Development of National Spatial Data Infrastructure (NSDI) in China: Progress and Applications

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Abstract:

The development and application of National Spatial Data Infrastructure (NSDI) has been a top priority of the central government of China since the late 1980s. Substantial human and financial resources has been invested in the establishment of national multi-scale fundamental databases, in setting up a new institutional framework and formulating NSDI-related policies, developing technical systems and standards, as well as developing network-based geo-information services. After more than ten years of development, China's NSDI has come to play significant roles in the nation's economic construction and social development.

1 Introduction

In the past ten years, substantial human and financial resources were invested in developing a National Spatial Data Infrastructure (NSDI) in China (more precisely Mainland China) (Jin, 1999, Yang, 1999). One driving force for this effort comes from the rapid increase in social demand for geo-spatial data. As the whole society is becoming more and more dependent on information, a variety of users urgently require multi-scale digital spatial data to support their planning, monitoring, management and decision-making needs. Such data is especially crucial in solving key problems that concern a nation or the whole world such as land resources, the environment, natural disasters and threats to human life (Xu, 1998; Chen et al., 2002). The second driving force is the rapid development and popularization of high technology and new technologies, such as Remote Sensing (RS), the Global Positioning System (GPS), the Geographic Information System (GIS) and Digital Data Communication (DDC). These new technologies have supplied new productive forces for the acquisition, procession, analysis, management and dissemination of geo-spatial information, and promoted a national surveying and mapping technical system in China to rapidly transform the existing system from a traditional to a modern and digital one (Li,1997; Coleman et al., 1997). More and more traditional surveying and mapping organizations have been transformed into Geomatics institutions with the development of spatial information products and services. The third driving force is that the central government of China has paid great deal of attention on the development of information technologies and the applications of information resources. Several national information engineering campaigns have been launched to strengthen the nation's information infrastructure, such as "Golden Bridge Engineering," which refers to a common information communication network.

Similar to NSDI in other countries, China's NSDI (CNSDI) consists of vertically and horizontally integrated geo-spatial databases and communication networks, as well as the necessary institutional arrangements for the effective flow and exchange of geo-spatial information (McLaughlin, 1991; Chen, 1999).

The second part of this paper presents the development of the institutional framework of CNSDI. The establishment of multi-scale fundamental (core) geo-spatial databases at the national, provincial and municipal levels is summarized in the third section. The fourth section introduces the progress that has been made in technical standards and systems. The network-based geo-spatial information service is briefly introduced in section 5. Section 6 illustrates some applications of CNSDI in the government administration, professional organizations, scientific research and among the general public respectively.

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2 Development of the institutional framework

2.1 Coordination at the national level

The State Committee for Geospatial Information Coordination (SCGIC) was established in 1999. This inter-department (ministry) organization is comprised of representatives from more than ten government departments (ministries) that have GIS-related activities. Its aim is to promote the national cooperative framework on geospatial information and to develop strategies and policies at the national level.

As a key member of SCGIC, the State Bureau of Surveying and Mapping (SBSM) is the key government agency involved in the planning and implementation of CNSDI. It has been actively engaged in national strategic planning and promoting inter-ministry cooperation. The development of a geo-spatial framework (or platform) for a digital China was proposed and implemented by SBSM as one of its new strategic directions. Moreover, more and more collaborative work or projects have been carried out or initiated by SBSM jointly with other ministries, such as the State Agency of Environmental Protection.

As a participating member of ISO/TC211, China has been actively involved in the activities of its working group, and some Chinese experts have taken part in the formulation of international geomatics standards. The National Technical Commission of Geographic Information Standardization (NTCGIS) was founded in 1997. Its aim is to promote the standardization of geographic information at the national level. The NTCGIS continues to organize the formulation and revision of national geographic information standards; coordinate, examine and approve geomatics standards; promote activities related to geomatics standards; and publicize geomatics standards.

