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A FUZZY MCDM APPROACH TO BUILDING A MODEL OF HIGH PERFORMANCE PROJECT TEAM – A CASE STUDY

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Abstract. *The operations of a project team play an important role in the discussion of building high performance project teams. This study focuses on building a model for high performance project teams. First, success and failure factors are evaluated across aspects of a project team that affect team effectiveness. Second, effective teams are analyzed to clarify what defines a high performance project team. Third, this analysis is combined with past results to build a model for high performance project teams. The model for high performance project teams is evaluated by fuzzy multi-criterion decision-making (fuzzy MCDM). The results show that all of the criteria have interactions, but that team effectiveness standard is the most influential dimension. On the contrary, the team process is the least influential dimension. From the viewpoint of experts, the most important ones of the 17 evaluation criteria are performance and satisfaction.*
Keywords: Project team, High performance project team model, Fuzzy DEMATEL (fuzzy decision-making trial and evaluation laboratory), ANP (analytical network processes), VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje)

1. **Introduction.** Project management practices and project team operations play a pivotal role in an enterprise, and project teams are widely employed across corporations in many different industries. However, it is difficult to find systematic research studies on effective project teams that explain how to manage human resources in project management, operate a project team effectively, build a high performance project team and enhance the capacity of a project team.

This paper is structured as follows. In Section 2, we analyze the success and failure factors of a project to clarify influential factors in building a high performance project team and we shows a model of success or failure factors of a project. Section 3 discusses the hybrid MCDM, which combines the fuzzy decision-making trial and evaluation laboratory (Fuzzy DEMATEL) technique with analytical network processes (ANP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Section 4 demonstrates an empirical study of building a high performance project team using the proposed hybrid MCDM model. Finally, conclusions are presented in Section 5.

2. **Literature Review.** This section discusses the review of existing knowledge and literature, including studies on success and failure factors in a project, models of team effectiveness and models of high performance project teams.

Success and failure factors in a project. Rubin and Seeling first introduced the success and failure factors of a project team in 1967. They investigated the impact of a project manager's experience on the success or failure of a project. Technical performance was used as a measure of success.

The framework depicted in Figure 1 addresses many of the flaws in the literature. We grouped the factors into the following four categories:

- factors related to a project;
- factors related to a project manager and team members;
- factors related to an organization;
- factors related to an external environment.

(1) *Factors related to a project.* Project characteristics have long been overlooked as critical success factors, whereas they constitute one of the essential dimensions of project performance.

(2) *Factors related to a project manager and team members.* The successful completion of projects is influenced by many factors related to project managers and team members.

(3) *Factors related to an organization.* One of the most critical factors for the successful completion of projects is top management support. Support is usually the strongest if

