# Research on Strengthen the Development and Utilization of Geospatial Data to Release the Value of Data Elements

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**Abstract**

As an important basic and strategic information resource of a country, geospatial data is widely used in economic construction, social development, national defense construction and other fields. Geospatial data as an important public data, promote its development and utilization, strengthen the circulation of geospatial data elements, and release the value of geospatial data elements. On the one hand, it is necessary to improve the New Spatial Data Infrastructure (NSDI), and strengthen the sharing and opening of geographic information data. On the other hand, it is necessary to deepen the application and innovation of geospatial data to enhance the security of geospatial data. Firstly, this paper gives the definition and connotation of circulation mode of geospatial data elements. Secondly, the basic requirements, technical indicators and overall architecture of circulation portal of geospatial data elements are designed, including basic operation environment configuration, construction under the scene of the Geospatial Data Exchange Mode (GDEM)/ Geospatial Data Opening Mode (GDOM)/ Geospatial Data Trading Mode (GDTM)/ Geospatial Data Sharing Mode (GDSM). Finally, the challenges and opportunities faced by the circulation of geospatial data elements were summarized, mainly focusing on construction of the NSDI and geospatial data circulation security governance.

## 1. Introduction

Surveying and mapping geographic information is an important strategic data resource and new factor of production in China, which supports the governance of the country, empowers all walks of life, and serves thousands of households. It has a fundamental and leading position and role in promoting high-quality development. As an important basic and strategic information resource of a country, geospatial data is widely used in economic construction, social development, national defense construction and other fields. Especially, confidential geographic information is directly related to national sovereignty, security and interests, and becomes "the most important tool of a country, not with people". On the other hand, as an important part of public data resources, it is necessary to explore and carry out authorized operation according to regulations, improve the development and utilization level of geospatial data resources, fully release the potential of geographic information data elements, and promote its compliance and efficient circulation and use under the premise of ensuring security.

Data circulation can be abstracted as a process of exchange and transfer of data resources between providers and demanders accompanied by the transfer of value, security and trust, involving the transfer of data ownership, management, use and income rights. The goal is to ensure that multi-party data can be controlled in the process of circulation and use, and effectively solve the problem of data security sharing and integration value-added. In order to accelerate the development and utilization of public data resources, fully release the potential of public data elements, and promote high-quality development, recently, the General Office of the CPC Central Committee and The General Office of the State Council issued the Opinions on Accelerating the Development and Utilization of Public Data Resources, which systematically deployed the development and utilization of public data resources at the central level for the first time. It is of great significance to the construction of specialized, diversified and integrated data application scenes, helps to accelerate the release of the element value of public data, and provides strong support for the construction of a smooth and orderly development and utilization system of public data resources. In January 2025, the National Development and Reform Commission and the National Data Administration of China successively promulgated the Interim Measures for the Registration and Management of Public Data Resources and the Implementation Standards for the Authorized Operation of Public Data Resources (Trial). And the "Notice on the Establishment of a Price Formation Mechanism for Authorized Operation of Public Data Resources" (hereinafter referred to as the "Administrative Measures", "Implementation Specifications", "Notice") three policy documents. The above three documents are important measures to implement the requirements of the Opinions of the General Office of the Communist Party of China Central Committee and The General Office of the State Council on Accelerating the Development and Utilization of Public Data Resources, and regulate activities related to authorized operations. Among them, the Administrative Measures clarify the basic requirements for the registration of public data resources, form a national integrated public data resources registration system, and lay the foundation for establishing a public data resources account and improving the availability of public data resources. The Implementation Specification focuses on establishing a unified institutional environment at the national level, clarifies the main principles and implementation paths that should be controlled by the authorized operation, is an important guarantee for promoting the orderly release of the value of public data resources, and provides guidance for the standardized implementation of the authorized operation of public data resources. Based on the characteristics of the authorized operation mechanism of public data resources, the Notice aims to better promote the healthy and standardized development of public data resources operating institutions (hereinafter referred to as operating

institutions) by establishing a price formation mechanism that conforms to the characteristics of public data elements.

Geospatial data as an important public data, promote its development and utilization, strengthen the circulation of its data elements, and release the value of its data elements. On the one hand, it is necessary to improve the New Spatial Data Infrastructure (NSDI), and strengthen the sharing and opening of geographic information data. On the other hand, it is necessary to deepen the application and innovation of geographic information data to enhance the security of geographic information data.

