Study on Dynamic Evaluation of River Health based on Theme Service

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Abstract: In view of the shortcomings of traditional river health evaluation, such as fixed indexes and poor adaptability, the information technology was applied to the evaluation, and a dynamic evaluation mode of river health based on theme service was proposed. First, determine the evaluation themes which based on river health issues. Second, establish the river health dynamic evaluation process which based on the theme service. Third, construct the evaluation index database and componentize the evaluation method. Finally, draw the knowledge map of the evaluation theme on the synthesis integrated platform and build the river health dynamic evaluation system. A case study was carried out to evaluate the river health in the Xianyang-Xi'an section of the main stream of Weihe River from two themes: river ecological environment quality and river social service function capacity. The results show that the dynamic evaluation of river health based on the theme service can be achieved quickly and from multiple angles, and the results are more credible, which can better meet the needs of decision makers compared with the traditional evaluation methods. The results are of great significance for promoting the construction of river ecological civilization and have practicability and popularization value.

1 INTRODUCTION

River health evaluation is a description and assessment of the current situation of the river. It is of great significance to propose effective river protection measures and scientific water resources allocation schemes for the sustainable development of the river, the ecological environment construction of the basin and the rational utilization of water resources (Pinto & Maheshwari, 2014). Many scholars at home and abroad have carried out study on river health and achieved many beneficial results. In the early stage of research, biological monitoring methods such as Australian River evaluation Plan, South Africa's scoring system and Fish Aggregate Integrity Index (FAII) were widely used to evaluate the health of rivers (Chen et al., 2014). However, river not only have biological integrity but also their specific physical structure integrity, and the overall situation of rivers cannot be comprehensively evaluated only by the damage of river organisms (Wang et al., 2019). After that, comprehensive index methods such as River Habitat Survey (RHS) (Raven et al., 1998), RCE score (Petersen, 1992) and Index of Stream Condition (ISC) in Australia (Anthony et al., 1999) have become a new research direction. China also put forward the indexes, standards, and methods of river health evaluation (for pilot projects) in 2010 to guide the pilot projects of national river health evaluation and provide an important reference for river health evaluation in China. Li et al. (2016) established the river ecosystem health evaluation index system of Huaihe River Basin (Henan Section) based on four indexes: hydrological characteristics, water quality, biological conditions, and geomorphic characteristics. Gu et al. (2018) established the North Canal River ecosystem health evaluation index system based on four indexes: hydrology, water quality, aquatic organisms, and habitat status. Chen et al. (2019) comprehensively considered the feasibility condition of Lhasa River, established a multi-level and multi-index evaluation system based on the characteristics of ecological environment, social and economic development of Lhasa River, to provide reference for the management and protection of Lhasa River Basin. Previous studies on river health

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evaluation mainly focus on the construction of index system or the selection of evaluation model, but there are some problems such as the fixed evaluation index system, and the evaluation model is difficultly to adapt to dynamic changes.

Aiming at the complex river health problems, this paper proposes a dynamic evaluation mode of river health based on Theme Service (Xie et al., 2015) to carry out dynamic evaluation of river health, the purpose is to solve the problems of fixed indexes and weak adaptability in traditional river health evaluation. By constructing the evaluation index database, the deviation of traditional evaluation caused by less evaluation indexes are avoided. By componentizing the evaluation method, the rapid and accurate river health evaluation service is provided. The evaluation process is visualized based on the synthesis integrated platform, which improves the credibility of the evaluation, can quickly modify the evaluation indexes and methods, and provide dynamic and feedback correction evaluation services. Taking the Xianyang-Xi'an section of the main stream of Weihe River as an example, based on field research, two evaluation themes were finally determined, a river health dynamic evaluation system based on theme service was established, and dynamic evaluation was carried out for each theme. The research results of this paper are of great significance to reasonably formulate the health protection measures, maintain the normal natural and social functions and promote the construction of ecological civilization of Weihe River.

