The Analysis for The Importance of The Service Performance of Sluice Engineering Based on The Game Theory

Qiulin CAO¹ Lingyu Shao¹ Lulu Jiang¹
¹College of Hydraulic, Energy and Power Engineering, Yangzhou University, Yangzhou 225009, Jiangsu China
Email: cjqlshy@163.com

Abstract: This paper mainly studies the importance of service performance of water brake engineering. From the technical feasibility, the effect reliability, the economic rationality, the construction convenience and the social environmental impact study the influence factor of the performance improvement measures. This paper establishes the evaluation system of the applicability evaluation sAystem of multi-level water sluice service, and puts forward the quantitative method of qualitative and quantitative indexes. Sequence relations and the variation coefficient method is used to the subjective and objective study on the importance evaluation index respectively, and put forward the subjective and objective weight fusion method based on the game theory, a more accurate service of sluice project importance evaluation index performance improvement measures are studied.

1. Research background
With the sluice service time growing, it will gradually bring lesions and defects, affecting the health of the sluice. However, the destruction process of the sluice often does not occur suddenly, and can be found by means of observation and detection analysis. Therefore, during the service period of the sluice, it is necessary to carry out safety inspection on a regular basis. According to the results of safety appraisal, reasonable maintenance and reinforcement can be selected to achieve long-term health service. This chapter will discuss the applicability of engineering measures to improve the service performance of sluices.

2. Analysis of applicability of lifting measures

2.1. Construction of comprehensive evaluation system for applicability of engineering measures
Optimization of sluice service performance improvement measures is for a specific promotion measures, analyzed from the technical feasibility, effect of reliability, economic rationality, construction convenience, social environment and other aspects, and one of the best measures is selected from many improvement measures. Because there are many factors affecting the promotion measures, the factors of different nature often need to be affected by a number of factors, so the evaluation of the suitability of the lifting measures belongs to a multi-level evaluation process. In order to realize the evaluation goal scientifically, five second-level evaluation factors, such as technical feasibility, economic rationality, effect reliability, construction convenience and social environment influence, can be selected to comprehensively analyze the applicability of the promotion measures from different emphases. The second-level evaluation factor is the concrete embodiment of the first-class factor. This paper established the sluice service performance evaluation index system of
measures to enhance the structure as shown in Figure 2.1. According to the evaluation system, bottom-up recursive layers, eventually won the applicability evaluation results of the measures.

2.2. Quantification of evaluation indexes
In the above evaluation system, there are both quantitative indexes and fuzzy qualitative indexes, due to different indexes of the unit and the magnitude of the difference, so that they are not comparable. Therefore, all indicators must be dimensionless and be unified on an evaluation scale. In this paper, all indexes including evaluation target are quantified to $[0,1]$, and at the same time, the greater the value is, the greater the quantity superior membership of the corresponding index is, and the better the applicability is.

1. Quantitative index data standardization. In the sluice reinforcement scheme, some evaluation indexes for positive index, value is more superior, some indexes such as strengthening the cost is negative index, the smaller the better plan. This article is dealt with in the relation as follow:

$$\mu_{ij} = \frac{x_i^0 - x_{ij}}{x_{i,\text{max}} - x_{i,\text{min}}} \quad (1)$$

Figure 2.1 Evaluation system of service performance improvement measures for Sluice Project
Among them: $x_{ij}$ is the i-th index value in the j-th reinforcement scheme; $x_{\text{max}}$ is the maximum value of the i-th index in all alternatives; $x_{\text{min}}$ is the minimum value of the i-th index in all alternatives; $x_{i0}$ is the reference quantity, when the positive index is $x_{\text{min}}$, the negative value is $x_{\text{max}}$.

The negative value is $x_{k}$. 

2 Qualitative index of standardization. There are many qualitative indexes which are difficult to get quantitative value in the evaluation index of service performance of sluice, in this paper, the weighted set-valued statistical method is used to quantify the qualitative evaluation index[1-4], so that the evaluation result is more realistic and objective.

