Postprint of GIS Application Research in the Construction of the Beijing-Tianjin-Hebei Science and Technology Resources Digital Map Platform

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Abstract

[Purpose/Significance] With the continuous improvement of Geographic Information System (GIS) technology, its applications have permeated various aspects of society. However, the application of GIS in the field of scientific and technological resources is relatively limited and remains in the exploratory stage. [Method/Process] Starting from the current status and issues in the construction of scientific and technological resource service platforms in the Beijing-Tianjin-Hebei region, based on the construction practice of the Beijing-Tianjin-Hebei scientific and technological resources digital map platform, this paper discusses the application of GIS in the platform construction process. [Results/Conclusion] Practical results demonstrate that GIS possesses distinct advantages in scientific and technological resource data management, analysis and visualization, scientific and technological resource evaluation, as well as dynamic monitoring and simulation prediction of scientific and technological resources, providing reliable intelligence information analysis and decision-making support for collaborative innovation in the Beijing-Tianjin-Hebei region.

Full Text

Preamble

Research on GIS-based technology resource visualization platforms has investigated the overall architecture for science and technology resource data, designing spatial data models and methods for associating spatial data with resource data [?]. Hu Haiying' s analysis of the Chengdu Science and Technology Resources Geographic Information System explored new models for innovative technology application services under information resource sharing conditions, providing a reference model for science and technology resource information sharing [?].

In practice, platforms such as the Zhejiang Provincial Science and Technology Innovation Cloud Service Platform, Ningbo Innovation Cloud Service Platform, Dongguan Innovation Map, and Gansu Provincial Science and Technology Innovation Capacity Digital Map display the spatial distribution of innovation entities and carriers as well as service resources through mapping. However, these platforms are limited to query and visualization functions, with significant deficiencies in spatial analysis capabilities for science and technology decision-making, preventing GIS from truly fulfilling its supporting role in this domain. Investigating GIS applications in the Beijing-Tianjin-Hebei science and technology resources digital map platform can provide effective support for regional science and technology resource information integration and sharing, spatial layout optimization, and strategic decision-making.

Surveys reveal that the Beijing-Tianjin-Hebei region' s science and technology resource service platforms feature diverse content and formats. Given the extensive scope of science and technology resources, platform types are equally varied, encompassing not only conventional library and information services and scientific literature, but also talent, projects, scientific equipment, technology transfer, and statistics sharing platforms. These platforms can be categorized by service object (enterprise services, innovation and entrepreneurship services, research services), by constructing entity (government-led public platforms such as property rights exchanges, productivity promotion centers, and intellectual property services, which constitute the majority; university or research institute-led professional platforms; and enterprise-led innovation service platforms such as science park information systems), by nature (R&D platforms, industrialization platforms, public service platforms), or by function (government affairs, management, communication, transaction, and knowledge service types).

However, these information sharing platforms remain relatively limited in content, service functions, and visualization expression. Most function as data-oriented service platforms, with few offering deep data correlation mining, intelligence forecasting, or decision support. Their strong regional character urgently demands cross-regional integrated service platforms and decision support platforms for science and technology resources.

1 Current Status of Science and Technology Resource Service Platform Construction

The significant disparities in informatization development levels across Beijing, Tianjin, and Hebei pose enormous challenges for cross-regional science and technology resource information sharing. Combined with long-standing administrative barriers and weak resource sharing awareness, these factors have resulted in fragmented and unclear basic information on science and technology resources, ambiguous supply and demand channels, and low resource sharing levels, all of which constrain the efficiency of Beijing-Tianjin-Hebei collaborative innovation. The depth and breadth of science and technology resource information sharing not only affect the leapfrog development of scientific and technological innovation in the region, but also influence further reforms to the local science and technology system [?].

Constructing science and technology resource service platforms represents a new approach to effective regional resource utilization and an important driving force for scientific and technological innovation and enhanced soft power in the information age. These platforms aim to promote resource sharing and facilitate scientific and technological innovation, operating under the principles of co-construction, sharing, collaboration, and service to address mismatches between science and technology resources and economic development while activating abundant resource reserves [?]. Such platforms constitute crucial means for improving regional science and technology resource utilization efficiency and effectiveness.