2.2 Custodianship of spatial data

A geomatics center is considered the official custodian of geo-spatial data in the institutional framework of CNSDI. The National Geomatics Center of China (NGCC) was established at the end of 1995 by re-engineering two former national surveying and mapping centers. NGCC is responsible for designing the database, and for developing, maintaining, updating and disseminating fundamental geographic information on the nation level, as well as for designing, planning and executing key national surveying and mapping projects. This includes establishing and maintaining national topographic databases, image databases, geodetic databases and thematic databases; managing and servicing digital and analogue products; designing, organizing and coordinating national geodesy projects; organizing and executing a national frontier survey; and collecting and archiving national surveying and mapping documents. The NGCC provides fundamental geographic information to users according to the government regulations, “National Fundamental Geographic Information License Management,” Such information could include digital topographic maps with a scale of 1: 4,000,000 to a scale of 1: 250,000, Digital Raster Graphs (DRGs) and Digital Elevation Models (DEMs) at a scale of 1: 50,000, and a national digital geographic base map at a scale of 1: 500,000. The NGCC offers various services related to the national astro-geodetic network, GPS network, gravity network and geoid, as well as various aerial and satellite images and thematic image data.

It has become a big challenge for NGCC to maintain and distribute these large geo-spatial databases as the amount of fundamental data grows larger and larger. One of the major initiatives of NGCC is to establish four key national databases and one archive center as well as eight management systems, as shown in Fig.1. The eight management systems are

a) Topographic information management system;
b) Image information management system;
c) Geodetic information management system;
d) Thematic information management system;
e) Archiving information management system;
f) Information service system;

g) Intranet-based running operation system, and
h) Computer network supporting system.

As of 2002, twenty-eight provincial Geomatics centers had been established by provincial and municipal surveying and mapping authorities. These centers are in charge of quality control, maintaining and revising databases, generating products, disseminating data and for offering information services on fundamental geographic information.