For discussion convenience, it is assumed that there are m feasible schemes, expressed by the set $X = \{x_1, x_2, ..., x_m\}$, there are n qualitative indicators reflecting the merits of these schemes, expressed by the set $C = \{c_1, c_2, ..., c_n\}$, and the expert set is S and there are K review experts. For the evaluation of an indicator $c_i$ ($c_i \in C, i = 1, 2, ..., n$) of any sample $x$, the corresponding evaluation range is $\xi_i$, and the evaluation interval given by the experts at $k$ ($k=1, 2, ..., K$) is recorded as $[r_{i1}^{(k)}, r_{i2}^{(k)}]$ and $[r_{a1}^{(k)}, r_{a2}^{(k)}] \in \xi_i$.

When the K intervals are superimposed, a distribution over the evaluation value axis $r$ is formed. According to the classical set of statistical theory, the formula can be described as follow:

$$
\bar{Y}_k(r) = \sum_{k=1}^{K} \sum_{i=1}^{n} Y_{c_i, k}(r) (r)
$$

(2)

Although the expert gives a range of judgments $[r_{a1}^{(k)}, r_{a2}^{(k)}]$ is a more objective choice, but different experts on the same issue give a different range of judgments, the smaller the range of judgment given by the expert is, the greater the graspability of the expert to the problem is. On the contrary, the opposite. From this we can see that experts have greater grasp of the problem. The weight assigned by the expert should be greater. On the contrary, the opposite. Ignoring this problem may make the evaluation value not accurate enough and affect the reliability of the overall evaluation. For this reason, we give the weight of the k-th expert based on the size of the judgment given by the expert:

$$
\omega_k = \frac{d_k}{\sum_{k=1}^{K} d_k}
$$

(3)

Among them

$$
d_k = \frac{1}{(r_{a2}^{(k)} - r_{a1}^{(k)})}
$$

(4)

So we get the formula

$$
\bar{Y}_k(r) = \sum_{k=1}^{K} Y_{c_i, k}(r) \omega_k
$$

(5)

Among them: $Y_{c_i, k}(r)$ is the falling shadow function, is an estimated function of the fuzzy coverage frequency sample, which is a vague level of good or bad. Further may be expressed as:

$$
\bar{Y}_k(r) = \begin{cases} 
1, & r_1^k \leq r_2^k \\
0, & \text{others}
\end{cases}
$$

$$
Y_{c_i, k}(r) = \begin{cases} 
1, & r_1 \leq r_2 \\
0, & \text{others}
\end{cases}
$$

(6)

Among them: $b_1, b_2, ..., b_L, b_{L+1}$ is a sequence of small to large bits of the $[r_{a1}^{(k)}, r_{a2}^{(k)}]$ ($k=1-K$) endpoint for each of the $\bar{Y}_k(r)$ evaluation intervals, $L$ is the number of intervals formed by the
sequence of this endpoint, \( a_l(l = 1, 2, ..., L) \) is the sum of weights given by all experts to evaluate the interval \( [r^{(l)}, r^{(l)}_{2}] \) including the interval \( [b_l, b_{l+1}] \) \( (l = 1, 2, ..., L) \),

That is

\[
a_l = \sum_{i=1}^{k} Y_{(i), (i), (i), (i)} (r) \cdot \omega_k
\]

Among them:

\[
Y_{(i), (i), (i), (i)} = \begin{cases} 
1 & r \in [b_l, b_{l+1}] \in [r^{(l)}_1 \leq r^{(l)}_2] \\
0 & \text{others}
\end{cases}
\]

According to the principle of set-valued statistics, the comprehensive evaluation value of the index \( c_i \) of sample \( x \) is taken as:

\[
E_i(r) = \frac{\int_{b_l}^{b_{l+1}} Y_i(r) r dr}{\int_{b_l}^{b_{l+1}} Y_i(r) dr}
\]

To prove further

\[
\int_{b_l}^{b_{l+1}} Y_i(r) dr = \frac{1}{a_l} \sum_{i=1}^{k} a_l (b_{l+1} - b_l)
\]

\[
\int_{b_l}^{b_{l+1}} Y_i(r) dr = \frac{1}{2} \sum_{i=1}^{k} a_l (b^2_l - b^2_l)
\]

By formula (10), (11) can be launched

\[
E_i(r) = \frac{\sum_{i=1}^{k} a_l (b^2_l - b^2_l)}{2 \sum_{i=1}^{k} a_l (b_{l+1} - b_l)}
\]

This is the quantitative evaluation value of the quantification of the \( i \)-th qualitative indicator in the sample \( x \) by \( K \) experts.

