1^1 , enterprise P^2 chooses strategy s_2^1 , and enterprise P^3 chooses strategy s_3^1 . The performance of enterprise P^1 is 0.5354 when enterprise P^1 chooses strategy s_2^1 , enterprise P^2 chooses strategy s_2^1 , and enterprise P^3 chooses strategy s_3^1 . The performance of enterprise P^1 is 0.4821 when enterprise P^1 chooses strategy s_3^1 , enterprise P^2 chooses strategy s_2^1 , and enterprise P^3 chooses strategy s_3^1 . Based on the strategy combinations in game model, the larger aggregated performance is the better strategy for the enterprise.

Step 4. Under the competitive situation, each enterprise hopes that the overall performance is higher than other enterprises as the probability of each strategy is computed. Therefore, the expected performance of the mixed strategy

of each enterprise should be higher than the performance of each enterprise although the strategies are selected by other enterprises. According to the aggregated performances of all strategies, enterprise P^1 will maximize the expected performance by formulating a linear programming model as follows:

$$\begin{aligned}
 & \text{Max } v^1 \\
 & \text{subject to } 0.5254 * \Phi_1^1 + 0.5354 * \Phi_2^1 \\
 & \quad + 0.4821 * \Phi_3^1 \geq v^1; \\
 & 0.6706 * \Phi_1^1 + 0.6365 * \Phi_2^1 \\
 & \quad + 0.5135 * \Phi_3^1 \geq v^1; \\
 & 0.6501 * \Phi_1^1 + 0.5338 * \Phi_2^1 \\
 & \quad + 0.4422 * \Phi_3^1 \geq v^1; \\
 & 0.5629 * \Phi_1^1 + 0.5220 * \Phi_2^1 \\
 & \quad + 0.5216 * \Phi_3^1 \geq v^1; \\
 & 0.6804 * \Phi_1^1 + 0.6352 * \Phi_2^1 \\
 & \quad + 0.5292 * \Phi_3^1 \geq v^1; \\
 & 0.5475 * \Phi_1^1 + 0.5978 * \Phi_2^1 \\
 & \quad + 0.4753 * \Phi_3^1 \geq v^1;
 \end{aligned}$$

TABLE 6: The PTFN performances of enterprise P^1 with respect to criteria for each strategy combination.

Strategy combination	D_1	c_1^1	D_2	D_3	D_1	c_2^1	D_2	D_3
s_1^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)
s_2^1, s_1^2, s_1^3	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.750, 0.875, 1.000)	(0.750, 0.875, 1.000)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)
s_3^1, s_1^2, s_1^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)
s_2^1, s_2^2, s_1^3	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)
s_3^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)
s_2^1, s_2^2, s_2^3	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_3^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)
s_1^1, s_2^2, s_2^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)	(0.750, 0.875, 1.000)	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)
s_2^1, s_2^2, s_2^3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)
s_3^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)
s_1^1, s_2^2, s_2^3	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)
s_2^1, s_2^2, s_2^3	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.000, 0.000, 0.125)
s_3^1, s_2^2, s_2^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)	(0.750, 0.875, 1.000)	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)
s_1^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.000, 0.125, 0.250)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)
s_2^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)
s_3^1, s_2^2, s_2^3	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)

TABLE 6: Continued.

Strategy combination	D_1	c_3 D_2	D_3	D_1	c_4 D_2	D_3
s_1^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)
s_2^1, s_1^2, s_1^3	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_3^1, s_1^2, s_1^3	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.000, 0.125, 0.250)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)
s_1^1, s_2^2, s_1^3	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)
s_2^1, s_2^2, s_1^3	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)
s_3^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.000, 0.125, 0.250)	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_2^3	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)
s_2^1, s_2^2, s_2^3	(0.000, 0.125, 0.250)	(0.500, 0.625, 0.750)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.125, 0.250, 0.375)
s_3^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)
s_1^1, s_1^2, s_2^3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)
s_2^1, s_1^2, s_2^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.000, 0.125, 0.250)
s_3^1, s_1^2, s_2^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)	(0.250, 0.375, 0.500)
s_1^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)
s_2^1, s_2^2, s_2^3	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_3^1, s_2^2, s_2^3	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_3^3	(0.750, 0.875, 1.000)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.000, 0.000, 0.125)	(0.875, 1.000, 1.000)
s_2^1, s_2^2, s_3^3	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.000, 0.000, 0.125)
s_3^1, s_2^2, s_3^3	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)

TABLE 7: The PTFN performances of enterprise P^2 with respect to criteria for each strategy combination.

Strategy combination	D_1	c_1^2 D_2	D_3	D_1	c_2^2 D_2	D_3
s_1^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)
s_1^1, s_1^2, s_1^3	(0.125, 0.250, 0.375)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)
s_1^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.125, 0.250, 0.375)
s_1^1, s_2^2, s_1^3	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)
s_1^1, s_2^2, s_1^3	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_1^3	(0.000, 0.000, 0.125)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_1^3	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_1^3	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_1^3	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_1^3	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)	(0.250, 0.375, 0.500)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)

TABLE 7: Continued.

