Study on Comprehensive Evaluation of Protection and Utilization of Artificial canal in Yichang City

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Abstract. In order to effectively evaluate the protection and utilization of artificial canals. This article takes the Dongshan Canal as an example, combining the characteristics of Dongshan Canal, and constructing artificial canal protection and utilization evaluation index system based on the conceptual model of “driving force-pressure-state-impact-response-management”. At the same time, the comprehensive evaluation method of the protection and utilization of the artificial canal is established by combining the analytic hierarchy process. The results show that: The comprehensive evaluation result of Dongshan canal protection and utilization is 0.80 (I grade), and the river has a high degree of protection and utilization. The evaluation results are consistent with the actual situation of Dongshan canal, which verifies the feasibility of the index system constructed in this paper.

1. Introduction

With the acceleration of industrialization, urbanization and modernization, the uncertainty and complexity of artificial canals in the large-scale development and utilization of human beings are stimulated, which leads to serious threats to the river ecosystem, and then to different degrees of degradation[1]. The issue of the protection and utilization of artificial canals has attracted the attention of the government and the community[2-4]. At present, ensuring the health of artificial canals has become an important management goal of the government.

The Dongshan Canal (DSC) built in 1960, also known as the Yichang canal, is an inter-basin and inter-regional water transfer project. DSC has played an important role in the urban development and hydropower industry in Yichang city since it was built and operated. It is a milestone of Yichang and even Hubei hydropower. In recent years, under the opportunity of the strategic background of the Yangtze river economic belt and the rise of central China, the social economy of Yichang city has developed rapidly and the urbanization process has also accelerated significantly. In the meanwhile, the pressure of DSC has also increased, and the status of river protection is worrying. Therefore, the DSC protection and utilization status is evaluated, the problems of river protection and utilization are analyzed, and corresponding river management measures are formulated to ensure the healthy development rivers in Yichang city and realize the DSC as the target of residents' leisure, entertainment, popular science and sightseeing places.

In view of this, this paper takes the DSC as the research area, combines the actual conditions and the characteristics of the DSC, based on the representative principles, operability, functional requirements, harmonious coexistence and long-term development and other index system construction principles, draws on the research results of river protection and utilization. [5-7], and
constructs the DSC protection and utilization evaluation system. At the same time, the analytic hierarchy process is used to establish a comprehensive evaluation model of river protection and utilization, and the protection and utilization of DSC is quantitatively evaluated, in order to provide a favorable reference for the control of artificial canal.

2. Research Area

2.1 Basic Situation of Watershed
DSC(111°18′～111°21′, 30°41′～30°51′), also known as the Yichang canal, is an inter-basin and inter-regional water transfer project. It is located on the left bank of the Yangtze river and north of Yichang City. It flows through Yiling district economic development zone, Xiaoxita street, Xinyaowan township, Xiling street, Yichang development zone, Dongshan Park, Dagong Bridge Xiling district and Wanshouqiao street, involving 5 township streets and 3 developments parks, and returns to the Yangze rive at Wanshouqiao street in Wujiagang district. The section from Tangduhe reservoir to Dongshan power station is an artificial river section with a river length of about 27 km and a drainage area of 11.2 km². The Dongshan power station to Wanshouqiao is a natural river channel with a river length of about 3.5 km and a drainage area of 10.7 km².

2.2 Current status of water resources development and utilization
The development and utilization of water resources in the DSC is relatively high. Its water intake is mainly for power generation and water intake, industrial water intake, urban life water intake (including domestic water, public water), agricultural water intake and other water use (landscape entertainment, ecological water use). According to the survey, there are currently two power generation and water supply facilities in the Dongshan Canal Basin, namely Dongshan Hydropower Station and Yaowan Water Plant. There is a reservoir in the basin, which is the Meiziya reservoir, which plays a more obvious role in regulating the water resources utilization of the basin and greatly improves the utilization of water resources. DSC, Tangduhe reservoir and Meiziyu reservoir are the spare water sources of Yichang city water supply plants.

