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Evaluation of Key Team Integration Indicators for New Product Success by Using a Two-step Methodology

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Abstract: Project team integration relates directly to the New Product Development (NPD) success. However, in new product management practice, there are too many team integration indicators to distinguish the importance of them. To solve the problem, this paper investigates the key integration indicators of project team, according to the influence of integration indicators on NPD success. Firstly, we constructed the evaluation model of integration indicator. Then, a two-step Fuzzy Analytic Hierarchy Process (FAHP) and Support Vector Regression (SVR) methodology was used to analyze the weights of NPD success factors and the optimal integration indicators. An F-test was also applied to identify the importance sequence of key integration indicators. The findings show that collective sense, information sharing, commitment from top management and leadership are the key indicators for NPD success. Finally, implications for research and practice are discussed.

Key words: New product success, team integration, key indicator, new product team

INTRODUCTION

As world economies evolve, New Product Development (NPD) is coming to rely more and more on team members from different disciplines and functions working collectively toward a common goal (Gemser and Leenders, 2011). In order to meet the ascension of the customers' needs and hyper-competitive business environments it is necessary for firms to integrate multi-disciplinary professional skills and knowledge into the process of product development and innovation (Nonaka *et al*., 2000). Accordingly, an increasing number of organizations design tasks around multi-disciplinary project teams and new product team integration is thought to be critical to new product success (Song *et al*., 1998). However, during the management practice of NPD process, there are too many team integration factors for the management practitioners to deal with. Thus, identifying the key team integration indicators is of great significance for new product success.

Issues related to team integration has brought increased attention in both theoretical and empirical study. Ibrahim *et al*. (2011) generalized indicators of team integration into seamless operation, communication, sharing Information, trust and respect, collective understanding, commitment from top management, 'no blame' culture and team flexibility. Baiden and Price (2011) interviewed nine project manager and pointed that team integration could improve cooperation performance. However, the proposed team integration indicator framework above mainly considered the member relationship, neglected the functions of leadership which is also important for team cohesion and integration (Wendt *et al*., 2009). Magent *et al*. (2009) treated team integration as one of project attributes and examined the project attributes on performance. Although the proposed framework is more reasonable, the differences between the weights of performance indicators are still lack of focus. Moreover, many scholars also explored the effects of single team integration indicators (i.e. knowledge integration and behavior integration) on NPD success (Carmeli and Schaubroeck 2006; Jayaram and Pathak, 2013). The comparison among different team integration indicators remains absent. NPD management practitioners are still not able to realize new product project success effectively through team integration.

In sum, to fill these gaps, in this paper we conduct a research on the evaluation of key team integration factors for NPD success by using a two-step Fuzzy Analytic Hierarchy Process (FAHP) and Support Vector Regression (SVR) methodology (Fig 1).

EVALUATION MODEL OF INTEGRATION INDICATOR

Integration indicator: In a highly integrated NPD team, the goal of team members is more consistent and the experts from different disciplines will have a better cooperation (Gemser and Leenders, 2011). Thus it is more likely for a highly integrated NPD team to achieve new product success. In light of Baiden *et al*. (2006), Baiden

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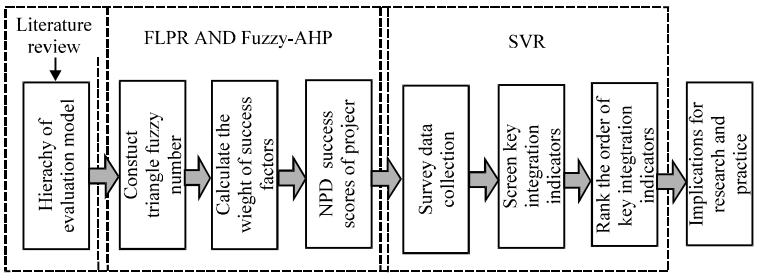

Fig. 1: Research process for this study

and Price (2011) and Ibrahim *et al.* (2011), the team integration indicators can be described as follows:

