Research on Efficiency Evaluation of Engineering Project Cost Management Based on SE-DEA Model

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Abstract. In this paper, the input-output index system is constructed by the idea of project cost management, in terms of the quality, duration, safety and contract of the project. The supper-efficiency DEA model is introduced to evaluate and sort the efficiency of construction cost management. The efficiency values of the traditional DEA model and the super-efficient DEA model are also compared and analyzed. The projection analysis of an invalid DMU from a radial perspective helps to transform it into an effective DMU.

Keywords: Super-efficiency DEA model; Project cost; Management efficiency

1 INTRODUCTION

In recent years, with the rapid development of the construction industry, it has become a pillar industry of China's national economy. Simultaneously, construction enterprises are also expanding and developing rapidly. As market competition intensifies, saving costs and maximizing profits have become the primary considerations for every construction enterprise. As one of the traditional three objectives of project management, project cost management directly affects the level and outcome of engineering project management, and also significantly impacts economic benefits.[8] Therefore, strengthening cost management is an important goal that cannot be ignored by every enterprise. Regarding cost management, scholars at home and abroad have proposed theories such as full-life cycle, full-process, and comprehensive project management, as well as all-staff, all-process, and all-round cost management. These methods have become the main methods of project cost management in China and many other countries around the world. Bi Xing proposed a cost performance evaluation analysis method based on summarizing project cost conclusions. Mao Hongtao and others revealed the mechanism of organizational environment on the cost management of engineering projects and its significance to enterprise cost management. Ji Li et al. studied the cost budget mechanism to test the impact of government intervention on project costs. Qi Jiantao started with the project cost management issues that are prone to arise throughout the construction process of engineering projects and proposed specific solutions. Wang Yankui et al. explored cost control in real estate development projects based on BIM technology. Most domestic and foreign scholars study the influencing factors and management issues of cost management, with less

V. Vasilev et al. (eds.), *Proceedings of the 2024 5th International Conference on Management Science and Engineering Management (ICMSEM 2024)*, Advances in Economics, Business and Management Research 306,
https://doi.org/10.2991/978-94-6463-570-6_128

research on the efficiency of cost management.[7][13] From the perspective of the owner, this article introduces the DEA model, focuses on project cost management, considers factors such as project quality, schedule, and contracts, constructs an evaluation model for the efficiency of construction cost management, evaluates and analyzes the economic efficiency of construction costs, and proposes improvement suggestions.

2 ESTABLISHMENT OF THE EVALUATION INDEX SYSTEM FOR CONSTRUCTION COST MANAGEMENT EFFICIENCY

In order to scientifically, objectively, and effectively evaluate the efficiency level of project cost management, the index system is selected based on the accurate reflection of the input-output level of construction cost efficiency, while fully considering the availability and adaptability of data, and referencing relevant research literature. Finally, the input and output indicators of construction cost efficiency are determined from the aspects of cost, schedule, contract, quality, and safety. The results are shown in Table 1.[12]

Table 1. Input and Output Indicators

Number	Indicator
X_1	Expected Cost
X_2	Expected Duration
X_3	Total Number of Management Staff
Y_1	Actual Cost
Y_2	Actual Duration
Y_3	Claim Loss Rate
Y_4	Accident Loss Rate
Y_5	Rework Loss Rate

The meanings of the input and output indicators in Table 1 are as follows:

Input Indicators:

X_1: Expected Cost, Refers to the estimated cost in advance for achieving the desired construction objectives.

X_2: Expected Duration, Represents the anticipated time required for the completion of the construction project from the official start to full completion.

X_3: Total Number of Management Staff, Refers to the total number of management personnel required throughout the entire construction process of the project.

Output Indicators:

Y_1:Actual Cost, Represents the actual cash or other equivalents paid for the construction of the building.

Y_2:Actual Duration, Refers to the actual time consumed from the start of construction to the completion and acceptance of the project.