This paper first gives the definition and connotation of circulation mode of geospatial data elements. Secondly, the basic requirements, technical indicators and overall architecture of circulation portal of geospatial data elements are designed, including basic operation environment configuration, construction under the scene of the GDEM/GDOM/GDTM/GDSM. Finally, the challenges and opportunities faced by the circulation of geospatial data elements were summarized, mainly focusing on construction of the NSDI and geospatial data circulation security governance.

## 2. Related Work

The research on the development and utilization of geospatial data and the circulation of data elements is still in its infancy.

In the academic community, since the emergence of spatio-temporal databases and their query languages in the mid-1980s, and the proposal of the concept of "spatio-temporal big data" in the 21st century, Harvey et al. proposed geographic data mining and knowledge discovery in 2015, and Li Deren, Wang Jiayao and other scholars used spatio-temporal big data for mining, analysis and visualization.

In the engineering field, the United States first launched the "Geospatial Platform" open government program in 2011. At the same time, the UK also launched the "Federal Government Data Sharing Scheme". In addition, Canada, Australia, Japan, South Korea, Singapore and other countries have established a series of open geospatial data sharing platform websites. China launched the National Spatial Data Infrastructure project in 2010 and has carried out a series of major projects, including the map of the Earth and the Natural Resources Database, the spatio-temporal cloud platform, and the Earth Big Data, which have effectively promoted the openness and sharing of geographic information data.

In the industry, the open use of public data has become an important part of promoting China's digital development, building digital government, digital economy and digital society. The central and local governments have issued a number of documents to promote the open use of public data. In December 2022, the Opinions of the CPC Central Committee and The State Council on Building a Data Infrastructure System to Better Play the Role of Data Elements proposed to "promote the conditional free use of public data used for public governance and public welfare undertakings, and explore the conditional and paid use of public data used for industrial development and industry development". For example, the departments of Natural Resources of Guizhou, Hunan, Hubei and other provinces, together with the provincial Big Data Administration Bureau, explore the establishment of special areas in data exchanges and commercial data trading platforms, and explore the authorized operation of geospatial data.

## 3. The Definition and Connotation of Circulation Mode of Geospatial Data Elements

The opening of public data and the effective flow of data resources are the basic prerequisites for the circulation of geospatial data elements, which mainly include four modes: exchanging, opening, trading and sharing, the technical architecture as shown in Figure 1.

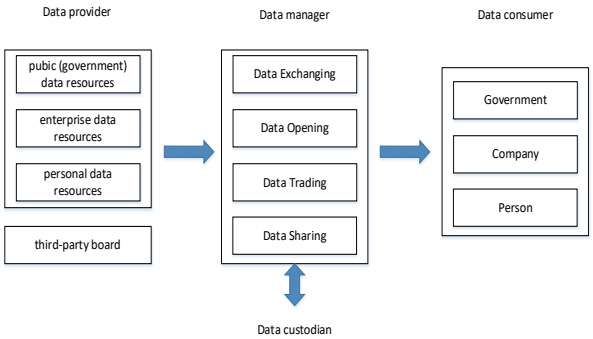


**Figure 1**. The technical architecture of the circulation of geospatial data elements.

### 3.1 Geospatial Data Exchanging Mode

Geospatial data exchange mode (GDEM) refers to the process of data management, provision and use by managers, providers and users of geospatial data through online service invocation and offline data copy.

### 3.2 Geospatial Data Opening Mode

Geospatial data open mode (GDOM) mainly refers to geospatial public data openness, that is, public management and service institutions provide public services with original, machine-readable and socially reusable data sets for natural persons, legal persons and other organizations. Government data openness is an important part of public data openness. Geospatial data is public data. Geospatial data opening belongs to a very important category of government data opening, which mainly adopts online and offline methods: Online means that it is open to the society through relevant geospatial data opening or service platforms.

### 3.3 Geospatial Data Trading Mode

Geospatial data trading mode(GDTM) which referring to the trading mechanism of physical commodities, the trading of data ownership is mainly the trading of geospatial data elements. At present, because the ownership mechanism of data elements is not clear and still under development, government-led data exchanges and commercial data trading platforms carry out centralized trading on the floor and decentralized trading on the sidelines.

### 3.4 Geospatial Data Sharing Mode

Geospatial data sharing mode(GDSM) without changing data ownership and management rights, it provides geospatial data access, use and other services, mainly for data use rights trading and service pricing, without involving ownership transactions.