2 DYNAMIC EVALUATION OF RIVER HEALTH

2.1 Support of Dynamic Evaluation Theme Service

The synthesis integrated platform is an information platform to realize component customization and call, evaluation model integration, knowledge map drawing and editing, knowledge accumulation and retrieval, and decision-making discussion (Lian et al., 2019). The platform system framework is designed based on Service-Oriented Architecture (SOA). The biggest difference from the traditional evaluation system is that there is no specific business function. All applications are built through knowledge map and components, and specific decision evaluation application systems can be gradually built through application combinations (Xie & Luo, 2010). It makes the application system have strong flexibility. It is the foundation and support for the realization of dynamic evaluation theme service. The synthesis integrated platform can establish and improve the feedback mechanism for the participation of decision makers and experts in the decision-making process and give full play to their experience and wisdom.

2.2 Process of Dynamic Evaluation Theme Service

The theme service of dynamic evaluation should start from defining the theme. Under the guidance of evaluation objectives, evaluators refer to the experience and knowledge of experts and themselves and divide complex evaluation problems into multiple core themes. Under the strong guidance of theme driven, through qualitative discussion, with professional theoretical knowledge as the master line, clarify the relevant concepts and relationships, and initially formulate the structure of evaluation knowledge map. In the evaluation process, select the evaluation indexes and method components related to the theme, combine the pre-developed indexes and method components with the knowledge map, quickly build the evaluation model suitable for different themes, and realize the dynamic evaluation of visible and credible with online rapid response and flexible correction of evaluation methods. The process of dynamic evaluation of theme services is shown in Figure 1. With the needs of management and decision-making, the continuous changes of evaluation objectives and the continuous development of evaluation work, themes can be constantly updated and accumulated to form a comprehensive and rich evaluation theme database, which can provide guidance for future evaluation and make effective use of knowledge.

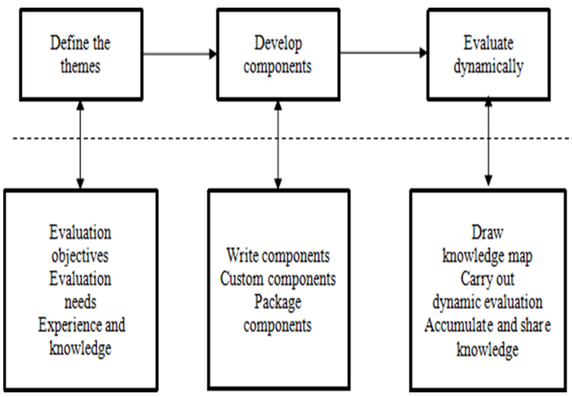

Figure 1: The basic process of dynamic evaluation.

2.3 Construction of Evaluation Index Database

Indexes usually do not exist independently, and there are often related and inclusive relationships among indexes. It is easy to generate disputes in the process of description, production and use. The reliability of index data itself and the processing process of data are very important. Only on the open and interoperable data-based platform, can indexes realize their potential (Wilsdon et al., 2015). In this paper, the definition and evaluation standard of the index are given. According to the index calculation method, the production process of the index is component-based, and the index is processed in the form of knowledge map, which can reduce misunderstanding as much as possible and give full play to the potential of the index. The index database is a complete set of indexes that may be involved in the evaluation of a certain field. It can be established by consulting relevant experts, querying scientific research literature and other ways. By componentizing these indexes, an evaluation index component database for this field is formed. Evaluators can find valuable indexes from the index database according to their needs.

2.4 Componentization of Evaluation Method

The evaluation method is component-based, that is, the evaluator develops and designs the weight calculation method components and evaluation method components according to the purpose of decision and evaluation. After testing, they are uploaded to the Web server, and finally the evaluation method component library is built. The use of component library is simple and low-cost. Evaluators only need to know the service objects and computing properties of all components in the component library, obtain the corresponding components through personalized customization and evaluation theme, and add them to the corresponding nodes of the knowledge map to calculate the weight of each evaluation index and the evaluation results.

Weight calculation component library: There are many methods to calculate the weight of each index in evaluation. In addition to AHP, there are principal component analysis, Delphi, mean square error, membership frequency, entropy determination and so on. Each method has its own advantages and disadvantages and application. If these weight calculation methods are packaged into components, the evaluators can use them on demand, or use a variety of weight determination methods for comparative analysis.

