DOI: 10.13434/j.cnki.1007-4546.2014.0404

Project Portfolio Ranking based on the Strategic Contribution Efficiency

WANG Lin, BAI Si-jun, GUO Yun-tao

School of Management, Northwestern Polytechnical University, Xi'an, P. R. China

Abstract: Project portfolio management is proved to be remarkable for an enterprise to attain competences. When selecting project portfolios, enterprises are willing to know which one has the largest return on investment rate when realizing enterprise strategy. A methodology for project portfolio ranking by adopting the concept of Strategic Contribution Efficiency (SCE) is proposed. SCE acts as the measure that demonstrates what degree a project portfolio would contribute to enterprise strategy at specific cost. Evaluation criteria are established according to the practical requirements of enterprises. Data Envelope Analysis (DEA) is combined with fuzzy set to calculate SCE and the ranking, which takes project portfolio as a whole rather than evaluates individual projects separately and considers information imprecision at the same time. At last, a numerical example is illustrated the specific process of project portfolio ranking based on SCE, from the portfolio generation to analysis, and the efficiency of proposed model is verified.

Key words: project portfolio ranking; strategic contribution efficiency; Data Envelope Analysis (DEA); fuzzy set; uncertainty

1 Introduction

Project Portfolio Management (PPM) is a widely used tool for enterprises to attain competences. How to select the proper project portfolios aligned to strategic objectives in significant measure, has aroused much concern. A methodology that could effectively define to what extend the strategy would be realized when a specific amount of money is invested to project portfolios is required to deal with this problem. Considering the multi-project context, fuzziness of strategy and information imprecision, the strategic contribution efficiency (SCE) evaluation model is proposed, which provides information for ranking and selecting the possible project portfolio alternatives.

Many theoretical and practical attempts have strengthened the linkage between project portfolios with enterprise strategy [1-2]. Kaiser et al. [3] studied the effects of fundamental strategic changes on the project selection and organizational structure. Smith-Perera et al. [4] proposed an approach to prioritize project portfolios based on project strategic index. Some experts take uncertainty in consideration. Zapata et al. [5] decomposed the project portfolio valuation problem into a set of single project sub-problems and did the valuation using Real options analysis (ROA), which considered substantial technological uncertainty. Vilkkumaa et al. [6] showed the Bayesian

Received 03 October 2014

This paper is supported by graduate starting seed fund of Northwestern Polytechnical University (NO.Z2014077), National Natural Science Foundation of China (NO. 71172123) and Aviation Science Fund (NO.2012ZG53083)

modeling of uncertainty in project portfolio selection problem, proposed a corresponding project performance measure defined as the probability that a given action belongs to the optimal portfolio and provided a re-evaluation process. Solak et al.[7] proposed a multistage stochastic integer program model with endogenous uncertainty to deal with project portfolio optimization problem; the maximization of expected total discounted return was taken to be the objective, with the uncertainties and resource limitations considered. Lin et al.[8] looked into the problem of portfolio selection for strategic management which involves numerous conflicting criteria, and developed an integrated framework that incorporates fuzzy theory into strategic portfolio selection based on the concepts of decision support system (DSS).

Literature above illustrated that few experts looked into quantitatively measure the contribution of project portfolios to strategy. Besides, most researches focus on evaluating individual projects but ignore the integrity of project portfolios, which will cause inaccurate results because the interactions exist among multiple projects. Thus, by taking project portfolio as a whole research object, we propose the concept of Strategic Contribution Efficiency (SCE) as quantitative measure and extend DEA model to give priorities of possible project portfolio alternatives. Considering the imprecise information, fuzzy theory is introduced to represent the uncertainty.

2 Strategic Contribution Efficiency Evaluation Criteria

For an enterprise, one of the most important tasks is to improve investment returns. When rank project portfolios, decision makers care about maximizing the strategy realization at the minimum investment. In order to give a practical measure, the concept of Strategic Contribution Efficiency (SCE) is proposed.

Definition of Strategic Contribution Efficiency means the strategic contribution degree which a project portfolio would make after it consumes per unit resource.

The resource and strategic contribution are separately input and output of a project portfolio. For the resource, the expected costis just taken as the criterion. Since the strategy is always an overall direction for the whole enterprise and hard to evaluate quantitatively. The customer satisfaction, organizational growth, technological superiority attainment and social responsibility accomplishment arechosen as the specific sub-criteria.