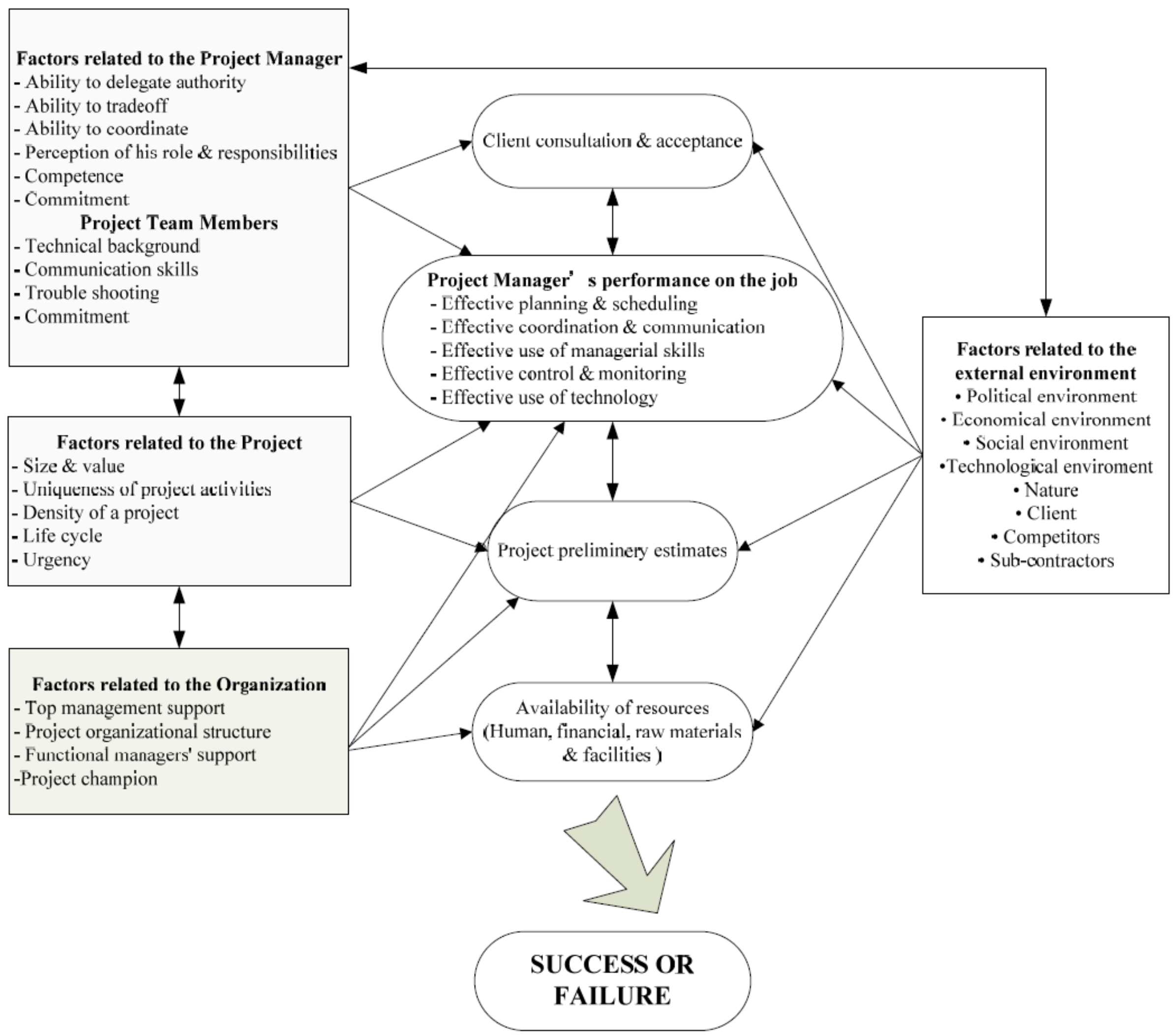

Figure 1. Success or failure factors of a project

there is a project champion that is from top management. The level of support provided by a functional manager is usually determined by the level of support from top management.

(4) *Factors related to an external environment.* This last group consists of factors that are external to an organization but still have an impact on project success. A number of environmental factors, including political, economic and social issues, as well as factors related to advances in technology or project performance, can affect a project's probability of success either positively or negatively.

3. **Research Method.** A hybrid MCDM model combined with fuzzy DEMATEL, ANP and VIKOR, for evaluating and improving problems is more suitable in the real world than the previously available methods. This study used the fuzzy DEMATEL technique to acquire the structure of the MCDM problems. There is performance evaluation framework in this research as shown in Figure 2.

