The Application of value engineering in highway engineering design change scheme

Bing Yang[a], Yubo Ren*[b], Boyu Gao[c]

[a]Yunnan Communications Investment Group Yunling Construction Co. LTD, Kunming, 650051, China,
[b]School of Highway, Chang'an University, Xi'an, 710064, China
[c]School of Highway, Chang'an University, Xi'an, 710064, China
[a]E-mail: 262096347@qq.com, [c]E-mail: 675117098@qq.com,
*[b]Corresponding author E-mail: ryb1185@163.com

Abstract. Value engineering is a kind of technical and economic thinking and technology that seeks to build products at the lowest cost under the premise of satisfying the use function. The highway construction project is a huge linear system project, involving many disciplines, long mileage, large scale, and spanning different natural areas. Due to various factors, it is impossible to fully understand the geological conditions along the line during the project survey stage, and it is impossible to fully conform to the actual conditions in the design process. Therefore, design changes are inevitable in actual construction. Based on the basic principle of value engineering, combined with the characteristics of change scheme and engineering requirements, this paper determines the weight coefficient of comparison selection index, calculates the value coefficient according to the function coefficient and cost coefficient, and determines the recommended scheme. The research results of this paper have been applied to the selection of expressway scheme in Yunnan mountainous area. The selection factors are comprehensive and the method is simple and easy.

Keywords: value engineering, design change, function coefficient, cost coefficient, value coefficient

1 Introduction

1.1 The Concept and Workflow of Value Engineering

Value engineering (VE) is a commonly used method in engineering economic analysis. It originated after the Second World War and was founded by Myers of General Electric Company. At that time, Myers believed that the purpose of purchasing materials was to obtain a certain function rather than the material itself. Therefore, as long as the function meets the requirements, we can seek to buy other materials that can realize the same function to replace them, reduce the product cost under the premise of ensuring the function, and then summarize a whole set of analysis methods, called value analysis[1-2]. After that, the method of value analysis was gradually accepted and

© The Author(s) 2023
V. Escudero et al. (Eds.): BADS 2022, AHCS 11, pp. 795–801, 2023.
https://doi.org/10.2991/978-94-6463-102-9_81

popularized by the industry, and was finally called value engineering by the Bureau of Ships of the United States Navy in the process of use.

Value engineering can be calculated by the following equation:

$$V=FC \tag{1}$$

Where V is the value of the research object, F is the function of the research object, and C is the cost of the research object.

Value engineering fully considers both function and cost in the process of analysis to effectively combine technology and economy[3-4]. Value engineering is a systematic work in highway engineering project management. In the application process, the main flow includes confirming the target, functional analysis and function, value evaluation, program formulation and program implementation[5].

1.2 The concept of highway design change

Design change of highway engineering refers to the modification and improvement of approved preliminary design documents, technical design documents or construction drawing design documents from the date of approval of preliminary design of highway engineering to the period of completion acceptance and formal delivery for use .Highways are huge linear system projects, and its construction has a long mileage, a wide range of spans, and many constraints. Highway construction must strictly comply with the relevant provisions of the State capital construction procedures, so as to survey first, design second and construct last. However, due to the limitations of topography, geology, construction period, funds, technical level, and geographical environment of the construction area, it is difficult to comprehensively consider various factors that may occur during the construction period (especially the highway in mountainous and hilly areas) in the design stage, resulting in inevitable design changes during the construction.

The function of highway transportation can be realized by a variety of schemes, such as subgrade, bridge, tunnel and so on. The cost required by each scheme is different. The scheme adopted not only has technical and economic constraints, but also national and local policies, laws and regulations and other constraints. Considering all kinds of factors comprehensively and using the method of value engineering to reasonably determine the construction scheme is conducive to saving resources and investment[6].

2 The Working Method of Value Engineering

2.1 The Working Procedure of Value Engineering

Value engineering is carried out in accordance with the procedures of problem analysis, comprehensive research and program evaluation. In the stage of problem analysis, the main work is to select value engineering objects, collect information, analyze and evaluate functions. Comprehensive research focuses on solution creation and mainly answers whether there are other ways to achieve the same function. In the program evaluation stage, the program is mainly evaluated and selected for each program 7-8].

