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TWO-STEP CONTROL GRADING METHOD

ZHOU Yao-lie(周耀烈), SHAO Dan(邵 丹)
(*College of Management, Zhejiang University, Hangzhou 310027, China*)

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Abstract: The incorrectness of function grading in value engineering has been an essential problem for decades. This paper proposes a new method, where the functions under consideration are ranked in queue according to their importance and then graded quantitatively. By using this method, the reviewers are more aware of the degrees of importance, and therefore will have an easier time grasping the standard and reducing the erroneous grading. In the first step, the sign test is used to discard incorrect data, to count the grading result and to arrange in queue according to the degrees of functional importance. In the second step the queued up functions undergo quantitative grading, where the "average value of fluctuation coefficient" is proposed to determine the control levels and to delete unreasonable data outside the controlled region so as to get more satisfactory grading value. The proposed method solves the problem of the incorrectness of function grading in value engineering. It has been proved that the correctness has been raised from the original 70% to over 95%. This new method is not only contributive to the discipline of value engineering but also suitable in the evaluation of technical economy.

Key words: two-step control, fixed quantity grading, grading method
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INTRODUCTION

The proposed two-step control grading method shown in Fig.1 arranges all kinds of functions in order of importance and then defines their degrees.

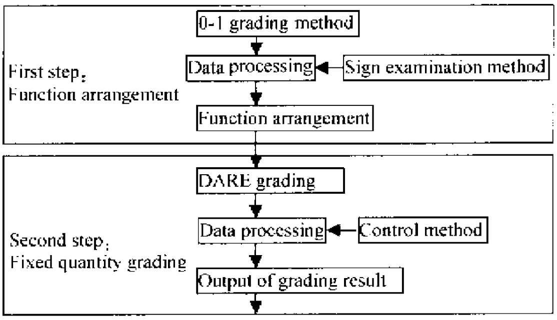

Fig.1 Two-step control grading method procedure

Fig.1 shows that the "0-1 grading method" first grades the functions and then use "sign examination method" to decide and arrange the functions in the order of their importance degrees (Yang, 1997); the second step is to use DARE (Decision Alternative Ratio Evaluation system) (Tao, et al, 1991) or other method to grade the functions, then use "control method" to process the graded data, reject unreasonable graded marks and finally get reasonable graded data.

METHODS

1. Sign examination method

"Sign examination method" is a statistical deductive method used in "mathematical statistics".

The method is as follows: suppose the importance degrees of function A and B are the same, and n mark-givers (representative of ender users) use $0-1$ method to grade these two functions. In the n pairs of figures received (a_1, b_1), $(a_2, b_2)\cdots(a_n, b_n)$, the opinion of $a_i > b_i (i=1,2,\cdots,n)$ should have the same probability $p=1/2$.

$$\text{Let } c_1 = \begin{cases} 1 & a_i > b_i \\ 0 & a_i < b_i \quad i=1,2,\cdots,n \end{cases}$$

then $c = c_1 + c_2 + \cdots + c_n$ would follow "two item distribution function," $p=1/2$.

Let: $a_i > b_i$, be as signed as " + ", n_+ is the number of " + "

$a_i < b_i$, be as signed as " − ", n_- is the number of " − "

If n_+ and n_- are close, the importance degrees of function A and B do not have much disparity, then it can be considered that the end mark-givers' grading is reasonable.

If there is great disparity between n_+ and n_-, then there is much difference in the importance degree of function A and B, suggesting that a few persons' grading is not reasonable, we should collect data according to the grading of the majority.

Then, to what extent of disparity between n_+ and n_-, then is there great difference in the importance degree of function A and B? This can be judged by "critical value of notability." First, we fix notability level α, (generally fixed at 1%, 5% or 10%, the smaller the α is, the higher the accuracy would be.) then look up γ^0 in the "sign check table"(see the attached Tables) according to α and $N(N = n_+ + n_-)$, let $\min[n_+ + n_-] = \gamma$, if $\gamma \leqslant \gamma^0$, it can be concluded that there is great difference in the importance degree of the two functions.

Similarly, if $\gamma > \gamma^0$, we can conclude that there is not much difference in the importance degree of the two functions, In this case we can use statistical method to calculate the functions of A and B.

2. Control method

Generally speaking, the marks of a certain function graded by the mark-givers assume "normal distribution"(Wang, 1994).

According to experience, about 95% of graded data will fall within the scope of $\mu - 2\sigma$, $\mu + 2\sigma$, that is to say, only about 5% of the marks would fall out of that scope.