## 4. Design and Construction of Circulation Portal of Geospatial Data Elements

Recently, China's National Development and Reform Commission, the National Data Administration, and the Ministry of Industry and Information Technology jointly issued the National Data Infrastructure Construction Guide (hereinafter referred to as the Guide). From the perspective of releasing the value of data elements, national data infrastructure is a new type of infrastructure that provides data collection, aggregation, transmission, processing, circulation, utilization, operation, and security services for the society. It is an organic whole that integrates hardware, software, model algorithms, standards, and mechanism design. Under the overall planning of the state, the national data infrastructure is composed of various data infrastructures such as regions, industries and enterprises. Network facilities and computing power facilities are closely related to the national data infrastructure, and through iterative upgrading, they continuously support the circulation and utilization of data. The NSDI is the data infrastructure of surveying and mapping geographic information industry, and it is also an important part of the national data infrastructure. It is necessary to design and construct portals in different modes based on the circulation of geospatial data elements.

### 4.1 Basic Operation Environment Configuration

It is necessary to configure the corresponding basic operating environment for the four different modes of geospatial data elements circulation, such as exchange, opening, transaction and sharing. The general configuration should generally include computing resource pool, storage resource pool, portal website, security system, etc., as shown in Table 1.

| Systems | Contents | Core configuration |
|---|---|---|
| Computing Resource Pool | Computing Hosting Services Application Elastic Compute Service; Configure Elastic Compute Service; Windows/Linux OS; Support x86 and ARM architecture | CPU ⩾ 8 cores, memory ⩾16GB, system disk ⩾ 300GB SSD storage. Among them, the CPU frequency is ⩾ 3.0GHz, the maximum internal network bandwidth is ⩾ 42Gbps, the maximum internal network packet sending and receiving is ⩾ 12 million PPS, the maximum throughput of SSD is ⩾350MB/s, and the access delay is ⩽1ms |
| Storage Resource Pool | Standard Object Storage Service; High Performance Elastic File Service; Virtual Hard Disk | The storage space is ⩾ 70TB, the single file is not more than 20KB and the concurrent QPS is not less than 40000 times /S, and the query response time is not more than 300ms; Provide ⩾1500GB high performance elastic file service, support NFS protocol; Maximum throughput of at least 2GB/s A maximum of 100K IOPS and read/write latency of less than 2ms are required; 4TB SSD hard disk space, SSD maximum throughput ≥250MB/s, support online expansion. A single virtual machine supports up to 16 cloud hard disks. |
| Portal Website | Messaging Services; RabbitMQ; Application operation and maintenance, log visual analysis | Provide verification code SMS, notification SMS resource package; Distributed messaging service RabbitMQ, CPU ⩾ 2 cores, memory ⩾ 4GB, storage space ⩾ 200GB, maximum throughput ⩾ 250MB/s, read and write latency ⩽ 1ms; Log collection; Log query and analysis; Log monitoring and alerting; Log analysis |
| Security System | Web Application Firewall; Situation Awareness; Container Security; Host Security Service; Database Audit Service; Vulnerability Scanning Service; SSL Certificates; Fortress Machine | Protection bandwidth ⩾ 1GB; Supports multi-dimensional CC defences; Provides a variety of threat detection and analysis services, including threat analysis, alarm setting, host vulnerability, website vulnerability, baseline inspection, security log management and other functions; Container images and operational security; Malware detection, web tamper proof; Provide behavior/data/performance anomaly monitoring; Web site scanning and host scanning; Business data transmission security; Real-time authorization from the authorizer is required to access the resource |

**Table 1**. The basic operating environment common configuration of the circulation of geospatial data elements.

### 4.2 Construction under the Scene of the GDEM

In the scene of the Geospatial Data Exchanging Mode (GDEM), the geospatial data resource directory should be prepared firstly. Secondly, the security risks of the whole life cycle of geospatial data circulation process should be analyzed and the data security risk assessment should be carried out. Finally, the geospatial data resources are classified and graded, especially the boundaries between public geospatial data and non-public geospatial data are clarified, and the classification and grading protection measures are formulated.


**Figure 2**. The National Geographic Information Resources Directory Service System portal website.

At present, geospatial data exchange is mainly carried out through the National Geographic Information Resources Directory Service System (webmap.cn), which provides services such as the publication of the directory of surveying and mapping geographic information resources, the display of results, data query and download, as shown in Figure 2.