As demand for science and technology information sharing continues to grow, numerous information sharing and service platforms have emerged, playing important roles in promoting regional scientific and technological development. However, these platforms generally suffer from limited information content, service functions, and visualization expression. Most remain data-oriented service platforms, with few providing deep data correlation mining, intelligence forecasting, or decision support capabilities. Their pronounced regional character creates an urgent need for cross-regional integrated service platforms and decision support platforms for science and technology resources.

2 Construction of the Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform

As Beijing-Tianjin-Hebei collaborative innovation accelerates, the transformation of major scientific and technological achievements from Beijing to Hebei and industrial upgrading processes will inevitably generate diverse demands for technology, talent, and other science and technology resource information. Efficiently integrating resource information across the three regions, enabling rapid information queries, intuitive visualization, and mining decision-valuable intelligence holds significant importance for Beijing-Tianjin-Hebei collaborative innovation.

The Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform (hereinafter referred to as "the Platform") is a cross-regional integrated service platform for science and technology resources led by the Beijing Municipal Institute of Science and Technology Information. Oriented toward the major demands of Beijing-Tianjin-Hebei collaborative innovation and industrial development, the Platform integrates information on scientific institutions, talent, achievements, projects, equipment, policies, statistics, and industrial data. Characterized by its "science and technology resources + digital maps + intelligence analysis + platform services" model, the Platform provides information and consulting services for governments, enterprises, and researchers. Built on a Web GIS framework, this innovative service platform enables science and technology resource information queries and statistics, spatial analysis and visualization, comprehensive evaluation and forecasting, and supply-demand matching and sharing services, representing both service and model innovation in GIS applications for the science and technology resource domain. Platform construction helps clarify the inventory of science and technology resources, facilitates the flow, reorganization, and optimal allocation of innovation factors across Beijing-Tianjin-Hebei, and will effectively support the exchange of scientific and technological information, promote open sharing of resources and achievements, serve collaborative innovation, and enhance the overall capabilities of intelligence service institutions.

2.1 Characteristics of Science and Technology Resource Information

Science and technology resources comprise the collection of elements that create scientific and technological achievements and drive economic and social development. Broadly defined, they include financial, human, material, and information resources; narrowly defined, they are limited to human and financial resources [**?**]. These resources provide material guarantees for scientific and technological activities and basic conditions for management, decision-making, and research, constituting important national strategic resources [**?**]. To meet the needs of resource integration, sharing, and efficient utilization, the Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform categorizes regional science and technology resource information into scientific institutions, talent, projects, achievements, equipment, statistics, and other information, based on comprehensive considerations of spatial visualization expression, data accessibility, and analyzability.

Beyond general information characteristics such as carrier dependence, value, timeliness, shareability, and processability, science and technology resource information possesses spatial characteristics. Through geocoding of institutions and attribute association, talent, projects, achievements, and other resources can be spatialized and visualized, providing scientific foundations for analyzing spatial distribution patterns and optimizing spatial layouts and resource allocation.

2.2 Distinctive Features of the Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform

Compared with general information service platforms, the Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform exhibits three distinctive features. First, the Platform incorporates spatial factors into its overall framework, enabling decision-makers to examine Beijing-Tianjin-Hebei science and technology resource development from a spatiotemporal perspective. Grounded in economic geography and regional economics theories, it considers the historical accumulation and endowment of regional science and technology resources, providing scientific foundations for macro-level decisions regarding spatial agglomeration, efficient allocation, and layout optimization. Second, the

Platform adopts an approach of overall design, phased implementation, and concurrent research and demonstration construction. Employing big data, Internet, cloud computing, and GIS technologies, it features the "science and technology resources + digital maps + intelligence analysis + platform services" model to create a cross-regional integrated service platform combining information queries, visualization and analysis, comprehensive evaluation, and decision support. Third, the Platform represents an application that integrates science and technology resources with GIS. It constructs a unified underlying database for science and technology resources and geospatial data, obtains spatial distributions of institutional resources through geocoding of institutional addresses, and uses institutional locations as the link and regions as the carrier to present human, financial, material, and information resources on maps, thereby achieving value mining and "value-added" for science and technology resource data [Figure 1: see original paper].

3 GIS Applications in the Beijing-Tianjin-Hebei Science and Technology Resource Digital Map Platform Construction

The spatial agglomeration of science and technology resources influences regional scientific and technological innovation capacity, while the spatial clustering of innovation subjects and carriers affects the formation of innovation networks and regional industrial development patterns. GIS technology can play a significant role in science and technology resource information queries, management, services, and decision-making. Its powerful capabilities in spatial data processing, map visualization, spatial analysis, and simulation prediction not only enable unified management and integrated sharing of science and technology resource data, but also facilitate spatial visualization expression and positive interaction with the public. GIS helps users quickly locate required science and technology resource information and mine valuable information for scientific decision-making, contributing to the construction of efficient, intelligent, and responsive intelligence service systems that provide specialized intelligence support for scientific decision-making.

