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Construction and Empirical Study of a Health Evaluation System for Science and Technology Information Service Ecosystems: Postprint

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Abstract

[Purpose/Significance] Addressing the deficiencies in current research on scientific and technological information service ecosystems, this study draws upon natural ecosystem health theory to construct a health evaluation system for scientific and technological information service ecosystems from an information ecology perspective, thereby guiding their stable and healthy development. [Method/Process] Based on literature research and expert interviews, and combined with the health characteristics of scientific and technological information service ecosystems, the evaluation system is constructed. The Analytic Network Process (ANP) is employed to estimate the relative importance weights of each indicator. Data are collected through interviews and questionnaires, and empirical research is conducted using the multi-level fuzzy comprehensive evaluation method. [Results/Conclusion] The results indicate that vitality is the most critical criterion dimension. The application of ANP and the multi-level fuzzy comprehensive evaluation method to construct the health evaluation system and estimate weights demonstrates good applicability, which can provide guidance and reference for improving scientific and technological information service functions and optimizing the structure of scientific and technological information service ecosystems, thus promoting their stable and healthy development.

Full Text

Preamble

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Construction and Empirical Research of a Health Assessment System for Science and Technology Information Service Ecosystems

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Abstract

[**Purpose/Significance**] In view of the deficiencies in current research on science and technology information service ecosystems, this paper draws on natural ecosystem health theory and constructs a health assessment system for science and technology information service ecosystems from an information ecology perspective to guide the stable and healthy development of such ecosystems. [**Method/Process**] Based on literature review and expert interviews, and combined with the health characteristics of science and technology information service ecosystems, this study constructs a health assessment system for these ecosystems. The Analytic Network Process (ANP) is used to estimate the relative importance weights of each indicator. Data were collected through interviews and questionnaires, and multi-level fuzzy comprehensive evaluation was employed for empirical research. [**Result/Conclusion**] The results show that vigor is the most critical criterion dimension. The application of ANP and multi-level fuzzy comprehensive evaluation to construct the assessment system and estimate weights demonstrates good applicability, providing guidance and reference for improving science and technology information service functions, optimizing ecosystem structure, and promoting stable and healthy development of science and technology information service ecosystems.

Classification Number: G252
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The national "13th Five-Year Plan" for informatization emphasizes the need to "develop green production models, accelerate the deep integration of informatization and ecological civilization construction," and "build a digital science and technology platform based on the informatization of scientific and technological condition resources, promote the sharing of scientific data and literature resources, construct a networked research environment, provide services to the whole society, and promote the transformation of scientific research methods and approaches" [1]. These policy documents provide guarantees for the development of science and technology information services in terms of policy, environment, and technology. In the digital economy era, data and information have become the most important production resources. Under the combined effects of policy guidance, demand-driven forces, and knowledge innovation, science and technology information service institutions have gradually recognized that science and technology data and information are key resources in economic construction, scientific research, and business management. As an emerging innovation form of science and technology information services, the science and technology information service ecosystem has relatively weak theoretical foundations. Existing research has mainly focused on information flow and ecosystem operation mechanisms, with insufficient attention paid to the ecosystem's structure, function, and sustainable development. Therefore, there is an urgent need to develop evaluation methods to guide science and technology information service institutions in optimizing their service functions and effectively coordinating relationships between service-related entities and service objects, thereby promoting system upgrading and development.

This study integrates information ecology theory, service ecosystem theory, and ecosystem health theory to construct a health assessment system for science and technology information service ecosystems. It explores diagnostic methods for evaluating the health status of these ecosystems, providing theoretical support and reference for the management and sustainable development of China's science and technology information service ecosystems.