Strategy combination	ζ_3^2		
	D_1	D_2	D_3
s_1^1, s_1^2, s_1^3	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)	(0.750, 0.875, 1.000)
s_2^1, s_1^2, s_1^3	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)
s_3^1, s_1^2, s_1^3	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.250, 0.375, 0.500)
s_2^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)
s_3^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)
s_2^1, s_3^2, s_1^3	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)
s_3^1, s_3^2, s_1^3	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)
s_1^1, s_1^2, s_2^3	(0.125, 0.250, 0.375)	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)
s_2^1, s_1^2, s_2^3	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)
s_3^1, s_1^2, s_2^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_2^3	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)
s_2^1, s_2^2, s_2^3	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)
s_3^1, s_2^2, s_2^3	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.000, 0.000, 0.125)
s_1^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)
s_2^1, s_3^2, s_2^3	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)
s_3^1, s_3^2, s_2^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)

TABLE 8: The PTN performances of enterprise P^3 with respect to criteria for each strategy combination.

Strategy combination	D_1	c_1^3 D_2	D_3	D_1	c_2^3 D_2	D_3
s_1^1, s_1^2, s_1^3	(0.125, 0.250, 0.375)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)
s_2^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.750, 0.875, 1.000)
s_3^1, s_1^2, s_1^3	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_1^3	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)
s_2^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)
s_3^1, s_2^2, s_1^3	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.750, 0.875, 1.000)
s_1^1, s_2^2, s_3^3	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.500, 0.625, 0.750)
s_2^1, s_2^2, s_3^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.250, 0.375, 0.500)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)
s_3^1, s_2^2, s_3^3	(0.000, 0.000, 0.125)	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)
s_1^1, s_1^2, s_2^3	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.750, 0.875, 1.000)
s_2^1, s_1^2, s_2^3	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.000, 0.125, 0.250)	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)
s_3^1, s_1^2, s_2^3	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_2^3	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.750, 0.875, 1.000)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)
s_2^1, s_2^2, s_2^3	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)
s_3^1, s_2^2, s_2^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)	(0.250, 0.375, 0.500)
s_1^1, s_2^2, s_3^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)
s_2^1, s_2^2, s_3^3	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.875, 1.000, 1.000)
s_3^1, s_2^2, s_3^3	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)	(0.125, 0.250, 0.375)	(0.000, 0.000, 0.125)	(0.000, 0.125, 0.250)

TABLE 8: Continued.

Strategy combination	D_1	C_3 D_2	D_3	D_1	C_4 D_2	D_3
s_1^1, s_1^2, s_1^3	(0.125, 0.250, 0.375)	(0.000, 0.000, 0.125)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.125, 0.250, 0.375)
s_2^1, s_1^2, s_1^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.750, 0.875, 1.000)
s_3^1, s_1^2, s_1^3	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.000, 0.125, 0.250)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.750, 0.875, 1.000)
s_2^1, s_2^2, s_1^3	(0.375, 0.500, 0.625)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)
s_3^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_1^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.000, 0.125, 0.250)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)	(0.125, 0.250, 0.375)
s_2^1, s_2^2, s_1^3	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)
s_3^1, s_2^2, s_1^3	(0.625, 0.750, 0.875)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)
s_1^1, s_1^2, s_2^3	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.750, 0.875, 1.000)
s_2^1, s_1^2, s_2^3	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.125, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.625, 0.750, 0.875)
s_3^1, s_1^2, s_2^3	(0.875, 1.000, 1.000)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.000, 0.125, 0.250)
s_1^1, s_2^2, s_2^3	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.125, 0.250, 0.375)
s_2^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.000, 0.125, 0.250)	(0.000, 0.000, 0.125)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)
s_3^1, s_2^2, s_2^3	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.000, 0.000, 0.125)	(0.625, 0.750, 0.875)
s_1^1, s_2^2, s_2^3	(0.375, 0.500, 0.625)	(0.000, 0.000, 0.125)	(0.500, 0.625, 0.750)	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.500, 0.625, 0.750)
s_2^1, s_2^2, s_2^3	(0.625, 0.750, 0.875)	(0.375, 0.500, 0.625)	(0.250, 0.375, 0.500)	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.750, 0.875, 1.000)
s_3^1, s_2^2, s_2^3	(0.875, 1.000, 1.000)	(0.250, 0.375, 0.500)	(0.625, 0.750, 0.875)	(0.000, 0.000, 0.125)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)

TABLE 9: The aggregated performance of each enterprise with respect to criteria under all strategy combinations.