2.2 Scheme Evaluation Method of Value Engineering

The scheme evaluation of value engineering uses the value coefficient method for scheme comparison, so as to select the scheme that meets the functional requirements and has the highest value coefficient. Therefore, it is necessary to determine the respective function coefficient and cost coefficient according to the characteristics of the proposed scheme[9-10]. The function coefficient and cost coefficient are calculated according to the following equation:

$$\text{Function coefficient(F)}=\frac{\text{The weighted total score of the program}}{\text{The sum of the weighted total scores for each scheme}} \tag{2}$$

$$\text{cost coefficient}(C)=\frac{\text{The cost of the scheme}}{\text{The sum of the cost of each scheme}} \tag{3}$$

$$\text{Value coefficient}(V)=\frac{\text{Function coefficient}(F)}{\text{cost coefficient}(C)} \tag{4}$$

In the actual scheme comparison selection, the value coefficient of each scheme is calculated respectively, and then the scheme with higher value coefficient is selected as the recommendation scheme.

3 The Engineering Case

3.1 Project Overview

The highway in a mountainous area of Yunnan province is designed with 4 lanes in both directions, the design speed is 80km/h, the roadbed is designed with a width of 25.5m. The first plan, with a bridge across the ravine, would have required the abandonment of 180,000 square metres of land. However, the capacity of the soil dump site is insufficient due to the fact that all the land around the route is basic farmland. The nearest dump site is about 9Km away from the bridge. The second scheme uses the ravine-filling scheme, which will consume about 110,000 square meters and help reduce the expropriation of abandoned land. The bearing capacity of the ravine foundation is high and can meet the requirements of soil filling. But in order to meet the needs of the drainage ditch, a 4×4m culvert must be installed.

3.2 Determination of Evaluation Index and Weight Coefficient

The Evaluation Index.
. Two schemes are drawn up for this project. The first scheme uses bridge to cross the ravine, and the second scheme uses roadbed + culvert to cross the ravine. In order to ensure adequate selection of schemes, five indicators including progress (F1), project

land (F2), project quality (F3), construction safety (F4) and environmental impact (F5) were drawn up for comparison in terms of functions.

The Weight Coefficient of the Evaluation Index

. The function coefficient of each scheme should be calculated when comparing and selecting each scheme. There are many factors affecting the functions of each scheme, so select several more important functions and score the importance of each function according to the actual situation of the project, so as to determine the weight coefficient of each function. By calculating the weighted score of the corresponding selected function in each scheme, the function coefficient is finally determined. Combined with the actual situation of the project, the 0-4 scoring method is used to calculate the weight coefficient of each index as follows:

Table 1. The weight coefficient of each function

Functions	F1	F2	F3	F4	F5	Score	Weight coefficient
F1	×	1	1	1	2	5	0.125
F2	3	×	1	1	2	7	0.175
F3	3	3	×	3	2	11	0.275
F4	3	3	1	×	1	8	0.200
F5	2	2	2	3	×	9	0.225
Total						40	1

As can be seen from the table, the functional evaluation coefficient of engineering quality (F3) of this project is 0.275, which is the key function considered, followed by environmental impact (F5), which is 0.225. When calculating the functional score of each scheme, the above coefficients will be used as weight coefficients to calculate the weighted score.

3.3 Determination of Functional Coefficients

The calculation of the function coefficient can be calculated by the compulsory determination method. The specific scoring system has 10 and 100 points, and this paper is calculated according to the 10 point system. The specific operation method is as follows:

Randomly select the relevant five experts in the industry, each expert independently analyzes according to the provided scheme and independently scores the evaluation indicators of all alternatives, and then calculates the evaluation score of each evaluation indicator corresponding to all alternatives according to the weight coefficient calculated in Section 3.2, and the weighted score is calculated according to equation (5) and equation (6):

$$\text{A weighted score for an indicator} = \text{Weight coefficients} \times \text{Expert scoring} \quad (5)$$

$$\text{Expert scoring} = \sum_{n=1}^{n}(a_1 + a_2 + \cdots + a_n)\,/n \quad (6)$$

Where n is the number of experts who participated in the rating, a_n is the score of each expert on a certain indicator.

The scoring results and calculation process of function coefficients are shown in Table 2 below:

Table 2. Score results and functional coefficient calculation table

Indicators	Weight coefficient	Bridge crossing scheme		Roadbed + culvert crossing scheme	
		score	Weighted score	Score	Weighted score
F1	0.125	8	1.00	10	1.25
F2	0.175	10	1.75	5	0.875
F3	0.275	10	2.75	8	2.2
F4	0.200	8	1.60	10	2
F5	0.225	10	2.25	7	1.575
Total score		46	9.35	40	7.9
Function coefficient		0.542		0.458	

It can be obtained from the above table that the functional coefficient of the bridge crossing scheme is 0.542, and the functional coefficient of the "roadbed + culvert" crossing scheme is 0.458. After the cost coefficient is determined, the two function coefficients will be used to calculate the value coefficient.

