Implicit Quality Cost Estimation Research Based On Taguchi Method in Construction Project*

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Abstract: The implicit quality cost of construction project will be mainly analyzed in the paper from two steps by taking advantage of Taguchi method: One involves establishment of implicit quality loss function so as to determine the standards of implicit quality loss evaluation. The other involves method choice of cost estimation in order to visualize the implicit quality cost. Thus, the implicit quality cost will be estimated successfully. By throwing a sprat to catch a whale, the paper aims at obtaining more concerns and inspiration of quality cost estimation from managers and researchers.

Keywords: Taguchi method; implicit quality cost; construction project

1 Introduction

In the early 1960s, the founder of total quality management, Armand Vallin Feigenbaum pointed out: The unsatisfied quality means the resources abuse and waste of materials, labors, machine and time, at last resulting in cost rising. Conversely, satisfactory quality means economical use of resources, prevention of waste and reduction of cost. Clearly, improving quality and reducing cost is related closely. In traditional concept, quality cost can be divided into four parts: prevent cost, test-checking cost, internal and external cost. Based on this pattern, quality cost is controlled in most of enterprises for a long time.

However, the traditional quality cost is not including implicit quality cost, because it is generally difficult to become aware of the implicit quality cost. Even today, with the increasing of knowledge ，people began to pay attention to the implicit quality cost, but it is still difficult to observe and estimate objectively, and it can’t be measured in accounting system usually. Although, in the book 《quality cost management》 of You Jianxin professor in Tongji University, some part of it had involved implicit quality cost, but there was still no in-depth study.

2 Analysis of implicit quality cost of construction project

2.1 The quality concept of Taguchi

Taguchi (the Japanese quality management expert) defined the product quality characteristic which avoid bringing about loss after leave factory, he deem that: "the quality is how much loss the products brings to the society after post marketing, but except the loss which produced by the function itself." So it can use "quality loss" to describe the quality of product quantitatively. quality loss including both direct loss and indirect loss which means the loss brought about by the product after leaving factory. However, the same products but their quality characteristics are different. Though they are good quality products, the characteristic values of the function also are changing, which are so-called quality fluctuation. And the reasons which cause quality changing are called quality disturbance. Because the quality noise exists objectively, so the product must have quality disturbance. Such as the accuracy will reduce, the output function will instable after using a period of time, which will bring about losses to the users. Due to the complexity of the environment, it is difficult to determine the loss of quality defect exactly. But to describe the quality loss quantitatively is also significant if considering the importance. Taguchi methods using monetary unit measure product quality-the lower social loss, the better product quality, conversely, the poorer product quality. It is said that the lesser quality fluctuation the lower implicit quality loss bring about. The study will research and discuss the im-

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plicit quality cost of construction project from the view of Taguchi.

2.2 The total quality cost system of construction project

In order to make a deep research about construction project, above all, we need to grasp the total quality cost system of construction project. The total quality cost system of construction project can be divided into two parts: explicit quality cost and implicit quality cost which according to the traditional quality cost. The explicit cost can be divided into four parts: prevention cost, test-checking cost, internal and external cost. The implicit Cost can be also divided into four parts: implicit prevention cost, implicit test-checking cost, implicit quality cost of qualified Divisional and Sub-divisional (DS) work and implicit quality cost of unqualified Divisional and Sub-divisional work. Its constitution diagram is as follow:

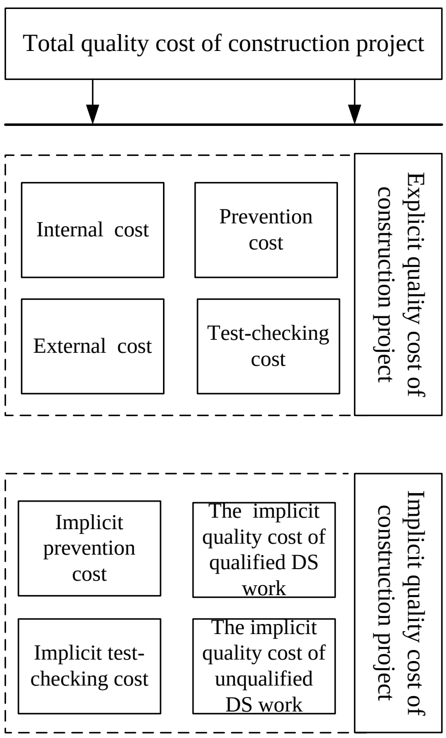

Figure 1: the Total quality cost system of construction project frame diagram

After introducing the total quality cost system of construction project, the concept of implicit quality cost of construction project will be more clearly. Next, the paper will accomplish the estimation of implicit quality cost of construction project by combining with different implicit quality cost functions.