Evaluation method component library: The starting point, evaluation mechanism and applicable objects of different comprehensive evaluation methods are different, and each method has its advantages and disadvantages. The evaluation conclusions of different methods for the same object may not be consistent. The evaluation method is packaged as a component, and the evaluation method component library is constructed. The advantages and disadvantages of these methods and the applicable objects are compared and summarized. The evaluator can customize different methods components at any time, dynamically get the evaluation results of different methods and support decision-making. Due to the limited space, the paper takes the compound fuzzy matter element method as an example to analyze how to make the evaluation method component based.

Step 1. the calculation steps of compound fuzzy matter element (Du et al., 2021):

(1) Using m eigenvalues of n things to construct m-dimensional composite fuzzy matter elements Q_{mn} of n things:

$$Q_{mn} = \begin{bmatrix} q_{11} & \cdots & q_{1n} \\ \vdots & & \vdots \\ q_{m1} & \cdots & q_{mn} \end{bmatrix} \tag{1}$$

q_{mn} is the corresponding index value.

(2) In fuzzy matter-element model, the fuzzy value is usually the relative membership degree $u(q)$ of each characteristic value. According to the characteristics and functions of the index, it can be divided into the larger the better type (Formula 2) and the smaller the better type (Formula 3). The calculation formulas are as follows:

$$u_{mn} = \frac{q_{mn}}{q_{max}} \tag{2}$$

$$u_{mn} = \frac{q_{min}}{q_{mn}} \tag{3}$$

Where u_{mn} is the normalized value of index q_{mn}; q_{max} and q_{min} is the maximum and minimum of each index.

(3) The relative membership of each eigenvalue is used to construct the fuzzy matter element with superior membership Q'_{mn}:

$$Q'_{mn} = \begin{bmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & & \vdots \\ u_{m1} & \cdots & u_{mn} \end{bmatrix} \tag{4}$$

(4) Using the constructed standard fuzzy matter element Q_{0n} and Q'_{mn} to calculate the difference square fuzzy matter element Q_{Δ}:

$$Q_{\Delta} = \begin{bmatrix} \Delta_{11} & \cdots & \Delta_{1n} \\ \vdots & & \vdots \\ \Delta_{m1} & \cdots & \Delta_{mn} \end{bmatrix} \quad (5)$$

Where $\Delta_{ij} = \left(u_{0i} - u_{ij}\right)^2 (i = 1,2,\cdots,m; j = 1,2,\cdots,n)$.

The u in standard fuzzy matter element takes the maximum value of the superior membership degree of each evaluation index, which is generally 1.

(5) Substitute the weight and difference squared fuzzy matter element Q_{Δ} into the calculation to get the Euclid nearness ρ_{Hi}, the ρ_{Hi} is used to represent the comprehensive index of river health. According to the closeness degree, the river health status is classified, and the evaluation grade is given.

$$\rho_{Hi} = 1 - \sqrt{\sum_{i=1}^{m} w_i \Delta_{ij}} \quad (6)$$

w_i is the weight value.

Step 2. According to the above steps, combined with the component development process, the compound fuzzy matter element method is divided into five computing components: compound fuzzy matter element construction component, relative membership calculation component, fuzzy matter element based on optimal membership degree construction component, difference square fuzzy matter element calculation component, Euclidean approach degree calculation component. According to the process in step 1, the logical relationship of the five computing components is determined as shown in Figure 2.

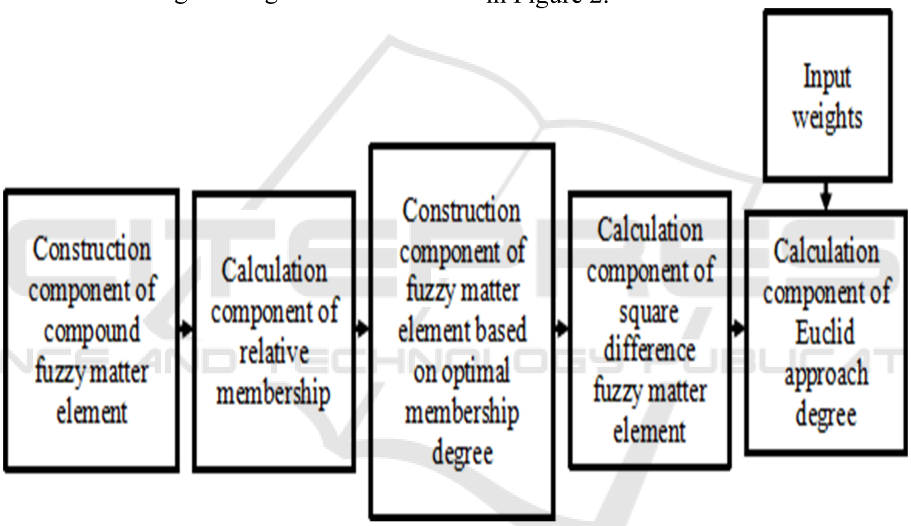

Figure 2: Composite fuzzy matter-element method calculation component module relationship map.