So we take $\mu - 2\sigma$ as the lower control limit of the grading data and $\mu + 2\sigma$ as the upper limit. All mark-givers' graded marks that fall within this scope can be taken as correctly graded marks, all the marks that fall out of this scope can be taken as unreasonable ones and discarded.

According to statistical theory, systematic average value μ can be replaced by sub-sample's average value $\bar{x}$ and systematic mean square deviation σ can be replaced by sub-sample's mean square deviation.

i.e. $\mu = \bar{x} = \dfrac{\sum_{i=1}^{n} x_i}{n} \quad \sigma = s = \sqrt{\dfrac{\sum(x_i - \bar{x})^2}{n}}$

In the formula, n is the number of graded data of a certain function.

The upper and lower control limits of a function are generally calculated as follows:

Upper control limit of graded marks = $\bar{x} + 2s$

Lower control limit of graded marks = $\bar{x} - 2s$

When we use the above method to control the graded marks, the accuracy of the grading is relatively high and the control is relatively strict, if the graded marks of a function are relatively close. If the marks are relatively different, then the accuracy of the grading is relatively low, and the control is relatively loose, so that such control is not reasonable in the same system, so a universal standard is required to control the graded marks of various functions. Obviously, this standard should be decided according to the fluctuation of all data (Shao, 1999).

Such being the case, we have to look for new upper and lower control limits of marks.

We already know the upper marks control limits of a certain function is $X_{UCL} = \bar{x} + 2s$

Let: $V_j = S_j / \bar{x}_j$

i.e. $S_j = V_j \bar{x}_j = 1, 2, \cdots, m$

In the formula:

V_j —— the fluctuation coefficient of function j

X_j —— the average graded mark of function j

S_j —— the standard deviation for the graded mark of function j

Thus: $X_{\mathrm{UCL}} = X_j + 2V_j X_j = X_j(1 + 2V_j)$

Generally speaking, the fluctuation extent of all graded marks should be the same, so this fluctuation coefficient should be the average value $\bar{V}$ of various functions' fluctuation coefficient (Zhou, 2000).

$$\bar{V} = \frac{\sum_{j=1}^{m} V_j}{m}$$

Then the upper control limit for graded marks of a certain function is

$$X_{\mathrm{UCL}} = \bar{x}_j + 2s_j = \bar{x}_j + 2\bar{V}\bar{X}_j = \bar{X}_j(1 + 2\bar{V})$$

The same is true of the lower control limit:

$$X_{\mathrm{LCL}} = \bar{x}_j - 2s_j = \bar{X}_j - 2\bar{v}\bar{X}_j = \bar{X}_j(1 - 2\bar{V})$$

When we use the above control limits to control the graded marks, the data that fall out of the limits is regarded as unreasonable marks, and should be rejected. The data that fall within the limits should be regarded as reasonable marks, and be kept to calculate the new graded value $\bar{X}'_j$.

3. Example

Suppose a certain product has four functions (A, B, C, D). We ask 15 mark-givers to grade the functions, so as to evaluate the coefficients of the functions.

First step: function arrangement

(1) 0 – 1 grading

0 – 1 grading is used to compare the function of the products against one another. The important function gets 1 and the unimportant function gets 0. One cannot regard every function as important and give 1 to everyone; neither can one regards every function as not important and give 0 to every function. We use "X" to indicate the functions which do not take part in the comparison. Table 1 is the grading result of grader A.

Table 1 0 – 1 grading table (i = No.1)

Function	Selection grading					
A	1	1	1	X	X	X
B	0	X	X	1	1	X
C	X	0	X	0	X	0
D	X	X	0	X	0	1

(2) Use sign examination method to count up the grading results

According to the principles of the sign examination method, the number of graders $N = 15$, in order to get higher accuracy, the level of notability should be lower. So we let $a = 5\%$; we can check the attached table according to N and a, and get $\gamma^0 = 3$, then $N - \gamma^0 = 12$.

Count up 15 grading tables. If 12 or more than 12 mark-givers consider function A is more important then function B, then fill "1" in the corresponding place of function A and "0" in the corresponding place of function B in Table 2.

If according to the statistical result, the number of graders who have the same opinion are less than 12, then we interpolate method and fill in the Table 2 with the statistical coefficient value.

For example, there are 6 mark-givers who consider function C is more important than function D, and 9 mark-givers who consider function D is more important than function C. statistical coefficient of function C is $(6/15) = 0.4$, and the statistical coefficient of function D is $(9/15) = 0.6$. Fill in these two data in the corresponding place of Table 2.

