Factor selection and weight determination in residential project price adjustment method

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Abstract. The code of valuation with bill quantity of construction works provides a formula basis for contract price adjustment caused by market price fluctuation. However, how to determine the price adjustment factor and its weight, or the recommended factors and weight tables for a certain type of construction projects have not been given. In order to solve the current difficulties in application, according to the engineering data, this study takes residential project as an example, proposes five adjustment factors and the factors weight calculation method. This study provides a thought and suggestion for the adjustment of contract price by using the formula price adjustment method in residential projects.

1. Introduction
The "Code of valuation with bill quantity of construction works" (GB50500-2013) provides a formula basis for the adjustment of contract price caused by the fluctuation of market prices. However, there is no clear solution for how to determine the price adjustment factor and its weight, and how to use the existing price information to adjust the contract price. At the same time, there are no suggestions and requirements for the parameters required by the formula in the open cost information of our provinces and cities. Therefore, the price adjustment factor and price index in the formula should be studied clearly so that the formula provided in the specification can be better applied. It can safeguard the interests of the owner and contractor, reduce the risk of the contractor's operation, and prevent the delay of the construction period.

2. The price index method
In China's Code of valuation with bill quantity of construction works (GB50500-2013), the price adjustment method of FIDIC is used for reference, that is, before the contract is signed, the two parties negotiate on the future price adjustment when the price fluctuations of labour, materials and equipment affect the contract price. It is agreed that some work items selected by both parties shall be included in the contract and the price index and weight table in the appendix to the tender letter shall be formed. When the price fluctuates in the later period, the difference shall be calculated according to the following formula and the contract price should be adjusted [1-2]:

\[
\Delta P = P_0[A + (B_1 \times \frac{F_{t1}}{F_{01}} + B_2 \times \frac{F_{t2}}{F_{02}} + B_3 \times \frac{F_{t3}}{F_{03}} + \cdots + B_n \times \frac{F_{tn}}{F_{0n}}) - 1]
\]

(1)

Among them: \( A + B_1 + B_2 + B_3 + \cdots + B_n = 1 \)
\( \Delta P \)—the price difference to be adjusted.
the amount of work that the contractor should receive in the agreed payment certificate. This amount shall not include price adjustment, withholding and payment of quality bonds, payment and deduction of advance payments.

\begin{align*}
P_0 & \quad \text{the amount of work that the contractor should receive in the agreed payment certificate. This amount shall not include price adjustment, withholding and payment of quality bonds, payment and deduction of advance payments.} \\
a & \quad \text{the fixed value weight (the weight of the non-adjustment part).} \\
B_1 ; B_2 ; B_3 \cdots B_n & \quad \text{the variable weight of each adjustable factor (the weight of the adjustable part) is the proportion of each adjustable factor in the total quotation in the tender letter.} \\
F_{t1} ; F_{t2} ; F_{t3} \cdots F_{tn} & \quad \text{the current price index of each adjustable factor, the price index of each adjustable factor 42 days before the last day of the agreed certificate of payment-related cycle;} \\
F_{01} ; F_{02} ; F_{03} \cdots F_{0n} & \quad \text{the basic price index of each adjustable factor, referring to the price index of each adjustable factor of the base date.} \\
\end{align*}

3. Selection principles of price adjustment factors

In order to ensure that the selected price adjustment factors have reference significance for most construction projects, the following principles should be paid attention to in the course of the price adjustment of residential projects:

1) Principle of universality: Since the construction industry involves government departments, trade associations, owners and contractors and other different levels of units, so the basic classification and compilation methods should be used to determine the price adjustment factors, so that the process and results of the factors obtained are of reference significance to the whole industry.

2) Principle of compatibility: Since the construction industry in China has a wide geographical span and a large time span, the factors and weights in the price adjustment formula should not be based on the cost data of a single contractor and owner, but should include the cost data of multiple contractors, owners and multiple project cases.