Step 3. Based on the synthesis integrated platform, the component technology is used to develop the computing components divided in step 2 and stored in the method component library of the platform. During the evaluation process, the relevant components can be called from the method component library for calculation.

2.5 Drawing of Evaluation Theme Knowledge Map

After determining the evaluation theme, establishing the relevant evaluation index database and modularizing the evaluation method, draw the knowledge map of the evaluation theme based on the synthesis integrated platform. Firstly, open the synthesis integrated platform, create a new knowledge map, draw the knowledge map according to the established evaluation process, retrieve the components related to the required evaluation indexes and methods from the component library, and add the components to the corresponding nodes of the knowledge map after customization; if the knowledge package has been drawn and meets the requirements of the evaluation theme, the existing knowledge map results can be opened through the knowledge pack management interface, and can be used directly or after modification on the original knowledge map. After the knowledge map is modified, it is packaged and released to achieve the purpose of knowledge accumulation and sharing. In the follow-up evaluation or evaluation for other themes, we can make full use of the existing relevant achievements of the theme database as a reference for solving similar complex decision-making problems. The main work of theme knowledge map includes drawing nodes, designing component interfaces, customizing components, etc. There are some connections between these works, such as the data requirements of front-end components flowing to subsequent components in the evaluation process, or the relationship between front-end nodes and back-end nodes in the knowledge map. Based on the drawn theme evaluation knowledge map, select and customize the method components suitable for the evaluation theme from the component library, quickly get the evaluation results of different methods, and realize dynamic evaluation.

3 APPLICATION EXAMPLES

3.1 Support of Dynamic Evaluation Theme Service

Weihe River is the largest tributary of the Yellow River, with a total length of 818 km and main stream of 502km in Shaanxi. It flows through Baoji, Xianyang, Yang ling agricultural demonstration area, Xi'an and Weinan and across Guanzhong Plain. In Shaanxi, the upstream section is above Baoji, the midstream section is from Baoji Gorge to Xianyang, and the downstream section is after Xianyang. The elevation difference between the upstream and downstream is nearly 3000m.

In this study, the watershed controlled by Xianyang hydrological station to Lintong hydrological station of Weihe River is selected as the study area. The Xianyang-Xi'an section of the main stream of Weihe River is about 63.48km long and the watershed area is about 11600km^2.This area is located in the downstream area of Weihe River, belonging to the impact plain, with gentle terrain and many tributaries. The total population of Xi'an and Xianyang is large, and the industry is relatively developed. Therefore, the main stream of Weihe River in this area is the direct receiving water body of industrial wastewater and domestic sewage on both banks of Weihe River, and this area is a relatively serious area of the whole main stream of Weihe River.

The data used in this paper come from Shaanxi water resources bulletin, Shaanxi Provincial monthly report on water environment and so on.

3.2 Establish the Themes and Methods of River Health Evaluation

According to the previous investigation on the Xianyang-Xi'an section of the main stream of Weihe River, considering the concerns of the management department and the actual situation of the river, and combined with the opinions of relevant experts, two types of themes for river health evaluation are determined. The themes determined in this paper mainly consider the river ecosystem structure and social service function, including the theme of river ecological environment quality and the theme of river social service function capacity. After determining the evaluation theme, the evaluation method is modularized according to Section 2.4. For the above two themes, by reviewing literature and consulting experts, this paper decides to use analytic hierarchy process, principal component analysis, fuzzy comprehensive evaluation, composite fuzzy matter-element method, and comprehensive index method to optimize and evaluate the indexes under different themes. Above methods are detailed in the literatures (Du et al., 2021; Zeng et al., 2020; Zhang et al., 2007; Liu et al., 2018; Shen, 2008) and are not repeated in the paper due to space constraints.