3.1 Applications in Science and Technology Resource Data Management, Analysis, and Visualization

The primary distinction between geographic information systems and other transaction information processing systems (such as banking management or library retrieval systems) lies in GIS's capacity to handle large amounts of geometric target information, including both position information of targets themselves and spatial relationship information between geographic features. Scientific institutions serve as the link connecting scientific talent, projects, achievements, and equipment, and can be accurately positioned on maps through location matching, thereby endowing science and technology resource data with spatial attributes and enabling direct presentation of related attribute data in electronic maps. Based on this foundation, several specific applications can be implemented.

First, precise querying and distribution display of science and technology resources. Using GIS attribute query functions, the Platform enables rapid and convenient querying and statistical analysis of science and technology resources, along with spatial distribution and detailed information display. Examples include querying and displaying research institutes in the Beijing-Tianjin-Hebei region or high-tech enterprises in the energy sector in Haidian District. This helps users understand the current spatial distribution and endowment of science and technology resources, facilitating problem and pattern identification.

Second, spatial querying and statistics of science and technology resources. Spatial querying represents a uniquely powerful GIS tool that enables queries based on spatial relationships. The Platform' s query methods include spatial positioning queries and spatial relationship queries. On one hand, the Platform provides graphical query capabilities, allowing users to query science and technology resource information using circles, rectangles, or arbitrary polygons. On the other hand, it offers spatial relationship queries such as buffer zone queries and topological relationship queries. For example, users can identify the distribution of technology enterprises and parks along major transportation arteries or in key areas, helping decision-makers understand industrial development status and spatial distribution patterns.

Third, data association analysis and map visualization of science and technology resources. Leveraging GIS mapping functions, the Platform symbolically represents science and technology resource data to produce various static or dynamic thematic maps. For instance, based on historical or current scientific and technological innovation resource data, the Platform can visualize spatial characteristics of innovation elements, relationships between innovation attributes and physical environments, and innovation spatial structures to create scientific and technological innovation resource maps. This visualization approach helps identify and analyze problems and key factors in the layout and collaborative development of Beijing-Tianjin-Hebei innovation resources, dynamically display new development trends, and reinterpret regional scientific and technological development patterns and collaborative innovation phenomena from a spatial perspective.

Currently, the Platform can produce three types of thematic maps. First, association analysis and distribution maps based on scientific institution (point) data. For example, using model construction to analyze and display patent cooperation in gallium nitride across Beijing-Tianjin-Hebei reveals that Beijing collaborates more with the Yangtze River Delta and Pearl River Delta regions than with Tianjin and Hebei in gallium nitride research. Similarly, analyzing the distribution of energy conservation and environmental protection institutions and industrial parks demonstrates that under the combined effects of agglomeration and selection, related institutional resources exhibit a "large agglomeration with small dispersion" pattern—forming a major agglomeration in

Beijing, minor agglomerations in Tianjin and Shijiazhuang, and dispersed distribution in other prefecture-level cities, with linear distribution along important transportation arteries. Second, regional statistical (area) data analysis and thematic map production, covering science and technology, industry, society, economy, resources, and environment. Regional statistical data directly reflect overall regional conditions and represent common analytical tools in scientific research. Using GIS mapping functions, the Platform can produce various spatiotemporal statistical thematic maps, both dynamic and static, such as changes in economic aggregates, scientific personnel, population distribution, and ecological environmental quality across Beijing-Tianjin-Hebei municipalities since the founding of the People' s Republic of China, providing fundamental support for scientific research and popularization. Third, integration of scientific institution data with regional statistical data, combining point and area data for comprehensive expression that helps reveal relationships between science and technology resources and regional development.