- Collective sense-all the team members put team objectives at the most important place and hardworking for them
- Seamless operation-operates without boundaries among the various organization members
- 'No blame' culture-a 'no blame' culture that encourages team members to meet their responsibilities together
- Information sharing- shares information freely among its members so that access is not limited to specific professions within the team
- Trust-everyone trusts each other in the NPD team
- Work collectively-has a new identity and is co-located, usually in a given common space
- Commitment from top management-the project team can get commitment form the senior management of that company
- Team flexibility-has a flexible member composition and can respond to change over the duration of the project
- Team prediction-is able to predict more accurately, time and cost estimates by fully use the collective skills and expertise of all team members
- Gain sharing-works towards mutually beneficial outcomes by ensuring that all the members support each other and achievements are shared throughout the team
- Leadership-evaluates the level of emotional, intellectual and managerial quality of team leaders
- Equal rights-offers its members equal opportunities

Dimensions of new product success measurement at the project level: According to the previous studies, a large number of success indicators had been used. Although many researchers have suggested that new product success should be measured using multiple criteria and that success could be measured at different levels, the most widely used success measures have been developed at a project level (Huang *et al.*, 2004). Thus, in this study we will conduct a research on the effects of team integration indicator on the new product success which is measured at the project level. According to the work of Huang *et al.* (2004), Cooper and Kleinschmidt (1987) and Griffin and Page (1996), We constructed a three-dimensions' product success framework which including fifteen indicators. The dimensions and indicators listed as follows:

- Financial performance- includes break-even time attain margin goal, attain profitability goal and attain return on investment goal
- Customer acceptance-includes meet revenue goal, revenue growth, meet market share goal, meet unit share goal, customer acceptance from emotions and customer satisfaction
- Technical measures-includes development cost, launched on time, achieve product performance goal, meet quality guideline and speed to market

After definition the indicators in this study, the hierarchy of team integration indicators evaluation is constructed, with the integration indicators as alternative, the product development success factors as criteria. The objective of the hierarchy model is to evaluate the key integration indicators for new product succes (Table 1)

EVALUATION OF THE INTEGRATION INDICATOR DIFFERENCES

A FLPR and FAHP based method for weight calculation: Considering the contribution of success factors to NPD success varies from each other it is necessary to distinguish the weights of each factor before evaluating the new product success of NPD project. Analytic Hierarchy Process (AHP) method is a suitable method to establish the weights of criteria. However, it mainly focuses on the decision matrix with crisp values which

Table 1: Hierarchy of team integration indicators evaluation

Objective	Criteria	Altemative
Evaluation the key team integration factors for NPD success		
Financial performance	(1) break-even time	(1) Collective sense
	(2) attain margin goal	(2) Seamless operation
	(3) profitability goal	(3) 'No blame' culture
	(4) return on investment	(4) Information sharing
Customer acceptance	(1) revenue goal	(5) Trnst
	(2) revenue growth	(6) Work collectively
	(3) market share goal	(7) Commitment from top management
	(4) unit share goal	(8)Team flexibility
	(5) customer acceptance from emotions	(9) Team prediction
	(6) customer satisfaction	(10) Gain sharing
Technical measures	(1) development cost	(11) Leadership
	(2) launched on time	(12) Equal rights
	(3) achieve product performance goal	-
	(4)meet quality guideline	-
	(5) speed to market	-

cannot reject expert opinions when modeling imprecise judgments. To solve the problem, the weights of success factors are calculated by a Fuzzy Linguistic Preference Relation (FLPR) and improved Fuzzy Analytic Hierarchy Process (FAHP) approach, proposed by Wang and Chen (2008). In addition it requires only n-1 comparison judgments to ensure consistency for a level with n criteria which reduces the workload and further improves the computing accuracy.