3 Implicit quality cost estimation in construction project

The implicit quality cost of construction project will be mainly analyzed in the paper from two steps by taking advantage of Taguchi methods: For one thing, it is how to establish implicit quality loss function which determines the standards of implicit quality loss evaluation. For another thing, it is how to finish the implicit quality cost estimation, which can realize the implicit quality cost visualization. No matter what deviation increase the cost, they always to expand the quality cost management by the Project Milestone in the construction project. So the quality cost of construction project always manifest by Nominal-The-Best. The traditional quality cost estimation method and classical Taguchi quality loss function would be draw forth firstly. And then, estimation method facing to the implicit quality cost of construction project would put forward based on the two methods above and the characters of the construction project, so as to realize the estimating function of implicit quality cost of construction project.

3.1 Implicit quality loss function

3.1.1 Traditional quality loss function

The traditional quality cost deems that the qualified products whose characteristic value is in the specification limit bringing about no losses; and the unqualified products whose characteristic value is beyond the specification limit bringing about losses. The traditional quality losses function can be manifested as follow:

$$L(x) = \begin{cases} A, & |x - T| > \Delta \\ 0, & |x - T| \le \Delta \end{cases} \tag{1}$$

Like: x--------product characteristic value

T------- target value

A-------the loss

Δ------ tolerance, upper specification limit value and lower specification Limit: U=T+Δ ; L=T-Δ

Traditional Nominal-The-Best quality Loss Function can be manifest by the figure visually as follow:

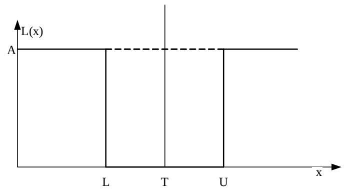

Figure 2: Traditional Nominal-The-Best quality Loss Function

Traditional Nominal-The-Best quality Loss Function only calculate the explicit quality cost, it doesn't consider the implicit quality cost in it.

3.1.2 Taguchi quality quadratic loss function

Taguchi putting forward quadratic quality loss function deemed that if the quality characteristic value deviates from the target value, it would bring about loss. The farther deviate from the target value, the more loss bring about. In fact, when the quality characteristic value is closer to the target value, it manifest that the better quality the projects have, when the quality characteristic value is closer to the upper specification limit value or the lower specification limit value, it manifest that the poorer quality the projects have.

However, this point is in according with the characters of construction project accidently. All the construction projects have their own standards to control the quality of project; under the lower specification limit value may result in a great loss, but if using exorbitant conservative design for avoiding the quality responsibility, it can also result in a great number of losses. So it is the principle of how to create the implicit quality cost in the construction project.

Supposing the quality characteristic value X deviate from the target value T, the quality loss is L(X), when X take T, then L(X) is minimum(zero).

$$L(T)=0 \qquad (2)$$

At the same time, when X close to T, then L(X) close to minimum, so that the differential coefficient of quality loss function take zero when X take T.

$$L'(T)=0 \qquad (3)$$

Expansion L(X) by Taylor's formula in the target value section can get the formula as follow:

$$L(x) = L(T) + \frac{L'(T)(x-T)}{1!} + \frac{L''(T)(x-T)^2}{2!} + \frac{L'''(T)(x-T)^3}{3!} + \cdots$$

$$= 0 + 0 + \frac{L''(T)(x-T)^2}{2!} + 0 + \cdots \quad , \ -\infty < x < \infty \qquad (4)$$

As （2）（3）show, the first term of this quality loss function is $K(x-T)^2$. If ignore $K'(x-T)^3$, it is easy to get the Taguchi quadratic quality loss function.

$$L(x) = K(x-T)^2 \qquad (5)$$

Taguchi quadratic quality loss function can manifest in the figure visually as follow:

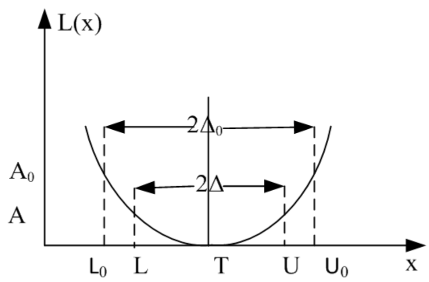

Figure 3: Taguchi quadratic quality loss function

In (5), K: quality loss coefficient. There are two kind methods calculate K.

1) The range of function Δ_0 and the loss of lose function A_0 calculate K; the range of function Δ_0 refers to the threshold value which judge the function of construction project whether effectiveness. When $|x-T| > \Delta_0$, the function of construction project lose efficacy; when $|x-T| \le \Delta_0$, the function of construction project effective. Suppose the loss when the function of construction project lose efficacy is A_0. Then :

$$K = \frac{A_0}{\Delta_0^2}$$

2) The tolerance Δ and disqualification loss A calculate K; the tolerance Δ refers to the threshold value which judge the quality of divisional and sub-divisional work whether up to standard. When $|x-T| > \Delta$, the divisional and sub-divisional work not up to the standard; When $|x-T| \le \Delta$, the divisional and sub-divisional work up to standard. Suppose the loss created by the divisional and sub-divisional work which not up to standard is A.

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Then:

$$K = \frac{A}{\Delta^2}$$

3.2 Taguchi modified quadratic quality loss function

Many scholars think that the Taguchi quadratic quality loss equation have some disadvantage. Such as:

1) From (4), when the quality characteristic values deviate from the desired value highly, it would be bring about infinitely great loss. Which is not fit the fact.