### 4.3 Construction under the Scene of the GDOM

In the scene of the Geospatial Data Opening Mode (GDOM), it is mainly for information disclosure and open use of publicly available geospatial data resources. On the one hand, it is necessary to expand the scope of geographic information that can be publicly expressed. On the other hand, the construction of the NSDI must be strengthened, such as the construction of the new generation platform for public geospatial information services (TIANDITU), Geological Cloud (geocloud.cgs.gov.cn), National Ocean Big Data Service Platform (oceancloud.nmdis.org.cn), etc. The offline mode is to provide data opening services to the society through the relevant archives and service halls, such as the National Archives of Surveying and Mapping, the National Geological Archive, and the government affairs service hall of the Ministry of Natural Resources.

**4.3.1 Expand the scope of geographic information that can be publicly expressed:** In view of the new requirements and new situations faced by geographic information data as production factors, the needs of various users such as government, enterprises and the public for geographic information content are investigated, and the latest confidentiality provisions related to geographic information in industries or departments are analyzed, focusing on the attribute value of geographic information elements. From the perspective of "element content" and "attribute", the content of geographic information that can be publicly expressed is further clarified, and the relevant work suggestions for better supporting the digital development of geographic information elements are put forward.

**4.3.2 The new generation platform for public geospatial information services (TIANDITU):** According to the document requirements of the General Implementation Plan for the Construction of the New Generation of Geographic Information Public Service Platform (TIANDITU), the construction of the TIANDITU should adhere to the principles of "problem-oriented, innovation-driven, integrated planning, safe and controllable", and comprehensively use new ideas, new technologies and new models to promote the transformation of the TIANDITU from single geographic information service to integrated geographic information service. From the data resources, service functions, update efficiency, operational support and other aspects of the comprehensive upgrade, as shown in Table 2, the formation of geographic information public service capabilities in line with economic and social development, contribute to the construction of digital China and the development of digital economy.

| Objectives | Contents of Construction |
|---|---|
| Data Resources | To establish a multi-source, multi-dimensional, multi-temporal and multi-category public service data resource system of geographic information, promote the new platform to realize the transformation and upgrading of the element content from basic geographic information to special geographic information in the field of natural resources, the coverage from domestic to global, from land to ocean, and from single temporal to multi-temporal remote sensing images. |
| Service Function | To meet the needs of various application scenes, the new platform is promoted to realize the transformation and upgrade from a single online map service to a variety of services such as deeply integrated results directory and standard map, from basic base map service to geographic information integrated service, from desktop service to mobile service. |
| Data Update | To establish a full-process online collaborative update technology system for data aggregation, sharing, integration and release, and promote the new platform to realize the transformation and upgrading of geographic information data from offline update to online update, from regular update of the whole page to timely update of important content. |
| Running Support | Relying on cloud computing technology, an efficient and stable integrated operation support system is created, and the new platform is promoted to realize the transformation and upgrading of computing resources from decentralized construction to moderately centralized and intensive sharing. |

**Table 2**. The construction content requirements of the new generation of geographic information public service platform (TIANDITU).

Cultivating and expanding public data application scenes is an important measure to implement the Opinions of the General Office of the CPC Central Committee and The General Office of the State Council on Accelerating the Development and Utilization of Public Data Resources. As the main channel for

natural resources departments to promote the open sharing of geographic information data and improve public services of geographic information, the TIANDITU has become an important spatio-temporal information infrastructure in the construction of digital China and the development of digital economy, as shown in Figure 3.


**Figure 3**. The National Platform for Public Geospatial Information Services (TIANDITU) portal website.

The "Upgrade the TIANDITU, Release the Value of Geographic information Data" led by the center was selected as the first batch of 18 key demonstration projects of the "Key Contact Demonstration Scene of the National Data Administration". The project aims to create a "geographic information public service" application scenario, and focuses on improving the service level of geographic information public data application.

This project focuses on enabling economic and social development and the application of geographic information data in government affairs. Through efficient convergence and deep integration of multi-source geographic information data across levels, fields and industries, this project realizes complementary advantages, efficient circulation and value mining, explores the construction of new models of open sharing and cooperation of geographic information data, and constructs a more perfect public service data resource system of geographic information. Promote the healthy development of geographic information public data application ecology.

Through the construction of this demonstration scene, we strive to improve the inclusive service level of the TIANDITU, promote the in-depth application of geographic information data in the fields of smart city, engineering planning, education and medical care, finance and insurance, and community governance, and further release the value of public data elements of geographic information.