3) Principle of expansion: As new engineering technology and new project management mode are constantly emerging in China’s construction project industry, the data of each factor and weight in the price adjustment formula should be obtained in a constantly accumulating and constantly enriching standard database.

4. Selection of price adjustment factors

The weight part of the formula can be divided into two types according to whether the fee can be charged at the time of settlement: the first is the fixed value weight part, which has only the weight value and no price index multiplier; the other is the variable weight part, which has both the weight value and the price index multiplier. Among them, the existence of fixed weight has the following reasons[3]: firstly, in order to prevent the contractor from transferring all the risk of price fluctuation to the owner, the existence of fixed weight makes the contractor bear part of the risk of price fluctuation, and help the owner to reduce the project cost. Secondly, the existence of fixed weight can make some cost components of the price which should not be adjusted not change.

Variable weight is one of the most important parts which affect the effect of formula price adjustment method. Choosing the right and appropriate price adjustment factors can make the formula price adjustment result the best.

Usually when we select the adjustment factor, one way is determining the material costs as a percentage of the project cost according to the project bidding documents. Another way is determining the material scope according to the professional project [4-5].

Therefore, this paper first makes statistics and analysis on the existing high-rise residential cost projects, and gets the proportion of labour, materials, machinery costs. Through the data, we can clearly understand that in a existing project, labour costs and material costs are the two largest proportion of direct engineering cost, the highest proportion of which can reach 27.06% and 81.33%. The cost of machinery is often less than labour costs and material costs. Therefore, this paper will focus on how to select the price adjustment factors in labour and machinery costs. And in this paper, we look the machinery costs as a fixed price adjustment factor.
After determining the labour costs and material costs as the main variable factors, the next step is to refine the cost proportion of each material. This paper also takes the cost ratio of the main engineering materials collected from 11 residential building projects. Details are shown in Table 1 below.

From Table 1, it is clear that the cost components of concrete, steel, wood and masonry usually account for a large proportion of the direct project cost. When the fifth category factor is counted, it will be found that the proportion of construction cost is usually less than 4%, and the category changes greatly. So we can say that it is difficult to classify.

### Table 1. Statistics of main materials for 11 residential buildings.

| Content              | First categories | Second categories | Third categories | Fourth categories | Fifth categories |
|----------------------|------------------|-------------------|------------------|-------------------|------------------|
|                      | Concrete         | Steel             | Wood             | Masonry           |                  |
| 1                    | 22.93%           | 33.41%            | 12.72%           | 6.35%             | plastic extruded board 4.06% |
| 2                    | 17.75%           | 17.66%            | 17.48%           | 2.54%             | waterproofing membrane 2.35% |
| 3                    | 19.81%           | 26.17%            | 4.59%            | 2.91%             | cement 0.16%     |
| 4                    | 25.22%           | 39.58%            | no information   | 4.14%             | waterproof coating 3.46% |
| 5                    | 22.99%           | 37.23%            | no information   | 4.96%             | mortar 6.02%     |
| 6                    | 28.98%           | 26.56%            | no information   | 8.08%             | cement 4.80%     |
| 7                    | 17.81%           | 19.45%            | 2.94%            | 2.89%             | cement 1.69%     |
| 8                    | 17.49%           | 30.73%            | 1.78%            | 3.40%             | cement 3.82%     |
| 9                    | 21.13%           | 29.08%            | 1.62%            | 4.97%             | cement 26.43%    |
| 10                   | 16.38%           | 27.07%            | 9.63%            | 1.28%             | no information None |
| 11                   | 16.24%           | 17.11%            | 3.28%            | 0.02%             | cement 0.01%     |

However, whether a factor should be determined as a variable factor, the adjustment factor needs a larger range of expected price fluctuations too. In order to find the historical price fluctuations of concrete, steel, wood and masonry, this paper intercepts the price information of construction projects published by Shenzhen Construction Cost Management Station from January 2013 to December 2017. From January 2013 to December 2017, the annual fluctuation of all materials exceeded 15%. Among them, the most serious fluctuation occurred in steel products, which fluctuated more than 40% between August 2014 and June 2015. Therefore, it can be considered that there are serious fluctuations in the history of building materials, the future also has the possibility of a large degree fluctuations.

