Research of AHP evaluation for operation performance of water reuse system in industrial park

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Abstract: The operation performance evaluation of water reuse system in industrial park is an extremely important and complex issue in the management of water reuse system. Based on constructing the operation performance evaluation index system of the water reuse system in industrial park in China, according to the characteristics of the analytic hierarchy process (AHP), evaluation system was established to evaluate the operation performance of the water reuse system in industrial park. AHP evaluation model fully considers the subjective and objective factors with effectiveness and scientific nature.

1. Introduction
Driven by various resources and policy, parks has become an important part of the regional economy in China. There are more than 2,600 parks at provincial-level and above, including 218 national-level economic and technological development zones, 168 national-level emerging development zones, 251 other types of national-level development zones, and 2000 provincial parks. If take parks at the county and city level into consideration, the number of local parks can exceed 7,000.

As a cluster of production enterprises, industrial parks play a key role in promoting national and local economic development. The transformation is the acceleration of China's urbanization construction, the improvement of urban residents' requirements for environmental standards, and the improvement of the park environment is the current focus and scenic spot[1].

Combining with the requirements and status of water reuse standardization work at home and abroad, fully taking into account the work progress and development needs of related fields, with the goal of improving water consumption efficiency and ensuring water safety, it is significantly important to carry out research on the quality and performance evaluation methods of water reuse in industrial parks. Standard development for the quality and performance evaluation methods of water reuse in industrial parks can provide support for promoting the gradual optimization of industrial water system integration and ensuring the safe and efficient use of reclaimed water.

2. Construction of the operation performance of water reuse system of industrial park

2.1. Design principles
The evaluation index system based on Globerson’s theory [2], and combining the operating characteristics and actual conditions of the water reuse in China, the following basic principles was
proposed when designing the evaluation index system of the operation performance of the operation performance of water reuse system of industrial park:

(1) Purposiveness. The operation performance evaluation index system of water reuse system of industrial park should accurately measure the operation status of the water reuse system of industrial park as well as find the bottleneck of low operation performance, therefore, the improvement method and improve the operation performance of the water reuse system of industrial park can be figured out.

(2) Systematicness. The water reuse system of industrial park has complex processing technology. The operation evaluation index system should be able to reflect the operation performance of each processing technology in a comprehensive, systematic and complete way from multiple views.

(3) Scientificalness. The index should be scientific and reasonable, concise and feasible. It can accurately reflect the actual operation of the water reuse system of industrial park, and help the enterprises explore the potential of competition by comparing their own evaluation indexes with the competitors at home and abroad.

(4) Feasibility. The index should be measurable and comparable, with simple calculation method, and the data should be easily accessed.

(5) Combination of quantitative and qualitative. The operation performance of water reuse system of industrial park is an abstract concept. The quantitative and qualitative index should be comprehensively considered in the evaluation. The qualitative index should have clear meaning with appropriate assignment, so that they can accurately reflect the nature of index; the calculation method should be provided for the quantitative index.

(6) Dynamics. The index system should reflect the present situation and the future trend of the water reuse industry for easy prediction and decision-making. At the same time, the index system content should be relatively stable within a certain period.

2.2. Operation performance evaluation index system of water reuse system of industrial park
Based on the principles mentioned above, the operation evaluation index system of water reuse system of industrial park is established consisting of 14 indexes in four categories at three levels as shown in Table 1.

Table 1. Operation evaluation index system for water reuse system of industrial park

| Target layer | Class I index layer | Class II index layer |
|--------------|---------------------|---------------------|
| Operation evaluation of water reuse system A | Environmental protection attribute B1 | Industrial water recycling rate C1 |
| | Resource and energy consumption B2 | Water reuse rate C2 |
| | | Wastewater discharge per 10,000 yuan of industrial output value C3 |
| Operational management B3 | Comprehensive energy consumption per 10,000 yuan of industrial output value C4 |
| | | Water consumption per 10,000 yuan of industrial output value C5 |
| | | Industrial output value per unit land area C6 |
| Key equipment status B4 | Emergency plan C7* |
| | Run maintenance account C8* |
| | Monitoring analysis platform C9* |
| | Personnel training C10* |
| | Good equipment rate C11 |
| | Equipment commissioning rate C12 |
| | Normal operation days of facilities C13 |
| | Technical advancement C14* |

Note: * indicates that the index is a qualitative evaluation index

3. Performance evaluation of water reuse system of industrial park
According to the research method of Zhang[3] , combined with ISO 20468-1 Guidelines for performance evaluation of treatment technologies for water reuse systems - Part 1: General, ISO
Guidelines for water quality grade classification for water reuse, Shanghai industrial park recycling reform evaluation standards (trial version) as well as the latest water reuse technology results from Beijing Economic Technological Development Zone, Analytic Hierarchy Process (AHP) [4] was used to calculate the performance weight of park water reuse.