Table 2 0 – 1 grading collection table ($N = 15$)

Function	Selection grading						Total
A	1	1	1	X	X	X	3
B	0	X	X	1	1	X	2
C	X	0	X	0	X	0.4	0.4
D	X	X	0	X	0	0.6	0.6

(3) Arrange the functions in order of importance

From Table 2, we can learn that the importance order of these four functions indicated in Table 3.

Table 3 Function importance order

Order	1	2	3	4
Function	A	B	D	C

Second step: fixed quantity grading

(1) Use DARE method to grade

Ask 15 mark-givers to give marks to every function according to the importance order of Table 3, by filling in Table 4. In Table 4, Grader No.1 supposes the importance of function C is "1", function D's importance is 1.15 times function C's, function B's importance is 1.8 times function D's and function A's importance is 1.35 times function B's.

Table 4 DARE method grading table (i = No.1)

Order	Function j	Tenatatively fixed importance coefficient X_{ij}
1	A	$X_{1A} = 1.35$
2	B	$X_{1B} = 1.8$
3	D	$X_{1D} = 1.15$
4	C	$X_{1C} = 1.00$

(2) Collect the data graded by all the mark-givers

Fill the tentative importance coefficient graded by 15 mark-givers in Table 5, and calculate the average graded value of every function.

$$\bar{X}_j = \frac{\sum_{i=1}^{15} X_i}{15} \quad (i = \text{No}.1, 2, 3, \cdots, 15 \quad j = A, B, C, D)$$

$$\bar{X}_A = (1.35 + 1.5 + \cdots + 2.0)/15 = 1.5,$$
$$\bar{X}_B = 2.0, \ \bar{X}_D = 1.2, \ \bar{X}_C = 1.0$$

Table 5 Collection table of graded data

Func.	Order(No.)							
	1	2	3	4	5	6	7	8
A	1.35	1.5	1.45	1.6	1.5	1.6	1.5	1.4
B	1.8	1.3	1.75	2.05	2.1	2.05	2.16	2.1
D	1.15	1.1	1.15	1.2	1.3	1.3	1.05	1.1
C	1	1	1	1	1	1	1	1

Func.	Order(No.)							
	9	10	11	12	13	14	15	$\bar{X}_j$
A	1.6	2.5	1.4	1.55	1.45	1.6	2.0	1.6
B	2.09	2.2	2.11	2.02	2.03	2.14	2.1	2.0
C	1.3	1.1	1.29	1.3	1.26	1.15	1.25	1.2
D	1	1	1	1	1	1	1	1

(3) Use control method to reject the unreasonable data and evaluate $\bar{X}_j$ of all functions

We know from Table 6 that function *C* is the standard level of grading radix, So we do not have to process the graded datum of function *C*. As for the data of other functions, we can use control method to process according to the following steps.

Table 6 Collection table of value $\bar{V}$

Function	$\bar{X}_j$	$\bar{S}_j$	$\bar{S}_j = \bar{S}_j/\bar{X}_j$	$V = \sum V_j/3$
A	1.6	0.28	0.175	(0.175 + 0.11 +
B	2.0	0.22	0.11	0.075)/3 = 0.12
D	1.2	0.09	0.075	

1) Calculate the standard deviation *S* of all functions' graded value.

Take function *A* for example:

$$S_A = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \cdots + (X_n - \bar{X})^2}{n}} = \sqrt{\frac{(1.35-1.6)^2 + (1.5-1.6)^2 + \cdots + (2.0-1.6)^2}{15}} = 0.28$$

We can calculate the graded value S of other function by using the same method, $S_B = 0.22$, $S_D = 0.09$, then fill them in Table 6.

2) Calculate the average $\bar{V}$ of the grading fluctuation coefficient of all function.

Use Table 6 to calculate $\bar{V}$, according to $\bar{X}_j$ in Table 5 and S_j that is already evaluated.

3) Decide the upper and lower control limits of all functions and then use them to control the graded data.

Again take function *A* for example:

$$X_{\text{UCL}} = \bar{X}_A(1 + 2\bar{V}) = 1.6(1 + 2(0.12) = 1.984$$
$$X_{\text{LCL}} = \bar{X}_A(1 - 2\bar{V}) = 1.6(1 - 2(0.12) = 1.216$$

Compare the lower limit 1.216 and upper limit 1.984 with the graded data of function *A* in Table 5, the datas "2.5" and "2.0" fall out of the control scope, so it should be rejected. We use the remaining 13 data to calculate and get new value $\bar{X}'_A = 1.5$.