The evaluation criteria are established in Figure 1.

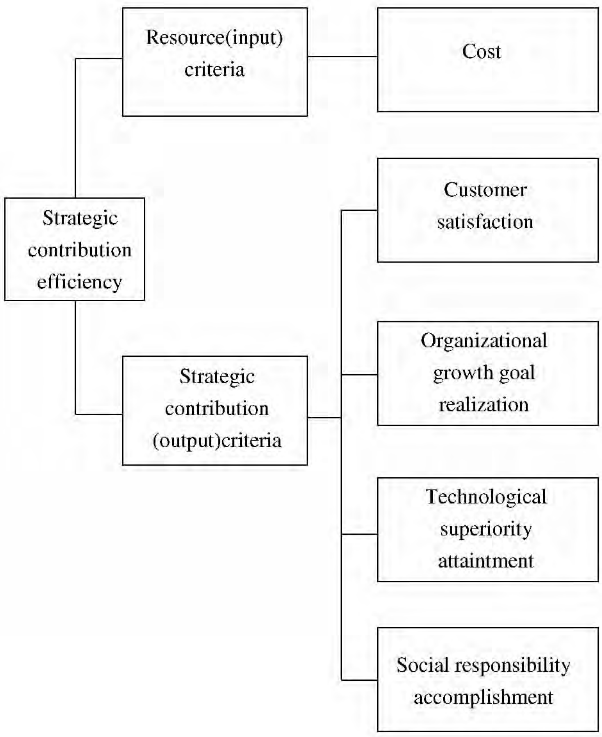

Figure 1 Project portfolio efficacy evaluation criteria

1) Resource (input) criteria

The expected cost is just considered to be the input criterion, since it is the main consideration of decision makers before implementing project portfolios. It is also easy to calculate and compare. Other criteria may be included according to the practical managerial context.

2) Strategic contribution (output) criteria

The description of four criteria chosen is as follows to describe specific strategic sub-objectives which would be realized by project portfolio implementation.

(1) Customer satisfaction improvement

Customer satisfaction improvement is always the main target of every enterprise. If customers are more willing to accept the products and services provided by the enterprise, it would attain enough profit and long-term development.

(2) Organizational growth

Organizational growth is one of the important aspects to gain sustainable development. Improvements in knowledge sharing, coordination capacity, organizational project management maturity, enterprise culture, and so on are what an enterprise really pursues. Project portfolios should contribute to this sub-strategy and not only finish the assigned task but also leave knowledge for the whole organization.

(3) Technological superiority attainment

Advanced technology attained is the core of enterprise development. The maturity and reliability of new technologies, application of these technologies and patent achieved are some aspects that reflect the technological level of an enterprise. By project portfolio management, the tangible resources and invisible knowledge should be efficiently transferred to technological superiority.

(4) Social responsibility accomplishment

Enterprises act social roles rather than just pursue profit growth. An enterprise is responsible for the staff, customers, stakeholders, society, environment and so on. To accomplish social responsibilities is the main strategic objective when evaluating project portfolios and it in turn will do benefits to the society like social reputation improvement and government support.

3 SCE based project portfolio ranking model

After the criteria being decided, the project portfolio ranking model according to the evaluation result of project portfolio SCE showld be proposed. As to the portfolio generation, the branching procedure presented by Eilat et al. [10]. The following numerical example will show how to generate portfolios under constraints from the candidate projects in detail.

Assuming that n project portfolio alternatives to be evaluated in an enterprise we have been generated, which are represented by $PO=\{PO_j \mid j=1,2,\cdots,n\}$. Each project portfolio consumes varying amounts of s different resources and contributes to m different strategic goals. Specifically, PO_i consumes amounts $\tilde{x}_{ij}(i=1,2,\cdots,s)$ of resources and produces amounts $\tilde{y}_{rj}(r=1,2,\cdots,m)$ of strategic contribution, s stands for the number of input criteria and m stands for the number of output ones. In this thesis, $s=1$, $m=5$. $\tilde{x}_{ij}$ and $\tilde{y}_{rj}$ are nonnegative fuzzy values.