1. Literature Review

1.1 Evaluation of Science and Technology Information Services

Science and technology information service evaluation refers to a scientific and complete assessment system composed of a series of interconnected, mutually constraining, and interacting evaluation elements, characterized by integrity, systematicity, and coordination. It can reflect the management and utilization status of science and technology information service systems. In recent years, domestic and international scholars have conducted increasingly in-depth research on this topic. S. Ghazinooory et al. [2] constructed a national science and technology evaluation system based on international practices from five dimensions: system function evaluation, interaction framework evaluation, organizational evaluation, funding model evaluation, and outcome evaluation. P. Castro et al. [3] established a multi-dimensional evaluation system for science, technology, and innovation instruments based on the GeoPI impact evaluation method to ensure certainty, multi-dimensionality, causality, and timeliness in technology assessment. M. C. Alves et al. [4] extracted dimensional indicators from the CAPES evaluation system report to establish scientific indicators based on information visualization for evaluating Brazil's scientific activities to assist in planning and implementing public management policies. A. Biranvand et al. [5] used the Six Sigma method to evaluate the service quality of regional science and technology information centers, focusing on analyzing the gap between user expectations and perceptions and satisfaction with service quality. Su Zhaohui and Su Meiqing [6] constructed an evaluation system for science and technology innovation platform services from a user perspective, drawing on the SERVQUAL model. Qu Peng [7] built an evaluation system for open environment science and technology text corpora based on big data for evaluating corpus construction processes and quality control in libraries and science and technology information service institutions.

1.2 Evaluation of Information Ecosystem Health

An information ecosystem is a dynamic system with self-regulating capabilities, representing a combination of artificial and natural ecosystems that requires both internal self-regulation and external artificial intervention [8]. Consequently, information ecosystems exhibit characteristics and patterns similar to natural ecosystems. In recent years, scholars have applied ecosystem health models to evaluate ecosystems in enterprises, industries, agriculture, cities, and information ecosystems. Liu Kailing [9] introduced ecosystem health theory into quantitative evaluation research on eco-industrial parks, constructing an evaluation index system model for industrial park ecosystem health based on emergy analysis. Xue Weishuang [10] constructed a health evaluation system for university digital library information ecosystems based on natural ecosystem evaluation methods from three aspects: system structure, system vitality, and system service capacity. Xiao Shuji [11] analyzed the basic components of enterprise information ecosystems and their interrelationships, using natural ecosystem theory to construct an evaluation system for enterprise information ecosystems. Marco Iansiti and Roy Levien [12] argued that a healthy business network ecosystem requires three types of indicators: enterprise system vitality, industrial system organizational capacity, and resilience representing the degree of adaptation to the peripheral environment.

These research findings provide a theoretical foundation for studying the health evaluation of science and technology information service ecosystems. Applying natural ecosystem health theory to social ecosystem research is feasible and applicable, offering new ideas for evaluating social ecosystems. However, existing evaluations of science and technology information services have focused primarily on service quality, user satisfaction, or outcomes, policies, and service platforms, with few studies evaluating the overall capability of the science and technology information service system from a holistic perspective.

2. Theoretical Foundation

2.1 Science and Technology Information Service Ecosystem

2.1.1 Connotation of Science and Technology Information Services

Science and technology information refers to information reflecting the dynamics and characteristics of scientific and technological research, invention, and application, representing the totality of scientific and technical information [13]. Science and technology information services refer to information services provided by science and technology information service or consulting institutions to various scientific and technological innovation entities through platforms, smart mobile terminals, email, and other means, including science and technology information retrieval, analysis of scientific and technological achievements, and science and technology information consultation. Service objects mainly consist of government agencies, enterprises, universities, research institutes, and scientific researchers. By providing services such as science and technology information retrieval, decision support, scientific evaluation, and knowledge services, these institutions provide information support for government decision-making, scientific and technological innovation, transformation of scientific and technological achievements, and deep integration of industry, academia, and research.

2.1.2 Connotation of Science and Technology Information Service Ecosystems An information ecosystem is an organic whole formed by the interconnection and interaction between information actors and the information ecological environment, possessing regulatory capabilities for information flow and information sharing [8]. A service ecosystem is a relatively independent, self-regulating whole that integrates resources, achieving value creation through resource integration and service exchange under the coordination and constraints of shared institutions [14]. The commonality between information ecosystems and service ecosystems lies in their ecological attributes—both are dynamic systems with self-regulating capabilities. The difference is that service ecosystems emphasize service interactivity more prominently. A science and technology information service ecosystem possesses both commonalities while highlighting service interaction characteristics. It is an information ecosystem with self-regulating functions, centered on information service institutions, formed by information users and other actors, and various information environments through information transmission and exchange [8].