In order to ensure the scientificity and practicality of this evaluation, experts and scholars from ecological protection and environmental pollution research, as well as relevant persons in charge in the field of water reuse in the park, were invited to make independent judgments when determining the weight of the indicators. Combined with the survey results of the status quo of water reuse in the park, the relative importance of related factors is evaluated, and the corresponding weight value is obtained. The three-scale matrix of the first-level indicators of the performance evaluation of water reuse in the park is shown in Table 9.

Table 2. The performance evaluation of the first-level indicator and three-scale matrix of the water reuse

| Operation evaluation A | B1 | B2 | B3 | B4 |
|------------------------|----|----|----|----|
| Environmental protection attribute B1 | 1 | 1 | 2 | 2 |
| Resource and energy consumption B2 | 1 | 1 | 2 | 2 |
| Operational management B3 | 0 | 0 | 1 | 1 |
| Key equipment status B4 | 0 | 0 | 1 | 1 |

Transforming the three-scale matrix into a nine-scale matrix, and use Excel to solve the maximum eigenvalue of the judgment matrix and the corresponding vector, as shown in Table 3.

Table 3. Nine-scale matrix of first-level indicators for performance evaluation of water reuse

| Operation evaluation A | B1 | B2 | B3 | B4 | W | Consistency check |
|------------------------|----|----|----|----|----|------------------|
| Environmental protection attribute B1 | 1 | 1 | 4 | 4 | 0.35 | $\lambda_{max}=4$ |
| Resource and energy consumption B2 | 1 | 1 | 4 | 4 | 0.35 | $C.R=C.I./R.I$ =0/0.89 =0 |
| Operational management B3 | 1/4 | 1/4 | 1 | 1 | 0.15 |
| Key equipment status B4 | 1/4 | 1/4 | 1 | 1 | 0.15 |

Among them, CR<0.1, which satisfying consistency.

3.1. The weight determination of environmental protection attribute indicators
The three-scale matrix of the performance evaluation secondary index (environmental protection attribute index) of water reuse in the park is shown in Table 4.
Table 4. Three-scale matrix of secondary indicators (environmental protection attributes) of the performance evaluation of water reuse in the park

| Environmental protection performance B1 | C1 | C2 | C3 |
|----------------------------------------|----|----|----|
| Industrial water recycling rate C1     | 1  | 1  | 1  |
| Water reuse rate C2                    | 1  | 1  | 1  |
| Wastewater discharge per 10,000 yuan of industrial output value C3 | 1  | 1  | 1  |

Transforming the three-scale matrix into the nine-scale matrix, and use Excel to solve the maximum eigenvalue of the judgment matrix and the corresponding vector, as shown in Table5.

Table 5. Nine-scale matrix of secondary indicators (environmental protection attributes) of the performance evaluation of water reuse in the park

| Environmental protection performance B1 | C1     | C2     | C3     | W      | Consistency check |
|----------------------------------------|--------|--------|--------|--------|-------------------|
| Industrial water recycling rate C1     | 1      | 1      | 1      | 0.333  | λ_{max}=3.0       |
| Water reuse rate C2                    | 1      | 1      | 1      | 0.333  | C.R=C.I/R.I=0/0.58=0 |
| Wastewater discharge per 10,000 yuan of industrial output value C3 | 1  | 1  | 1  | 0.333 |                     |

Among them, CR<0.1, which satisfying consistency.

3.2. The weight determination of resource and energy consumption indicators

The three-scale matrix of the performance evaluation secondary index (Resource and energy consumption index) of water reuse in the park is shown in Table 6.

Table 6. Three-scale matrix of secondary indicators (Resource and energy consumption) of the performance evaluation of water reuse in the park

| Resource and energy consumption B2 | C4     | C5     | C6     |
|-----------------------------------|--------|--------|--------|
| Comprehensive energy consumption per 10,000 yuan of industrial output value C4 | 1      | 1      | 1      |
| Water consumption per 10,000 yuan of industrial output value C5 | 1      | 1      | 1      |
| Industrial output value per unit land area C6 | 1  | 1  | 1  |

Transforming the three-scale matrix into the nine-scale matrix, and use Excel to solve the maximum eigenvalue of the judgment matrix and the corresponding vector, as shown in Table7.
Table 7. Nine-scale matrix of secondary indicators (Resource and energy consumption) of the performance evaluation of water reuse in the park

| Resource and energy consumption B2 | C4 | C5 | C6 | W | Consistency check |
|-----------------------------------|----|----|----|---|-------------------|
| Comprehensive energy consumption per 10,000 yuan of industrial output value C4 | 1 | 1 | 1 |   | λ_{max}=3.0 |
| Water consumption per 10,000 yuan of industrial output value C5 | 1 | 1 | 1 | C.R=C.I./R.I =0/0.58 =0 | 0.333 |
| Industrial output value per unit land area C6 | 1 | 1 | 1 |   | 0.333 |

Among them, CR<0.1, which satisfying consistency.

3.3. The weight determination of Operational management indicators

The three-scale matrix of the performance evaluation secondary index (Operational management index) of water reuse in the park is shown in Table 8.