2.2.1. Example

In order to examine the applicability of the improvement measures of Jiangsu sluice, take the technical feasibility as \( A_1 \), the economic rationality \( A_2 \), the effect reliability \( A_3 \), the construction convenience \( A_4 \), the social environmental impact \( A_5 \) on the on the basis of the characteristics of the sluice reinforcement measures. Technical feasibility \( A_1 \) includes: adaptability of the reinforcement program and risk factors \( b_1 \), the adaptability of the program and sluice \( b_2 \), advanced technology of the reinforcement program \( b_3 \), adaptability of the reinforcement program duration \( b_4 \); economic rationality \( A_2 \) include: reinforcement costs \( b_5 \), costs of the reinforcement after maintenance \( b_6 \); effectiveness of reliability \( A_3 \) include: the degree of requirements to meet sluice risk \( b_7 \), the sustainability of reinforcement \( b_8 \), durability of reinforcement program \( b_9 \); construction convenience \( A_4 \) includes: the degree of technical complexity \( b_{10} \), the satisfaction of construction conditions \( b_{11} \), the level of local construction \( b_{12} \), transport conditions of special construction equipment \( b_{13} \); social environmental impact \( A_5 \) include: the degree of environmental pollution \( b_{14} \), social resource consumption \( b_{15} \).

In order to get a more reliable comprehensive evaluation results, deal with adaptability of the reinforcement program and risk factors \( b_1 \), the adaptability of the program and sluice \( b_2 \), advanced technology of the reinforcement program \( b_3 \), adaptability of the reinforcement program duration \( b_4 \), costs of the reinforcement after maintenance \( b_6 \), the degree of requirements to meet sluice risk \( b_7 \), the sustainability of reinforcement \( b_8 \), durability of reinforcement program \( b_9 \), the degree of technical complexity \( b_{10} \), the satisfaction of construction conditions \( b_{11} \), the level of local construction \( b_{12} \), transport conditions of special construction equipment \( b_{13} \), the degree of environmental pollution \( b_{14} \),
social resource consumption b15 quantified when evaluate the system of the logistics information synthetically.

There are four sluice reinforcement measures to improve the program. Program one: deep pond remediation selecting articulated concrete block protection, apron reinforcement selecting bag concrete protection; program 2: deep pond remediation selecting articulated concrete block protection, apron reinforcement selecting ripstone protection; program three: deep pond remediation selecting mold bag concrete protection, apron reinforcement selecting bag concrete protection; program four: deep pond remediation selecting mold bag concrete protection, apron reinforcement selecting ripstone protection. This paper assumes that the qualitative indicators of the program quantification in [0,1], that is, the scope of evaluation. Prefect is 1 and the worst is 0.

By using formula \( E_r = \sum_{i=1}^{l} a_i (b_i^r - b_i^l) \), the specific value of qualitative indexes can be obtained, by using formula \( \mu_{ij} = \frac{x_{ij} - x_{ij}^*}{x_{ij}^* - x_{ij}^*} \), the specific values of quantitative indexes can be obtained. The calculation results are shown in Table 2.1.