Strategy combination	Enterprise P^1			Enterprise P^2		
	c_1^1	c_2^1	c_3^1	c_4^1	c_1^2	c_2^2
s_1^1, s_1^2, s_1^3	(0.375, 0.500, 0.625)	(0.417, 0.542, 0.667)	(0.542, 0.667, 0.792)	(0.333, 0.458, 0.542)	(0.542, 0.667, 0.792)	(0.583, 0.708, 0.833)
s_2^1, s_1^2, s_1^3	(0.375, 0.458, 0.583)	(0.417, 0.542, 0.667)	(0.292, 0.417, 0.542)	(0.542, 0.667, 0.792)	(0.083, 0.167, 0.292)	(0.292, 0.417, 0.542)
s_3^1, s_1^2, s_1^3	(0.375, 0.458, 0.542)	(0.625, 0.750, 0.875)	(0.042, 0.125, 0.250)	(0.250, 0.375, 0.500)	(0.542, 0.667, 0.792)	(0.125, 0.208, 0.333)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.833)	(0.458, 0.583, 0.667)	(0.542, 0.667, 0.792)	(0.542, 0.667, 0.750)	(0.250, 0.375, 0.500)	(0.292, 0.417, 0.542)
s_2^1, s_2^2, s_1^3	(0.083, 0.167, 0.292)	(0.583, 0.708, 0.792)	(0.417, 0.542, 0.667)	(0.583, 0.708, 0.792)	(0.292, 0.375, 0.500)	(0.625, 0.750, 0.875)
s_3^1, s_2^2, s_1^3	(0.625, 0.750, 0.833)	(0.292, 0.417, 0.542)	(0.208, 0.292, 0.417)	(0.125, 0.250, 0.375)	(0.500, 0.625, 0.708)	(0.292, 0.417, 0.542)
s_1^1, s_2^2, s_2^3	(0.667, 0.792, 0.875)	(0.500, 0.625, 0.708)	(0.375, 0.500, 0.625)	(0.667, 0.792, 0.875)	(0.042, 0.083, 0.208)	(0.417, 0.542, 0.667)
s_2^1, s_2^2, s_2^3	(0.500, 0.625, 0.708)	(0.708, 0.833, 0.917)	(0.167, 0.250, 0.375)	(0.542, 0.667, 0.750)	(0.708, 0.833, 0.917)	(0.292, 0.417, 0.542)
s_3^1, s_2^2, s_2^3	(0.542, 0.667, 0.792)	(0.417, 0.500, 0.583)	(0.458, 0.583, 0.708)	(0.292, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.542, 0.667, 0.792)
s_1^1, s_1^2, s_2^3	(0.667, 0.792, 0.875)	(0.417, 0.542, 0.625)	(0.500, 0.625, 0.708)	(0.667, 0.792, 0.875)	(0.208, 0.333, 0.458)	(0.250, 0.375, 0.500)
s_2^1, s_1^2, s_2^3	(0.458, 0.583, 0.667)	(0.583, 0.708, 0.833)	(0.667, 0.792, 0.875)	(0.417, 0.542, 0.625)	(0.542, 0.667, 0.792)	(0.500, 0.625, 0.750)
s_3^1, s_1^2, s_2^3	(0.458, 0.583, 0.708)	(0.333, 0.458, 0.583)	(0.542, 0.667, 0.792)	(0.292, 0.417, 0.542)	(0.667, 0.792, 0.875)	(0.417, 0.542, 0.667)
s_1^1, s_2^2, s_2^3	(0.333, 0.417, 0.542)	(0.417, 0.500, 0.625)	(0.417, 0.542, 0.667)	(0.667, 0.792, 0.875)	(0.417, 0.500, 0.583)	(0.458, 0.583, 0.667)
s_2^1, s_2^2, s_2^3	(0.417, 0.500, 0.625)	(0.375, 0.458, 0.583)	(0.375, 0.458, 0.583)	(0.500, 0.625, 0.750)	(0.458, 0.583, 0.667)	(0.458, 0.542, 0.667)
s_3^1, s_2^2, s_2^3	(0.667, 0.792, 0.875)	(0.042, 0.083, 0.208)	(0.375, 0.500, 0.625)	(0.667, 0.792, 0.917)	(0.125, 0.250, 0.375)	(0.417, 0.500, 0.625)
s_1^1, s_2^2, s_3^3	(0.208, 0.292, 0.417)	(0.542, 0.667, 0.792)	(0.417, 0.542, 0.667)	(0.583, 0.667, 0.708)	(0.375, 0.458, 0.583)	(0.250, 0.375, 0.500)
s_2^1, s_2^2, s_3^3	(0.583, 0.708, 0.833)	(0.500, 0.625, 0.708)	(0.167, 0.292, 0.417)	(0.583, 0.667, 0.708)	(0.583, 0.708, 0.833)	(0.458, 0.583, 0.708)
s_3^1, s_2^2, s_3^3	(0.167, 0.250, 0.375)	(0.625, 0.750, 0.875)	(0.542, 0.667, 0.750)	(0.167, 0.208, 0.333)	(0.333, 0.417, 0.542)	(0.542, 0.667, 0.750)

TABLE 9: Continued.