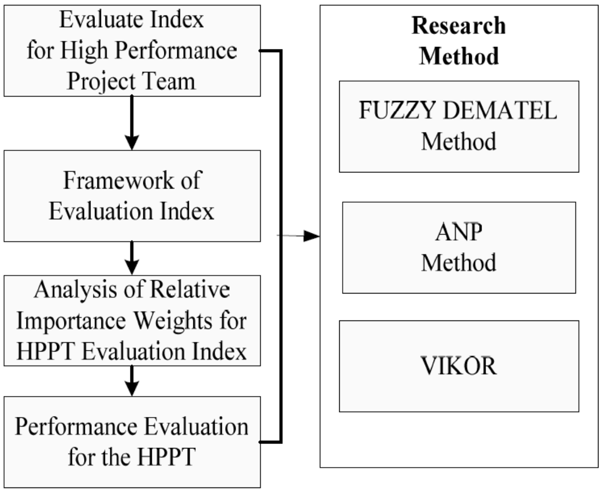

Figure 2. Performance evaluation framework

3.1. **Fuzzy DEMATEL method.** The application of the fuzzy DEMATEL method expresses different degrees of influences or causalities obtained from crisp DEMATEL using five linguistic terms (Very high, High, Low, Very low, No) and their corresponding positive triangular fuzzy numbers [14,27]. The linguistic terms and corresponding fuzzy numbers are shown in Table 1.

Tzeng et al. (2007) [11] indicate that DEMATEL can help understand special problems, collaborate with problem groups, and provide feasible ideas. The method can be applied as follows:

Table 1. Fuzzy DEMATEL linguistic terms and fuzzy numbers

Linguistic terms	Fuzzy number
Very High Influence (VH)	$(0.75, 1.0, 1.0)$
High Influence (H)	$(0.5, 0.75, 1.0)$
Low Influence (L)	$(0.25, 0.5, 0.75)$
Very Low Influence (VL)	$(0, 0.25, 0.5)$
No Influence (No)	$(0, 0, 0.25)$

Step 1: *Calculate the initial average matrix A by using scores.*

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

Step 2: *Calculate the initial influence matrix X.*

$$X = m \times A \tag{2}$$

$$m = \min \left[\frac{1}{\max\limits_i \sum\limits_{j=1}^{n} |a_{ij}|}, \frac{1}{\max\limits_j \sum\limits_{i=1}^{n} |a_{ij}|} \right] \tag{3}$$

Step 3: *Derive the full direct/indirect influence matrix* $\boldsymbol{T}$.

$$\boldsymbol{T} = \boldsymbol{X} + \boldsymbol{X}^2 + \boldsymbol{X}^3 + \cdots + \boldsymbol{X}^q = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}$$

Proof:

$$\begin{aligned} \boldsymbol{T} &= X(I + X + X^2 + \cdots + X^{q-1})(I - X)(I - X)^{-1} \\ &= \boldsymbol{X}(I - \boldsymbol{X}^q)(\boldsymbol{I} - \boldsymbol{X})^{-1} \end{aligned}$$

when $q \to \infty$, $\boldsymbol{X}^q = [0]_{n\times n}$, then

$$\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1} \tag{4}$$

where $\boldsymbol{T} = [t_{ij}]_{n\times n}$, $i, j = 1, 2, \ldots, n$.

Step 4: *Build the Network Relation Matrix based on the vectors* $\boldsymbol{r}$ *and* $\boldsymbol{c}$.

$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij} \right]_{n\times 1} \tag{5}$$

$$\boldsymbol{c} = [c_j]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij} \right]_{n\times 1} \tag{6}$$

where r denotes the sum of the row "i" in matrix T, and c denotes the sum of the column "j" in matrix T.

3.2. **Combining DEMATEL and ANP for calculating the weights of criteria.** ANP is the general form of the analytic hierarchy process (AHP) [27], which has been used in MCDM to relax the restriction of hierarchical structure. Within ANP, there is an outer dependence among clusters and an inner dependence within the criteria of clusters, as illustrated in Figure 3.