| \( E_r \) | Plan one | Plan two | Plan three | Plan four |
|---|---|---|---|---|
| \( b_1 \) | 0.8024 | 0.7024 | 0.6625 | 0.4835 |
| \( b_2 \) | 0.8475 | 0.6475 | 0.6475 | 0.4272 |
| \( b_3 \) | 0.7995 | 0.7995 | 0.5193 | 0.5193 |
| \( b_4 \) | 0.8054 | 0.8054 | 0.5213 | 0.3713 |
| \( b_5 \) | 1.0000 | 0.8877 | 0.3123 | 0.2000 |
| \( b_6 \) | 0.8850 | 0.7350 | 0.5382 | 0.2882 |
| \( b_7 \) | 0.8823 | 0.7380 | 0.6380 | 0.3380 |
| \( b_8 \) | 0.8384 | 0.7380 | 0.5193 | 0.5193 |
| \( b_9 \) | 0.8350 | 0.6970 | 0.6970 | 0.4451 |
| \( b_{10} \) | 0.6382 | 0.6382 | 0.7937 | 0.7937 |
| \( b_{11} \) | 0.7977 | 0.5398 | 0.5398 | 0.2921 |
| \( b_{12} \) | 0.8054 | 0.7695 | 0.7213 | 0.5713 |
| \( b_{13} \) | 0.5382 | 0.5382 | 0.6970 | 0.6970 |
| \( b_{14} \) | 0.6993 | 0.8379 | 0.5455 | 0.5455 |
| \( b_{15} \) | 0.7485 | 0.6970 | 0.5835 | 0.5455 |

2.2.2. Ordinal relation analysis (The method of G1)

Ordinal relation analysis[5-6] is an improved subjective weighting method based on analytic hierarchy process (AHP), which is a combination of qualitative and quantitative, systematic and hierarchical decision analysis, it embodies the basic characteristics of people’s decision-making thinking, decomposition, judgment, synthesis, easy to grasp, and easy to use. Because the analytic hierarchy process needs to construct the judgment matrix and it is difficult to pass the limitations of the consistency test when the sample is large, the method of ordinal relation analysis is improved without the need of constructing a judgment matrix and conducting consistency checking, which greatly reduces the amount of computation. The calculation steps are as follows:

The decision makers select the index which is considered one of the most important recorded as \( x_{ij}^* \) in the index evaluation set \( \{x_1, x_2, \ldots, x_m\} \), and then from the remaining m-1 indicators, select the index
which is considered one of the most important recorded as \( x^*_2 \); and so on, after \( m \) times the selection, the remaining evaluation index recorded as \( x^*_m \), so that the only order relation is determined as:

\[
x^*_1 > x^*_2 > \ldots > x^*_m
\]  
(13)

In order not to lose generality, the formula is recorded as:

\[
x_1 > x_2 > \ldots > x_m
\]  
(14)

(1) Give the comparative judgment of the relative importance between \( x_{k-1} \) and \( x_k \)

Suppose experts' rational judgment about the ratio \( \omega_{k-1}/\omega_k \) of the degree of importance of the evaluation indicators \( x_{k-1} \) and \( x_k \) is

\[
\omega_{k-1}/\omega_k = r_k, \ k = m, m-1, m-2, \ldots, 3, 2
\]  
(15)

(2) When \( m \) is large, the order relation (15) can take \( r_m = 1 \).

(3) Calculation of weight coefficient \( \omega_k \)

\[
\omega_m = (1 + \sum_{k=2}^{m} r_k)^{-1}
\]  
(16)

\[
\omega_{k-1} = r_k \omega_k, \ k = m, m-1, \ldots, 3, 2
\]  
(17)

| \( r_k \) | Explain |
|---------|---------|
| 1.0     | indicator \( x_{k-1} \) is as important as indicator \( x_k \) |
| 1.2     | indicator \( x_{k-1} \) is slightly more important than indicator \( x_k \) |
| 1.4     | indicator \( x_{k-1} \) is obviously more important than indicator \( x_k \) |
| 1.6     | indicator \( x_{k-1} \) is strongly more important than indicator \( x_k \) |
| 1.8     | indicator \( x_{k-1} \) is extremely more important than indicator \( x_k \) |

2.3. Variance coefficient method objective weighting

The coefficient of variation method is an objective weighting method that directly deals with the index data and calculates the weight of the index[7-12]. Its characteristic is that the relative change range of the index data is taken into full consideration, and the dynamic weighting of the index is realized, and greatly reduces the interference of subjective factors.