Strategy combination	Enterprise P^2		Enterprise P^3		
	c_2^3	c_1^3	c_2^3	c_3^3	c_4^3
s_1^1, s_1^2, s_1^3	(0.667, 0.792, 0.875)	(0.250, 0.375, 0.500)	(0.292, 0.417, 0.542)	(0.125, 0.208, 0.333)	(0.333, 0.458, 0.583)
s_2^1, s_1^2, s_1^3	(0.333, 0.458, 0.583)	(0.375, 0.500, 0.625)	(0.667, 0.792, 0.917)	(0.542, 0.667, 0.792)	(0.583, 0.708, 0.833)
s_3^1, s_1^2, s_1^3	(0.250, 0.333, 0.458)	(0.333, 0.417, 0.542)	(0.458, 0.583, 0.708)	(0.458, 0.583, 0.708)	(0.500, 0.625, 0.708)
s_1^1, s_2^2, s_1^3	(0.458, 0.583, 0.708)	(0.458, 0.583, 0.708)	(0.458, 0.583, 0.667)	(0.333, 0.458, 0.583)	(0.583, 0.708, 0.792)
s_2^1, s_2^2, s_1^3	(0.500, 0.625, 0.708)	(0.375, 0.500, 0.583)	(0.500, 0.625, 0.750)	(0.458, 0.583, 0.708)	(0.417, 0.542, 0.667)
s_3^1, s_2^2, s_1^3	(0.750, 0.875, 0.917)	(0.417, 0.542, 0.667)	(0.833, 0.958, 1.000)	(0.583, 0.708, 0.792)	(0.333, 0.458, 0.583)
s_1^1, s_2^2, s_1^3	(0.625, 0.750, 0.833)	(0.333, 0.458, 0.542)	(0.458, 0.583, 0.708)	(0.375, 0.500, 0.583)	(0.125, 0.250, 0.375)
s_2^1, s_2^2, s_1^3	(0.583, 0.708, 0.792)	(0.375, 0.500, 0.625)	(0.208, 0.333, 0.458)	(0.250, 0.375, 0.500)	(0.583, 0.708, 0.833)
s_3^1, s_2^2, s_1^3	(0.458, 0.583, 0.708)	(0.500, 0.583, 0.667)	(0.417, 0.542, 0.667)	(0.500, 0.625, 0.750)	(0.583, 0.708, 0.833)
s_1^1, s_1^2, s_2^3	(0.208, 0.292, 0.417)	(0.583, 0.708, 0.792)	(0.583, 0.708, 0.833)	(0.500, 0.625, 0.750)	(0.667, 0.792, 0.875)
s_2^1, s_1^2, s_2^3	(0.458, 0.583, 0.708)	(0.083, 0.208, 0.333)	(0.250, 0.333, 0.458)	(0.458, 0.583, 0.708)	(0.458, 0.583, 0.708)
s_3^1, s_1^2, s_2^3	(0.375, 0.500, 0.625)	(0.250, 0.333, 0.458)	(0.542, 0.667, 0.792)	(0.625, 0.750, 0.833)	(0.375, 0.500, 0.625)
s_1^1, s_2^2, s_2^3	(0.542, 0.667, 0.750)	(0.542, 0.667, 0.792)	(0.750, 0.875, 0.917)	(0.333, 0.458, 0.583)	(0.250, 0.375, 0.500)
s_2^1, s_2^2, s_2^3	(0.208, 0.333, 0.458)	(0.208, 0.333, 0.458)	(0.417, 0.542, 0.625)	(0.500, 0.625, 0.708)	(0.167, 0.250, 0.375)
s_3^1, s_2^2, s_2^3	(0.167, 0.250, 0.375)	(0.375, 0.500, 0.583)	(0.250, 0.333, 0.458)	(0.333, 0.417, 0.500)	(0.500, 0.583, 0.667)
s_1^1, s_2^2, s_2^3	(0.458, 0.583, 0.708)	(0.458, 0.583, 0.708)	(0.667, 0.792, 0.875)	(0.292, 0.375, 0.500)	(0.500, 0.625, 0.750)
s_2^1, s_2^2, s_2^3	(0.542, 0.667, 0.792)	(0.583, 0.708, 0.833)	(0.667, 0.792, 0.875)	(0.417, 0.542, 0.667)	(0.625, 0.750, 0.833)
s_3^1, s_2^2, s_2^3	(0.625, 0.750, 0.833)	(0.208, 0.333, 0.458)	(0.042, 0.125, 0.250)	(0.583, 0.708, 0.792)	(0.167, 0.250, 0.375)

TABLE 10: The defuzzified performance of each enterprise with respect to criteria under all strategy combinations.