2.3 Feature positioning
From the completion of the Yaowan water plant during 1962 to 2002, the DSC has been the main source of water for urban use in the past 40 years. In recent years, with the development of the city, the water environment and ecology of the DSC have been seriously damaged. After the “Dongyi project” was officially put into operation, the water source of Yichang Yishui plant was changed from the canal to the Dongfengqu Guanzhuang reservoir. The status of the canal was reduced from the original “main source of Yichang urban water supply” to “important standby living water source”. Combined with the current situation of water resources development, environmental protection, ecological landscape, and related planning requirements of DSC, the characteristics of DSC are: urban leisure, ecological corridor, standby water source, taking into account power generation and irrigation functions.
2.4 Source of information
The basic data used in this paper comes from the “one river and one river policy”, “procedures for the planning of river basin planning” (SL201-2015), “guidelines for the compilation of river and lake shoreline protection and utilization planning” (trial), “national ecological protection red line-technical guide for delineation of ecological function red lines (trial)”, (circular [2014] No. 10) and other policy plans. Taking into account the integrity and reliability of the data, the water quality data is derived from the actual monitoring of the Yichang water resources bureau.

3. Construction of indicator system
3.1 Indicator system
The construction of index system is the basis of river protection and utilization evaluation. However, due to the difference of natural conditions and the influence of human activities, the river ecosystem has regional characteristics. Based on the existing research and field investigation of DSC, referring to DPSIRM conceptual framework, and following five principles of scientificity, integrity, operability, functional needs, harmonious coexistence and long-term development, this paper constructs an evaluation index system for DSC protection and utilization. The key indicators are listed in Table 1.

3.1.1 Driving force index. The DSC covers a drainage area of 21.9 km², with a population of 0.88 million along the coast, and its affected area involves nearly 200,000 residents. The DSC mainly provides water for power generation and water supply along the canal enterprises of Dongshan power plant, and provides ecological environment water for the canal city section. Runoff and population are important driving factors for the protection and utilization of DSC. Therefore, this paper chooses the runoff of dry-flow period to account for the annual average runoff ratio and population density as the driving force indicator.
3.1.2 Pressure indicators. Combined with the social and economic development of DSC and the development and utilization of the basin, this paper selects the protection and utilization pressure of DSC from three aspects: water resources, water environment and riparian zone:

- Water resources pressure index. At present, the development and utilization of water resources in DSC is relatively high. The water intake is mainly for power generation and water intake, industrial water intake, urban life water intake (including domestic water, public water), agricultural water intake and other water use (landscape entertainment, ecological water use). Therefore, this paper selects urban residents' water quota, rural residents' water quota, total water use, irrigation water utilization coefficient as water resource pressure.

- Water environmental pressure index. The water pollution in the basin is dominated by urban (township) domestic pollution and agricultural planting pollution. The downstream section of the Meiziya reservoir is densely populated, and a large amount of domestic sewage is discharged into the river. At the same time, the sewage collection pipeline along the DSC is still not perfect, and the downstream urban section has not fully realized the distribution of rain and sewage. There are many domestic sewage and mixed sewage discharges along the line. Therefore, this paper chooses the waste water discharge as the water environment pressure.

- The riparian belt uses the pressure index. Riparian vegetation plays an important role in maintaining the health of river ecosystems[8]. Deforestation and destruction of vegetation planted on river banks will have a direct impact on the stability and health of river ecosystems, and lead to threats to human health and safety that depend on river ecosystems[9]. Therefore, this paper selects the vegetation coverage rate of forest grass as an indicator to reflect the utilization status of the riparian zone.

3.1.3 Status indicators. Considering the influence of the pressure index and the driving force index, the state indicators are divided into three aspects: water resources, water environment, and riparian zone:

- Water resource status indicator. According to the statistical information of the DSC on the national economic and social development statistics, the population growth rate of the DSC is calculated. Considering that the urbanization rate of the DSC will be improved in the future, combined with the alternate water source and irrigation function of the DSC, this paper chooses the water supply guarantee rate as the water resource status indicator.

- Water environment status indicators. The water environment status indicator is based on the "Planning of the water intake, sewage outlet and emergency water source along the Yangtze River Economic Belt along the Yangtze River", the water quality target meets the Class III or better than the Class III water standard as the “suitable water intake zone” and “not suitable water intake zone”. The proportion of water quality conforming to or better than Class III is selected as the water environment state.