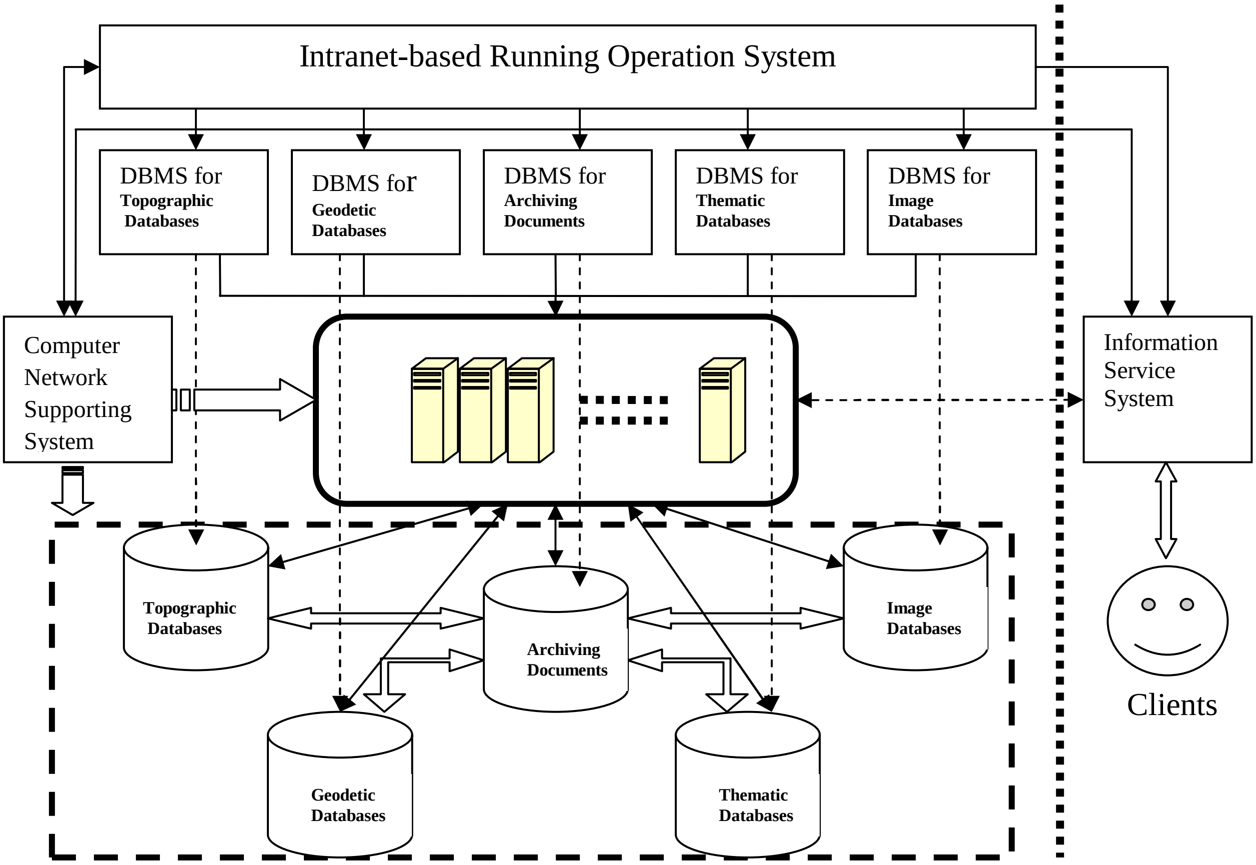

Figure 1 Key Databases and management systems in NGCC

2.3 The GIS association at the national level

In order to promote the development of GIS professionals in China, an association was set up at the national level in 1994. It is called the China Association of GIS (CAGIS). Its main objectives are to foster exchanges between users, manufacturers and academics, to promote the operational use of GIS, and to disseminate new technology and experiences (http://www.cagis.org.cn).

The CAGIS has ten commissions:
a) Commission I: Theory and Methodology;
b) Commission II: Standardization and Quality Control;
c) Commission III: Geo-spatial Data;
d) Commission IV: Education and Popularization;
e) Commission V: Resources and Environment Applications;
f) Commission VI: Urban Information Systems;
g) Commission VII: Government GIS;
h) Commission VIII: Engineering Applications;
i) Commission IX: Software Industry and
j) Commission X: Market Promotion.

The CAGIS now has about 3,000 individual members and about 300 corporate members. It also publishes a professional journal – GIS World (in Chinese). CAGIS also organizes biennial GIS conferences and many other symposiums and workshops.

3 Development of multi-scale fundamental databases

As in many other developing countries, the availability of data was a bottleneck in the earlier development of GIS in China. The development of multi-scale fundamental (core) geo-spatial databases has been a top priority of the central government since the late 1980s. Substantial human and financial resources have been invested to establish national basic geographic databases and various thematic databases. The national, provincial and municipal governments continue to be the biggest providers of geo-spatial data for GIS applications.

3.1 Development of databases at the national level

At the national level, China's 1:1million scale and 1:250,000 scale topographic databases were completed by SBSM in 1994 and 1998 respectively. The 1:250,000 scale database is composed of topographic datasets, geographic name datasets and DEM datasets. There are 816 map sheets and 14 feature layers in the topographic datasets. The geographic name dataset consists of 805,431 place names. The DEM datasets have two grid sizes: one is 100 meters by 100 meters and the other is 3 seconds by 3 seconds (Chen, 1999).

SBSM began developing its 1:50,000 database in 1999. Among its seven datasets, the DRG dataset was completed in 2000. The DEM data of 25 meter by 25 meter has been generated. The Landsat 7 and SPOT images covering the mainland were collected and used to produce 1:50,000 scale digital orthoimage models (DOM). Geographic names at the 1:50,000 scale were collected or investigated. A pilot study has been conducted to design the DLG dataset, land cover dataset and metadata. The DLG dataset is composed of topographical (contours, elevation points, etc.), boundary, transportation, residential area and hydrographic features. The 1:50,000 scale database is scheduled to be completed by the end of 2005. The 1:10,000 scale DEM and DOM data for a key flood control area of 340,000km^2, covering seven major river catchments, were also completed by SBSM in 1998.