3.1 Analysis methodologies

Data Envelope Analysis (DEA) is a suitable methodology to compare between the strategic contribution efficiencies of different portfolios and do the ranking. The efficiency in DEA model means the ratio of output value to input value, which meets the managerial requirement of SEC evaluation. It not only has testified functions for the calculation, but also takes every portfolio (considered as DMUs in DEA) as a whole, which hides the hard-to-measure interactions among individual projects. A traditional dual linear programming statement for the CCR model of DEA in the following:

$$\begin{cases} \min Z = \theta \\ \text{s.t. } \theta x_{ip} - \sum_{j=1}^{n} \lambda_j x_{ij} \geqslant 0 & \forall i \\ \sum_{j=1}^{n} \lambda_j y_{rj} \geqslant y_{rp} & \forall r \\ \lambda_j \geqslant 0 & \forall j \end{cases} \tag{1}$$

Considering that many evaluation criteria are mostly qualitative and hard to give a crisp value, the triangular fuzzy numbers to represent the imprecise information is adopted. As shown in Figure 2, the membership function $u_x(z): R \in [0,1]$ of a triangular fuzzy variable x satisfies the following equation:

$$u_x(z) = \begin{cases} \dfrac{z - x^l}{x^m - x^l} & x^l \leqslant z \leqslant x^m \\ \dfrac{x^u - z}{x^u - x^m} & x^m \leqslant z \leqslant x^u \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Where x^m, x^l, x^u are respectively the core, lower and upper bounds of the variable x.

The cut α transforms the fuzzy variable to an interval meaning the risk of accepting level α. This parameter shows the preference of decision makers on risk acceptance.

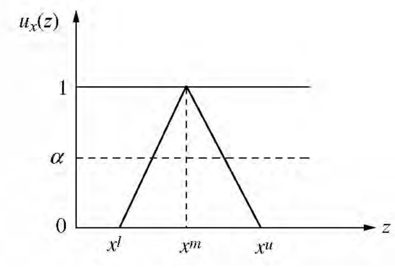

Figure 2 Triangular fuzzy variable $\hat{x} = (x^l, x^m, x^u)$

Thus, evaluation value of resources and strategic contribution is as $\tilde{x}_{ij} = (x_{ij}^l, x_{ij}^m, x_{ij}^u)$ and $\tilde{y}_{rj} = (y_{rj}^l, y_{rj}^m, y_{rj}^u)$ given by experts, respectively.

3.2 Project portfolio ranking model

The standard DEA models can only derive the ranking of inefficient project portfolios with the SCE less than 1, but for the efficient ones, SCEs are all assigned to 1. Thus we need to modify the model for the ranking is needed to modify.

Based on the model given by SAATI et al. [8], let $\tilde{x}_{ij} = (x_{ij}^l, x_{ij}^m, x_{ij}^u)$ and $\hat{y}_{rj} = (y_{rj}^l, y_{rj}^m, y_{rj}^u)$, the dual linear programming statements for the (input oriented) CCR model considering the fuzzy variables is extended in the following:

$$\begin{cases} \min Z = \theta \\ \text{s.t. } (\theta x_{ip}^l, \theta x_{ip}^m, \theta x_{ip}^u) \geqslant \left(\sum_{j=1}^{n} \lambda_j x_{ij}^l, \sum_{j=1}^{n} \lambda_j x_{ij}^m, \sum_{j=1}^{n} \lambda_j x_{ij}^u \right. & \forall i \\ (y_{rp}^l, y_{rp}^m, y_{rp}^u) \leqslant \left(\sum_{j=1}^{n} \lambda_j y_{rj}^l, \sum_{j=1}^{n} \lambda_j y_{rj}^m, \sum_{j=1}^{n} \lambda_j y_{rj}^u \right) & \forall r \\ \lambda_j \geqslant 0 & \forall j \end{cases} \tag{3}$$

By introducing α-cut concept, the variables can be altered to the following intervals.

$$x_{ip} \in [\alpha x_{ip}^m + (1-\alpha) x_{ip}^l, \alpha x_{ip}^m + (1-\alpha) x_{ip}^u]$$

$$y_{rp} \in [\alpha y_{rp}^m + (1-\alpha) y_{rp}^l, \alpha y_{rp}^m + (1-\alpha) y_{rp}^u]$$

$$\hat{x}_{ij} \in [\alpha x_{ij}^m + (1-\alpha) x_{ij}^l, \alpha x_{ij}^m + (1-\alpha) x_{ij}^u]$$

$$\hat{y}_{ij} \in [\alpha y_{rj}^m + (1-\alpha) y_{rj}^l, \alpha y_{rj}^m + (1-\alpha) y_{rj}^u]$$

