Chapter 3
A Priority Analysis Algorithm for Technology Innovation Risks of Research Solutions for Complex Project

Ning-sheng Guo and Xiansheng Qin

Abstract For complex project, there are many risks about technology innovation according to multifarious research solutions. It is very difficult to analyze the magnitude of these risks of research solutions. This paper purposed a priority analysis algorithm for technology innovation risks (TIR) of research solutions for complex project based on multi-objective and colony-deciding method to choose the research solution by the constraints of multifarious risks. The multi-objective and colony-deciding method is applied to analyze project complexity, technology difficulty, technique capability and so on to obtain multi-TIRs sequence, and the research solution of minimal TIR is optimum. The algorithm is successful to analysis an example which performed quiet well.

Keywords Technology innovation risk (TIR) · Research solution · Priority analysis · Multi-objects · Colony-deciding

3.1 Introduction

For complex project, there are many risks about technology innovation according to multifarious research solutions. It is very difficult to analyze the magnitude of these risks of research solutions. There are two type of risk management: risk analysis and risk quantification. For risk analysis, there are risk analysis based on the triangular fuzzy number and Analytic Hierarchy Process (Zou et al. 2012; Chen et al. 2012), and expert evaluation (Yang et al. 2011; Fallet et al. 2011; Hall 2011). This paper will analysis the multi-objects constrains as project complexity, technology difficulty, technique capability and so on, apply the colony-deciding

N. Guo (✉) · X. Qin
School of Mechanical Engineering, Northwestern Polytechnical University,
Xi'an, China
e-mail: guons2012@163.com

E. Qi et al. (eds.), *The 19th International Conference on Industrial Engineering and Engineering Management*, DOI: 10.1007/978-3-642-38427-1_3,
© Springer-Verlag Berlin Heidelberg 2013

method (Zhang 2008; Quan-lin and Hong 2003) to solve the sequence of TIRs of research solutions, to gain the research solution whose TIR is minimal.

3.2 TIRs' Priority of Research Solutions for Complex Project

The TIRs' priority of multifarious research solutions for complex project based on colony-deciding method was analyzed by $l(l \geq 3)$ experts made up of project managers, research experts, experiment experts, and so on. Under the restrictions of project complexity, technology difficulty and technique capability, the experts define the TIRs' Priority relationship between two research solutions, and perform the deciding process of non-negative priority degree $\beta(\beta \geq 0)$ with the coefficient $w = (w_1, w_2, \ldots w_{n-1})^T$ which means:

$$I_k = \left\{ |(k(t), k'(t))| Tir_{k(t_k)} \succ Tir_{k'(t_k)}, t = 1, 2, \ldots, t_k \right\}.$$

Tir_k is the kth research solution.

Suppose the number of research solutions for a complex project is n, and the research solutions can be performed as $Tir_1, Tir_2, \ldots, Tir_n$; the number of constrain objects is supposed to be m, and the constrain objects can be performed as $P_1, P_2, \ldots, P_m$; (There constrain objects are project complexity, technology difficulty, technique capability, and so on); the number of experts coming from project manager, research and experiment who take part in the decision supposed to be l.

Each TIR according to constrain objects can be performed as matrix T, which means:

$$T = \begin{bmatrix} t_{11} & t_{12} & \ldots & t_{1m} \\ t_{21} & t_{22} & \ldots & t_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ t_{n,1} & t_{n,2} & \ldots & t_{n,m} \end{bmatrix}.$$

t_{ij} stands for the constrain objects P_j of Tir_i, and $0 \leq t_{ij} \leq 1$, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$.

Purpose that $W \subset E_+^n$ represents the closed convex cone, W represents the important degree of each constrain object. Each expert comes to agree a preference among the attributes. Such as: $W = \left\{ w \subset E_+^n | w_1 \geq w_2 \geq \cdots \geq w_n \geq 0 \right\}$, where $w = (w_1, w_2, \ldots, w_n)^T$.