Strategy combination	Enterprise P^1				Enterprise P^2			Enterprise P^3			
	c_1^1	c_2^1	c_3^1	c_4^1	c_1^2	c_2^2	c_3^2	c_1^3	c_2^3	c_3^3	c_4^3
s_1^1, s_1^2, s_1^3	0.500	0.542	0.667	0.444	0.667	0.708	0.778	0.375	0.417	0.222	0.458
s_2^1, s_1^2, s_1^3	0.472	0.542	0.417	0.667	0.181	0.417	0.458	0.500	0.792	0.667	0.708
s_3^1, s_1^2, s_1^3	0.458	0.750	0.139	0.375	0.667	0.222	0.347	0.431	0.583	0.583	0.611
s_1^1, s_2^2, s_1^3	0.736	0.569	0.667	0.653	0.375	0.417	0.583	0.583	0.569	0.458	0.694
s_2^1, s_2^2, s_1^3	0.181	0.694	0.542	0.694	0.389	0.750	0.611	0.486	0.625	0.583	0.542
s_3^1, s_2^2, s_1^3	0.736	0.417	0.306	0.250	0.611	0.417	0.847	0.542	0.931	0.694	0.458
s_1^1, s_2^2, s_2^3	0.778	0.611	0.500	0.778	0.111	0.542	0.736	0.444	0.583	0.486	0.250
s_2^1, s_2^2, s_2^3	0.611	0.819	0.264	0.653	0.819	0.417	0.694	0.500	0.333	0.375	0.708
s_3^1, s_2^2, s_2^3	0.667	0.500	0.583	0.389	0.625	0.667	0.583	0.583	0.542	0.625	0.708
s_1^1, s_2^2, s_3^3	0.778	0.528	0.611	0.778	0.333	0.375	0.306	0.694	0.708	0.625	0.778
s_2^1, s_2^2, s_3^3	0.569	0.708	0.778	0.528	0.667	0.625	0.583	0.208	0.347	0.583	0.583
s_3^1, s_2^2, s_3^3	0.583	0.458	0.667	0.417	0.778	0.542	0.500	0.347	0.667	0.736	0.500
s_1^1, s_2^2, s_3^3	0.431	0.514	0.542	0.778	0.500	0.569	0.653	0.667	0.847	0.458	0.375
s_2^1, s_2^2, s_3^3	0.514	0.472	0.472	0.625	0.569	0.556	0.333	0.333	0.528	0.611	0.264
s_3^1, s_2^2, s_3^3	0.778	0.111	0.500	0.792	0.250	0.514	0.264	0.486	0.347	0.417	0.583
s_1^1, s_2^2, s_3^3	0.306	0.667	0.542	0.653	0.472	0.375	0.583	0.583	0.778	0.389	0.625
s_2^1, s_2^2, s_3^3	0.708	0.611	0.292	0.653	0.708	0.583	0.667	0.708	0.778	0.542	0.736
s_3^1, s_2^2, s_3^3	0.264	0.750	0.653	0.236	0.431	0.653	0.736	0.333	0.139	0.694	0.264

TABLE 11: The linguistic weight of each criterion.

	Enterprise P^1				Enterprise P^2			Enterprise P^3			
	c_1^1	c_2^1	c_3^1	c_4^1	c_1^2	c_2^2	c_3^2	c_1^3	c_2^3	c_3^3	c_4^3
D_1	EH	EH	L	F	H	EH	L	EH	F	L	F
D_2	ML	MH	F	L	H	ML	MH	H	MH	F	H
D_3	ML	F	L	VH	EH	MH	ML	F	H	EH	VH

$$\Phi_1^1 + \Phi_2^1 + \Phi_3^1 = 1;$$

$$\Phi_1^1 \geq 0;$$

$$\Phi_2^1 \geq 0;$$

$$\Phi_3^1 \geq 0.$$

(11)

By solving this linear programming model, the optimal probability of strategies s_1^1 , s_2^1 , and s_3^1 are $\Phi_1^1 = 0.2632$, $\Phi_2^1 = 0.7368$, and $\Phi_3^1 = 0.0000$, respectively.

According to the aggregated performances of all strategies, enterprise P^2 will maximize the expected performance by formulating a linear programming model as follows:

$$\text{Max } v^2$$

$$\text{subject to } 0.7056 * \Phi_1^2 + 0.4354 * \Phi_2^2$$

$$+ 0.3978 * \Phi_3^2 \geq v^2;$$

$$0.3416 * \Phi_1^2 + 0.5577 * \Phi_2^2$$

$$+ 0.4631 * \Phi_3^2 \geq v^2;$$

$$0.3234 * \Phi_1^2 + 0.5627 * \Phi_2^2$$

$$+ 0.6527 * \Phi_3^2 \geq v^2;$$

$$0.6339 * \Phi_1^2 + 0.5126 * \Phi_2^2$$

$$+ 0.6559 * \Phi_3^2 \geq v^2;$$

$$0.4426 * \Phi_1^2 + 0.5960 * \Phi_2^2$$

$$+ 0.6302 * \Phi_3^2 \geq v^2;$$

$$0.6349 * \Phi_1^2 + 0.3443 * \Phi_2^2$$

$$+ 0.5748 * \Phi_3^2 \geq v^2;$$

$$\Phi_1^2 + \Phi_2^2 + \Phi_3^2 = 1;$$

$$\Phi_1^2 \geq 0;$$

$$\Phi_2^2 \geq 0;$$

$$\Phi_3^2 \geq 0.$$

(12)

By solving this linear programming model, the optimal probability of strategies s_1^2 , s_2^2 , s_3^2 are $\Phi_1^2 = 0.2136$, $\Phi_2^2 = 0.4629$, and $\Phi_3^2 = 0.3235$, respectively.

According to the aggregated performances of all strategies, enterprise P^3 will maximize the expected performance by formulating a linear programming model as follows:

TABLE 12: The PTFN information of each criterion.