The best part of project portfolios with the optimal SCE is $(\alpha X_p^m + (1-\alpha) X_p^l, \alpha Y_p^m + (1-\alpha) Y_p^u)$ and the inner part of the efficiency frontier is $\left(\sum_{j=1}^{n} \lambda_j (\alpha X_j^m + (1-\alpha) X_j^u), \sum_{j=1}^{n} \lambda_j (\alpha Y_j^m + (1-\alpha) Y_j^l)\right)$. The SCE based ranking model of project portfolios is then proposed in the following.

$$\begin{cases} \min Z = \theta \\ \text{s.t. } \theta(\alpha x_{ip}^m + (1-\alpha) x_{ip}^l) \geqslant \sum_{j=1}^{n} \lambda_j (\alpha x_{ij}^m + (1-\alpha) x_{ij}^u) & \forall j \\ \alpha y_{rp}^m + (1-\alpha) y_{rp}^u \leqslant \sum_{j=1}^{n} \lambda_j (\alpha y_{rj}^m + (1-\alpha) y_{rj}^l)) & \forall j \\ \lambda_j \geqslant 0 & \forall j \end{cases} \tag{4}$$

Eq (4) transmits the fuzzy linear programming problem to a crisp one. α is a parameter decided by experts with the interval of [0, 1]. By running Eq (4) n times for each project portfolio alternative, SCE value of each project portfolio will be calculated and compared for the ranking.

4 Numerical example

An enterprise NE is implemented by using several project portfolios from 7 projects. For the limitation of investment, it has to find which project portfolio alternative benefits the most to enterprise strategy from these candidate projects. The above demonstrated model assists with the ranking process.

1) Portfolio generation

First of all, all the possible portfolios under the constraint of investment should be generated. A branch-and-bound procedure proposed by Eilat et al.[10] is used. We start with empty portfolio at node 0. In the first level, a single project to node 0 and branch the problem to n sub-problems is branched, represented by node1 to node n. For each node $i(i=1,2,\cdots n)$ formed in the previous level, this process is repeated. If a portfolio at one branch exceeds the limitation of investment, its descendants stops.

After continuing the above-mentioned process, four project portfolio alternatives are generated which meet the investment limitation. The portfolios are represented by $PO=\{P0_i \mid i=1, 2, 3, 4\}$.

2) SCE evaluation

According to the strategic plan, input and output criteria have been established. The input criterion is the expected cost of project portfolios in millions of dollars (I_1). The output criteria according to enterprise strategy are customer satisfaction improvement (O_1), organizational growth (O_2), technological superiority attainment (O_3) and social responsibility accomplishment (O_4). Their description is demonstrated in Table 1.

Table 1 SCE evaluation criteria

Type	Criterion	Description
Input	Cost(I_1)	The expected cost of each project portfolio
Output	Customer satisfaction improvement(O_1)	The degree project portfolio implementation would meet the requirement of customers and improve the brand reputation and the potential market share.
	Organizational growth(O_2)	The degree that enterprise work-flow, culture and information sharing improve, as well as the knowledge attained grows by project portfolio implementation.
	Technological superiority attainment(O_3)	The degree that the new and advanced technology obtained, the proficiency improvement and technical staff trained by project portfolios, which would help enterprise win over other competitors on technology.
	Social responsibility accomplishment(O_4)	The degree that the project portfolio benefits would satisfy stakeholders, employees and government requirements. Moreover, they should also be environmental friendly.

Experts evaluate each criterion of project portfolio PO_i, $i = 1, 2, 3, 4$. For output criteria, which are qualitative, we use the triangular fuzzy variable in the interval $[0,1]$ to give the evaluation values. And for the quantities one, we just give a triangular fuzzy number. The evaluation result is demonstrated in Table 2.