According to Ou Yang et al. (2008) [30], a supermatrix normalizes the matrix by assuming each pair of criteria has the same weight. Although such a method can easily normalize it, it also neglects the fact that different groups have a different degree of impact. In this study, the following steps are used:

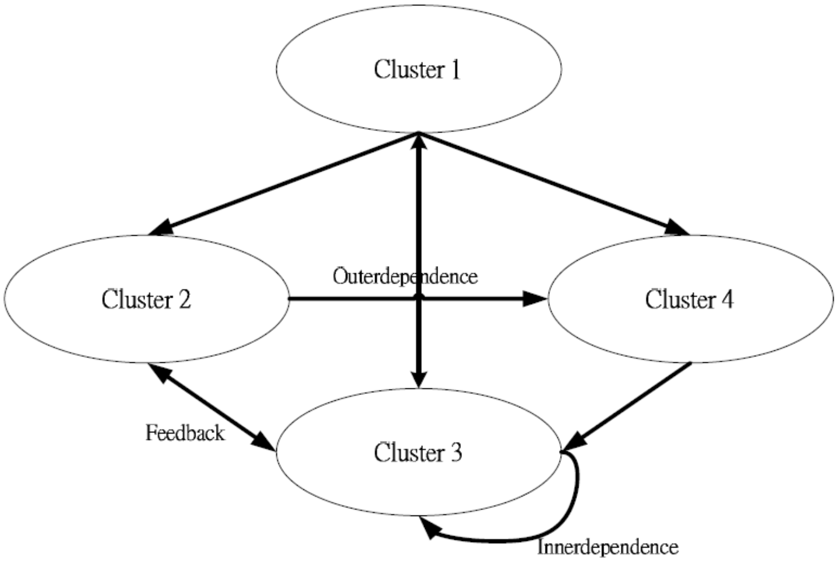

FIGURE 3. Relation of clusters

Step 1: *Compare the criteria in the supermatrix.*

$$\boldsymbol{W} = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ e_{11}e_{12}\cdots e_{1n} & e_{21}e_{22}\cdots e_{2n} & \cdots & e_{N1}e_{N2}\cdots e_{Nn} \end{array} \\ \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n} \end{array} \\ \vdots & \vdots \\ C_n & \begin{array}{c} e_{N1} \\ e_{N2} \\ \vdots \\ e_{Nn} \end{array} \end{array} & \begin{bmatrix} \boldsymbol{W}_{11} & \boldsymbol{W}_{12} & \cdots & \boldsymbol{W}_{1N} \\ \boldsymbol{W}_{21} & \boldsymbol{W}_{22} & \cdots & \boldsymbol{W}_{2N} \\ \vdots & \vdots & & \vdots \\ \boldsymbol{W}_{N1} & \boldsymbol{W}_{N2} & \cdots & \boldsymbol{W}_{NN} \end{bmatrix} \end{array} \quad (7)$$

Step 2: *Obtain the weighted supermatrix by multiplying the normalized matrix, which is derived according to the DEMATEL method.*

$$\boldsymbol{T}_\alpha = \begin{bmatrix} t_{11}^\alpha & \cdots & t_{1j}^\alpha & \cdots & t_{1n}^\alpha \\ \vdots & & \vdots & & \vdots \\ t_{i1}^\alpha & \cdots & t_{ij}^\alpha & \cdots & t_{in}^\alpha \\ \vdots & & \vdots & & \vdots \\ t_{n1}^\alpha & \cdots & t_{nj}^\alpha & \cdots & t_{nn}^\alpha \end{bmatrix} \quad (8)$$

where if $t_{ij} < \alpha$, then $t_{ij}^\alpha = 0$ else $t_{ij}^\alpha = t_{ij}$, and t_{ij} is an ij criteria of the total-influence matrix T. Dividing by the following value makes the α-cut total-influence matrix $\boldsymbol{T}_\alpha$

normalized.

$$d_i = \sum_{j=1}^{n} t_{ij}^{\alpha} \tag{9}$$

Therefore, we normalize the α-cut of the total-influence matrix and denote it as T_n.