Enterprise P^1				
	c_1^1	c_2^1	c_3^1	c_4^1
D_1	(0.875, 1.000, 1.000)	(0.875, 1.000, 1.000)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)
D_2	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)
D_3	(0.250, 0.375, 0.500)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.750, 0.875, 1.000)
The integrated opinions	(0.458, 0.583, 0.667)	(0.583, 0.708, 0.792)	(0.208, 0.333, 0.458)	(0.417, 0.542, 0.667)
The defuzzied opinions	0.569	0.694	0.333	0.542
Enterprise P^2				
	c_1^2	c_2^2	c_3^2	
D_1	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.125, 0.250, 0.375)	
D_2	(0.625, 0.750, 0.875)	(0.250, 0.375, 0.500)	(0.500, 0.625, 0.750)	
D_3	(0.875, 1.000, 1.000)	(0.500, 0.625, 0.750)	(0.250, 0.375, 0.500)	
The integrated opinions	(0.708, 0.833, 0.917)	(0.542, 0.667, 0.750)	(0.292, 0.417, 0.542)	
The defuzzied opinions	0.819	0.653	0.417	
Enterprise P^3				
	c_1^3	c_2^3	c_3^3	c_4^3
D_1	(0.875, 1.000, 1.000)	(0.375, 0.500, 0.625)	(0.125, 0.250, 0.375)	(0.375, 0.500, 0.625)
D_2	(0.625, 0.750, 0.875)	(0.500, 0.625, 0.750)	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)
D_3	(0.375, 0.500, 0.625)	(0.625, 0.750, 0.875)	(0.875, 1.000, 1.000)	(0.750, 0.875, 1.000)
The integrated opinions	(0.625, 0.750, 0.833)	(0.500, 0.625, 0.750)	(0.458, 0.583, 0.667)	(0.583, 0.708, 0.833)
The defuzzied opinions	0.736	0.625	0.569	0.708

TABLE 13: The weighted performance of each enterprise with respect to criteria under all strategy combinations.

Strategy combination	Enterprise P^1				Enterprise P^2			Enterprise P^3			
	c_1^1	c_2^1	c_3^1	c_4^1	c_1^2	c_2^2	c_3^2	c_1^3	c_2^3	c_3^3	c_4^3
s_1^1, s_2^2, s_3^3	0.1331	0.1759	0.1039	0.1126	0.2892	0.2448	0.1716	0.1046	0.0987	0.0480	0.1230
s_2^1, s_1^2, s_3^3	0.1257	0.1759	0.0649	0.1688	0.0783	0.1440	0.1011	0.1395	0.1875	0.1439	0.1901
s_3^1, s_2^2, s_1^3	0.1220	0.2435	0.0216	0.0950	0.2892	0.0768	0.0766	0.1201	0.1382	0.1259	0.1640
s_1^1, s_2^2, s_1^3	0.1960	0.1849	0.1039	0.1653	0.1627	0.1440	0.1287	0.1627	0.1349	0.0989	0.1864
s_1^1, s_2^2, s_1^3	0.0481	0.2255	0.0844	0.1759	0.1687	0.2592	0.1348	0.1356	0.1480	0.1259	0.1454
s_1^1, s_2^2, s_1^3	0.1960	0.1353	0.0476	0.0633	0.2651	0.1440	0.1869	0.1511	0.2204	0.1499	0.1230
s_1^1, s_2^2, s_1^3	0.2071	0.1984	0.0779	0.1970	0.0482	0.1872	0.1624	0.1240	0.1382	0.1049	0.0671
s_2^1, s_2^2, s_1^3	0.1627	0.2661	0.0411	0.1653	0.3555	0.1440	0.1532	0.1395	0.0789	0.0809	0.1901
s_3^1, s_2^2, s_1^3	0.1775	0.1623	0.0909	0.0985	0.2711	0.2304	0.1287	0.1627	0.1283	0.1349	0.1901
s_1^1, s_1^2, s_2^3	0.2071	0.1714	0.0952	0.1970	0.1446	0.1296	0.0674	0.1937	0.1678	0.1349	0.2088
s_2^1, s_2^2, s_2^3	0.1516	0.2300	0.1212	0.1337	0.2892	0.2160	0.1287	0.0581	0.0822	0.1259	0.1566
s_3^1, s_2^2, s_2^3	0.1553	0.1488	0.1039	0.1055	0.3374	0.1872	0.1103	0.0969	0.1579	0.1588	0.1342
s_1^1, s_2^2, s_2^3	0.1146	0.1668	0.0844	0.1970	0.2169	0.1968	0.1440	0.1860	0.2007	0.0989	0.1007
s_2^1, s_2^2, s_2^3	0.1368	0.1533	0.0736	0.1583	0.2470	0.1920	0.0735	0.0930	0.1250	0.1319	0.0708
s_3^1, s_2^2, s_2^3	0.2071	0.0361	0.0779	0.2005	0.1085	0.1776	0.0582	0.1356	0.0822	0.0899	0.1566
s_1^1, s_2^2, s_2^3	0.0813	0.2165	0.0844	0.1653	0.2049	0.1296	0.1287	0.1627	0.1842	0.0839	0.1678
s_2^1, s_2^2, s_2^3	0.1886	0.1984	0.0455	0.1653	0.3073	0.2016	0.1471	0.1976	0.1842	0.1169	0.1976
s_3^1, s_2^2, s_2^3	0.0703	0.2435	0.1017	0.0598	0.1868	0.2256	0.1624	0.0930	0.0329	0.1499	0.0708