If $\exists \beta \in E^1$, and

$$(w_1, w_2, \ldots, w_n)^T \in W \cap \left\{ w | e^T w = 1, w \geq 0 \right\}.$$

which made $\sum_{i=1}^{n} w_k a_{ik} \geq \sum_{i=1}^{n} w_k a_{jk} + \beta$, and Tir_i was priority of Tir_j as DIO β, which means $Tir_i \succ Tir_j$, $a_s^r = (a_{r1} - a_{s1}, a_{r2} - a_{s2}, \ldots, a_{rn} - a_{sn})$. Where $1 \leq i, j \leq n$, $i \neq j$, $e = (1, 1, \ldots, 1)^T \in E^n$, and $(r, s) \in \bigcup_{k=1}^{l} I_k$.

We purpose $\bar{\beta} \geq 0$,

$\bar{w} = (\bar{w}_1, \bar{w}_2, \ldots, \bar{w}_{n-1})^T \in W$, $e^T \bar{w} = 1, \bar{w} \geq 0$

which made $a_r^s \bar{w} \geq \bar{\beta}$, $(r, s) \in \bigcup_{k=1}^{l} I_k$. $\bar{w}$ is accordant and $\bar{\beta}$ is the accordant exponent in the TIR.

3.3 Priority Analysis Algorithm of TIRs Based on Multi-Objective and Colony-Deciding Method

The priority analysis algorithm for TIRs based on multi-objective and colony-deciding method can be described as:

(1) The priority relationship of TIRs of the research solution from l experts coming from project manager, research and experiment can be described as:

$$Tir_{k(1)} \succ Tir_{k'(1)}, Tir_{k(2)} \succ Tir_{k'(2)}, \ldots, Tir_{k(t_k)} \succ Tir_{k'(t_k)}, k = 1, 2, \ldots, l$$

Where:

$$k(t), k'(t) \in \{1, 2, \ldots, n\}, k(t) \neq k'(t), t = 1, 2, \ldots, t_k, t_k \geq 1$$

Marked as:

$$I_k = \left\{ |(k(t), k'(t))| Tir_{k(t_k)} \succ Tir_{k'(t_k)}, t = 1, 2, \ldots, t_k \right\}$$
$$a_s^r = (a_{r1} - a_{s1}, a_{r2} - a_{s2}, \ldots, a_{rn} - a_{sn})$$

Where $(r, s) \in \bigcup_{k=1}^{l} I_k$.

(2) for the instants:

$$(P) \begin{cases} \max \beta, \\ a_r^s w \geq \beta, (r, s) \in I_k, \\ e^T w = 1, w \geq 0, w \in W. \end{cases}$$

Purposed the optimal solution is $\left(\hat{w}, \hat{\beta}\right)$, if $\hat{\beta} \geq 0$, then priority relationship made by the experts coming from project manager, research and experiment is harmonious.

$$Tir_r \succ Tir_s, \ (r, s) \in \bigcup_{k=1}^{l} I_k$$

And $\hat{w}$ is the accordant; if $\hat{\beta} < 0$, go to(3).

(3) marked $I_k = \left\{(r,s)|a_s^r\hat{w} = \hat{\beta}, (r,s) \in I_k\right\}$, $k = 1, 2, \ldots, l$,$\forall\ (r', s') \in \mathop{\cup}\limits_{k=1}^{l} \hat{I}_k$, to solve:

$$\left(P_{s'}^{r'}\right)\begin{cases} \max\ a_{s'}^{r'}\hat{w}, \\ a_r^s w \geq \hat{\beta}, (r,s) \in \hat{I}_k, \\ e^T w = 1, w \geq 0, w \in W. \end{cases}$$

Purpose the optimal solution of $\left(P_{s'}^{r'}\right)$ is: $\hat{w}$, $(r', s') \in \mathop{\cup}\limits_{k=1}^{l} \hat{I}_k$.