$$\begin{aligned} T_n &= \begin{bmatrix} t_{11}^{\alpha}/d_1 & \cdots & t_{1j}^{\alpha}/d_1 & \cdots & t_{1n}^{\alpha}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\alpha}/d_i & \cdots & t_{ij}^{\alpha}/d_i & \cdots & t_{in}^{\alpha}/d_i \\ \vdots & & \vdots & & \vdots \\ t_{n1}^{\alpha}/d_n & \cdots & t_{nj}^{\alpha}/d_n & \cdots & t_{nn}^{\alpha}/d_n \end{bmatrix} \\ &= \begin{bmatrix} t_{11}^{n} & \cdots & t_{1j}^{n} & \cdots & t_{1n}^{n} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{n} & \cdots & t_{ij}^{n} & \cdots & t_{in}^{n} \\ \vdots & & \vdots & & \vdots \\ t_{n1}^{n} & \cdots & t_{nj}^{n} & \cdots & t_{nn}^{n} \end{bmatrix} \end{aligned} \tag{10}$$

where $t_{ij}^{n} = t_{ij}^{\alpha}/d_i$. This study adopts the normalized α-cut total-influence matrix T_n. The unweighted supermatrix W is changed in the weighted supermatrix W_w through Equation (11), which shows the level of influence values in the weighted supermatrix.

$$W_w = \begin{bmatrix} t_{11}^{n} \times W_{11} & t_{21}^{n} \times W_{12} & \cdots & t_{n1}^{n} \times W_{1n} \\ t_{12}^{n} \times W_{21} & t_{22}^{n} \times W_{22} & \cdots & t_{ni}^{n} \times W_{in} \\ \vdots & \vdots & & \vdots \\ t_{1n}^{n} \times W_{n1} & t_{2n}^{n} \times W_{n2} & \cdots & t_{nn}^{n} \times W_{nn} \end{bmatrix} \tag{11}$$

Step 3: *Limit the weighted supermatrix by raising it to a sufficiently large power p, as shown in Equation (12),*

$$\lim_{p \to \infty} W_w^p \tag{12}$$

This formula is limited the weighted supermatrix, when $p \to \infty$, the W_w has converged and become a long-term stable supermatrix.

3.3. **The VIKOR method for ranking and improving the alternatives.** The VIKOR method was developed to optimize complex systems based on multi-criteria. It determines the compromised ranking, the compromised solution, and the weight stability intervals needed to realize the preferred stability of the compromised solution obtained with the initial (given) weights. Suppose the feasible alternatives are represented by $A_1, A_2, \ldots, A_k, \ldots, A_m$. The performance score of the alternative and the jth criterion are denoted A_k and f_{kj}; w_j is the weight (relative importance) of the jth criterion, where $j = 1, 2, \ldots, n$; and n is the number of criteria. The VIKOR method results in the form of L_p-metric:

$$L_k^p = \left\{ \sum_{j=1}^{n} [w_j(|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|)]^p \right\}^{1/p},$$

where $1 \leq p \leq \infty$; $k = 1, 2, \ldots, m$; weight w_j is derived from the ANP. To formulate the ranking and gap measure, $L_k^{p=1}$ (as S_k) and $L_k^{p=\infty}$ (as Q_k) are used in the VIKOR method

[23,24].

$$S_k = L_k^{p=1} = \sum_{j=1}^{n} [w_j(|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|)],$$
$$Q_k = L_k^{p=\infty} = \max_j \{(|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|)|j = 1, 2, \ldots, n\}.$$

The compromised ranking algorithm, as developed by the VIKOR method, has the following steps:

Step 1: *Obtain an aspired or tolerable level.*

$$r_{kj} = (|f_j^* - f_{kj}|)/(|f_j^* - f_j^-|) \tag{13}$$

Step 2: *Calculate the mean of group utility and maximal regret by computing*

$$S_k = \sum_{j=1}^{n} w_j r_{kj} \text{ and } Q_k = \max_j \{r_{kj}|j = 1, 2, \ldots, n\}. \tag{14}$$