Max v^3

$$0.5549 * \Phi_1^3 + 0.4207 * \Phi_2^3 \geq v^3;$$

$$\text{subject to } 0.3743 * \Phi_1^3 + 0.7051 * \Phi_2^3 \geq v^3;$$

$$0.4895 * \Phi_1^3 + 0.6963 * \Phi_2^3 \geq v^3;$$

$$0.5829 * \Phi_1^3 + 0.5862 * \Phi_2^3 \geq v^3;$$

$$0.5482 * \Phi_1^3 + 0.5478 * \Phi_2^3 \geq v^3;$$

$$0.4341 * \Phi_1^3 + 0.5986 * \Phi_2^3 \geq v^3;$$

$$0.6444 * \Phi_1^3 + 0.4643 * \Phi_2^3 \geq v^3;$$

$$0.6610 * \Phi_1^3 + 0.4228 * \Phi_2^3 \geq v^3;$$

$$0.6160 * \Phi_1^3 + 0.3466 * \Phi_2^3 \geq v^3;$$

TABLE 14: The aggregated performances in multiperson multicriteria noncooperation game of each enterprise.

Enterprise P^1	Enterprise P^3	Enterprise P^2		
		s_1^2	s_2^2	s_3^2
s_1^1	s_1^3	(0.5254, 0.7056, 0.3743)	(0.6501, 0.4354, 0.5829)	(0.6804, 0.3978, 0.4341)
	s_2^3	(0.6706, 0.3416, 0.7051)	(0.5629, 0.5577, 0.5862)	(0.5475, 0.4631, 0.5986)
s_2^1	s_1^3	(0.5354, 0.3234, 0.6610)	(0.5338, 0.5627, 0.5549)	(0.6352, 0.6527, 0.4895)
	s_2^3	(0.6365, 0.6339, 0.4228)	(0.5220, 0.5126, 0.4207)	(0.5978, 0.6559, 0.6963)
s_3^1	s_1^3	(0.4821, 0.4426, 0.5482)	(0.4422, 0.5960, 0.6444)	(0.5292, 0.6302, 0.6160)
	s_2^3	(0.5135, 0.6349, 0.5478)	(0.5216, 0.3443, 0.4643)	(0.4753, 0.5748, 0.3466)

Note: $(\bullet, \bullet, \bullet)$ represents the performance of each enterprise under different strategy combination (P^1, P^2, P^3) .

TABLE 15: The strategy combination occurrence probability distribution of each strategy of each enterprise.

Enterprise P^1	Enterprise P^3	Enterprise P^2		
		$s_1^2 \Phi_1^2 = 0.2136$	$s_2^2 \Phi_2^2 = 0.4629$	$s_3^2 \Phi_3^2 = 0.3235$
$s_1^1 \Phi_1^1 = 0.2632$	$s_1^3 \Phi_1^3 = 0.5956$	0.0335	0.0726	0.0507
	$s_2^3 \Phi_2^3 = 0.4044$	0.0227	0.0493	0.0344
$s_2^1 \Phi_2^1 = 0.7368$	$s_1^3 \Phi_1^3 = 0.5956$	0.0937	0.2031	0.1420
	$s_2^3 \Phi_2^3 = 0.4044$	0.0636	0.1379	0.0964
$s_3^1 \Phi_3^1 = 0.0000$	$s_1^3 \Phi_1^3 = 0.5956$	0.0000	0.0000	0.0000
	$s_2^3 \Phi_2^3 = 0.4044$	0.0000	0.0000	0.0000

$$\Phi_1^3 + \Phi_2^3 = 1;$$

$$\Phi_1^3 \geq 0;$$

$$\Phi_2^3 \geq 0.$$

(13)

By solving this linear programming model, the optimal probability of strategies s_1^3 and s_2^3 is $\Phi_1^3 = 0.5956$ and $\Phi_2^3 = 0.4044$, respectively.

Step 5. For the strategy combination, the occurrence probability distribution of each strategy of each enterprise can be calculated as Table 15. For example, the probability is 0.2031 for the strategy combination (s_2^1, s_2^2, s_1^3) of enterprise P^1 , P^2 , and P^3 . It means that the probability is 0.2031 when enterprise P^1 chooses strategy s_2^1 , enterprise P^2 chooses strategy s_2^2 , and enterprise P^3 chooses strategy s_1^3 simultaneously. Every enterprise can prepare to face the future competition scenario based on the occurrence probability distribution of each strategy of each enterprise.

4.3. The Meanings of Management. According to the execution probability of each strategy, the priority of enterprise P^1 is s_2^1 , s_1^1 , and s_3^1 . The execution priority of enterprise P^2 is s_2^2 , s_3^2 , and s_1^2 . The execution priority of enterprise P^3 is s_1^3 and s_2^3 . The probability of each strategy combination is shown as Table 16. Each enterprise can prepare to handle the future possible competitive scenario based on the probability of each strategy combination. Therefore, the competition ability of enterprises can be compared based on the probability of each strategy combination.