Currently, science and technology information service institutions apply new-generation information technologies such as big data, cloud computing, and mobile internet networks. Through interactive collaboration with various information service entities, they provide scientific and technological users with comprehensive ecological services throughout the entire process from information organization, retrieval, mining, and analysis to decision-making, service evaluation, and management, forming a new model of science and technology information services. Drawing on the theoretical concepts of information ecosystems and service ecosystems, and referencing definitions of information service ecosystems by different scholars, this study defines the science and technology information service ecosystem as follows: An open, complex, dynamically regulated, and symbiotically competitive ecosystem based on science and technology information resources and technology, led by science and technology information service institutions, with participation from various science and technology information service entities and users, aimed at supporting scientific and technological innovation and decision-making, centered on co-creation of science and technology information value, and driven by information flow to interconnect value flow, talent flow, service flow, and capital flow.

2.2 Ecosystem Health Theory

Ecosystem health theory is an important means to effectively achieve ecosystem management and sustainable human development. American ecologists D. J. Rapport (1985) and R. Costanza (1992) successively conducted research on ecosystem health theory. D. J. Rapport et al. defined ecosystem health as "the state, condition, or performance of an ecosystem defined against appropriate goals," encompassing two aspects: the ability to meet reasonable human social demands and the ecosystem's capacity for self-maintenance and renewal. A healthy ecosystem is stable and sustainable, possesses vitality, can maintain its organization and self-operation capabilities, and has certain resilience to external pressures [15]. A healthy ecosystem is not only ecologically sound but also conducive to socio-economic development and can maintain healthy human populations. D. J. Rapport noted that ecosystem health is interdisciplinary in nature, providing new methods and concepts for understanding the relationships among human activities, ecological changes, ecosystem services, economy, and human health. R. Costanza pointed out that a good ecosystem health assessment method should reflect ecosystem function, structure, and resistance to external interference [16].

In August 1999, the International Conference on Ecosystem Health established VOR (vigor, organization, resilience) as indicators for ecosystem health diagnosis, using these three metrics to characterize ecosystem stability, sustainability, and integrity. Within certain temporal and spatial scopes, ecosystem health is measured by the status of comprehensive characteristics of basic functions. The ecosystem health index (HI) is expressed as:

$$HI = O \cdot V \cdot R$$

where vigor (V) represents ecosystem function and the ability to produce and accumulate energy, an important indicator measuring system activity, metabolism, or primary productivity and the fundamental material basis for ecosystem existence; organization (O) reflects ecosystem structure, describing the effectiveness of connections among ecosystem components; and resilience (R) reflects ecosystem tolerance to external interference or the ability to return to its original state after disturbance removal. With deepening research, scholars have proposed measuring ecosystem health from additional perspectives including ecosystem management choices, reduced external inputs, impacts on neighboring systems, and human health effects [17].

Currently, ecosystem health theory is widely applied in health assessment research of natural and social ecosystems. By studying the correlation between environmental stress and changes in ecological parameters representing main ecosystem characteristics, natural ecosystem health theory addresses issues of destruction and imbalance in natural ecosystems [18]. Environmental stress refers to the comprehensive pressure of external environmental factors on ecosystem interference, damage, and impact, while ecological parameters mainly include ecological indicators, physicochemical indicators, and socio-economic indicators [19]—characteristic values describing ecosystem health status. This study aims to reveal the correlation between system vigor, organization, resilience, and ecosystem health through research on the science and technology information service ecosystem health assessment index system, addressing imbalance issues and promoting sustainable development.

2.3 Connotation of Science and Technology Information Service Ecosystem Health

The science and technology information service ecosystem is a product combining natural and artificial ecosystems. With advanced technologies such as internet, big data, and cloud computing, the stability, sustainability, and integrity of these ecosystems have been extended while facing more challenges. Drawing on information service ecosystem theory and referencing various definitions of ecosystem health, combined with characteristics of science and technology information services, this study defines science and technology information service ecosystem health as: A system with rich, high-quality science and technology information resources and products, sound and fully utilized information service functions, good and continuously optimized service environments, reasonable, stable, and sustainable organizational structures, capable of meeting information needs of users and innovation entities, and bringing abundant benefits to service entities and users.