Calculate the coefficient of variation of the evaluation index

\[
V_k = \sigma_k / \bar{X}_k, \quad k = 1, 2, \ldots, m
\]  
(18)

\( V_k \) —— Coefficient of variation of the \( k \)-th indexes;

\( \sigma_k \) —— Standard deviation of the \( k \)-th indices;

\( \bar{X}_k \) —— Arithmetic mean of the \( k \)-th indexes.

Calculate the weight of coefficient of variation of evaluation index

\[
\omega^0_k = \frac{V_k}{\sum_{k=1}^{m} V_k}, \quad k = 1, 2, \ldots, m
\]  
(19)

\( \omega^0_k \) —— The weight of the coefficient of variation of the \( k \)-th index.

2.4. Comprehensive weighting of indicators based on Game Theory

The traditional methods to determine the weights of evaluation indexes are analytic hierarchy process
(AHP), entropy weight method[13], expert investigation method, simple association function method, etc. Usually, when a method is used to evaluate the index, either there are larger subjective factors, or they do not consider the importance of the indicators themselves. In fact, the degree of importance of index factors is the objective existence, and is affected by the decision-maker’s subjective intention, only considering the subjective and objective weights in order to fully reflect the importance of evaluation index. In view of this, this paper adopts the comprehensive weighting method based on Game Theory[14-19], the subjective weights determined by order relation method are combined with the objective weights determined by the coefficient of variation method, so as to get the comprehensive weights of the evaluation indexes of the applicability of the sluice lifting measures, the concrete calculation method is as follows:

For the multi-index evaluation system, assume that the use of L methods to obtain the weight of the index, and the weight vector is as follows

$$\omega_k = (\omega_{k1}, \omega_{k2}, ..., \omega_{kn}) , \quad (k=1,2,...,L) ;$$  \hspace{1cm} (20)

We can get a basic weight set $\omega$, L kinds of the linear combination of weight vectors are

$$\omega = \sum_{k=1}^{L} a_k \cdot \omega_k^T, (a_k > 0) ;$$  \hspace{1cm} (21)

In order to select the most satisfactory weight vector $\omega^*$, the linear combination coefficient $a_k$ should be optimized, thus minimizing the deviation of $\omega$ from each $\omega_k$, and thus the gaming model can be derived:

$$\min \sum_{k=1}^{L} a_k \cdot |\omega_k^T - \omega_k| , \quad (k=1,2,...,L) ;$$  \hspace{1cm} (22)

According to the differential property of the matrix, the first derivative of the formula (22) can be derived

$$\sum_{k=1}^{L} a_k \cdot \omega_k^T = \omega \cdot \omega_k^T$$  \hspace{1cm} (23)

$(a_1,a_2,...,a_L)$ can be obtained by formula (23), and then normalized by the formula (24), then the integrated weight vector $\omega^*$ can be obtained.

$$a_k^* = a_k / \sum_{k=1}^{L} a_k$$  \hspace{1cm} (24)

$$\omega^* = \sum_{k=1}^{L} a_k \cdot \omega_k^T$$  \hspace{1cm} (25)

2.5. Case study on the applicability of lifting measures

In this paper, an example of a water gate reinforcement project in Jiangsu province is presented as follows:

The main construction of the project includes three parts: sluice repair and reinforcement project, sluice upstream pond regulation project, sluice downstream apron reinforcement project.

(1) Sluice repair and reinforcement project

Dismantle and build operating bridge, bent, headstock gear room, control room and tide keeping room, reinforce the gate body, sealing the water on the part of the concrete epoxy sealing, deal with seam pier, replace the hoist, re-corrosion 3 gates of 6#, 7#, 8#, increase the operating gate leaf sacrificial anode cathodic protection (9 doors), replace repair gate, water seal, rebuild electrical and automatic equipment, repair observation facilities, improve production and living facilities, etc.

(2) Sluice upstream pond regulation project

Dredge 1.515km river left bank siltation of the gate pile number 0+285~1+800 section, the fill pond on the right bank is filled with dredger fill bags, according to the geological conditions of the river channel, two kinds of protection types of articulated concrete block protection and concrete bag
protection are selected for the deep pond protection on the sluice.
The sluice’s right bank of river bend and left bank of adjust river are protected by articulated concrete block, and the foot is protected by riprap. The technical and economic comparison between the two schemes is shown in Table 2.3.