In the past few years, there several projects related to the development of a national spatial reference framework have been launched. One project is the National 2000 Basic Gravity Network for re-establishing a national basic gravity network. It was jointly initiated by SBSM and the Military and National Bureau of Seismology in 1999. It consists of 137 points, including 18 fiducial points and 119 basic points. The field work was completed in the end of 2000 and the processing of the data is underway. Another project is the Crustal Movement Monitoring Network. One thousand two hundred GPS points with high positioning accuracy were set up mainly along the tectonic belts in China. Moreover, 25 permanent GPS stations had been established in China by the end of 2000. These stations serve to maintain a national geocentric reference framework for providing GPS-related products, supporting studies on geodynamics, and promoting the application of local area differential GPSs as well as wide area differential GPSs.

Quite a number of projects have also been undertaken by other ministries and agencies to develop their thematic geo-spatial databases. For instance, the Ministry of Land Resources has digitized the 1:500,000 landuse and geological maps. In 1999, it initiated a national project to digitize larger-scale landuse maps and geological maps. Furthermore, some natural resource and environmental databases at the scale of 1:500,000, 1:1,000,000 and 1:4,000,000 have also been set up by the Chinese Academy of Sciences (CAS) and other agencies. The main contents of these data sets include soil, vegetation, forests, geology, mines, earthquakes, and so forth.

3.2 Development of databases at the provincial and municipal levels

Provincial surveying and mapping authorities are responsible for the development of 1:10,000 scale topographic databases. Many provincial surveying and mapping authorities have continued or started developing such databases. By the end of 2000, more than 35,439 sheets of maps at scale

1:10,000 had been updated and 21,340 sheets had been digitized. The provincial land administrators are in the process of digitizing 1:10,000 landuse maps.

Larger-scale digital datasets are produced by municipalities. For instance, besides the 322 map sheets of 1:10,000 scale data sets, the municipality of Shanghai has produced 7,511 sheets of a 1:2,000 scale digital map covering the whole municipality, 5,060 sheets at 1:1,000 scale for the urban fringes, 7,758 sheets at 1:500 scale for the downtown area, and 2,463 sheets of DOM at the 1:2,000 scale. Shanghai has also established its GIS for the management of real estate tenures and land use planning. The Guangzhou Municipal Bureau of Planning has established databases with 1:500 digital topographical maps covering its 700 km^2 developing area, 1:500 digital maps of underground pipelines covering its built-up area, and 1:2,000 digital topographical and digital orthoimage maps covering the whole city.

3.3 Challenges of updating

The updating or revision of the multi-scale fundamental databases poses a big challenge to the surveying and mapping community in China. A national campaign was organized by SBSM to update its 1:250,000 databases in 2001-2002. Satellite imageries (such as Landsat 7 and SPOT), aerial photographs, as well as ground investigations were used for the purpose of updating the databases. In the municipality of Shanghai, the revision cycles are 2, 3, 4 and 5 years, respectively, for digital maps at the 1:500, 1:1,000, 1:2,000 and 1:10,000 scales. In order to provide timely geo-spatial data resources, efforts have been devoted to establishing an updating and budgeting mechanism for fundamental geographical information in China. In 1997, the central government listed fundamental surveying and mapping in the State Economic and Social Development Plan for China. The revised National Law on Surveying and Mapping recently stated that regular updating of the national fundamental databases should be implemented.

4 Standards and technical systems

4.1 Standards at the national level

Since 1991, several national standards have been worked out and published, as follows (Liu and Jiang, 1997):

a) Geographic grid (GB 12409-90),
b) Classification and codes for national fundamental geographic information (GB 13923-92),
c) Classification and codes for forest resources;,
d) Coding system of the names of rivers in China,
e) Classification and codes for features on topographic maps at scales of 1:500,1:1000 and 1:2000 (GB 14804-93),
f) Guide to standardization for urban GIS, coding structure and rules for urban geographic features- city roads, road intersections, blocks and municipal piping systems (GB 14395-93), and
g) National standard for the spatial transfer of data (GB/T 17798-1999);

It is worth noting here that it has taken only a few years for China to develop its national standard for the spatial transfer of data. The standard is a compromise of the SDTS of the U.S. and of the data file formats used by major GIS vendors in China. Features have been taken from various standards such as the SDTS, ISO 8211, DIGEST, NTF, GLD, DEM, DOQ and DRG. Indeed, some concepts used in SDTS and ISO 8211 have been improved or adopted with modifications.