Marked as

$$\hat{\hat{I}}_k = \left\{(r', s')|a_{s'}^{r'}w_{s'}^{r'} = \hat{\beta}, (r', s') \in \hat{I}_k\right\}, k = 1, 2, \ldots, l$$

(4) The experts can modify the priority relationship between the research solutions, according to two instances. (1) giving up the priority relationship $Tir_{r'} \succ Tir_{s'}$; (2) upending the relationship, which means transforming $Tir_{r'} \succ Tir_{s'}$ to $Tir_{s'} \succ Tir_{r'}$.

(5) If the first instance is chosen, all experts decide to give up the priority relationship $Tir_{r'} \succ Tir_{s'}$. Then it was equal to solve $\left(\bar{w}, \bar{\beta}\right)$ as:

$$\left(\hat{P}_1\right)\begin{cases} \max\ \beta, \\ a_r^s w \geq \beta, (r,s) \in \mathop{\cup}\limits_{k=1}^{l} I_k \backslash \mathop{\cup}\limits_{k=1}^{l} \hat{\hat{I}}_k, \\ e^T w = 1, w \geq 0, w \in W. \end{cases}$$

Otherwise if the second instance is chosen, all experts decide to upend the relationship and to transform $Tir_{r'} \succ Tir_{s'}$ to $Tir_{s'} \succ Tir_{r'}$. Then it was equal to solve $\left(\bar{w}, \bar{\beta}\right)$ as:

$$\left(\hat{P}_2\right)\begin{cases} \max\ \beta, \\ a_r^s w \geq \beta, (r,s) \in \mathop{\cup}\limits_{k=1}^{l} I_k \backslash \mathop{\cup}\limits_{k=1}^{l} \hat{\hat{I}}_k, \\ a_r^s w \geq \beta, (r,s) \in \mathop{\cup}\limits_{k=1}^{l} \hat{\hat{I}}_k, \\ e^T w = 1, w \geq 0, w \in W. \end{cases}$$

(6) If $\bar{\beta} \geq 0$, then $\bar{w}$ was the accordant made by l experts coming from project manager, research and experiment; otherwise if $\bar{\beta} < 0$, repeat(3), until $\bar{\beta} \geq 0$.

3.4 Instance Analysis

We select a project from the National High-Tech R&D Program. There are four research solutions of this project. And the four solutions have their own TIRs: $Tir_1, Tir_2, Tir_3, Tir_4$. For the multi-objects constrains from project complexity, technology difficulty and technique capability, four experts coming from project manager, research and experiment must decide which research solution be selected. And $W \subset E_+^4$. The four experts give the initial relationship between two TIRs as follows:

$$\begin{cases} Expert1: Tir_1 \succ Tir_2, I_{11} = \{(1,2)\}; Tir_4 \succ Tir_3, I_{12} = \{(4,3)\}; \\ Expert2: Tir_1 \succ Tir_2, I_{21} = \{(1,2)\}; Tir_1 \succ Tir_3, I_{22} = \{(1,3)\}; \\ Expert3: Tir_2 \succ Tir_3, I_{31} = \{(2,3)\}; Tir_4 \succ Tir_1, I_{32} = \{(4,1)\}; \\ Expert4: Tir_4 \succ Tir_2, I_{41} = \{(4,2)\}; Tir_1 \succ Tir_2, I_{42} = \{(1,2)\}; \end{cases}$$

And they give decision-coefficients about project complexity, technology difficulty and technique capability as follows:

$$T = \begin{bmatrix} 0.6 & 0.2 & 0.2 \\ 0.6 & 0.1 & 0.3 \\ 0.5 & 0.3 & 0.2 \\ 0.5 & 0.2 & 0.3 \end{bmatrix}$$

After deleting the same initial relationships, we can get the coefficients about initial relationship.

