Assessment of water-saving status of civil buildings in Jiangsu Province based on AHP method

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Abstract. The shortage of water resources, serious water pollution, and the destruction of aquatic ecology have become important factors restricting the economic and social development of the region. In 2014, General Secretary Xi Jinping stood at the strategic height of sustainable development, and proposed a water management policy of “water conservation priority, space balance, system governance, and two-handed efforts”. Among them, water conservation is given top priority. This article takes Jiangsu Province as an example. It determines the water-saving assessment indicators for civil buildings in Jiangsu Province by reading relevant codes and standards. It is based on the AHP Analytic Hierarchy Process to give weight to each indicator. Through expert scoring, get the score of the current status of water-saving implementation of civil buildings in Jiangsu Province, comprehensively analyze the current status and problems of water conservation in civil buildings in Jiangsu Province, establish a typical water-saving model for buildings, play a demonstration and lead role, and promote the water-saving work of civil buildings in other provinces.

1. Introduction

The uneven spatial and temporal distribution of water resources in Jiangsu Province. There are resource-based water shortages in some areas, coupled with high population density, high industrial concentration, and high pollution discharge intensity. There are water-quality water shortages to varying degrees, which restricts Jiangsu’s economic, social, and ecological environment. For quality development, there is an urgent need to strengthen water conservation, improve water resource utilization efficiency, and has achieved remarkable results in urban water-saving work. The ninth batch (2018) of the list of national water-saving cities shows that the number of national water-saving cities in Jiangsu Province had increased to 22, ranking first in all provinces in the country, is a typical and representative province of the country.

Building water saving refers to saving water in the buildings that have been completed and put into use, including reducing water consumption, improving water use efficiency, and effectively preventing water leakage in three aspects. Generally speaking, the water conservation of buildings at this stage is mainly considered from four aspects: one is to reduce the amount of inefficient and wasteful water consumption; the other is to develop and promote efficient water-saving appliances to improve the water efficiency of water appliances; the third is to improve the replacement rate of unconventional water resources; the fourth is to strengthen management to prevent water supply and drainage system leakage and secondary pollution[1].

Using the AHP method, combining the policy documents in the table on the provisions of the main water-saving indicators with the water-saving potential to preliminary measure the structure judgment matrix, determine the weight of each indicator and establish the civil building water-saving evaluation
index system of Jiangsu Province. The scores on the status of each indicator carried out by the experts, combined with the weight of each indicator, finally come to the overall score of the current situation of water-saving in civil buildings in Jiangsu Province.

2. The establishment of water-saving evaluation system for civil buildings in Jiangsu Province based on Analytic Hierarchy Process

2.1. Establishing the Hierarchical Model
According to the “water-saving design standards for civil buildings”, water-saving civil building design is mainly regulated in four aspects: water appliances, water consumption, green irrigation, landscape water, and use of unconventional water sources[2]. In addition, combined with policy documents such as the "Water-saving City Assessment Standards" and "Water-saving Community Assessment Standards" and other policy documents, the implementation of water-saving civil buildings should also include the organizational management of various units, system operation maintenance and evaluation, and various units Internal publicity activities and other safeguard management measures. The hierarchical model is established as follows.

![Figure 1. Water-saving hierarchical model for civil building of Jiangsu Province](image)

2.2. Constructing the judgment matrix
According to Water-saving Design Standards for Civil Buildings, compare the importance of each water-saving measure, the calculation process is as follows:

Now assume a residential area with a land area of 10,000 square meters. According to China's Construction Building Area Calculation Code, set the volume ratio as 2.0, 2.0 × 10000 = 20000. The average household construction area is 80 square meters, 20000/80 = 250 households. The Regulations on urban greening management of Jiangsu Province stipulate that the rate of green space in new residential areas is not less than 30%. Without considering the situation of waterscape in the community, the area of green space in the district is 35.5%, the area of asphalt and concrete pavements such as roads and squares covers an area of 20%, and the building covers 45.5%.

(1) Domestic water saving P1
Annual water conservation for residential water $Q_{na}$:

$$Q_{na} = \frac{q_{na}D_2}{1000}$$  \hspace{1cm} (1)

$Q_{na}$ —— Annual water conservation for residential living water (m3/a);
$q_z$ —— Water-saving quota. Take 120L/person·d according to the Water Saving Quota of Average Daily Domestic Water in Residential Buildings, 145L/person·d according to the water quota of Jiangsu Province;

$n_z$ —— Resident number. Based on 3-5 people/household, occupancy rate of 60% to 80%;

$D_z$ —— Annual water consumption days (d/a), set $D_z$ as 365d/a.

$n_z = 250 \times 0.8 \times 4 = 800$ person;

$Q = (145 - 120) \times 800 \times 365 / 1000 = 7300$ (m$^3$)

Among them, $P_1$ is mainly $P_2$ plus household water-saving measures, there it is not calculated separately.