Y_3: Claim Contribution Rate, Represents the percentage of the claim amount as a proportion of the difference between the actual cost and the expected cost.

Y_4: Accident Contribution Rate, Refers to the percentage of the accident loss value as a proportion of the difference between the actual cost and the expected cost.

Y_5: Rework Contribution Rate, Represents the percentage of the loss value due to quality issues causing rework as a proportion of the difference between the actual cost and the expected cost.

3 ESTABLISHMENT OF SUPER EFFICIENCY DEA MODEL

3.1 DEA Model

Data Envelopment Analysis (DEA), created by A. Charnes and W.W. Cooper in 1978, is a method based on linear programming models to evaluate the relative effectiveness of similar decision-making units (DMU). It is commonly used in multi-objective decision-making to evaluate DMUs with multiple input variables and multiple output variables. To determine whether DEA is effective is essentially to judge whether DEA is located on the frontier of the production possibility set.[1][2]

The DEA model does not require the determination of weights for indicators during the evaluation process. In most cases, objective data is directly used, avoiding subjective influences, and it is gradually being used more and more.

Assuming there are n DMUs, each DMU has m types of inputs and s types of outputs. x_{ij} is the input amount of the j-th decision unit for the i-th type input; y_{rj} is the output amount of the j-th decision unit for the r-th type output. v_i is a measure of thee i-th input; u_r is a measure of the r-th output. Taking the efficiency index of the j_0 decision unit as the goal and the efficiency index of all the decision units as constraints, the following C^2R model is constructed:

$$\max h_{j0} = \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}}$$

$$s.t.\quad \frac{\sum_{r=1}^{s} u_r y_{rj0}}{\sum_{i=1}^{m} v_i x_{ij0}} \le 1 \quad j = 1,2\cdots,n$$

$$v = (v_1, v_2, \cdots, v_m)^T \ge 0$$

$$u = (u_1, u_2, \cdots, u_s)^T \ge 0$$

Change the inequality constraints into equality constraints, the slack variable s^+ and the residual variable s^- are introduced.

$$
\begin{cases}
\min\theta \\
s.t. \sum_{j=1}^{n} \lambda_j x_j + s^+ = \theta x_0 \\
\sum_{j=1}^{n} \lambda_j y_j - s^- = y_0 \\
\lambda_j \geq 0 \ j = 1,2,\cdots,n \\
\theta \ no \ constraint \\
s^+ \geq 0, s^- \geq 0
\end{cases}
$$

3.2 Super-efficiency DEA Model

When the DMU uses the traditional DEA method for efficiency evaluation, when there is more than one DMU presenting valid status, it is impossible to sort the DEA effective DMU. Andersen and Petersen proposed the super-efficiency DEA model in 1993, which is to identify the efficiency between these effective DMUs. The mathematical expression is as follows.[3]

$$
\min\left[\theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)\right]
$$

$$
\text{s.t.} \sum_{\substack{j=1 \\ j\neq k}}^{n} X_{ij}\,\lambda_j + s_i^- = \theta X_0
$$

$$
\sum_{\substack{j=1 \\ j\neq k}}^{n} Y_{rj}\,\lambda_j - s_r^+ = Y_0
$$

$$
\lambda_j \geq 0; j = 1,2,\cdots,n
$$

$$
s_i^- \geq 0; s_r^+ \geq 0
$$

4 CASE ANALYSIS

Select 10 completed framed office building projects as evaluation objects, forming 10 decision-making units (DMUs). Collect the relevant input-output indicator data for these 10 DMUs based on the input-output indicators constructed above. As shown in the following table:

Table 2. Input-Output Indicator Data

DMU	Estimated Cost (Yuan/ Square Meter)	Estimated Duration (Days)	Total Number of Man-agers	Actual Cost (Yuan/ Square Meter)	Actual Duration (Days)	Claim Loss Rate (%)	Accident Loss Rate (%)	Rework Loss Rate (%)
1	2541.6	360	20	2278	375	36%	24%	36%
2	2640.8	370	21	2284.9	360	21%	9%	28%
3	2565.5	347	19	2887.9	395	45%	32%	21%
4	2387.4	300	25	2438.2	315	19%	15%	25%
5	2569.2	400	23	2498.3	386	9%	22%	12%
6	2451.6	370	24	2364.9	368	33%	16%	15%
7	2598.3	350	19	2564.3	350	12%	18%	21%
8	2259.6	300	28	2370.9	320	19%	26%	19%
9	2426.3	380	25	2531.5	359	24%	15%	19%
10	2654.2	350	20	2698	362	36%	13%	13%

Since the output indicators Y_1、 Y_2 、 Y_3、 Y_4、 Y_5 are cost-related metrics, while the DEA model requires benefit-related metrics for its output indicators, it is necessary to perform corresponding transformations on the output data. The multiplicative inverse transformation (MLT) method is adopted to carry out the necessary transformation. Based on the evaluation model established earlier and the processed data, the data is imported into the CCR-O model and the Supper CCR-O model, respectively. Using the DEA-Solver software, the efficiency values of each project are calculated and summarized in Table 3.

Table 3. Project efficiency value and ranking

DMU	CCR-O	Rank	Super-CCR-O	Rank
1	1	1	1.053581	8
2	1	1	1.295803	2
3	0.998686	9	0.998686	9
4	1	1	1.139709	5
5	1	1	1.564264	1
6	1	1	1.053984	7
7	1	1	1.230242	4
8	1	1	1.115214	6
9	0.975536	10	0.975536	10
10	1	1	1.240035	3

Based on the above table2&3, the efficiency values of most DMUs are 1, indicating that they have achieved DEA effectiveness. This suggests that the cost management of most construction projects is relatively effective. For the two DMUs (Project 3 and Project 9) that are not DEA effective, their efficiency values are also relatively high, indicating that the level of cost management for these construction projects is still relatively high. According to the super-efficiency DEA values, there is not much difference in management levels among the various projects, indicating that project cost management has reached a relatively mature state.

To further determine the reasons for the DEA ineffectiveness of DMUs and identify the improvement values for their inputs and outputs, let's take Project 9 as an example to analyze the DEA-ineffective DMUs. The results are summarized in Table 4.

Table 4. Efficiency Value Analysis Table

No.	DMU I/O	Score Data	Projection	Difference	%
9	9	0.975536			
	Expected Cost	0.914	0.914	0	0.00%
	Expected Duration	0.95	0.837135	-0.112865	-11.88%
	Total Number of Management Staff	0.893	0.829305	-6.37E-02	-7.13%
	Actual Cost	0.9	0.922569	2.26E-02	2.51%
	Actual Duration	0.877	0.898993	2.20E-02	2.51%
	Claim Loss Rate	0.375	0.384404	9.40E-03	2.51%
	Accident Loss Rate	0.6	0.615046	1.50E-02	2.51%
	Rework Loss Rate	0.632	0.647849	1.58E-02	2.51%

From Table 4, we can determine how much each input and output indicator needs to change in order to turn the originally ineffective DEA efficiency value into 1. Taking Project 9 as an example, its efficiency value is 0.975536. To make it DEA effective, its input and output values should be appropriately improved. The estimated duration should be reduced by 11.88%, from the original 380 days to 335 days. The total number of management personnel should be reduced by 7.13%, from the original 25 to 23. Since the data has been transformed, the actual cost, actual duration, claim contribution rate, accident loss rate, and rework loss rate should also be reduced accordingly. The high number of management personnel indicates that the desired cost management effect has not been achieved. The significant deviation between the estimated cost and estimated duration suggests that there is a lack of accurate prediction, and the technical proficiency of cost estimators needs to be improved, along with strengthening management. The need to reduce the claim contribution rate, accident contribution rate, and rework loss rate indicates that contract management, safety, and quality are not being managed effectively. It is necessary to improve organizational systems, enhance employee incentive and evaluation mechanisms, and ensure that management personnel can effectively fulfill their duties. Local governments should also reduce their interference in projects and minimize the indirect costs they impose on them.