3.4 Determination of Cost Coefficient

To determine the cost coefficient, we must first calculate the project cost of each program, and then determine the cost coefficient of each scheme. According to the calculation, the project cost of the bridge crossing scheme is 33.67 million yuan, and the project cost of the "roadbed + culvert" crossing scheme is 18.83 million yuan, which saves 14.84 million yuan compared with the former one. The cost coefficients of the two schemes calculated according to Equation (3) are shown in Table 3 below:

Table 3. Cost coefficients of the two schemes

Scheme		Cost(CNY)
Bridge crossing scheme		33,670,000
Roadbed + culvert crossing scheme		18,830,000
Total		52,500,000
Cost coefficient	Bridge crossing	0.6413
	Roadbed + culvert crossing	0.3587

3.5 Comparison and Selection of Schemes

According to the calculation results, the function coefficient of the scheme using bridge crossing is higher than that using "roadbed + culvert" crossing, but the cost coefficient is also higher than that using "roadbed + culvert" crossing. To get the best scheme, we can compare the ratio of functionality to cost, which is called the value coefficient.

Table 4. Value coefficient calculation results

Schemes	Bridge crossing	Roadbed + culvert crossing
Function coefficient	0.5420	0.4580
Cost coefficient	0.6413	0.3587
Value coefficient	0.8452	1.277

Through comparative analysis, it can be seen that the value coefficient of the "roadbed + culvert" crossing scheme is higher than that of the bridge crossing scheme. Therefore, from the perspective of value engineering, this project should choose the "roadbed + culvert" crossing scheme.

3.6 Scheme Evaluation

After the scheme is selected and implemented, the implementation effect of the program should be evaluated in order to continuously improve the evaluation method. In this example, because the bridge site has less basic farmland, in order not to occupy the basic farmland, it is changed to fill. Although part of the land is increased, but the abandoned area is reduced. In general, the land use area increases less, and under the geological and topographic conditions, the fill height and roadbed construction quality are also easy to control. After expert review, it was finally implemented according to the changed scheme, which greatly reduced the investment in the project.

4 Conclusion

This paper introduces how to use value engineering method to make design change and optimize design scheme comparison. By using the value engineering method to determine the recommendation scheme, the index which is difficult to quantify can be further converted into quantifiable numerical index for comparison. In addition, the numerical index can simultaneously synthesize the weight of various factors and the opinions of experts within the industry. The comparison factors are comprehensive, the method is simple and easy, and the compared conclusion is more intuitive. The technical personnel can use the thought and method of value engineering to determine the recommended scheme when determining the design change scheme or selecting the scheme in the design stage, so that the determined scheme is more reasonable.

References

1. Leng L. M. (2011). The application of value engineering in highway traffic field. Transpoworld, 07, 296-297.
2. Ma Y. J. (2018). Cost Control Analysis of Value Engineering Theory at Construction Stage. Value Engineering, 37(15), 63-65.
3. Chen J.L., & WANG K. (2016). Highway Reconstruction and Extension Based on Value Engineering Evaluation of Interchange Design Scheme. Value Engineering, 35(02), 224-226.
4. Zhang X.J. (2012). Application of value engineering in cost control of highway construction. Technology and business, 5, 26.
5. Zhang J.W. (2018). The application of value engineering in highway engineering project management. Transportation World, 17, 168-169.
6. Song X.D. (2009). Application of value engineering in optimizing construction plan of pile foundation. Journal of ChangSha University, 23(5), 52-54.
7. Yan S.M., & Guo C.L. (2006). The application of value engineering in highway engineering construction. Technology & Economy in Areas of Communications, 1, 63-64.
8. An H.J. (2010). Discussion on the Cost Control Strategies of Highway Construction Project. Value Engineering, 29(21), 96.
9. Liu N. (2021). Comparison of Sports Ground Reconstruction Schemes Based on Value Engineering. Engineering Economy, 31(10), 14-17.
10. Chen S. C., Li J., & Chen X. Z. (2022). Research on Optimization of building facade design scheme based on Value Engineering. Fujian Architecture & construction, 03, 29-32.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.