3.3 Construction of Evaluation Index System under Different Themes

Due to the complexity of river health status and the differences of health problems in different rivers, there is no fixed index system that can be applied to the health evaluation of any river. It is necessary to update the theme and modify the index system according to the actual situation of the river. Through the early investigation and analysis of the health status of the Xianyang-Xi'an section of the main stream of Weihe River, combined with expert opinions, the evaluation indexes corresponding to each theme are selected from the 42 evaluation indexes (omitted) in the evaluation index database constructed in Section 2.3, the initial evaluation index system is established, and then the indexes are optimized in combination with subjective experience and expert opinions. The evaluation indexes are optimized by fusing multi-source data (Yang et al., 2015). The methods mainly include： using the calculation results of analytic hierarchy process to eliminate the indexes with small weight, using common diagnosis and correlation analysis to eliminate the indexes with high correlation degree, using sensitivity analysis to eliminate the indexes with low discrimination, and using principal component analysis to calculate the load matrix of each initial index. Extract the indexes with high load, and finally construct the evaluation index system suitable for each theme. Through the screening and sensitivity analysis of the initial evaluation index system. 19 evaluation indexes are finally determined in Figure 3, including 13 indexes of river ecological environment quality and 6 indexes of river social service function capacity.

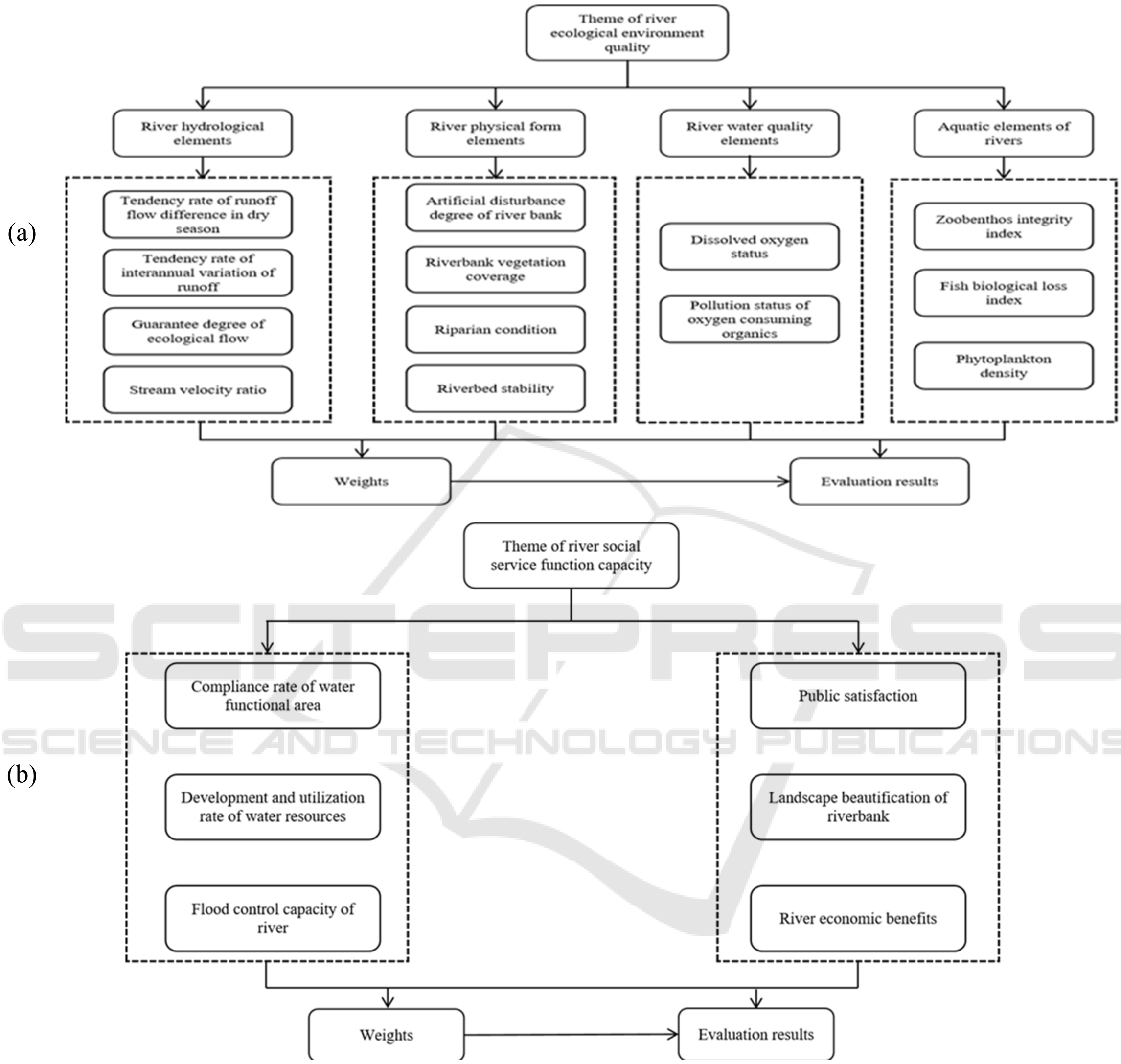

Figure 3: Evaluation index system of different themes of river health in the Xianyang-Xi'an section of the main stream of Weihe River.

3.4 Dynamic Evaluation based on the Synthesis Integrated Platform

Based on the synthesis integrated platform, the evaluation index systems corresponding to different themes constructed above are described and visualized, and the evaluation knowledge maps corresponding to different indexes are drawn, as shown in Figure 4 and Figure 5. According to the knowledge map, call the weight calculation method component developed in Section 2.4 to calculate the weight of each theme of evaluation indexes. After calculating the weight of each evaluation index, obtain the statistical data of each evaluation index from the database, and call the evaluation method component developed in Section 2.4 to calculate the evaluation results of the theme. Considering the complexity and dynamism of the actual situation of different rivers, when the river needs to increase the evaluation theme or supplementary evaluation index when the great change takes place, based on the synthesis integrated platform, the knowledge map can be modified rapidly, and the new evaluation index weight and evaluation results can be calculated from the component library, and the dynamic process of evaluation is realized.

Figure 4: Theme evaluation knowledge map of river ecological environment quality in the Xianyang-Xi'an section of the main stream of Weihe River.

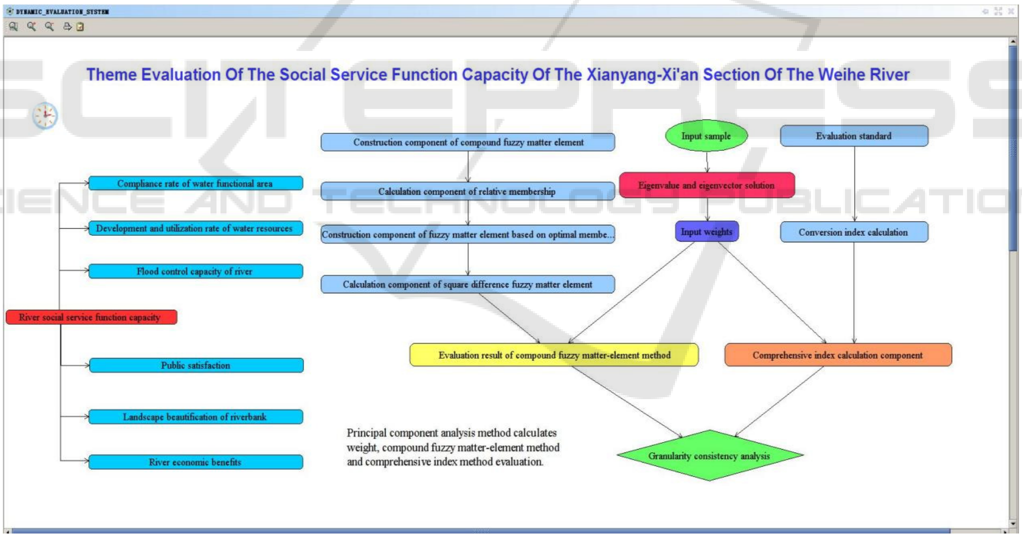

Figure 5: Theme evaluation knowledge map of river social service function capacity in the Xianyang-Xi'an section of the main stream of Weihe River.