Given $A=\{a_1,a_2\ldots a_n\}$, with n>2 is a finite set of alternatives to be pairwise assessed by experts. r_{ij} denotes the degree to which experts prefer a_i to a_j. Considering r_{ij} is measured by a 1-9 scale, thus $r_{ij}\in(1/9,9)$. Fuzzy linguistic preference relation (P_{ij}) is similar to r_{ij} and can be conversed by equation 1:

$$P_{ij} = g(r_{ij}) = 1/2(1+\log_9 r_{ij}) \quad (1)$$

For a reciprocal fuzzy preference relation P_{ij}, the following statements are equivalent:

$$P_{ij} + P_{jk} + P_{ki} = 3/2 \quad \forall i < j < k \quad (2)$$

$$P_{i(i+1)} + P_{(i+1)(i+2)} + \ldots + P_{(i+k-1)(i+k)} + P_{(i+k)i} = (k+1)/2 \quad \forall i \quad (3)$$

According to consistent fuzzy preference relations and fuzzy linguistic assessment variables, fuzzy preference relations matrices $\tilde{P} = (\tilde{p}_{ij}) = (p_{ij}^L, p_{ij}^M, p_{ij}^R)$ is established and the assignment values are shown in Table 2. To ensure the consistency of fuzzy preference relationship matrices, the variables in fuzzy preference relations matrices should meet the following equations:

$$P_{ij}^L + P_{ji}^R = 1 \quad \forall i,j \in \{1,\ldots n\} \quad (4a)$$

$$P_{ij}^M + P_{ji}^M = 1 \quad \forall i,j \in \{1,\ldots n\} \quad (4b)$$

Table 2: Assignment to fuzzy linguistic evaluation variables

Linguistic variables	Triangle fuzzy No.
Very poor (VP)	(0,0,0.1)
Poor (P)	(0,0.1,0.3)
Medium poor (MP)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium good (MG)	(0.5,0.7,0.9)
Good (G)	(0.7,0.9,1)
Very good (VG)	(0.9,1,1)

$$P_{ij}^R + P_{ji}^L = 1 \quad \forall i,j \in \{1,\ldots n\} \quad (4c)$$

$$P_{i(i+1)}^L + P_{(i+1)(i+2)}^L + \ldots + P_{(i+n-1)(i+n)}^L + P_{(i+n)(i)}^R = (n+2)/2 \ \forall i \in \{1,\ldots n\} \quad (5a)$$

$$P_{i(i+1)}^M + P_{(i+1)(i+2)}^M + \ldots + P_{(i+n-1)(i+n)}^M + P_{(i+n)(i)}^M = (n+2)/2 \ \forall i \in \{1,\ldots n\} \quad (5b)$$

$$P_{i(i+1)}^R + P_{(i+1)(i+2)}^R + \ldots + P_{(i+n-1)(i+n)}^R + P_{(i+n)(i)}^L = (n+2)/2 \ \forall i \in \{1,\ldots n\} \quad (5c)$$

Notably, if the values of the obtained matrix P_{ij} is in the interval [-c, 1+c] (c>0), not in the interval [0, 1], the obtained fuzzy numbers would need to be transformed to avoid the reciprocity and additive consistency:

$$f(P_{ij}^L) = P_{ij}^L/(1+2c) + c/(1+2c) = (P_{ij}^L + c)/(1+2c) \quad (6a)$$

$$f(P_{ij}^M) = P_{ij}^M/(1+2c) + c/(1+2c) = (P_{ij}^M + c)/(1+2c) \quad (6b)$$

$$f(P_{ij}^R) = P_{ij}^R/(1+2c) + c/(1+2c) = (P_{ij}^R + c)/(1+2c) \quad (6a)$$

Then, the weights of criteria can be calculated as follows:

$$\tilde{P}_i = [\tilde{P}_{i1} \times \tilde{P}_{i2} \times \ldots \times \tilde{P}_{in}]^{1/n} \quad \forall i \in \{1,\ldots n\} \quad (7)$$

Table 3: Fuzzy linguistic preference relation score for success factors

C		C1		C2		C3	
C_1-C_2	MG	C_{1A}-C_{1B}	MP	C_{2A}-C_{2B}	M	C_{3A}-C_{3B}	MP
C_2-C_3	G	C_{1B}-C_{1C}	VG	C_{2B}-C_{2C}	G	C_{3B}-C_{3C}	MG
		C_{1C}-C_{1D}	M	C_{2C}-C_{2D}	MG	C_{3C}-C_{3D}	MG
				C_{2D}-C_{2E}	M	C_{3D}-C_{3E}	MP
				C_{2E}-C_{2F}	G		