### 4.4 Construction under the Scene of the GDTM

In the scene of the Geospatial Data Trading Mode (GDTM), it is mainly for the circulation trading of geospatial public data resources on and off the data exchange, including the registration, price formation and authorized operation of geospatial public data resources. For example, Guizhou Province has set up a "Geographic information spatio-temporal big data zone" and released geographic information data trading products, as shown in Figure 4. Hunan Big Data Exchange has opened a "geospatial information data trading special board", and Hubei Province Data Circulation trading platform has issued surveying and mapping geospatio-temporal data trading certificates.


**Figure 4**. Guiyang Big Data Exchange Geographic Information Spatio-temporal Big Data area portal website by People's Government of Guizhou Province.

(https://www.gzdex.com.cn/topic/common?id=19&ifDemand=undefined)

### 4.5 Construction under the Scene of the GDSM

In the scene of the Geospatial Data Sharing Mode (GDSM), it is mainly for free sharing of geospatial data resources, including but not limited to online browsing, downloading, offline copying, etc., such as the purchase of geospatial data processing services in specific scenes, and the pre-deployment of customized geographic information service platforms.

## 5. Challenges and Opportunities of Geospatial Data Elements Circulation

With the release of policy documents such as the Guidelines for the Construction of National Data Infrastructure and the Implementation Plan for Improving the Security Governance of Data Circulation to Better Promote the Marketization and Value of Data Elements, the development and security of geospatial data must be coordinated to strengthen the development and security of geospatial data circulation, establish and improve the security governance mechanism of geospatial data circulation, and enhance the security governance capacity of geospatial data. To promote the compliance and efficient circulation and utilization of geospatial data elements, the value of geospatial data can be better released.

### 5.1 Construction of the NSDI

The ability and efficiency of the Internet in supporting the construction of geospatial data, especially the geospatial public data elements market and data governance system, are far from enough. The high cost of geospatial data sharing and circulation restricts the release of data value and the development of digital economy. Under the existing Internet technology system, the whole life cycle of geospatial public data is controlled by the information application systems on the Internet, and geospatial data is not an independent resource that can be directly managed on the Internet. The circulation and sharing of geospatial public data based on the Internet requires cooperation between applications, and the circulation and sharing cost is high. To this end, a new set of "data-centric" infrastructure layers, namely the NSDI, needs to be built.

**Data Aggregation:** The NSDI relies on the high-speed communication network of ubiquitous interconnection such as 5G, high-speed optical fiber, IPv6, next generation Internet and satellite Internet, and superimposed a series of technologies

such as Internet of things, blockchain, identity coding and parsing, which can efficiently access, credibly registration and accurately confirm the rights of multi-source and multi-dimensional data. Effectively improve the universality, convenience and accuracy of data aggregation.

**Data Processing:** The NSDI uses cloud computing, edge computing, distributed computing, big data processing, AI analysis, green and low carbon technologies to provide efficient, convenient, safe and reliable data element storage, calculation and analysis capabilities for participants, effectively promoting data processing to achieve high efficiency, low cost and high intelligence.

**Data Circulation:** The NSDI realizes the "available invisible" and "controllable and measurable" data between different subjects through data space, privacy computing, blockchain, data desensitization, data sandbox and other technologies, provides a credible data sharing, opening, and trading environment for different industries, different regions, and different institutions, and effectively improves the security and reliability level of data circulation.

**Data Application:** The NSDI provides data applications with universal intelligent decision-making, auxiliary design, intelligent management and other capabilities, helping data applications optimize the whole process of design, production, management, sales and service, further reducing the threshold of data application and improving the level of digitalization. In particular, since this year, breakthroughs have been made in generative artificial intelligence technology, and data infrastructure should also make full use of the latest achievements of big artificial intelligence models, better promote data elements to empower thousands of industries, and promote digital transformation and intelligent upgrading.

**Data Operation:** The NSDI promotes the orderly and efficient operation of data aggregation, processing, circulation, application, trading and other functions through the coordination and linkage of a series of technical tools and rules, promotes the accurate matching of supply and demand in the data factor market, and ensures the high-quality development of a series of public services such as clearing and settlement, audit supervision and dispute arbitration. Effectively support the efficient allocation of all kinds of resources in the data factor market.