Step 3: *Calculate the index value by*

$$R_i = v(S_k - S^*)/(S^- - S^*) + (1 - v)(Q_k - Q^*)/(Q^- - Q^*), \tag{15}$$

where $k = 1, 2, \ldots, m$

Step 4: *Rank or improve the alternatives for a compromised solution. Order them decreasingly by the value of* S_k*,* Q_k *and* R_k*.*

4. **High Performance Project Team at IBM Global Business Services: An Empirical Case Study.** As the world's largest consulting services organization, IBM Global Business Services has over 60,000 experienced professionals working in 160 countries. Combining world-class industry and business process insight with leading technology expertise, IBM Global Business Services provides clients with a broad set of solutions spanning strategic and change management, supply chain management, human capital, information technology, and business process outsourcing.

4.1. **Background and problem description.** Since the 1990s, the environment surrounding management has been complex and variable due to the development of knowledge economics. Enterprises have to leverage their efficiency, elasticity and quality to deal with a contingency or emergency and to ensure they can survive and develop. An increasing number of enterprises are starting to change into project-oriented organizations.

Many organizations are using project teams to manage multiple projects at the same time. Therefore, high performance project team mandates most often include measurable improvement in the management of projects – on time, on budget and meeting customer requirements [2].

4.2. **Data collection.** Project experts and managers (including scholars) were the subjects of this research. A total 20 samples were divided into 12 project team members and 8 PM experts of company. This study was carried out in December 2010, and it took 30 to 60 minutes for every expert to fill out the questionnaires and be interviewed.

4.3. **Calculating weights of fuzzy DEMATEL and ANP.** To analyze the interrelationships between the 17 determinants found in the literature review, the DEMATEL method introduced in Section 3.1 was used. The NRM (Network Relation Matrix) was constructed by $\boldsymbol{r}$ and $\boldsymbol{c}$, the sum of influences given and received on criteria and dimension, as shown in Tables 2 and 3. As a result, a high performance model for project teams (HPPT) was built, as shown in Figure 4.

Table 2. The sum of influences given and received on criteria

Criteria	$\boldsymbol{r_i}$	$\boldsymbol{c_i}$	$\boldsymbol{r_i + c_i}$	$\boldsymbol{r_i - c_i}$
$\boldsymbol{C_1}$	2.43	2.11	4.54	0.31
$\boldsymbol{C_2}$	2.48	2.18	4.66	0.29
$\boldsymbol{C_3}$	2.24	1.87	4.12	0.37
$\boldsymbol{C_4}$	2.10	2.14	4.24	−0.04
$\boldsymbol{C_5}$	2.06	2.13	4.19	−0.06
$\boldsymbol{C_6}$	2.17	2.10	4.27	0.07
$\boldsymbol{C_7}$	2.05	2.18	4.23	−0.13
$\boldsymbol{C_8}$	2.18	1.67	3.85	0.51
$\boldsymbol{C_9}$	2.27	1.71	3.99	0.56
$\boldsymbol{C_{10}}$	2.14	2.19	4.33	−0.05
$\boldsymbol{C_{11}}$	1.91	1.92	3.83	−0.01
$\boldsymbol{C_{12}}$	2.00	2.12	4.12	−0.12
$\boldsymbol{C_{13}}$	2.04	1.78	3.82	0.26
$\boldsymbol{C_{14}}$	1.89	1.82	3.70	0.07
$\boldsymbol{C_{15}}$	1.85	2.67	4.53	−0.82
$\boldsymbol{C_{16}}$	1.85	2.66	4.51	−0.81
$\boldsymbol{C_{17}}$	2.02	2.42	4.43	−0.40

Table 3. The sum of influences given and received on dimensions

Dimensions	$\boldsymbol{r_i}$	$\boldsymbol{c_i}$	$\boldsymbol{r_i + c_i}$	$\boldsymbol{r_i - c_i}$
$\boldsymbol{D_1}$	0.69	0.61	1.30	0.08
$\boldsymbol{D_2}$	0.62	0.62	1.24	−0.00
$\boldsymbol{D_3}$	0.65	0.54	1.19	0.10
$\boldsymbol{D_4}$	0.58	0.56	1.14	0.02
$\boldsymbol{D_5}$	0.56	0.76	1.32	−0.20

According to the literature review described in Section 2, internal and external factors of a team can be generalized into five dimensions and seventeen criteria. The five dimensions are team organization, team process, team structure, teamwork and team effectiveness standards. A high performance model of the project team is shown in Figure 4.