3.2 Applications in Comprehensive Evaluation of Science and Technology Resources

Spatial analysis constitutes the core of GIS, representing quantitative research on geographic spatial phenomena to obtain and analyze information about spatial position, distribution, form, formation, and evolution of geographic objects. GIS spatial analysis includes buffer analysis, overlay analysis, network analysis, and spatial statistical analysis, widely applied in urban planning, pollution monitoring, disaster analysis, resource evaluation, terrain analysis, healthcare, and military fields, though less so in science and technology resources. On one hand, spatial analysis methods such as hotspot analysis, spatial autocorrelation analysis, spatial clustering analysis, geographically weighted regression analysis, and network analysis can evaluate science and technology resource potential and collaborative layout, yielding results on resource hotspots, potential assessments, and spatiotemporal characteristics and developmental patterns of coordination between industrial allocation and science and technology resources.

On the other hand, based on geocoding of scientific institution addresses to obtain spatial distributions of various institutional resources, the Platform comprehensively employs measurement methods such as location entropy indices, SP indices, and spatial Gini coefficients to construct evaluation models for spatial agglomeration effects of scientific institution resources. These models assess spatial clustering effects of universities, research institutes, technological innovation institutions, enterprises, and other innovation organizations such as parks and alliances. The Platform also constructs spatiotemporal coupling models between high-tech enterprises and science and technology resources, using correlation and coupling degree evaluation methods to analyze coupling development situations from temporal and spatial perspectives. These GIS-based models help reveal spatial patterns, evolutionary processes, and relational mechanisms of science and technology resources, providing intelligence support for resource management and scientific decision-making.

3.3 Applications in Dynamic Monitoring and Simulation Prediction of Science and Technology Resources

GIS technology offers unparalleled advantages in dynamic monitoring and simulation prediction, widely applied in urban planning, environmental monitoring, disaster simulation, and prediction when combined with remote sensing technology. In the science and technology resources domain, these advantages manifest in three aspects. First, based on constructed evaluation indicator systems for Beijing-Tianjin-Hebei science and technology resources (such as regional scientific and technological innovation capacity evaluation and agglomeration effect evaluation), the Platform conducts dynamic monitoring of indicators, rapidly obtaining evaluation results to support decision-making. Second, following principles combining historical data with qualitative and quantitative approaches, the Platform dynamically simulates and predicts development trends of scientific and technological development or agglomeration areas. Third, the Platform simulates how environmental changes affect innovation factor flows and new pattern formation. For example, when transportation or policy environments change, the Platform can simulate and predict how micro-level elements such as innovative talent, enterprises, and consumers agglomerating in a particular area respond and what new patterns emerge. It can also simulate how policies in different periods affect science and technology resources, particularly spatial pattern changes, helping decision-makers understand and evaluate policy impacts on scientific and technological innovation and providing scientific foundations for policy formulation and macro-level decision-making.

Additionally, GIS finds extensive application in planning, with influential cases including the U.S. MetroGIS project, Brno' s master and regional planning system in the Czech Republic, post-war reconstruction development strategies in Beirut, Lebanon, the Tacoma Dome District renewal plan in Washington State, and ancient building protection planning in Delphi, Greece. Similarly, GIS can be applied in science and technology resources domains such as spatial layout and planning of industrial agglomeration areas like Silicon Valley. By comprehensively employing spatial analysis methods such as site selection analysis and network analysis, the Platform can conduct applied research on current situation analysis, spatial feasibility analysis, spatial layout analysis, infrastructure planning, and planning outcome integration and implementation management, enhancing planning feasibility and scientific rigor while providing support platforms for subsequent planning management and research.

4 Conclusion

From a geographic spatial perspective, the concentrated distribution of science and technology resources affects regional scientific and technological innovation capacity, while the spatial agglomeration of innovation subjects and carriers influences the formation of innovation network patterns and regional industrial development. Due to the spatiotemporal characteristics of science and technology resource data, GIS integration becomes possible. GIS plays a substantial role in science and technology resource information queries, services, and decision-making. Its powerful capabilities in data management, visualization, and spatial analysis not only enable querying, visualization, and spatial analysis of science and technology resource data, but also support resource evaluation, dynamic monitoring, simulation prediction, and site selection planning for science and technology resource agglomeration areas, thereby providing information and intelligence support for Beijing-Tianjin-Hebei regional collaborative innovation. Currently, GIS application research and practice in the science and technology resources domain remain in the exploratory stage. With continuous GIS technology development and ongoing Platform improvement, GIS will deliver greater value in regional science and technology collaborative innovation and application services.

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Author Contributions

Li Mei: Manuscript writer; Miao Runlian: Provided input on overall framework and science and technology resource evaluation methods.

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

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