3.5 Analysis and Discussion on Evaluation Results of Different Indexes

According to the relevant data collected, the river health evaluation years of different themes are unified to four years from 2015 to 2018. Due to the different emphasis and evaluation indexes of different evaluation themes, different evaluation methods are used to evaluate different themes in this paper. Due to the componentization of the corresponding evaluation methods in Section 2.4, the corresponding evaluation method components can be quickly called for calculation based on the synthesis integrated platform. When applied to the health evaluation of other rivers in China, the evaluation model adopted in this paper is also applicable.

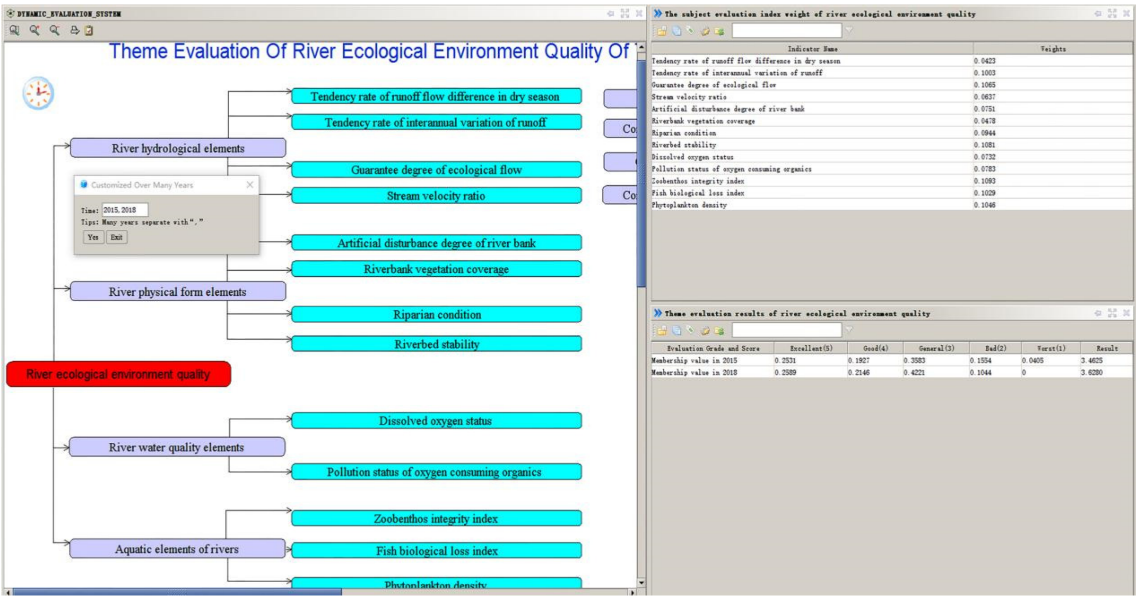

Figure 6: Theme evaluation results of river ecological environment quality in the Xianyang-Xi'an section of the main stream of Weihe River.

3.5.1 Theme Evaluation Results and Analysis of River Ecological Environment Quality

AHP is used to determine the weight of the evaluation index of the river ecological environment quality theme in the Xianyang-Xi'an section of the main stream of Weihe River. Fuzzy comprehensive evaluation method is used to comprehensively evaluate the river ecological environment quality theme in 2015 and 2018. The results are shown in Figure 6. According to the calculated membership values, the results of the theme evaluation of river ecological environment quality in 2015 and 2018 were 3.4625 and 3.6280 respectively by weighted calculation with the score of the evaluation grade. Among them, the membership of the corresponding grade "general" was the largest, which was 0.3583 and 0.4221 respectively. The river ecological environment quality in 2015 and 2018 was between "good" and “general”, and the situation in 2018 was improved compared with that in 2015. Through statistical data analysis and practical investigation, it is found that the evaluation results are basically in line with the actual situation.