$$\begin{cases} a_2^1 = (a_{11} - a_{21}, a_{12} - a_{22}, a_{13} - a_{23}) = (0, 0.1, -0.1); \\ a_3^4 = (a_{41} - a_{31}, a_{42} - a_{32}, a_{43} - a_{33}) = (0, -0.1, 0.1); \\ a_3^1 = (a_{11} - a_{31}, a_{12} - a_{32}, a_{13} - a_{33}) = (0.1, -0.1, 0); \\ a_3^2 = (a_{21} - a_{31}, a_{22} - a_{32}, a_{23} - a_{33}) = (0.1, -0.2, 0.1); \\ a_1^4 = (a_{41} - a_{11}, a_{42} - a_{12}, a_{43} - a_{13}) = (-0.1, 0, 0.1); \\ a_2^4 = (a_{41} - a_{21}, a_{42} - a_{22}, a_{43} - a_{23}) = (-0.1, 0.1, 0). \end{cases}$$

For Problem (P):

$$(P)\begin{cases} \max\beta; \\ 0.1w_2 - 0.1w_3 \geq \beta; \\ -0.1w_2 + 0.1w_3 \geq \beta; \\ 0.1w_1 - 0.1w_2 \geq \beta; \\ 0.1w_1 - 0.2w_2 + 0.1w_3 \geq \beta; \\ -0.1w_1 + 0.1w_3 \geq \beta; \\ -0.1w_1 + 0.1w_2 \geq \beta; \\ w_1 + w_2 + w_3 = 1; \\ w_1 \geq 0; w_2 \geq 0; w_3 \geq 0. \end{cases}$$

Obtain the optimal values of β, w_1, w_2, w_3 as follows:

$$\hat{\beta} = 0, \hat{w}_1 = \hat{w}_2 = \hat{w}_3 = \frac{1}{3}$$

When $\hat{\beta} \geq 0$, the problem (P) is harmonious. Here $w = (w_1, w_2, w_3)^T = \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right)^T$.

$$Tir_4 \succ Tir_1 \succ Tir_2 \succ Tir_3$$

We can obtain the sequence of priority relationship as $Tir_4, Tir_1, Tir_2, Tir_3$ of four research solutions. So we think TIR of the third research solution is minimal for this project from the National High-Tech R&D Program.

3.5 Conclusion

This paper presented a priority analysis algorithm for TIRs of research solutions for complex project based on colony-deciding method for multi-objects. We accomplished to decide how to select the minimal TIR of research solution from many research solutions by multi-objects and multi-experts.

Acknowledgments The work is supported by State Science and Technology Support Program in China (Grant No. 2011BAF13A01). The authors are also grateful to the editors and the reviewers for helpful comments.

References

Chen S-M, Munif A, Chen G-S, Liu H-C, Kuo B-C (2012) Fuzzy risk analysis based on ranking generalized fuzzy numbers with different left heights and right heights. Expert Syst Appl 39(7):6320–6334

Fallet G, Duval C, Simon C, Weber P, Iung B (2011) Expert judgments collecting and modeling: application to the integrated risks analysis (IRA) methodology. In: 3rd international workshop on dependable control of discrete systems, DCDS'11-conference proceedings, pp 72–77

Hall AJ (2011) Creating an expert system risk assessment tool for precursor analysis. In: Proceedings-annual reliability and maintainability symposium, IEEE, pp 1–4

Yang J, Huang H-Z, He L-P, Zhu S-P, Wen D (2011) Risk evaluation in failure mode and effects analysis of aircraft turbine rotor blades using Dempster-Shafer evidence theory under uncertainty. Eng Fail Anal 18(8):2084–2092

Qiang Z, Jianzhong Z, Chao Z, Lixiang S, Cao J (2012) Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP. Stoch Env Res Risk Assess 218(3):847–855

Quan-lin W, Hong Y (2003) Optimization theory and model. Science Press, Beijing (in Chinese)

Zhang K, Zhang J, Li Y (2008) Wireless communications, networking and mobile computing, WiCOM'08. In: 4th international conference on IEEE, pp 1–4