Table 4: Contribution weights of cooperative performance indicators

C		C_1		C_2		C_3	
C_1	0.46	C_{1A}	0.32	C_{2A}	0.22	C_{3A}	0.3
C_2	0.38	C_{1B}	0.39	C_{2B}	0.22	C_{3B}	0.32
C_3	0.23	C_{1C}	0.18	C_{2C}	0.18	C_{3C}	0.26
		C_{1D}	0.18	C_{2D}	0.16	C_{3D}	0.2
				C_{2E}	0.16	C_{3E}	0.27
				C_{2F}	0.13		

$$\tilde{w}_i = \tilde{P}_i / (\tilde{P}_{i1} \times ... \times \tilde{P}_{in}) \quad \forall i \in \{1,..n\} \tag{8}$$

Results of weight calculation: Before we began to calculation the weights in criteria, the three dimensions and fifteen success factors are numbered:

- (C_1) financial performance, (C_{1A}) break-even time, (C_{1B}) attain margin goal, (C_{1C}) profitability goal, (C_{1D}) return on investment
- (C_2) objective customer acceptance, (C_{2A}) revenue goal, (C_{2B}) revenue growth, (C_{2C}) market share goal, (C_{2D}) unit share goal, (C_{1E}) customer acceptance from emotions, (C_{1F}) customer satisfaction
- (C_3) technical measures, (C_{3A}) development cost, (C_{3B}) launched on time, (C_{3C}) achieve product performance goal, (C_{3D}) meet quality guideline, (C_{3E}) speed to market

Experts were asked to express according to one of the opinions contained in Table 2. Table 3 lists the pairwise comparison matrix for the goal and all criteria, based on the experts' fuzzy linguistic preference relation scores. Table 4 lists the weights of NPD success factors.

KEY INTEGRATION INDICATORS FOR NPD SUCCESS

Data collection: The integration of new product team aims to increase ability of product competition and to achieve project success (Sarin and Mahajan, 2001). Considering NPD teams were widely used in high-tech industries and team integration is highly emphasized in their high level of product development activity (Henderson and Lee, 1992). High-tech industry in China was chosen to be treated as a context for our study. We contacted 48 high-tech enterprises that were randomly selected from the Chinese Top 500 enterprises list, and 31 enterprises agreed to participate in the study. The questionnaire was adapted from the work of Baiden and Price (2011), Huang *et al.* (2004) and Muller *et al.* (2012), including 15 scales for NPD success and 12 scales for team integration. The items were measured on a seven-point likert scale (with 1= strongly disagree and 7 = strongly agree). In order to ensure all the issues were well-understood, a pilot study was conducted before the data was collected.

In the data collection phase, a web-based questionnaire was administered to 109 team leaders or NPD managers from 109 new product projects. All individuals were contacted by using e-mail with a link to web survey. At last, 84 responses were obtained and 69 responses were fully useable. The 15 success factors of each project were summed according to the weights calculated in table 4 and the values were treated as NPD success scores for further research.

Evaluation for key integration indicators: In general, analysis of key integration indicators can be realized through traditional regression methods based on a linear hypothesis, such as multiple linear regression, stepwise linear regression and partial least-squares regression. However, the integration indicators in this study not only have a complex effect on NPD success but also on each other which is not a simple linear relationship. Besides, the accuracy of above regression methods highly rely on the sample size. When the sample size is small it is hardly to achieve a significant result. Moreover, multiple linear regression and partial least-squares regression are not able to reduce the numbers of variables. Thus, if numbers of variables become much greater it is hard to acquire an accurate result. Given the limitations above, support vector regression is employed in this study which is effective to avoid the problems brought by small sample, nonlinear and dimensional disaster.

The SVR version used in our study is LIBSVM 2.88. The kernel function is Radial Basis Function (RBF). The optimal values of punish coefficient C, kernel function parameter g and the loss function parameters p are calculated through the search function of software (C□[100,1000] step 50, g□[0,5] step 1, log2p□[-10,1] step 1) (Chang and Lin, 2011).