The healthy state of a science and technology information service ecosystem has the following basic characteristics: (1) Good ecosystem vitality, meaning high-quality information resource guarantee rates and efficient information service productivity. The basic function is to create valuable science and technology information products and services for innovation and decision support, improving support, guarantee, and utilization efficiency. (2) Reasonable ecosystem organization. A reasonable community structure is the inherent characteristic and requirement for health, which can be analyzed from the population numbers of service entities and users, service chain structure, and service entity structure. The ecosystem's function and overall efficiency depend not only on the vitality of each service entity but also on their coordination—without scientific coordination mechanisms, a healthy ecosystem is difficult to achieve. (3) Sustainable strong resilience. When the information environment "deteriorates," a healthy ecosystem should have resistance strategies to ensure structural integrity and normal function, mainly manifested in ecological adaptability and vitality when the ecological chain structure becomes abnormal or the service environment suffers pollution, damage, or attacks.

3. Health Assessment System for Science and Technology Information Service Ecosystems

3.1 Indicator Determination

Based on the connotation and characteristics of science and technology information service ecosystem health, and referencing existing social ecosystem health evaluation indicators, this study uses the three characteristic states of vigor, organization, and resilience to measure ecosystem stability, sustainability, and integrity—that is, the ability to maintain organizational structure, self-regulation, and stress resistance in temporal and spatial dimensions.

Vigor refers to the ecosystem's capacity to provide service functions, produce service products, and accumulate service energy, measurable through resource vigor, technical vigor, and personnel vigor. Resource vigor ensures material sources for services, reflected in resource types, update speed, authority, sharing status, and transformation effectiveness. Technical vigor is crucial for functional diversity, service timeliness, efficiency, and specialization, manifested in information presentation forms, retrieval methods, platform interface design, and service functions such as statistical analysis, competitive intelligence, knowledge management, and decision support. Personnel vigor includes both information providers and users, with provider vigor reflected in professionalism, education level, service timeliness, and knowledge update frequency, while user information literacy affects understanding and acceptance of system functions.

Organization is an important indicator characterizing relationships among ecosystem components, reflecting structural complexity and diversity. Generally, more complex organizational structure indicates healthier ecosystems, typically evaluated using organizational diversity indicators [20,21]. In science and technology information service ecosystems, this manifests in two aspects: internal ecosystem chain interdependence structure diversity and cross-organizational ecosystem chain interdependence structure diversity. Internal diversity refers to diverse interdependence relationships among different information actors or internal system service functions within the ecosystem dominated by science and technology information service institutions, including: (1) diversity of service models (personalized customization, one-stop services, embedded services, multi-mobile terminal services); (2) diversity of service personnel disciplinary backgrounds to serve different professional fields; and (3) diversity of user structures allowing mutual learning from different user types. Cross-organizational diversity refers to diverse interdependence relationships between the science and technology information service ecosystem and other information ecosystems, manifested in cooperation between and across research institutions. In relatively loose cross-organizational network relationships, trust is the cornerstone of cooperation and necessary for mutual benefit, with cooperation degree depending on trust mechanism coordination. The ecosystem involves multi-organizational interaction and cooperation among service institutions, information providers, platform providers, and other service institutions, where sound benefit balance mechanisms regulate stability and vitality to maintain ecological chain diversity. Complex cross-organizational cooperation networks can easily lead to ecological chain rupture, requiring corresponding information transmission mechanisms to ensure smooth communication.

Resilience refers to the ecosystem's "resistance" when the environment undergoes human-induced or force majeure changes—that is, when an ecological chain breaks, the system can promptly use alternative structures to ensure normal information flow and exchange, maintaining structural and functional stability. Resilience is manifested through internal and external environmental recovery capacity. Internal environmental resilience refers to system recovery when encountering internal pressure, measurable through reliability, security, stability, and artificial recovery capabilities. External environmental resilience refers to basic support conditions required for ecosystem operation and development, specifically government funding, market funding, and legal support for science and technology information services.

Based on ecosystem health theory and combining the connotation and characteristics of science and technology information service ecosystem health, this study constructs a health assessment system with three primary indicators (vigor, organization, resilience), seven secondary indicators (resource vigor, technical vigor, personnel vigor, internal ecosystem chain interdependence structure diversity, cross-organizational ecosystem chain interdependence structure diversity, internal environmental resilience, and external environmental resilience), and 27 tertiary indicators including science and technology information resource types and government funding intensity.