Use the same method to process the graded data of function *B* and *D*. (i.e. Function *B*:

$$X_{\text{UCL}} = 2(1 + 2 \times 0.12) = 2.48$$
$$X_{\text{LCL}} = 2(1 - 2 \times 0.12) = 1.52$$

Function *D*: $X_{\text{UCL}} = 1.2(1 + 2 \times 0.12) = 1.488$

$$X_{\text{LCL}} = 1.2(1 - 2 \times 0.12) = 0.912$$

We can find that there is a datum "1.3" falling out of the control limits after checking. So this unreasonable datum should be rejected).

Again we get new graded average value after calculation: $\bar{X}'_B = 2.05$, $\bar{X}'_D = 1.2$.

Table 7 Function coefficient table of DARE method

Function	Tentative importance coefficient $\bar{X}'_j$	Processed importance coefficient	Function coefficient
A	1.50	3.69	0.442
B	2.05	2.46	0.294
C	1.20	1.20	0.144
D	1	1	0.120
Σ		8.35	1.000

(4) Calculate the grading coefficients of all functions.

Fill in Table 7 with average value $\bar{X}'_j$ in which all the unreasonable graded data are rejected. These tentative importance coefficients can represent the ideas of all mark-givers rather precisely. Then we use DARE method to calculate the coefficients of all functions.

In the table:

The processed importance coefficient of function $D = 1.00 \times 1.20 = 1.20$ (i.e. The importance degree of Function D is 1.20 times Function C's).

The processed importance coefficient of function $B = 1.20 \times 2.05 = 2.46$ (i.e. The importance degree of Function B is 2.46 times as much as Function C's).

The function coefficient of function $A = 3.69/8.35 = 0.442$ (i.e. The importance degree of Function A is 44.2% of the total function).

The function coefficient of Function $B = 2.46/8.35 = 0.294$ (i.e. The importance degree of Function B is 29.4% of the total function).

Up to now, we have got the correct graded result and finished the procedure of grading with two-step control method.

NOTES

1. The first step of the two-step control grading method is to obtain the importance order of all functions. Grading can be a little bit rough and there can be fewer people to take part in. The second step is to decide the importance degree of the functions, so the graded data should be precise, and there should be more people to take part in.

2. We use sign check method to process the graded data of the first step and use control method to-process the graded data of the second step. The reasons are as follows: (1) Using sign check method to process the data is only to make comparison between the figures, it does not require the accuracy of the data. This coincides with the aim of the first step and the characteristics of 0 – 1 grading method. Using the control method to process data can increase the accuracy of the data, and coincides with the aim of the second step and the characteristics of DARE grading method. (2) the advantage of the sign check method is simplicity and intuition, but this method has less accuracy. The shortcomings of these two methods can be made up by their combined advantages. So the arrangement of the steps is proper and meets the requirements of the two-step grading.

3. The two-step control method uses scientific procedure to arrange the functions in order of importance first, grade with the fixed quantity second. It enables the graders to grade precisely, and uses statistic fundamentals to process the graded data and reject unreasonably graded data. The grading accuracy rate can reach 95%, it guarantees the accuracy of the final results of function grading.

4. This method can be used in all places that need fixed quantity grading.

Appendix Table: Sign examination r^0

No.	α(%)			No.	α(%)			No.	α(%)		
	1	5	10		1	5	10		1	5	10
6		0	0	11	0	1	2	16	2	3	4
7		0	0	12	1	2	2	17	2	4	4
8	0	0	1	13	1	2	3	18	3	4	5
9	0	1	1	14	1	2	3	19	3	4	5
10	0	1	1	15	2	3	3	20	3	5	5

References

Shao Peiji, 1999. Scientific research achievements evaluation decision method. *Journal of Industrial Engineering and Engineering Management*, **13**(3): 45 – 48 (in Chinese).

Tao Shuren, Huang Yuxiang, Huang Jingming, 1991. Appraisal of Technical Economy. Publishing House of Senior Education. 1st Ed., p.192 – 205(in Chinese).

Wang Pinghui, 1999. Summarization of methods in science research assessment. *Science Research Management*, **20** (3): 18 – 24(in Chinese).

Wang Jun, 1994. Function ratio-grading method. *Value Engineering*, **4**(63): 13 – 16(in Chinese).

Yang Hantao, 1997. Recognizance to force ascertainment method. *In*: Value Engineering, 3rd Ed., p.15 – 17 (in Chinese).

Zhou Yaolie, 2000. Grading method for scientific research program and procedure. *Science Research Management*, **21**(5): 76 – 83(in Chinese).