(2) Utilization of non-traditional water source $P_3$

Analysis of runoff coefficient: Runoff coefficient needs to determine an average runoff coefficient, which can be obtained by weighted average method, the formula can be found as follows:

| The quality of road surface | Green place of park | Asphalt and concrete pavements | Construction | Water | The average runoff coefficient $\overline{\varphi}$ |
|-----------------------------|---------------------|--------------------------------|--------------|-------|-----------------------------------------------|
| Run off coefficient         | 0.15                | 0.9                            | 0.9          | 1.0   | 0.634                                         |
| Percentage of pavement      | 35.5%               | 20%                            | 44.5%        | 0     | 100%                                          |

Now choose the average monthly rainfall in Jiangsu Province 85mm, you can find the available amount of rain $Q$ is:

$Q_{\text{sup}} = \overline{\varphi} \times A \times H = 0.634 \times 10000 \times (85/1000) = 538.9$ (m$^3$)

According to the provisions of The Building and Community Rainwater Use Engineering And Technical Specifications, the rainwater which can be used back in accordance with the rainwater collection is considered as about 60%-70%$^{[3]}$. Taking into account that the initial part of the rainwater cannot be used, which should be discarded, the rainwater reuse rate choose 60%, so:

$Q_{\text{rec}} = Q_{\text{sup}} = 0.6 \times 12 = 538.9 \times 0.6 = 323.34 \times 12 = 3880.08$ (m$^3$)

(3) Green irrigation water $P_4$

Table 2. The total annual irrigation amount of watering the lawn and greening(m$^3$/m$^2$·a)

| Lawn types               | Total irrigation |
|--------------------------|------------------|
|                          | Super conservation | Primary conservation | Secondary maintenance |
| Cold season              | 0.66             | 0.50                | 0.28                  |
| Warm season              | -                | 0.28                | 0.12                  |

Determine the annual water consumption of green irrigation after adopting water saving measures according to the warm season type and the first-class maintenance standard: $W = 0.28 \times 3550 = 994$ (m$^3$/a)

Using sprinkler irrigation generally saves 30% - 50% of water than ground flood irrigation. Therefore, the water saving of green irrigation after water saving measures is $994 / 0.6 - 994 = 662.67$ (m$^3$)

(4) Landscape water $P_5$

The water loss of landscape water mainly includes water surface evaporation and soil infiltration on the bottom and sides of water bodies. The average daily water supply and annual water consumption of landscape water bodies should be calculated according to the following formulas:

$W_{jd} = W_{sd} + W_{sd} + W_{id}$

$W_{ja} = W_{jd} \times D_j$

$W_{jd}$ —— Average daily water supply (m$^3$/d);
Wzd——Daily average evaporation(m³/d), Calculated based on the daily average evaporation thickness of the local water surface multiplied by the water surface area;
Wsd——Penetration(m³/d), It is the product of water infiltration area and infiltration rate;
Wfd——Processing station machine room water consumption, etc.(m³/d);
Wja——Annual water consumption of landscape water bodies(m³/a);
Dj——Annual average operating days(d/a).

The water conservancy profile data of the Department of Water Resources of Jiangsu Province shows that the annual precipitation in Jiangsu Province is 700-1250mm, and the average annual evaporation is 950-1100mm[^4]. The precipitation can basically meet the average daily evaporation, the average daily water replenishment is only the permeability and the self-consumption of the processing station room, etc. Considering that the area of landscape water bodies is much smaller than the green area, the annual replenishment of landscape water bodies of the same area is much smaller than the water consumption of green irrigation.

In summary, the comparison of the water-saving capacity of various water-saving measures is: P1>P2>P3>P4>P5. In addition, P4, P5, and P6 were judged through questionnaires and interview. According to the comparison scales specified in the AHP hierarchical analysis method, the specific judgment matrix is as follows.

|   | A | C1 | C2 |
|---|---|----|----|
| C1 | 1 | 3  |    |
| C2 | 1/3 | 1  |    |

Table 3. Z-C judgment matrix

|   | P1 | P2 | P3 | P4 | P5 |
|---|----|----|----|----|----|
| P1 | 1  | 2  | 3  | 5  | 7  |
| P2 | 1/2 | 1  | 3  | 3  | 5  |
| P2 | 1/3 | 1/3 | 1  | 5  | 7  |
| P4 | 1/5 | 1/3 | 1/5 | 1  | 3  |
| P5 | 1/7 | 1/5 | 1/7 | 1/3 | 1  |

Maximum eigenvalue: 5.3832;
CI=(5.3832-5)/(5-1)=0.0958;
Find the Consistency Index Table, the consistency ratio CR=0.0958/1.12=0.0855<0.1, and pass the consistency test.

|   | P6 | P7 | P8 |
|---|----|----|----|
| P6 | 1  | 5  | 3  |
| P7 | 1/5 | 1  | 1/3 |
| P8 | 1/3 | 3  | 1  |

Maximum eigenvalue: 3.0385;
Consistency index CI=(3.0385-3)=0.0193;
Consistency ratio=0.0193/0.58=0.0332<0.1, passing the consistency test.
2.3. The water-saving implementation status score table of Jiangsu province civil building

According to the judgment matrix to calculate the weight of each indication, combined with the standard specification and the specific situation of Jiangsu Province to determine the scoring standard, establish the score table and determine the score by expert scoring average. The total score of the implementation of water-saving in civil building in Jiangsu Province was 7.019 points, the specific score is as follows.