3.2 Model Construction and Weight Determination

3.2.1 Construction of the Health Assessment Model Analysis of the health assessment indicators reveals that the health status of science and technology information service ecosystems is influenced by multiple aspects and factors with interdependent relationships, presenting a multi-level, multi-criteria network structure. Therefore, this study adopts the Analytic Network Process (ANP) to determine element weights. ANP is a decision-making method developed from the Analytic Hierarchy Process, suitable for non-independent hierarchical structures [22]. Due to the complexity of ANP calculations, this study uses SuperDecisions software for ANP assignment calculations.

The assessment model includes control layer objectives, control layer criteria, control layer sub-criteria, network layer with 3 primary indicators, 7 secondary indicators, and 27 tertiary indicators. Using SuperDecisions software, ANP weighting is implemented. First, the ANP structural model for the science and technology information service ecosystem health assessment is constructed, as shown in Figure 1 [Figure 1: see original paper].

3.2.2 Model Testing and Indicator Weight Determination Using SuperDecisions software with a 1-9 scoring scale, judgment matrices were constructed. Ten professionals engaged in science and technology information services and experts in the information service field were invited to conduct pairwise comparisons of indicator importance. The mode of the ten experts' scores was used as the indicator weight. SuperDecisions automatically calculated matrix weights and consistency test results using the eigenvalue method. During calculation, two indicators—"relevant science and technology information service legal perfection" and "multimedia technology support"—failed the consistency test. After deleting these indicators, experts re-evaluated the matrices. All matrices achieved Inconsistency < 0.1, indicating satisfactory consistency. Test results and indicator weights are shown in Table 1 .

Table 1 shows that the three criterion dimensions rank by importance as: vigor, organization, and resilience. Vigor is the most critical dimension, with resource vigor and technical vigor being important indicators affecting ecosystem health. This indicates that science and technology information resources and technology are key factors influencing ecosystem health.

4. Health Assessment Methods for Science and Technology Information Service Ecosystems

Current ecosystem health assessment methods mainly include fuzzy comprehensive evaluation, analytic hierarchy process, and entropy method. Science and technology information service ecosystem health assessment is a complex system problem involving all aspects of information services centered on science and technology information service institutions, with diverse data types and fuzzy evaluation criteria. To reduce the influence of subjective factors, this study adopts the multi-level fuzzy comprehensive evaluation method to determine health assessment scores. The multi-level fuzzy comprehensive evaluation process proceeds from lower to higher levels [23,24].

4.1 Determination of Evaluation Indicator Factor Set

Assume a certain type of matter is determined by n factors, constituting the evaluation factor set U = (U_1, U_2, U_3…U).

4.2 Determination of Evaluation Set

Assume there are m possible evaluations for this matter, constituting the evaluation set V = (v_1, v_2, v_3,…v).

4.3 Determination of Weight Values

As described above, ANP has been used to determine indicator weight values A, A_1……A_{31}, A_{32}.

4.4 Determination of Fuzzy Judgment Matrix

Each evaluation object should establish a comprehensive evaluation matrix R, where the m single-factor judgment matrix R for U is:

$$R = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1n} \\ r_{i21} & r_{i22} & \cdots & r_{i2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{im1} & r_{im2} & \cdots & r_{imn} \end{bmatrix}, \quad (i = 1, 2, 3\ldots 31, 32)$$

where m is the number of elements in evaluation indicator set U , and n is the number of elements in evaluation set V.

4.5 Multi-level Fuzzy Comprehensive Evaluation

Based on the weights obtained in 4.3 and the single-factor fuzzy evaluation judgment matrices obtained in 4.4, multi-level fuzzy comprehensive evaluation is conducted from the lowest level upward. First, fuzzy comprehensive evaluation is performed on the lowest-level evaluation factors U to obtain comprehensive evaluation set B . Then, evaluation proceeds upward level by level to obtain the final comprehensive evaluation set B:

$$B_i = A_i \cdot R_i = (b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5}) \quad (i = 1, 2, 3...31, 32)$$

$$B = A \cdot R = A \cdot \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_m \end{bmatrix} = (b_1, b_2, b_3, b_4, b_5)$$