Table 2.3 Comparison of technical and economic forms of upstream

| Articulated concrete block protection | Mould bag concrete protection |
|--------------------------------------|------------------------------|
| **Advantages**                       |                              |
| Surface is smooth, construction speed is fast, quality is easy to control, the integrity of river slope bottom protection is strong, ecological effect is good. | Construction difficulty is small, large machinery is not required. |
| **Disadvantages**                    |                              |
| the requirements of construction is high, lifting machinery and guidance of professional manufacturers are required. | Construction quality is not easy to control, ecological effect is poor. |
| **Cost**                             |                              |
| 9,220,000                            | 10,140,000                   |

(3) Sluice downstream apron reinforcement project
35m long mold bag concrete protection is added to the existing stone groove, so as to repair the damaged slope under the floodgate, mold bag concrete protection is increased of new 35m sea range within the height of 0.00m to -4.0m river slope, and the anti-scour trench is provided at the end.

Combined with the past similar engineering strengthening experience and the actual situation of this project, two kinds of protective pattern of concrete bag and riprap are selected. The advantages and disadvantages of the two schemes are shown in Table 2.4.

Table 2.4 Comparison of Moulded Bag Concrete and riprap protection scheme

| Mould bag concrete protection | Riprap protection |
|-----------------------------|-------------------|
| **Advantages**              |                   |
| Small construction difficulty, Strong integrity, good stability and long service life. | Local materials, simple construction |
| **Disadvantages**           |                   |
| Poor ecological effect      | Surface roughness is difficult to control |
| **Investment**              |                   |
| 750,000                     | 900,000           |

In summary, there are four combinations of reinforcement measures for the sluice, scheme one: the upper reaches of deep pond are protected by hinged concrete blocks, and the bag concrete is used for strengthening the apron; scheme two: the upper reaches of deep pond are protected by hinged concrete blocks, and the riprap protection is used for the apron; scheme three: the upper reaches of deep pond and the apron are protected by bag concrete; scheme four: the upper reaches of deep pond are protected by bag concrete, and the riprap protection is used for the apron.

2.5.1 Indicator system construction
According to the evaluation system of the reinforcing scheme of the sluice system, primary index is sluice’s applicability of reinforcement measure $A$; secondary index: technical feasibility is $B_1$, economic rationality is $B_2$, effect reliability is $B_3$, construction convenience is $B_4$, social environmental impact is $B_5$; 3-level index: the adaptability of the reinforcement scheme and the risk factors is $C_i$, the adaptability of the scheme to the location of the gate is $C_2$, the technical advance of the reinforcement scheme is $C_3$, the adaptability of the reinforcement scheme and construction period is $C_4$, the cost of the reinforcement scheme is $C_5$, the maintenance cost of the reinforcement is $C_6$, the risk requirement of the sluice is $C_7$, the sustainability of the reinforcement is $C_8$, the durability of the reinforcement scheme is $C_9$, the degree of complexity of reinforcement technology is $C_{10}$, the satisfaction of construction conditions is $C_{11}$, the construction level of the local construction unit is $C_{12}$, the transportation conditions of special construction equipment is $C_{13}$, the degree of environmental pollution is $C_{14}$, the social resource depletion is $C_{15}$.
2.5.2 Ordinal relation analysis (G1)
With four indexes of technical feasibility $B_i$, the adaptability of the reinforcement scheme and the risk factors $C_i$, the adaptability of the scheme to the location of the gate $C_2$, the technical advance of the reinforcement scheme $C_3$, the adaptability of the reinforcement scheme and construction period $C_4$ as the evaluation object, the calculation process is as follows:

The ordering relation given by experts according to experience is:

$$C_1 > C_2 > C_3 > C_4$$

For convenience, mark it as $x_1 > x_2 > x_3 > x_4$

And $r_1 = \frac{\omega_1}{\omega_2} = 1.8$, $r_2 = \frac{\omega_2}{\omega_3} = 1.2$, $r_3 = \frac{\omega_3}{\omega_4} = 1.2$. Then $r_2 r_4 = 2.592, r_3 r_4 = 1.440, r_1 = 1.200$.