Figure 4 depicts the impact-direction map for an HPPT building model, that is identified the dimension and criteria that were found influential in HPPT building criteria by reviewing the literature to construct the theoretical model.

Scholars and managers of projects were studied in the primary survey. The level of importance (global weights) of 17 criteria was calculated by ANP. According to the ranking order of criteria's weights from experts, we acknowledge the priorities of the criteria. In this research of building HPPT decision model, the experts considered that "Performance" (C_{15}) and "Satisfaction" (C_{16}) are the most important criteria (weight is 0.083). Also, experts consider "Cohesion" (C_{17}) is important as well (weight is 0.076), shown in Table 4.

4.4. **Compromise ranking by VIKOR.** The VIKOR model was applied to the ranking after the weights of determinants were calculated by ANP in Section 4.3. For the selection of a program in the project planning office at IBM, 12 project team members and 8 project management experts gave scores from 1 to 10. The selected program gave the result as shown in Table 5.

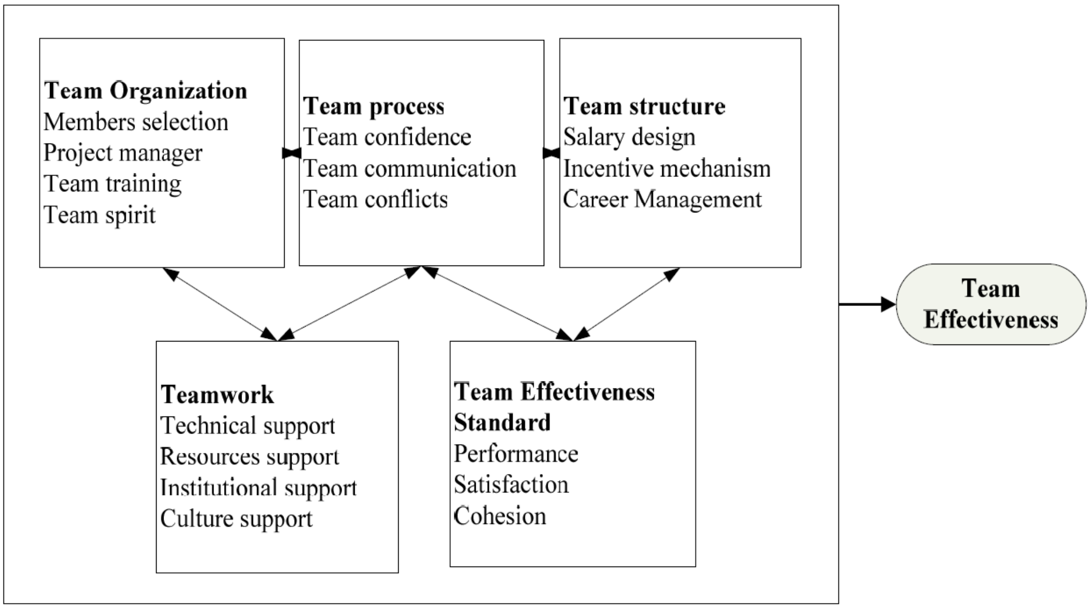

FIGURE 4. High performance model of the project team

TABLE 4. The weights of criteria for evaluating elements of a PMO

Dimensions/Criteria	Local Weight	Global Weight (by ANP)
Team organization	***0.197***	
Members selection	*0.254*	*0.050 (11)*
Project manager	*0.264*	*0.052 (9)*
Team training	*0.223*	*0.044 (13)*
Team spirit	*0.259*	*0.051 (10)*
Team process	***0.201***	
Team confidence	*0.333*	*0.067 (5)*
Team communication	*0.328*	*0.066 (6)*
Team conflicts	*0.338*	*0.068 (4)*
Team structure	***0.176***	
Salary design	*0.301*	*0.053 (8)*
Incentive mechanism	*0.307*	*0.054 (7)*
Career Management	*0.392*	*0.069 (3)*
Teamwork	***0.184***	
Technical support	*0.245*	*0.045 (12)*
Resources support	*0.272*	*0.050 (11)*
Institutional support	*0.245*	*0.045 (12)*
Culture support	*0.239*	*0.044 (13)*
Team effectiveness standard	***0.242***	
Performance	*0.343*	*0.083 (1)*
Satisfaction	*0.343*	*0.083 (1)*
Cohesion	*0.314*	*0.076 (2)*

Table 5. The weights of criteria and total performance

Dimensions/Criteria	Local Weight	Global Weight (by ANP)	HPPT	
			score	gap
Team organization	***0.197***		***6.726***	***0.159***
Members selection	*0.254*	*0.050 (11)*	*5.667*	*0.217*
Project manager	*0.264*	*0.052 (9)*	*8.000*	*0.104*