Table 8. Three-scale matrix of secondary indicators (Operational management) of the performance evaluation of water reuse in the park

| Operational management B3 | C7 | C8 | C9 | C10 |
|--------------------------|----|----|----|-----|
| Emergency plan C7*       | 1  | 1  | 1  | 1   |
| Run maintenance account C8* | 1  | 1  | 1  | 1   |
| Monitoring analysis platform C9* | 1  | 1  | 1  | 1   |
| Personnel training C10*  | 1  | 1  | 1  | 1   |

Transforming the three-scale matrix into the nine-scale matrix, and use Excel to solve the maximum eigenvalue of the judgment matrix and the corresponding vector, as shown in Table 9.

Table 9. Nine-scale matrix of secondary indicators (Operational management) of the performance evaluation of water reuse in the park

| Operational management B3 | C7 | C8 | C9 | C10 | W | Consistency check |
|--------------------------|----|----|----|-----|---|-------------------|
| Emergency plan C7*       | 1  | 1  | 1  | 1   |   | λ_{max}=3.0 |

0.25
Among them, CR<0.1, which satisfying consistency.

3.4. The weight determination of Key equipment status indicators
The three-scale matrix of the performance evaluation secondary index (Key equipment status index) of water reuse in the park is shown in Table 10.

Table 10. Three-scale matrix of secondary indicators (Key equipment status) of the performance evaluation of water reuse in the park

| Key equipment status | B4 | C11 | C12 | C13 | C14 |
|----------------------|----|-----|-----|-----|-----|
| Good equipment rate  | C11| 1   | 1   | 1   | 1   |
| Equipment commissioning rate | C12| 1   | 1   | 1   | 1   |
| Normal operation days of facilities | C13| 1   | 1   | 1   | 1   |
| Technical advancement | C14*| 1   | 1   | 1   | 1   |

Transforming the three-scale matrix into the nine-scale matrix, and use Excel to solve the maximum eigenvalue of the judgment matrix and the corresponding vector, as shown in Table11.

Table 11. Nine-scale matrix of secondary indicators (Operational management) of the performance evaluation of water reuse in the park

| Key equipment status | B4 | C11 | C12 | C13 | C14 | W | Consistency check |
|----------------------|----|-----|-----|-----|-----|---|------------------|
| Good equipment rate  | C11| 1   | 1   | 1   |     | 0.25| $\lambda_{max}=3.0$ |
| Equipment commissioning rate | C12| 1   | 1   | 1   |     | 0.25| C.R=C.I./R.I =0/0.58 =0 |
| Normal operation days of facilities | C13| 1   | 1   | 1   |     | 0.25|   |
Among them, CR<0.1, which satisfying consistency.

4. Level total ranking
The level single sorting is completed through the above calculations, and then the level total sorting is performed to synthesize the superiority and inferiority order of each layer to the higher one, as shown in Table 12.

Table 12. Total ranking results of levels

| Level | B1  | B2  | B3  | B4  | Total ranking |
|-------|-----|-----|-----|-----|---------------|
|      | 0.35| 0.35| 0.15| 0.15|               |
| C1    | 0.333|    |    |     | 0.1167        |
| C2    | 0.333|    |    |     | 0.1167        |
| C3    | 0.333|    |    |     | 0.1167        |
| C4    | 0.333|    |    |     | 0.1167        |
| C5    | 0.333|    |    |     | 0.1167        |
| C6    | 0.333|    |    |     | 0.1167        |
| C7    | 0.25 |    |    |     | 0.0375        |
| C8    | 0.25 |    |    |     | 0.0375        |
| C9    | 0.25 |    |    |     | 0.0375        |
| C10   | 0.25 |    |    |     | 0.0375        |
| C11   | 0.25 |    |    |     | 0.0375        |
| C12   | 0.25 |    |    |     | 0.0375        |
| C13   | 0.25 |    |    |     | 0.0375        |
| C14   | 0.25 |    |    |     | 0.0375        |

The consistency check is as follows:
CT = Σ_{i=1}^{9} B_i × CI_i = 0.35×0 +0.35×0 + 0.15×0 +0.15×0=0
RT = Σ_{i=1}^{9} B_i × RI_i = 0.35×0.58 + 0.35×0.58 + 0.15×0.89 +0.15×0.89 =0.673
CR=CT/RT=0/0.673=0<0.1.

Among them, CR<0.1, which satisfying consistency.

5. Conclusion
This study mainly conducted evaluation of the performance evaluation of water reuse in the park. First, the analytic hierarchy process is used to calculate the index weight, and at the same time, in order to simplify the calculation, it also uses tools to program to establish the relative importance of each index in the comprehensive evaluation index system. The specific result is that the environmental protection attribute index and resource and energy consumption index have the larger impact of 0.35 respectively, followed by the operation management index and key equipment status index have the lower impact of 0.15 respectively. Secondly, categorize qualitative indicators and quantitative indicators for the selected indicators, and establish quantitative indicators and quantitative indicator evaluation standards based on statistical data, laying the foundation for further quantification of scores. Finally, through the sum of the product of the weight of each index and the evaluation score of the corresponding index, a comprehensive evaluation model is established.
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