Table 6. Status quo score of water-saving implementation in civil buildings in Jiangsu Province

| Guidelines | Indicators project | Grading standards\(^ {2,3,5}\) | score | The weight score |
|------------|-------------------|---------------------------------|-------|-----------------|
| Basic measures | Water appliances | Penetration rate of water-saving appliances ≥ 95% [8-10]; penetration rate of water-saving appliances ≥ 85% [5-7]; penetration rate of water-saving appliances < 85% [1-4] | 7.8 | 0.317 | 2.536 |
| | Water consumption | Per capita household water consumption is 2-3 cubic meters [8-10]; per capita household water consumption is 3-4.8 cubic meters [5-7]; per capita household water consumption is greater than 4.8 cubic meters [1-4] | 6.4 | 0.203 | 1.218 |
| | Unconventional water use | For green irrigation, garage and road flushing, toilet flushing, cooling and replenishment water [8-10]; for irrigation, road flushing [5-7]; no non-traditional water use systems [1-4] | 6.5 | 0.143 | 0.858 |
| | Afforestation irrigation | Using reclaimed water or rainwater [8-10]; using water-saving irrigation system [5-7]; artificial sprinkling [1-4] | 7.6 | 0.057 | 0.399 |
| | Landscape water | Set up water-saving control measures such as soil humidity sensors and automatic shutdown devices in rainy days, or plant plants that do not need permanent irrigation [8-10]; with recycled or recycled water, and rainwater [5-7]; with municipal tap water and underground well water [1-4] | 8.2 | 0.029 | 0.232 |
| Management measures | Water-saving organization management | There are rewards and penalties [8-10]; part-time water-saving personnel, and detailed organization [5-7]; without fixed water-saving managers [1-4] | 6.5 | 0.159 | 0.954 |
| | Operation Maintenance and Evaluation | Make the technical plan and plan for the system operation effect assessment [8-10]; have the records of inspection, debugging, operation and calibration [5-7]; have the system of repair and the implementation records [1-4] | 6.6 | 0.026 | 0.182 |
| | Water conservation campaign | Residents generally have the awareness of water-saving [8-10]; and often carry out water-saving publicity and education [5-7]; water-saving signs are set in the community [1-4] | 6.8 | 0.065 | 0.39 |
| Total | | | 10 | 1.000 | 7.019 |

3. Conclusion

(1) The data released by the Jiangsu Statistical Yearbook shows that the per capita domestic water consumption is highest in southern Jiangsu, followed by central Jiangsu and northern Jiangsu. The growth rate of water consumption in southern Jiangsu is relatively slow.

(2) The popularization rate of water-saving appliances is high, which can reach more than 95% in water-saving communities. However, the random inspection results of Jiangsu Quality Supervision Bureau show that there are still a large number of unqualified water appliances on the market, which make water-saving performance and product quality greatly reduced.

(3) Greening actively adopts micro-jetting technology. In buildings with landscape water, recycled water can generally be used for landscape water. In communities with rainwater reuse systems, landscape water replenishment and irrigation water sources mainly come from collected rainwater.
Except for a few months with less rainfall, tap water supply is needed. The amount can basically meet the requirements of greening and landscape water supply.

(4) There are only a few months in Jiangsu Province where the shortage of rainwater needs to be replenished with tap water. The amount of rainwater provided in other months can fully meet or even greatly exceed the needs of greening and road watering, and there is great potential for improvement[6]. The investment in rainwater collection and treatment systems needs to be further increased.

(5) Under the continuous advancement of institutional reform, the provincial, city, and county three-level full-time water-saving management institution system that has been basically formed in Jiangsu Province supervises and manages the water-saving work of civil buildings. In addition, each property generally has a full-time and part-time section. Water-saving organizations composed of water managers.

(6) At present, the routine inspection and maintenance of pipelines in various projects in Jiangsu Province are well implemented, which can basically guarantee the daily inspection of public water use parts, prevent groundwater pipe rupture, and ensure the normal operation of various water and electricity meters. For the leakage of indoor pipes of residents, it can be repaired and recorded in time.

(7) The activity form mainly uses community windows and publicity boards to issue water-saving proposals to residents, and widely publicizes water-saving common sense. A few communities also carry out water-saving publicity through various publicity methods such as cultural performances and invitations to popular science lectures by experts. However, residents' awareness of the current situation of water resources in China and Jiangsu Province is generally more optimistic.

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