Taking the NPD success as dependent variable Y, team integration indicators as independent variable X, including collective sense (X_1), seamless operation (X_2), 'No blame' culture (X_3), information sharing (X_4), trust (X_5), work collectively (X_6), commitment from top management (X_7), team flexibility (X_8), objective customer acceptance (X_9), gain sharing (X_{10}), leadership (X_{11}), equal rights (X_{12}). We got rid of the independent variables one after another, calculated the Mean Square Error (MSE)

Table 5:Results of screening integration indicators of project team

Round	MSE	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	Del
1	13.85	13.11	11.04	6.72	7.23	8.26	5.84	13.24	10.66	7.56	14.37	8.94	10.18	X_6
2	5.84	10.62	10.42	5.17	8.12	7.23	-	8.72	9.39	4.91	6.15	6.23	7.52	X_3
3	5.17	6.01	6.36	-	7.58	7.93	-	9.16	3.88	4.85	11.68	7.49	7.09	X_8
4	3.88	11.59	5.45	-	4.09	2.48	-	7.56	-	3.83	10.02	4.17	6.50	X_5
5	2.48	6.95	6.53	-	2.34	-	-	4.12	-	1.54	7.09	2.91	3.93	X_9
6	1.54	2.66	1.53	-	1.56	-	-	1.42	-	-	0.51	0.92	1.11	X_{10}
7	0.51	2.44	0.31	-	0.35	-	-	6.81	-	-		2.24	0.55	X_2
8	0.31	0.61	-	-	0.26	-	-	1.78	-	-		0.56	0.16	X_{12}
9	0.16	0.84	-	-	0.43	-	-	1.04	-	-		0.33	-	-

accordingly. The independent variable X_n was eliminated, if it was not able to improve the accuracy of prediction. For example, MSE denotes the mean square error value influenced by 12 independent variables and MSE (i) denotes the mean square error value when X_i (i = 1,2,...12) is got rid of. If MSE>MSE (j) = min[MSE(i)], the independent variable X_j is eliminated. Take MSE(j) as the new MSE value and test the remaining 11 independent variables. Repeat this step until MSE<min[MSE(i)] and the key integration factors that most related to NPD success can be obtained. Then, we conduct a F-test for SVR, proposed by Tan *et al.* (2009).

The results of screening integration indicators are listed in Table 5, where collective sense (X_1), information sharing (X_4), commitment from top management (X_7) and leadership (X_{11}) are the key indicators for NPD success. F values of each key integration indicators are : F_{X1}=52.1, F_{X4}=29.4, F_{X7}=18.3, F_{X11}=34.7. Thus, we obtained the sequence of most important integration indicators: F_{X1} (collective sense)>F_{X11} (leadership)>F_{X4} (information sharing)>F_{X7} (commitment from top management).

CONCLUSION

NPD team integration which is crucial to NPD project success, has been emphasized in many studies. However, there are too many integration indicators for NPD managers to deal with and the issues related to what are the key integration factors are still unclear. To solve the problem, we conducted a research to identify the key team integration indicators from three NPD success dimensions (financial performance, customer acceptance and technical measures) and outlined the most important indicators for NPD success.

In previous study, the investigations on team integration mainly focus on the mutual relationship between team members and leadership is not considered as an integration indicator. However, an excellent team leader possesses not only good decision and strain capacities bualso the abilities to motivate the team members and to enhance the cohesion of team. Accordingly, leadership should be closely related to team integration. According the results, leadership is the key indicator for NPD success which is more significant than many other integration indicators in achieving project success. Thus it is reasonable to take leadership as a team integration indicator.

Our findings also showed that collective sense, information sharing, commitment from top management and leadership were key indicators for NPD success. Although there are quite a lot of indicators, not all the indicators are essential for NPD project management. By screening the key integration indicator, the decision supports can be provided for NPD managers and team leaders in their management activities. Moreover, the difficulty of integration indicator control varies in different NPD projects. The management practitioners should synthesize external and internal contexts in their decision making process.

Like other studies, this one also has its limitation. In the evaluation process, we mainly focus on the effects of the independent variables on dependent variables, neglecting the interactions between the independent variables. In addition, the mechanisms about how team integration indicators effect NPD success are also lacked. The problems need to be further solved in a follow-up study.

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