Team training	*0.223*	*0.044 (13)*	*5.333*	*0.205*
Team spirit	*0.259*	*0.051 (10)*	*7.667*	*0.119*
Team process	***0.201***		***8.557***	***0.097***
Team confidence	*0.333*	*0.067 (5)*	*8.667*	*0.089*
Team communication	*0.328*	*0.066 (6)*	*8.333*	*0.110*
Team conflicts	*0.338*	*0.068 (4)*	*8.667*	*0.091*
Team structure	***0.176***		***6.123***	***0.223***
Salary design	*0.301*	*0.053 (8)*	*4.333*	*0.300*
Incentive mechanism	*0.307*	*0.054 (7)*	*6.333*	*0.198*
Career Management	*0.392*	*0.069 (3)*	*7.333*	*0.184*
Teamwork	***0.184***		***6.576***	***0.158***
Technical support	*0.245*	*0.045 (12)*	*6.000*	*0.180*
Resources support	*0.272*	*0.050 (11)*	*6.333*	*0.183*
Institutional support	*0.245*	*0.045 (12)*	*7.333*	*0.120*
Culture support	*0.239*	*0.044 (13)*	*6.667*	*0.147*
Team effectiveness standard	***0.242***		***7.219***	***0.225***
Performance	*0.343*	*0.083 (1)*	*7.000*	*0.249*
Satisfaction	*0.343*	*0.083 (1)*	*7.333*	*0.221*
Cohesion	*0.314*	*0.076 (2)*	*7.333*	*0.203*

According to the scores from experts, research findings indicated that the dimensions of highest importance is "Team process" (D_2), scored at 8.557, followed by "Team effectiveness standard"(D_5) at 7.219 and "Team organization" (D_1) at 6.726.

5. **Conclusions.** This research adopts a novel MCDM model, including DEMATEL and ANP, for exploring high performance project team. We prove that all criteria influence one another and find relative importance of essential criteria of HPPT.

In evaluating the HPPT model, experts considered performance and satisfaction to be the most important criteria (the weight is 0.083). This shows that in the limited time and cost, program managers of organization should consider that first when they have to build the HPPT.

Program managers should also consider "cohesion" because this is the second most important criterion in building an HPPT (cohesion has a weight of 0.076). In addition, Figure 4 depicts the impact-direction map for an HPPT model. This map identifies the dimensions and criteria that were found to be influential in HPPT by reviewing literature. These dimensions and criteria were used to construct the theoretical model, applying the novel MCDM to explore the relationships among criteria, and surveying experts for the optimal priorities in building an HPPT.

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