3.5.2 Theme Evaluation Results and Analysis of River Social Service Function Capacity

Principal component analysis was used to determine the evaluation index weight of the theme of social service functional capacity. Due to the deep-seated interaction among the evaluation indexes of the theme of social service functional capacity, such as the substandard water functional area, the poor flood control capacity of the river and the low degree of river bank landscaping will reduce public satisfaction; The low utilization of river water resources will also affect the economic benefits of the river. Therefore, the composite fuzzy matter-element method and the comprehensive index method are used to conduct a comprehensive evaluation on the four years of 2015, 2016, 2017 and 2018, and the granularity analysis is used to judge the consistency of the evaluation results of the two methods, and the results are shown in Figure 7. It can be seen from the evaluation results that the evaluation ranking of the two methods is consistent. From 2015 to 2018, the social service function capacity has improved year by year, and each evaluation index has developed healthily year by year. The evaluation results are consistent with the actual situation that Xi'an and Xianyang have carried out Weihe River control measures in recent years to ensure the safety of river flood discharge, so that there are beautiful green forest belts, landscape parks and ecological wetlands on the bank side of Weihe River, and the public satisfaction has been greatly improved.

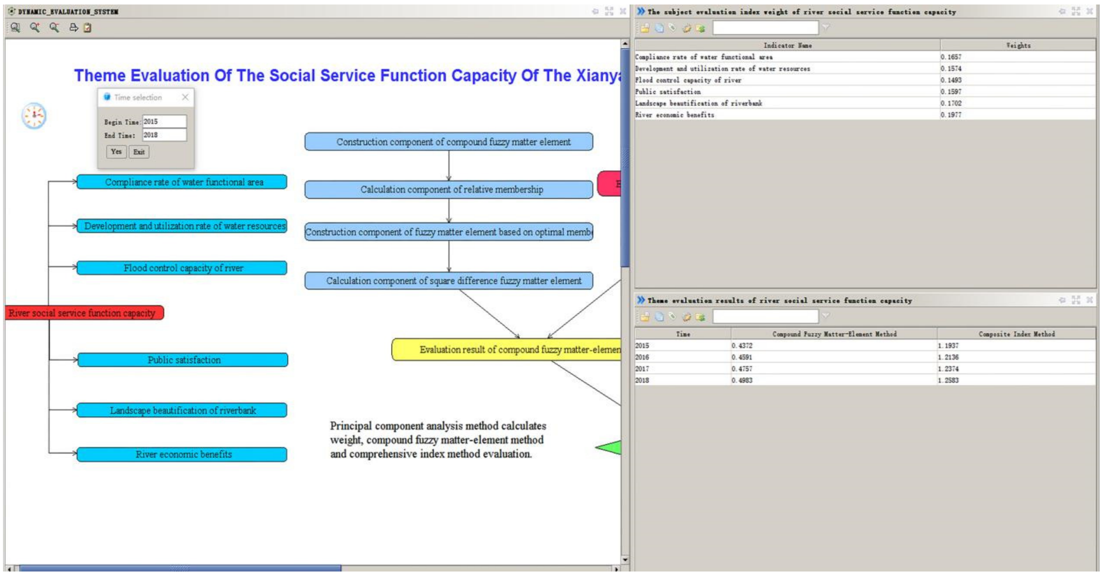

Figure 7: Theme evaluation results of river social service function capacity in the Xianyang-Xi'an section of the main stream of Weihe River.

4 CONCLUSIONS

This paper puts forward the dynamic evaluation mode of river health based on theme service, builds the dynamic evaluation system of river health based on theme service through the synthesis integrated platform, and draws different theme knowledge maps to make the whole evaluation process visible and credible. By developing components and drawing theme knowledge map, complex evaluation problems are simplified with the help of information technology. The component technology is used to establish the evaluation index weight calculation component library and evaluation method component library. For the same or different evaluation themes, the method components can be quickly extracted, and the evaluation system can be quickly built to obtain the evaluation results of different index systems and multiple evaluation methods. Based on the synthesis integrated platform, the evaluation index system can be updated quickly, the knowledge map can be modified dynamically, and dynamic evaluation can be realized.

The application example of the Xianyang-Xi'an section of the main stream of Weihe River shows that: Based on theme service mode can realize river health evaluation quickly and from multiple angles, which has more advantages than traditional evaluation methods. The results show that: In 2015 and 2018, the river ecological environment quality was between "good" and "general", and the situation in 2018 was improved compared with that in 2015. From 2015 to 2018, the social service function capacity and evaluation indexes of rivers have been improved year by year. The evaluation results of different themes are consistent with the field research and previous research results, which shows that the dynamic evaluation results based on theme services proposed in this paper are credible, practical and worth popularizing.

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