- Riverside status indicators. Combined with the functional orientation of the canal city leisure and ecological corridor, this paper selects the natural degree of the bank slope as the riparian state indicator.

3.1.4 Impact indicators. The DSC has comprehensive benefits such as water supply and irrigation. However, according to the water quality monitoring data, the water quality of DSC is poor, which can not meet the requirements of class II water quality target in water function area. In order to visually reflect the impact of the DSC, this paper selects the water availability and drinking water safety ratio as the impact indicators.

3.1.5 Response indicators. In view of the functional characteristics and existing problems of the DSC, considering the current situation of water resources development, environmental protection, ecological landscape in the DSC basin and the relevant planning requirements of Yichang city, this paper chooses the sewage treatment capacity and the degree of ecological water security as the response indicators.
3.1.6 Management indicators. In the full interpretation of the existing ecological function red line zoning, water environment quality red line zoning, water environment function zoning, water function zoning, livestock breeding area, other industry development plans, national and local laws and regulations on river protection in the DSC basin, this paper chooses the soundness of river protection and management system, the adaptability of flood control standards, the degree of river and cross-strait cleaning, and the establishment of environmental supervision system around rivers as management indicators.

Table 1. River protection and utilization indicators and implications.

| Target layer | Factor layer | Indicator layer | Indicator meaning | Indicator type |
|--------------|--------------|-----------------|-------------------|---------------|
| Driving force| Runoff accounted for annual average runoff ratio during dry season | Characterizing natural factors driving water resources | + |
| | The population density (people/km²) | Characterizing population density to drive river ecosystems | - |
| | Urban residents’ water quota (L/people/day) | The pressure of urban economic development on water resources | - |
| | Rural residents’ water quota (L/people/day) | The pressure of rural economic development on water resources | - |
| | Total water use (L. (people.d)⁻¹) | Characterizing the pressure of regional socioeconomic development on water consumption | - |
| Pressure | Irrigation water utilization fact(%) | Characterizing the degree of protection of agricultural water use by farmland water conservancy facilities | + |
| | Waste water discharge | Representing the pressure of social development on the water environment | - |
| River protection and utilization | Forest and grass vegetation coverage(%) | Indicates the percentage of the vertical projected area of the plant per unit area | + |
| | Water supply guarantee rate(%) | Reflecting the carrying capacity of the water environment in the basin | + |
| Status | Water quality meets or exceeds class III ratio(%) | Reflecting the carrying capacity of the water environment in the basin | + |
| | Shore slope natural degree(%) | Reflecting the degree of human interference in the riparian zone | + |
| Influence | Water availability (108m³) | Indicates the impact of water resources | + |
| | Drinking water safety ratio(%) | Indicates the impact of the water supply | + |
| Response | Sewage treatment capacity(%) | Representing a response to water environmental governance, direct means | + |
| | Ecological water security(%) | Indicates the level of ecological water demand protection | + |
The soundness of river protection and management system indicates the soundness of the river system.

Flood protection standard adaptability indicates the validity of management standards.

River and cross-strait cleaning indicates the effectiveness of the river system.

Establishment of environmental supervision system around the river indicates the implementation status of the river system.

### 3.2 Grading standards

According to the established DSC protection and utilization evaluation index system, combined with domestic and foreign river health index standards, relevant policies and planning objectives, DSC protection and utilization evaluation grades are divided. The specific grading standards are as follows:

#### Table 2. DSC Protection and Utilization Evaluation Grade

| Target layer | Factor layer | Indicator layer | Grading |
|--------------|--------------|-----------------|---------|
| Management   | The soundness of river protection and management system | Indicates the soundness of the river system | + |
|             | Flood protection standard adaptability | Indicates the validity of management standards | + |
|             | River and cross-strait cleaning | Indicates the effectiveness of the river system | + |
|             | Establishment of environmental supervision system around the river | Indicates the implementation status of the river system | + |