TABLE 16: The probability of strategy combination.

Strategy combination	Probability
s_2^1, s_2^2, s_1^3	0.2031
s_2^1, s_3^2, s_1^3	0.1420
s_2^1, s_2^2, s_2^3	0.1379
s_2^1, s_3^2, s_2^3	0.0964
s_2^1, s_2^2, s_1^3	0.0937
s_1^1, s_2^2, s_1^3	0.0726
s_2^1, s_2^2, s_1^3	0.0636
s_1^1, s_3^2, s_1^3	0.0507
s_1^1, s_2^2, s_2^3	0.0493
s_1^1, s_3^2, s_2^3	0.0344
s_1^1, s_2^2, s_1^3	0.0335
s_1^1, s_2^2, s_1^3	0.0227
Others	0.0000

The expected performance value (EPV) can be used to compare the competition ability of enterprises by considering the aggregated performance of each enterprise and the probability of each strategy combination. The higher expected performance value is, the higher enterprise competition ability is in the competitive environment.

According to Tables 14, 15, and 16, The EPV of enterprise P^1 can be computed as

$$\begin{aligned}
 & (0.5254 * 0.0335 + 0.6076 * 0.0227 \\
 & + 0.5354 * 0.0937 + 0.6365 * 0.0636 \\
 & + 0.4821 * 0.0000 + 0.5135 * 0.0000 \\
 & + 0.6501 * 0.0726 + 0.5629 * 0.0493
 \end{aligned}$$

$$\begin{aligned}
& + 0.5338 * 0.2031 + 0.5220 * 0.1379 \\
& + 0.4422 * 0.0000 + 0.5216 * 0.0000 \\
& + 0.6804 * 0.0507 + 0.5475 * 0.0344 \\
& + 0.6352 * 0.1420 + 0.5978 * 0.0964 \\
& + 0.5292 * 0.0000 + 0.4753 * 0.0000) = 0.5800.
\end{aligned} \tag{14}$$

The EPV of enterprise P^2 can be computed as

$$\begin{aligned}
& (0.7056 * 0.0335 + 0.3416 * 0.0227 \\
& + 0.3234 * 0.0937 + 0.6339 * 0.0636 \\
& + 0.4426 * 0.0000 + 0.6349 * 0.0000 \\
& + 0.4354 * 0.0726 + 0.5577 * 0.0493 \\
& + 0.5627 * 0.2031 + 0.5126 * 0.1379 \\
& + 0.5960 * 0.0000 + 0.3443 * 0.0000 \\
& + 0.3978 * 0.0507 + 0.4631 * 0.0344 \\
& + 0.6527 * 0.1420 + 0.6559 * 0.0964 \\
& + 0.6302 * 0.0000 + 0.5748 * 0.0000) = 0.5381.
\end{aligned} \tag{15}$$

The EPV of enterprise P^3 can be computed as

$$\begin{aligned}
& (0.3743 * 0.0335 + 0.7051 * 0.0227 \\
& + 0.6610 * 0.0937 + 0.4228 * 0.0636 \\
& + 0.5482 * 0.0000 + 0.5478 * 0.0000 \\
& + 0.5829 * 0.0726 + 0.5862 * 0.0493 \\
& + 0.5549 * 0.2031 + 0.4207 * 0.1379 \\
& + 0.6444 * 0.0000 + 0.4643 * 0.0000 \\
& + 0.4341 * 0.0507 + 0.5986 * 0.0344 \\
& + 0.4895 * 0.1420 + 0.6963 * 0.0964 \\
& + 0.6160 * 0.0000 + 0.3466 * 0.0000) = 0.5386.
\end{aligned} \tag{16}$$

According to the EPV of each enterprise, the ranking order of competition ability is $P^1 > P^3 > P^2$.

5. Conclusion and Future Research

Facing the dynamic and competitive environment, a new decision making model is presented to deal with group MCDM problems by combining MCDM with game theory in this paper. Original game model usually considers one dimension to make decision based on crisp values. By using the linguistic variables, the decision makers can express their opinions flexibly and easily in the proposed method. According to the proposed method, each player in a game can develop the best strategy or alternative by

considering the performance with respect to multiple criteria and the reactions of competitors simultaneously. A particular strongpoint of this proposed method is that the evaluation criteria can be flexible to determine by players for fitting their objections. Under this situation, the proposed method provides a more reasonable and systematic solution for each player in a competitive environment.

In fact, the number of players of a game model can increase more than two players flexibly in the proposed method. In addition, the most important contribution of proposed method is to present the expected performance value (EPV) to judge the competitive ability of each player in a game model. In the future, multiple types of decision information will be considered in the proposed model such as interval value, crisp value, and type-2 fuzzy set. In order to enhance the computational efficiency, an interactive program will be designed based on the proposed model.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

This work is financially supported partially by the National Science Council of Taiwan, Grant no. NSC 101-2410-H-239-004-MY2.

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