4.6 Calculation of Evaluation Score C

The fuzzy comprehensive evaluation result B for the evaluation object is combined with the scoring evaluation set V to obtain the final score C for each evaluation object:

$$C = B \cdot V = (b_1, b_2, b_3, b_4, b_5) \cdot (v_1, v_2, v_3, v_4, v_5)$$

5. Empirical Research

This study selected a science and technology information service institution in Jilin Province as the evaluation object for empirical research. The institution primarily provides decision support for government departments and information services including retrieval, statistics, analysis, and evaluation for enterprises, universities, research institutes, and scientific researchers. Through long-term cooperation, communication, and services, the institution has played an important bridging role in the integration of industry, academia, and research in Jilin Province. With information flow, service flow, capital flow, and value flow, it has formed a science and technology information service ecosystem centered on this institution. The constructed assessment system was applied to evaluate the health status of this ecosystem, yielding a specific health index score. By referring to the health assessment standards, the ecosystem's health status can be determined.

5.1 Determination of Evaluation Factor Set

Control layer objective factor set: U = (U_1, U_2, U_3)
Control layer criterion factor sets: U_1 = (U_{11}, U_{12}, U_{13}), U_2 = (U_{21}, U_{22}), U_3 = (U_{31}, U_{32})

Control layer sub-criterion factor sets: $U_{11} = (U_{111}, U_{112}, U_{113}, U_{114}, U_{115})$, $U_{12} = (U_{121}, U_{122}, U_{123})$, $U_{13} = (U_{131}, U_{132}, U_{133}, U_{134}, U_{135})$, $U_{21} = (U_{211}, U_{212}, U_{213})$, $U_{22} = (U_{221}, U_{222}, U_{223})$, $U_{31} = (U_{311}, U_{312}, U_{313}, U_{314})$, $U_{32} = (U_{321}, U_{322})$

5.2 Health Assessment Standards and Evaluation Set

Human health evaluation levels are divided into three states: healthy, sub-healthy, and diseased. Some scholars have divided urban and industrial ecosystem health evaluation levels into five categories: very healthy, healthy, sub-healthy, unhealthy, and deteriorated [25]. This study refers to these classifications and divides science and technology information service ecosystem health levels into five grades: 90-100 (healthy), 80-<90 (relatively healthy), 70-<80 (sub-healthy), 60-<70 (unhealthy), and 50-<60 (deteriorated). Each factor at every level requires a corresponding evaluation set with five grades: $V = (v_1, v_2, v_3, v_4, v_5)$ = (healthy, relatively healthy, sub-healthy, unhealthy, deteriorated). For more intuitive results, specific scores are assigned: healthy = 90, relatively healthy = 80, sub-healthy = 70, unhealthy = 60, deteriorated = 50.

5.3 Determination of Indicator Weights

As described above, ANP has been used to determine indicator weight values A, A_1……A_{31}, A_{32}.

5.4 Determination of Fuzzy Judgment Matrix

Based on the constructed health assessment model, this study conducted interviews and questionnaires with the Jilin Province science and technology information service institution and its users to investigate objective and subjective evaluation indicators. Interviews with reference consultants and information service professionals revealed the institution's specific operation methods. A 16-question survey was designed using a 5-point Likert scale. Fifty questionnaires were distributed to enterprise users, government users, and scientific researchers with long-term stable cooperative relationships, yielding 42 responses with 40 valid questionnaires. These users had repeatedly used the institution's services, and some had established industry-academia-research cooperation relationships. Interview and survey results were converted into matrix form to obtain single-factor fuzzy judgment matrices. Following fuzzy comprehensive evaluation procedures, the fuzzy judgment matrix R_{11} for the resource vigor criterion was constructed as follows:

$$R_{11} = \begin{bmatrix} 0.5 & 0.375 & 0.125 & 0 & 0 \\ 0.5 & 0.375 & 0.125 & 0 & 0 \\ 0.125 & 0.625 & 0.25 & 0 & 0 \\ 0.5 & 0.25 & 0.25 & 0 & 0 \\ 0.125 & 0.625 & 0.125 & 0.125 & 0 \end{bmatrix}$$

5.5 Multi-level Fuzzy Comprehensive Evaluation

Based on fuzzy judgment matrix R_{11} and ANP weight values A_{11}, the fuzzy evaluation result B_{11} is obtained through fuzzy relation operation A • B:

$$B_{11} = A_{11} \cdot R_{11} = (0.11617, 0.04183, 0.16892, 0.37933, 0.29374) \cdot R_{11} = (0.32650, 0.44325, 0.19353, 0.03672, 0)$$