#### Driving force

| Indicator | Grading |
|-----------|---------|
| Runoff accounted for annual average runoff ratio during dry season(%) | 1.2-2 1.1-1.3 0.9-1.1 0.7-0.9 ≥2 or<0.4 |
| The population density (people/km²) | >400 400-600 600-140 1400-350 3500-500 |
| Urban residents' water quota (L/people/day) | <190 190-210 210-230 230-400 >400 |
| Rural residents' water quota (L/people/day) | <50 50-70 70-90 90-110 >110 |
| Total water use (L. (people.d)⁻¹) | 1.5-4.5 4.5-7.5 7.5-10.5 10.5-13.5 13.5-16.5 |
| Irrigation water utilization fact (%) | 80-100 60-80 40-60 20-40 <20 |
| Waste water discharge | <0.05 0.05-0.075 0.075-0.1 0.1-0.125 >0.125 |
| Forest and grass vegetation coverage (%) | <10 10-20 20-30 30-50 >50 |

#### Pressure

| Indicator | Grading |
|-----------|---------|
| Water supply guarantee rate (%) | >80 70-80 60-70 50-60 <50 |
| Water quality meets or exceeds class III ratio (%) | 100 70-100 60-70 50-60 <50 |
| Shore slope natural degree (%) | >95 80-95 65-80 50-65 <50 |
| Water availability (108m³) | >170 140-170 110-140 80-110 <80 |
| Drinking water safety ratio (%) | <5 5-10 10-30 30-50 >50 |
| Sewage treatment capacity (%) | >95 80-95 65-80 50-65 <50 |
| Ecological water security (%) | ≥90 70-90 60-70 40-60 <40 |
The soundness of river protection and management system

| Management | Flood protection standard adaptability | Adaption | Basic adaptation | Not adapted |
|-----------|---------------------------------------|-----------|------------------|-------------|
|           | low                                  | lower     | medium           | higher      |

| River and cross-strait cleaning | Establishment of environmental supervision system around the river |
|---------------------------------|------------------------------------------------------------------|
| high                            | excellent                                                        |
| higher                          | well                                                              |
| medium                          | general                                                           |
| lower                           | qualified                                                         |
| low                             | Failed                                                            |

3.3 Evaluation method

The Analytic Hierarchy Process (AHP) was first proposed by American operations researcher T.L. Saaty et al. in the 1970s. It is a hierarchical and structured multiple target decision analysis method that combines quantitative and qualitative methods[8], has the characteristics of system, flexibility and conciseness, and can better solve the problem of multilevel and Multiple structure in the river system. In general, after determining the evaluation indicators for the study of the river section, the evaluation of each layer by the analytic hierarchy process can be divided into the following steps:

3.3.1 Determination of indicator weight.

(1) Structural judgment matrix. After establishing an index system with hierarchical institutions, the factors in the same layer are compared in pairs, and the relative merits and demerits of the indicators are judged by the scoring method. Finally, judgment results results form a judgment matrix. The specific scale is defined as shown in Table 3 below.

| Table 3. Judgment matrix scale definition |
|------------------------------------------|
| Scaling | meaning | |
| 1       | Two elements are of equal importance |
| 3       | One is slightly more important than the other compared to the other |
| 5       | One is more important than the other compared to the two elements |
| 7       | One is stronger than the other compared to the two elements |
| 9       | One element is more important than the other compared to the other |
| 2, 4, 6, 8 | Intermediate value of the above two adjacent judgments |
| reciprocal | If the factors i and j must have the importance ratio of the judgment matrix to be a_{ij}, then the ratio of the factors j to i is a_{ij}=1/a_{ij}. |

- Hierarchical single sorting and consistency test. The feature vector corresponding to the largest eigenvalue of the matrix is normalized, which is the ordering of the corresponding elements of the same level corresponding to the relative importance of the upper layer, which is the weight. The specific calculation steps are as follows. First calculate the maximum eigenvalue of the judgment matrix $\lambda_{\text{max}}$:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$  \hspace{1cm} (1)

In the formula, n is the order of the decision matrix

- Calculate the average random consistency ratio CR

$$CR = \frac{CI}{RI}$$  \hspace{1cm} (2)
• In the formula, RI is the average consistency indicator and its value is determined as shown in the table.
• When CR < 0.10, the results of the analytic hierarchy process are considered to be satisfactory.