2) When the quality characteristic value beyond the specification limit value and the losses are same in the upper and lower specification limit value, we need to add the biggest loss in the (4).

3) When the quality characteristic value beyond the specification limit value and the losses are different in the upper and lower specification limit value, we not only need to add the biggest loss in the (4), but also to modify (4).

3.2.1 Symmetric modified quadratic quality loss function

When the quality characteristic value of construction project beyond the specification limit value, and the losses are same in the upper and lower specification limit value, it can take the symmetric modified quadratic quality loss function.

$$L(x) = \begin{cases} A, & |x - T| > \Delta \\ K(x - T)^2, & |x - T| \le \Delta \end{cases} \tag{6}$$

A is the biggest loss value. K is quality loss coefficient. The symmetric modified quadratic quality loss function is just like bellow:

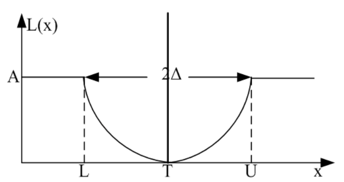

Figure 4: The symmetric modified quadratic quality loss function.

3.2.2 Asymmetric modified quadratic quality loss function

When the quality characteristic value of construction project outside specification limit value and the loss are different from in the upper and lower specification limit value, we need take the asymmetric modified quadratic quality loss function to calculate the implicit quality cost of construction project. For instance, the reworks loss which result of the concealed project of one construction project is unqualified, will definitely different from the quality loss which caused by higher quality standard. So in that time, it needed to take the asymmetric modified quadratic quality loss function to estimate the implicit quality cost of construction project. The asymmetric modified quadratic quality loss function is as follow:

$$L(x) = \begin{cases} A_1, & x < L \\ k_1(x - T)^2, & L \le x \le T \\ k_2(x - T)^2, & T \le x \le U \\ A_2, & x > U \end{cases} \tag{7}$$

The asymmetric modified quadratic quality loss function figure just like bellow:

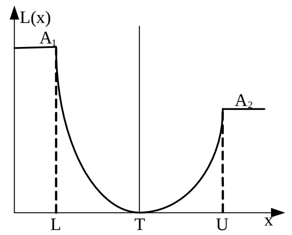

Figure 5: Asymmetric modified quadratic quality loss function

3.3 The implicit quality cost estimation in construction project

The idea which estimate the implicit quality cost of construction project basis on the modified Taguchi method is suppose that the distribution function of quality characteristic value x is known, and its probability density function $f(x)$, searching for the right quality loss function $L(x)$, so it can get the expectation of $L(x)$ as follow:

$$E(L(x)) = \int_{-\infty}^{+\infty} L(x) f(x)\,dx \tag{8}$$

$E(L(x))$ refer to the average quality loss of the divisional and sub-divisional work in economics. Expand $E(L(x))$ as follow:

$$E(L(x)) = \int_{-\infty}^{+\infty} L(x)f(x)\,dx$$

$$= \int_{-\infty}^{L} L(x)f(x)\,dx + \int_{L}^{U} L(x)f(x)\,dx + \int_{U}^{+\infty} L(x)f(x)\,dx \tag{9}$$

Supposes:

$$C_1 = \int_{-\infty}^{L} L(x)f(x)\,dx$$

$$C_2 = \int_{U}^{+\infty} L(x)f(x)\,dx$$

$$C = \int_{L}^{U} L(x)f(x)\,dx$$

C_1 as the loss of divisional and sub-divisional work which under the lower specification limit value; C_2 as the loss of divisional and sub-divisional work which beyond the upper specification limit value; C as the loss of divisional and sub-divisional work (including unqualified divisional and sub-divisional work) which is the average implicit quality cost; suppose the probability of qualified divisional and sub-divisional work is q, the implicit quality cost of qualified divisional and sub-divisional work is C_0.

Then $q = \int_{L}^{U} f(x)\,dx$, $C_0 = \frac{C}{q}$

C_0 as the implicit quality cost of qualified divisional and sub-divisional work is, so as that the implicit quality cost of unqualified divisional and sub-divisional work is must shift into the qualified divisional and sub-divisional work is. For instance, there are 12 divisional and sub-divisional work is in a construction project, the qualified probability is 96% at first time, the implicit cost of divisional and sub-divisional work is 110000 Yuan. According to the formulations above can calculate the unit qualified divisional and sub-divisional work C_0=114583.33 Yuan. Therefore, it can calculate the implicit cost of construction project to 114583.33×12×96%=1320000 Yuan. Furthermore, according to the implicit quality of qualified divisional and sub-divisional work can also calculate the implicit quality cost of this construction project: 110000×12=1320000Yuan.

4 Conclusion

In practical project，the implicit quality cost can not be accounted and checked easily because of its characteristic of elusive, singleton and complexity. So, a new method named Taguchi implicit quality cost estimation method in construction project can be got after the research of the traditional quality cost method and the classic Taguchi implicit quality cost method. According to this method, the implicit quality cost can be estimated, and it is very important to control total cost for a construction project when the implicit quality cost became visible.

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