Similarly: B_{12} = (0.45906, 0.37500, 0.12500, 0.04093)
B_{13} = (0.37870, 0.29523, 0.32607, 0, 0)
B_{21} = (0.22281, 0.38290, 0.19715, 0.19715, 0)
B_{22} = (0.21615, 0.76525, 0.01861, 0, 0)
B_{31} = (0.58585, 0.31062, 0.10354, 0, 0)
B_{32} = (0, 0, 1, 0, 0)

$$B_1 = A_1 \cdot R_1 = A_1 \cdot \begin{bmatrix} B_{11} \\ B_{12} \\ B_{13} \end{bmatrix} = (0.38915, 0.39882, 0.17717, 0.03485, 0)$$

$$B_2 = A_2 \cdot R_2 = A_2 \cdot \begin{bmatrix} B_{21} \\ B_{22} \end{bmatrix} = (0.21948, 0.57408, 0.10788, 0.09858, 0)$$

$$B_3 = A_3 \cdot R_3 = A_3 \cdot \begin{bmatrix} B_{31} \\ B_{32} \end{bmatrix} = (0.51262, 0.27179, 0.21560, 0, 0)$$

$$B = A \cdot R = A \cdot \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = (0.32410, 0.46607, 0.14960, 0.06025, 0)$$

5.6 Calculation of Evaluation Score C

$$C = B \cdot V = (0.32410, 0.46607, 0.14960, 0.06025, 0) \cdot (90, 80, 70, 60, 50) = 80.5$$

5.7 Analysis of Results

The evaluation results show that the science and technology information service ecosystem centered on the Jilin Province institution has a health index score of 80.5. According to the evaluation standards, this ecosystem has just reached the relatively healthy level, at the critical value between sub-healthy and relatively healthy states. The ecosystem's vigor, organization, and resilience are good. This indicates that its service functions can meet user needs, the diversity of ecological chain interdependence relationships can ensure healthy development, and the system can conduct timely self-regulation when encountering external environmental impacts to ensure normal operation of the ecological chain. The institution can currently provide various types of information services and has established long-term cooperative relationships with government, enterprise, and research units. Therefore, the evaluation results accurately reflect reality and have certain applicability. However, the ecosystem still needs to strengthen science and technology information resource construction, build diverse service models, and enhance the diversity of ecological chain interdependence structures to effectively improve its vigor and organization, thereby maintaining and improving its healthy state.

Currently, research on science and technology information service evaluation from a service ecosystem perspective is limited, and existing studies have not achieved ideal integration of comprehensiveness and practicality, nor have they produced evaluation methods that can both reflect overall ecosystem stability, sustainability, and integrity and be applied in practice. The reason may be that information ecosystem evaluation is often not centered on information service institutions, while information service evaluation often cannot be conducted from a holistic ecosystem perspective. The operation of science and technology information service ecosystems is influenced by multiple information actors in the ecological chain, and health assessment has fuzzy characteristics. This study employs multi-level fuzzy comprehensive evaluation to construct a health assessment system including three dimensions of vigor, organization, and resilience, and conducts empirical research. Results show that the proposed system and method can effectively address issues of hierarchy, diversity, complexity of influencing factors, and fuzziness of evaluation standards, providing specific and operable tools for research and practice.

Limitations include: (1) The invited experts, though representative, were not broad enough in scope, requiring wider investigation for indicator and weight evaluation; (2) The empirical analysis primarily targeted long-term stable cooperative users, whose needs satisfaction may lead to potentially inflated health scores; (3) Only one institution-centered ecosystem was analyzed, requiring further verification of the indicator system's applicability. Future research will expand expert consultation scope, strengthen cooperation with service institutions, and continuously optimize the assessment system to improve accuracy and applicability.

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Author Contributions

Liu Jia: Proposed research proposition and ideas, wrote and revised the paper, and finalized the manuscript.
Shao Shiya: Participated in writing and revising the paper.
Peng Peng: Conducted questionnaire surveys and data organization.

Note: Figure translations are in progress. See original paper for figures.

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