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

3.3.2 Establishment of evaluation model. The evaluation model adopts the analytic hierarchy process combining qualitative and quantitative analysis. Considering the simplicity and ease of operation of the evaluation model, the evaluation index of river protection and utilization control planning is calculated according to the following formula:

\[
E = \sum_{i=1}^{n} \lambda_i \times \left\{ \sum_{j=1}^{m_i} \lambda_{ij} M_j \right\}
\]  

In the formula, \( \lambda_i \) is the weight of the \( i \)-th criterion layer, \( n \) criteria layers in total; \( \lambda_{ij} \) is the weight of the \( j \)-th indicator selected for the \( i \)-th criterion layer in the criterion layer; \( M_j \) is the score of the \( j \)-th indicator selected for the \( i \)-th criterion layer.

3.3.3 Determination of evaluation level. According to the comprehensive index obtained from the evaluation model, the status of river protection and utilization control planning can be evaluated. The larger the comprehensive index is, the higher the degree of river protection and utilization is. The evaluation results are now divided into 5 levels, as shown in the following table.

| River protection and utilization grade | Composite index |
|--------------------------------------|-----------------|
| grade 1 (high)                       | >0.8            |
| grade 2 (Higher)                     | 0.8-0.7         |
| grade 3 (general)                    | 0.7-0.6         |
| grade 4 (Lower)                      | 0.6-0.5         |
| grade 5 (low)                        | <0.5            |

4. DSC evaluation

4.1 River protection and utilization evaluation
According to the requirements of AHP, through expert consultation and combined with a large number of river protection and utilization research judgment, the indicators of each layer are discriminated and tested for consistency according to table 3, and the index weight is calculated. Similarly, the weight of each criterion layer is calculated, and the results are as shown in Table 6.

| Factor layer | Indicator layer | Index Weight | Indicator value | Scale value | Evaluation index |
|--------------|-----------------|--------------|-----------------|-------------|------------------|
| Driving force| Runoff accounted for annual average runoff ratio during dry season | 0.06 | <0.4 | 0.20 | 0.01 |
|              | The population density (people/km²)                  | 0.06 | 400-600 | 0.80 | 0.05 |
|                      |                |        |        |        |
|----------------------|----------------|--------|--------|--------|
| Urban residents' water quota (L/people/day) | 0.03          | <190   | 1.00   | 0.03   |
| Rural residents' water quota (L/people/day) | 0.03          | 90-110 | 0.40   | 0.01   |
| Total water use (L. (people.d)^{-1}) | 0.05          | 1.5-4.5| 1.00   | 0.05   |
| Irrigation water utilization factor (%) | 0.04          | 40-60  | 0.60   | 0.02   |
| Wastewater discharge | 0.04          | 0.1-0.125| 0.40 | 0.02   |
| Water supply guarantee rate (%) | 0.06          | 70-80  | 0.80   | 0.05   |
| Shore slope natural degree (%) | 0.06          | 80-0.95| 0.80   | 0.05   |
| Water availability (10^3 m^3) | 0.06          | <5     | 1.00   | 0.06   |
| Drinking water safety ratio (%) | 0.11          | 40-70  | 0.40   | 0.05   |
| Sewage treatment capacity (%) | 0.06          | 65-80  | 0.60   | 0.04   |
| Ecological water security (%) | 0.06          | 70-90  | 0.80   | 0.05   |
| The soundness of river protection and management system | 0.06          | Basic adaptation | 0.80 | 0.05   |
| Flood protection standard adaptability | 0.03          | Basic adaptation | 0.60 | 0.02   |
| River and cross-strait cleaning | 0.03          | Basic adaptation | 0.80 | 0.02   |
| Establishment of environmental supervision system around the river | 0.05          | well | 0.80   | 0.04   |
| composite index | 1              | -      | -      | 0.70   |