**Data Security:** The NSDI helps participants establish a data security system through privacy protection, data encryption, digital identity and other technical means, and promotes participants to form best practices in data compliance construction, throughout the whole process of the data life cycle to ensure data credibility, integrity and security.

### 5.2 Geospatial Data Circulation Security Governance

The circulation of geospatial data, especially geospatial public data, is a key part of the construction of the data factor market. Only through the full circulation, full development and utilization of geospatial public data across subjects and industries, can the value of data be efficiently released and the multiplier effect of geospatial data elements be exerted. However, the cross-subject circulation and use of geospatial data is also accompanied by a series of security risks, such as personal information leakage, data abuse, and illegal use, which hinder the high-quality development of the digital economy. Therefore, it is essential to integrate development and security.

**5.2.1 Digital watermark:** Some marking information is directly embedded into the digital carrier (including multimedia, documents, software, etc.) or interactively expressed (modify the structure of a specific area), and does not affect the use value of the original carrier, and is not easy to be detected and modified again, but can be identified and identified by the manufacturer. Through the information hidden in the carrier, it can achieve the purpose of identifying the creator and buyer of the content, transmitting the secret information or judging whether the carrier has been tampered with. Digital watermarking is an effective way to protect information security, realize anti-counterfeiting traceability and copyright protection.

**5.2.2 Blockchain:** A decentralized recording technique. Blockchain technology is a technical solution that does not rely on a third party and carries out the storage, verification, transmission and communication of network data through its own distributed nodes. Therefore, from the perspective of financial accounting, some people regard blockchain technology as a distributed, open and decentralized large-scale network ledger. Anyone and any time can use the same technical standards to add their own information, extend the blockchain, and continue to meet the data entry needs brought by various needs. Blockchain is the core and infrastructure of Bitcoin, which is a decentralized ledger system.

**5.2.3 Privacy-preserving Computing (PC):** The Privacy-preserving Computing is a kind of information technology that analyzes and calculates data on the premise of ensuring that the original data is not disclosed by the data provider, and ensures that the data is "available but not visible" in the whole process of data flow, such as generation, storage, calculation, application and destruction.

**Federated Learning (FL)**: The Federated Learning is a distributed machine learning approach where the training of a model takes place on multiple local devices or servers instead of centralized at a central location. In federated learning, the data is stored locally and only the updated parameters of the model are transferred over the network. This enables the model to learn locally on the device and does not require the raw data to be transferred to a central server.

**Secure Multi-party Computation (MPC):** To solve the privacy-preserving collaborative computation problem among a group of mutually untrusted participants, it should ensure the independence of the input, the correctness of the computation, and not reveal the input value to other participants.

**Homomorphic Encryption (HE):** A cryptographic technique based on the computational complexity theory of mathematical problems that allows one to perform certain algebraic operations on a ciphertext to obtain a result that is still encrypted, and decrypt it to obtain the same result as the same operation on the plaintext. In other words, this technology allows people to perform operations such as searching and comparing on encrypted data to get the correct result without decrypting the data during the whole process.

**Confidential Computing (CC):** The Confidential Computing protects data in use by executing computations in a hardware-based trusted execution environment (TEE), which provides a certain level of data integrity confidentiality and code integrity.

**5.2.4 National Data Circulation and Utilization Infrastructure:** In the field of data circulation utilization, it mainly includes trusted data space, data internet, data component and so on.

**Trusted Data Space (TDS):** It is a kind of data circulation and utilization infrastructure based on consensus rules, which links multiple subjects and realizes the sharing and sharing of data resources. By constructing a data sharing trust mechanism, it provides a safe and credible data circulation environment for various subjects, industries and regions, and promotes the orderly circulation of data. At the same time, it uses high-value application scenes and multi-benefit rule mechanisms to attract data providers, users, service providers and other multi-agents to jointly control and excavate data value, gather collaborative development momentum, and build an application ecology for co-creation of data value.

**Data Internet (DI):** It is composed of data circulation access terminals, data circulation networks and data circulation service platforms, providing one-point access, extensive connection, standard delivery, security and credibility, compliance supervision, and open and compatible data circulation services.

**Data Component (DC):** It provides data storage and processing services that are unified standard, independent and controllable, safe and reliable, and supervised in the whole process. As the "intermediate state" connecting the two ends of data supply and demand, the data component "decouples" the original data from the data application. Based on the related components of the data component, the data element development and control of the whole life cycle from data collection to data element processing and trading are realized.

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