5 CONCLUSION

This article establishes an indicator system to measure the efficiency of project cost management based on cost management theory. It introduces the DEA model and the super-efficiency DEA model to evaluate and analyze the cost management efficiency of 10 completed office buildings with a frame structure. The research finds that:

(1) The introduction of the super-efficiency DEA model has no impact on the distinction between effective DMUs and ineffective DMUs. The efficiency values of ineffective DMUs under the super-efficiency DEA model are equal to those of the DEA model.

(2) By ranking the construction cost management of the 10 office buildings, it is concluded that there is currently not much difference in cost management among various projects, but attention should be paid to managing weaknesses. This provides a reference for projects to clarify their positioning within the industry and provides a basis for estimating future construction projects.

(3) Based on a radial perspective, the projection values under the super-efficiency DEA model are analyzed, and adjustments are made to ineffective DMUs to transform them into effective DMUs. Therefore, methods are provided to optimize project costs for various projects.

ACKNOWLEDGEMENT

Funding Project: Qingdao City University School-level Scientific Research Team - "Digital and Intelligent Services for the Entire Process of Engineering Project Cost Management Based on Big Data and BIM Technology"(QCU22TDKJ01)

REFERENCES

1. Charnes A, Cooper W W, Rhodes E.:Measuring the efficiency of decision-making units. European Journal of Operational Research 3(4), 339 (1979).
2. Anderson P, Peterson N C.:A procedure for ranking efficient units in data envelopment analysis. Management Science 1(10), 1261-1264 (1993).
3. Chen Hongming, Yang Yiying.:Evaluation of Enterprise Operating Performance Based on Super-efficiency DEA Model. Journal of Changsha University of Science and Technology (Social Science Edition)33(01), 103-109 (2018).
4. Wei Quanling.: Data Envelopment Analysis Model for Evaluating Relative Effectiveness. China Renmin University Press, Beijing (2012).
5. Du Dong, Pang Qinghua, Wu Yan.: Selected Cases and Methods of Modern Comprehensive Evaluation. 3rd edn.Tsinghua University Press,Beijing (2015).
6. Ji Li, Deng Bofu, Mao Hongtao.:Budget Constraints, Government Intervention, and Engineering Project Costs. Nankai Business Review17(01), 94-102 (2014).

7. He Shaobo, Xiao Min, Zhang Honghu, Chen Guangyu.:Research on the Efficiency Evaluation Method of Construction Engineering Projects Based on the Cross DEA Model. Project Management Technology15(03), 7-12 (2017).
8. Liao Qiyun, Song Nannan.:Evaluation of Safety Management Efficiency of Construction Projects Based on DEA. Project Management Technology14(11), 40-44 (2016).
9. Li Xiaoyi, Liang Danlin.:Environmental Cost Management Efficiency in the Building Materials Industry Based on the DEA Model- A Case Study of Company T. Journal of Changsha University37(04), 81-90 (2023).
10. He Lidong.:Research on Optimization Strategies of Engineering Cost Management Based on ERP Database. Engineering Cost Management35(01), 30-36 (2024).
11. Chen Zhao, Sun Jingnan, Zhou Zilong.:Research on Performance Evaluation of Safety Management in Highway Construction Site Based on DEA Method. Journal of Changsha University of Science and Technology (Natural Science)19(01), 105-114 (2022).
12. Cao Yuqi, Yao Deli.:Research on Cost Management Efficiency Based on DEA and Malmquist Index. Journal of Heilongjiang Institute of Technology37(01), 38-43 (2023).
13. Feng Zhaoli.:Research on Cost Control of Engineering Projects in Small and Medium-sized Construction Enterprises. Construction Economy45(03), 22-27 (2024).