So $\omega_i = (1 + 2.592 + 1.440 + 1.200)^{-1} = 0.1605$, $\omega_2 = r_2\omega_3 = 1.2 \times 0.1605 = 0.1926$, $\omega_3 = r_3\omega_4 = 1.2 \times 0.1605 = 0.2311$, $\omega_4 = r_4\omega_1 = 1.8 \times 0.2311 = 0.4159$.

As a result of $\sum_{i=1}^{4} \omega_i = 1$, and the weight of the four indexes of $C_1, C_2, C_3, C_4$ is

$$W_i = [0.4159 \ 0.2311 \ 0.1926 \ 0.1605]$$

2.5.3 Weight calculation of coefficient of variation method
Similarly, with four indexes of technical feasibility $B_i$, the adaptability of the reinforcement scheme and the risk factors $C_i$, the adaptability of the scheme to the location of the gate $C_2$, the technical advance of the reinforcement scheme $C_3$, the adaptability of the reinforcement scheme and construction period $C_4$ as the evaluation object, the calculation process is as follows:

Calculate the coefficient of variation of the evaluation index

$$\sigma_1 = 0.1332, \ \sigma_2 = 0.1717, \ \sigma_3 = 0.1618, \ \sigma_4 = 0.2162$$

$$\bar{X}_1 = 0.6627, \ \bar{X}_2 = 0.6424, \ \bar{X}_3 = 0.6594, \ \bar{X}_4 = 0.6258$$

$$V_1 = 0.2209, \ \ V_2 = 0.2673, \ \ V_3 = 0.2453, \ \ V_4 = 0.3454$$

$$\omega_1^0 = 0.1898, \ \omega_2^0 = 0.2524, \ \omega_3^0 = 0.2317, \ \omega_4^0 = 0.3262$$

2.5.4 Weight fusion
By the G1 method, the weight is obtained: $\omega = (0.2311, 0.1605, 0.4159, 0.1926, 0.5455, 0.4545, 0.2920, 0.1825, 0.5255, 0.1657, 0.2651, 0.4772, 0.0920, 0.5455, 0.4545)$

By the coefficient of variation, the weight is obtained: $\omega = (0.1898, 0.2524, 0.2317, 0.3262, 0.6137, 0.3863, 0.4207, 0.2911, 0.2882, 0.1571, 0.4770, 0.1800, 0.1860, 0.5919, 0.4081)$

According to equation (2.24), we can obtain the first order equations of the comprehensive weighting of game theory:

$$\begin{bmatrix} 2.0261 & 1.8451 & 0.6139 \\ 1.8451 & 1.9664 & 0.4240 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} 2.0261 \\ 1.9664 \end{bmatrix}$$

The normalized linear combination coefficient can be obtained:

$$\alpha_1^* = 0.5915, \ \alpha_2^* = 0.4085$$

According to equation (2.25), we can obtain the normalized comprehensive weight $\omega = (0.2142, 0.1980, 0.3407, 0.2471, 0.5733, 0.4267, 0.3445, 0.2269, 0.4286, 0.1622, 0.3517, 0.3558, 0.1304, 0.5644, 0.4356)$

The weight of other safety indicators is calculated also by the above calculation process, the calculation results are shown in table 2.5.
Table 2.5 Index weight table of lifting measures for a sluice of JiangSu

| Weight combination weight | Weight | index weight of lift measures for a sluice of JiangSu |
|---------------------------|--------|-----------------------------------------------------|
|                           | 0.2142 | Applicability of reinforcement schemes and risk factors |
|                           | 0.1980 | Suitability of the scheme and location |
|                           | 0.3407 | Technical advance of reinforcement scheme |
|                           | 0.2471 | Duration adaptability of reinforcement scheme |
|                           | 0.5733 | The cost of the reinforcement scheme |
|                           | 0.4267 | Cost of repairs after reinforcement |
|                           | 0.3445 | Satisfaction of gate risk requirements |
|                           | 0.2269 | Sustainability after reinforcement |
|                           | 0.4286 | Durability of reinforcement scheme |
|                           | 0.1622 | The complexity of the reinforcement technique |
|                           | 0.3517 | Satisfaction of construction conditions |
|                           | 0.3558 | Construction costs of local construction units |
|                           | 0.1304 | Transportation conditions for special construction equipment |
|                           | 0.5644 | The status of environmental contamination |
|                           | 0.4356 | Social resource depletion |

3. Conclusion

(1) In this paper, the suitability evaluation index system of service performance improvement measures of sluices is constructed, and the reasonable quantification method of each index is put forward.