4.2 Comprehensive evaluation of DPSIR river protection and utilization in DSC

According to the above method, the comprehensive evaluation index of DSC is 0.7, and the degree of river protection and utilization is high. From the weight of the criterion layer, the impact factors of the DSC protection and utilization are as follows: stress factor (0.17) > management factor (0.13) > impact factor (0.11) > state factor (0.1) > response factor (0.09) > kinetic force factor (0.06). Pressure factor is the main pressure on river protection and utilization caused by various socio-economic driving forces [11]. The reduction of water supply guarantee rate and the increase of total water consumption are the direct causes of water pressure on the DSC. Therefore, the stress factor has the greatest impact on river protection and utilization, and the weight in the protection and utilization evaluation system is also the largest. The management factor is the emphasis and refinement of the active intervention and recovery measures of human response in the response indicators [12]. The large management factor indicates that management policies and means are of great significance for river protection and utilization, and should be highly valued by relevant departments. The influence factors refer to the feedback results and influence degree of the change of river ecosystem status on the social and economic development, human life, resources and environment under the pressure and driving force. The large weight indicates the high development and utilization of the river ecosystem. The natural ecological environment and human society of the DSC are greatly affected, so effective measures need to be taken for timely control. The state factor and response factor are important indicators of river protection and utilization, and the two factors are equally important for river protection and utilization. The driving force factor is the fundamental driving force and potential driving force for the change of river ecosystem [13], and its weight is large, indicating that the degree of development and utilization is high. The natural ecological environment of DSC is greatly affected by human society, so effective measures should be taken to control it in time. State factor and response factor are important indicators of river protection and utilization, and they play an equally important role in river protection and utilization. The weights of the two factors are small and similar, indicating that the DSC has a good
protection and utilization status at present, and the control is relatively small. The driving force factor is the fundamental driving force and potential incentive for the change of river ecosystem[14]. Because DSC is an artificial canal, it is mainly affected by human disturbance activities, so the driving factor weight is small. Judging from the scoring index of the criterion layer, the ecological driving and social driving of the DSC basin are not large. The pressure on the water resources, water environment and riparian zone in the basin is small, and the pressure on the river is also small. Therefore, the DSC is in good condition and can basically meet the control requirements for river protection and utilization. However, the low response and management values indicate that the local awareness of the protection and utilization of DSC is relatively weak, and the management level needs to be improved. It is necessary to enhance the management and control capabilities of river protection and utilization.

From the index level, in the comprehensive evaluation index system of DSC protection and utilization, there are 12 indexes whose scores are more than 0.8 or above, accounting for 63.16%, and 7 indexes whose scores are less than 0.6 or below, accounting for 36.84%. This shows that although the protection and utilization degree of DSC is relatively high, there are still some abnormal changes in its structure, which are mainly manifested in the following aspects: large rural water quota, low efficiency of irrigation water utilization, large amount of sewage discharge, small proportion of drinking water safety, and low sewage treatment capacity. According to the weight value of each indicator in Table 6 and the evaluation index of each index, the safety ratio of drinking water, the guarantee rate of water supply, the natural degree of bank slope, the water quality meet or exceed the proportion of class III, the natural degree of bank slope, and the river cutoff throughout the year can be found. The frequency, the degree of ecological water security, and the soundness of the river protection and management system are the main influencing factors for the protection and utilization of the DSC. Therefore, the next river protection work of the DSC should focus on the red line of water resources, the red line of sewage discharge, and the red line of shoreline protection.

5. Conclusion
The evaluation index system of the control planning for the protection and utilization of the artificial canal involves a wide range of contents, including technical level and management level. The value of evaluation index and weight is also restricted by many factors, so it is difficult to value and quantify. Based on the DPSIRM model, the DSC protection and utilization comprehensive evaluation index system is used to calculate the river protection and utilization in the study area by using the analytic hierarchy process, which can better reflect the actual situation of the DSC protection and utilization. The analysis shows that:

- The degree of protection and utilization of DSC is relatively high, but there are still some abnormal changes in some structures. Combined with the weights of various indicators and the index of various indicators, it can be seen that water resources, water environment and riparian zone are the main influencing factors of DSC. Therefore, the next river protection work of the DSC should focus on the red line of water resources, the red line of sewage discharge, and the red line of shoreline protection.

- The river protection and utilization index system established in this study has broadened the ideas and theories of river protection and utilization research to a certain extent, but there are still many deficiencies, such as the selection and analysis of some indicators is too subjective, and the DSC is not analyzed. The applicability of the research results is also limited by the dynamic changes of different years, but the research results are reliable for the analysis of river protection and utilization in the study area, which can better meet the research objectives.

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