To sum up, this paper will determine labour, concrete, steel, wood, masonry five types of cost elements as adjustable factors, and the use of machinery and other building materials as a fixed factor.

### 5. Determining the weight range of each factor of the formula

Weight is an index to weigh the influence of individual factors on the change of total index. At present, in the practical application, the methods of determining the weight are more attention to the determination of the weight value, but they can’t determine the reasonable range of the weight. In order to solve this problem, this paper argues that the normal distribution can be introduced to determine the weight value and weight range.

Usually, the weight of a project cost index is affected by many factors, such as building structure type, architectural design ideas, construction quantity, market prices and so on. But at the same time, the same type of construction cost index will be similar, because of the limitation of these factors. We can assume that the weight ratio of the five adjustable factors to the direct engineering cost in the typical high-rise residential buildings obeys the normal distribution. Therefore, the Kolmogorov-Smirnov test of labour and material costs is carried out by using the lillietest function in MATLAB to verify whether the distribution obeys the specified orthodox distribution. The concrete expression in MATLAB is as follows:
According to the test formula in MATLAB, the ratio of labour costs and material costs is tested by normal distribution. The results are shown in Table 2. The H value of both costs is 0, indicating that the existing data do not reject the previous hypothesis. That is to say, on the basis of the existing data, the weight value of labour costs is about 0.23, its scope is roughly [0.20, 0.25].

Table 2. Normality test results table for direct engineering cost.

|                | mean value | variance | L  | cv   |
|----------------|------------|----------|----|------|
| Labour costs   |            |          |    |      |
| H              | 0.2292     | 0.2057   |    |      |
| Material costs |            |          |    |      |
| H              | 0.7324     | 0.6993   |    |      |

Similarly, by calculating the weights of concrete, steel, wood and masonry, Table 3 can be obtained. The results show that the H values of the four factors are 0, indicating that the existing data do not reject previous assumptions. It can not be denied that these four factors are not normally distributed at 0.05 confidence level.

Table 3. Normality test results table for material costs.

|            | mean value | variance | L  | cv   |
|------------|------------|----------|----|------|
| concrete   |            |          |    |      |
| H          | 0.2081     | 0.1830   |    |      |
| steel      |            |          |    |      |
| H          | 0.2844     | 0.2357   |    |      |
| wood       |            |          |    |      |
| H          | 0.0676     | 0.0185   |    |      |
| masonry    |            |          |    |      |
| H          | 0.0387     | 0.0248   |    |      |

In summary, the weight ratio in the price adjustment formula can be obtained by fitting the orthodox distribution. And the five adjustment factors are labour costs, concrete, steel, wood and masonry. The final recommended weight list are shown in Table 4 below.

Table 4. Recommended weight list.

|                | Weight value | Mean lower limit | Mean upper limit |
|----------------|--------------|------------------|------------------|
| Fixed weight   | A            | 0.17             |                  |
| Labour cost    | B1           | 0.23             | 0.2057           | 0.2527           |
| Concrete cost  | B2           | 0.21             | 0.1830           | 0.2332           |
| Steel cost     | B3           | 0.28             | 0.2357           | 0.3331           |
| Wood cost      | B4           | 0.07             | 0.0185           | 0.1166           |
| Masonry cost   | B5           | 0.04             | 0.0248           | 0.0527           |

6. Summary
To sum up, according to the construction cost index and market prices information published from the websites of local cost information associations in China, this paper determines five adjustment factors and the cost components which should be contained in the fixed part. And then this paper uses the normal distribution to reasonably determine the weight range of the variable factor. It provides an idea and a reference range for the contractor to adjust the contract price by using the formula adjustment method in the future.

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