Table 2 Project Portfolio SCE evaluation data

	PO_1	PO_2	PO_3	PO_4
I_1	(155,160,165)	(412,435,458)	(215,223,229)	(386,390,394)
O_1	(0.35,0.4,0.45)	(0.73,0.89,0.95)	(0.19,0.2,0.21)	(0.19,0.22,0.25)
O_2	(0.55,0.57,0.59)	(0.62,0.65,0.68)	(0.40,0.44,0.48)	(0.52,0.53,0.54)
O_3	(0.12,0.15,0.18)	(0.53,0.58,0.62)	(0.37,0.39,0.41)	(0.64,0.64,0.64)
O_4	(0.43,0.45,0.48)	(0.77,0.79,0.81)	(0.52,0.56,0.60)	(0.48,0.52,0.56)

3) Project portfolio ranking and result analysis

Project portfolio alternatives are ranked according to the evaluation result of SCE by using fuzzy DEA model proposed above. The result is demonstrated in Table 3.

Table 3 Project Portfolio ranks based on SCE at different α-cut

α	PO_1	PO_2	PO_3	PO_4
0	1.44	1.38	1.22	1.02
0.25	1.31	1.27	1.16	1.00
0.75	1.09	1.08	1.05	0.96
1	1.00	1.00	1.00	0.94

From the table above, we find that at different α level, the efficiency ranks are the same, which is $PO_1 > PO_2 > PO_3 > PO_4$. And when $\alpha = 0.75$ and 1, PO_4 is inefficient. Thus decision makers would choose the preferred project portfolios, which would contribute to strategy more at the lower cost.

5 Conclusion

A methodology for project portfolio ranking is proposed by adopting Strategic Contribution Efficiency (SCE), which would measure the degree a project portfolio would contribute to enterprise strategy at specific cost. According to the practical requirements of enterprises Criteria are established for the evaluation of SCE, and DEA are combined with fuzzy set to calculate SCE and the ranking. The information for project portfolio decision making is provided. Further research would focus on quantifying project interactions, adopting uncertainty during project portfolio implementation when evaluating and reducing the calculation burden by using proper algorithm.

References

[1] Brook J W, Pagnanelli F. Integrating sustainability into innovation project portfolio management-A strategic perspective [J]. Journal of Engineering and Technology Management, 2014,34: 46-62

[2] Spilsbury M J, Norgbey S, Battaglino C. Priority setting for evaluation: developing a strategic evaluation portfolio [J]. Evaluation and Program Planning, 2014,46: 47-57

[3] Kaiser M G, Arbi F E, Ahlemann F. Successful project portfolio management beyond project selection techniques: Understanding the role of structural alignment [J]. International Journal of Project Management, 2015,33(1)

[4] Aida Smith-Perera, Mónica García-Melón, Rocío Poveda-Bautista, *et al*. A project strategic index proposal for portfolio selection in electrical company based on the analytic network process [J]. Renewable and Sustainable Energy Reviews, 2010,14(6):

1569-1579

[5] Zapata J C, Reklaitis G V. Valuation of project portfolios: an endogenously discounted method [J]. European Journal of Operational Research. 2010,206(3):653-666

[6] Vilkkumaa E, Liesi J, Salo A. Optimal strategies for selecting project portfolios using uncertain value estimates [J]. European Journal of Operational Research. 2014,233(3): 772-783

[7] Solak S, Clarke John-Paul B, Johnson E L, *et al*. Optimization of R&D project portfolios under endogenous uncertainty [J]. European Journal of Operational Research, 2010,207(1):420-433

[8] Lin Chinho, Hsieh Ping-Jung. A fuzzy decision support system for strategic portfolio management [J]. Decision Support Systems. 2004,38(3):383-398

[9] Saati S M, Memariani A, Jahanshahloo G R. Efficiency analysis and ranking of DMUs with fuzzy data [J]. Fuzzy Optimization and Decision Making, 2002,1(3):255-267

[10] Eilat H, Golany B, Shtub A. Constructing and evaluating balanced portfolios of R&D projects with interactions: a DEA based methodology [J]. European Journal of Operational Research. 2006,172:1018-1039

Brief Biographies

WANG Lin is now a Ph. D candidate in the School of Management, Northwestern Polytechnical University. Her research interests include project management and decision making. linwang.nwpu@gmail.com

BAI Si-jun is a Ph. D, professor, doctor supervisor in the School of Management, Northwestern Polytechnical University. His research interests include project management and management systems engineering. baisj@nwpu.edu.cn

GUO Yun-tao is a Ph. D, associate professor in the School of Management, Northwestern Polytechnical University. His research interests include project management and management systems engineering. yuntguo@nwpu.edu.cn