(2) The subjective and objective importance of the factors affecting the lifting measures are analyzed by using the ordinal relation method and the coefficient of variation method, and the game theory is used to fuse the subjective and objective weighting, the results show that the fusion weight is more reasonable.

(3) Based on the data of a sluice in Jiangsu, the importance of lifting measures is analyzed, and the importance of each influence factor is obtained.

References

[1] ZHANG Weihua, WANG Jianjun. Qualitative index quantification method research in coal mine logistics information system evaluation [J]. Logistics technology, 2007, (07): 31-34.

[2] Wang Shenglin. Research on Evaluation System of green building [D]. Changsha: Central South University, 2013.12.

[3] Zhang Cunjian. Study on Evaluation of Tashan Coal Mine construction project [D]. Beijing: China Mining University, 2016.1.

[4] Sun Jiuchun, Shi Jianjun. Application of weighted set-valued statistical theory and centroid decision theory in bridge evaluation [J]. Shanghai highway, 2001, (04): 20-22.

[5] Chen Wu, Xu Xinyi, Wang Hongrui, Wangwei. Evaluation of sustainable utilization of water resources in Beijing based on improved ordinal relation method [J]. Journal of Natural Resources, 2015, (01): 164-176.

[6] Wang Yonggang, Wang Yibu, Geng Hao. Comprehensive evaluation of airport safety management capability based on order relation method and entropy method [J]. Journal of Safety and
[7] Zhao Wei, Lin Jian, Wang Shufang, Liu Jilai, Chen Zhongrong, Kou Wenjie. Variation coefficient method to evaluate the influence of human activities on Groundwater Environment[J]. Environmental sciences, 2013, (04): 1277-1283.

[8] Hu Cuiping. Evaluation of scientific and technological competitiveness of sub provincial cities in China based on AHP- coefficient of variation method[J]. Science and Technology Management Research, 2012, (20): 77-80.

[9] Zhuang Ping, Li Yanxi. Evaluation model and Empirical Study of enterprise investment risk based on G1- coefficient of variation method[J]. Soft science, 2011, (10): 107-112+120.

[10] Chu Sha, Chen Lai. Evaluation of energy saving and emission reduction in Anhui Province Based on coefficient of variation method[J]. Chinese population. Resources and environment, 2011, (S1): 512-516.

[11] Zhang Xiaohong. Application of grey relational model based on coefficient of variation in bidding optimization of water saving irrigation project[J]. Water saving irrigation, 2009, (08): 54-56.

[12] He Yuchun, Xie Mingyong, Long Dejiang. Application of grey relational model based on coefficient of variation in optimal selection of hydropower project investment plan[J]. Journal of water resources and water engineering, 2009, (02): 127-129.

[13] Zhang Chao, Li Zhemin, Dong Xiaoxia, Peng Chunyan. Analysis of agricultural development level in BRICS——Comparative study based on entropy weight method and coefficient of variation method[J]. Science and economic, 2014, (06): 42-46.

[14] Wu Xiaoping, Chengcheng, Li Yueguang, Wu Xitao, Xie Shuashua. Application of game theory in environmental impact assessment of Expressway Construction[J]. Journal of Zhengzhou University (Engineering Edition), 2012, (06): 36-40.

[15] Chen Jialiang. Research on evaluation method of combination weighting based on Game Theory[J]. Fujian Computer, 2003, (09): 15-16.

[16] Lu Yao, Xu Linrong, Chen Shuyang, Cao Lulai. Risk assessment of debris flow based on combination weighting of game theory[J]. Science of disaster, 2014, (01): 194-200.