During the establishment of the 1: 250,000 scale national database, which was completed in 1998, several types of guidelines for standards were developed. They are, for instance (Jiang and Liu, 1999):

a) regulations for 1:250,000 topographic databases (general and data acquisition);
b) specifications for the collection of geographic name databases;
c) guidelines for the interfaces between the topographic databases and geographic name databases;

d) guidelines for quality control for the 1:250,000 databases; and
e) metadata for the 1:250,000 databases.

Some other standards are under development, such as for the control and estimation of data quality, symbol systems for the digital mapping of navigational maps at scales ranging from 1:500 to 1:1,000,000, metadata standards, standards for data products and their distribution, etc. The use of these standards lays out the basis for sharing geo-spatial data in the country.

4.2 Development of technical systems

In order to improve the ability to acquire, process, analyze, manage and disseminate geo-spatial data, the SBSM has developed digital surveying and mapping systems (DSMSs) by integrating GIS with Remote Sensing, GPS and digital data communication (DDC) technology. Figure 2 shows the digital production system employed by the SBSM. The homegrown digital photogrammetric workstations, raster to vector conversion packages, laser scanners and other digital surveying and mapping systems have become the mainstream technology in the surveying and mapping community.

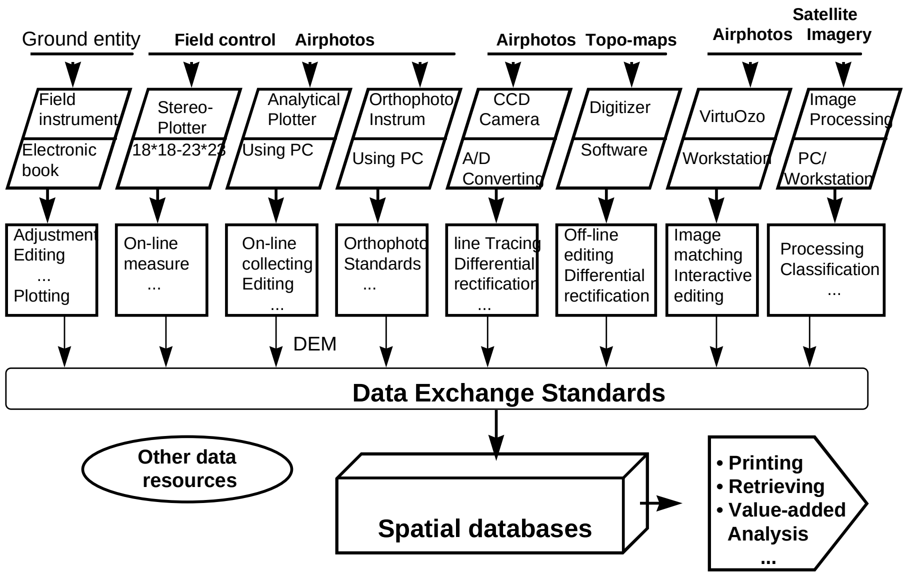

Figure 2. Digital surveying and mapping system in China

The VirtuOzo and JX4 are the two major digital photogrammetric workstations in use. They have not only captured 90% of the domestic market but also entered the international market for competition. Popular software products for collecting field data, converting data and processing images include EPSW2000, EPSCAN 2000, Geoway, Photomapper, LT VRMap, and so forth.

In the early stage of development, most GIS software was imported. Since the late 1980s, efforts have been made to develop homegrown GIS software systems. The initial efforts came from university laboratories and research institutes. Several GIS software packages were developed as the result of research projects. Since the mid-1990s, attention has been paid to the commercialization of such software (Li, 1997; Chen and Li, 2002).

In order to promote the industrialization and commercialization of homegrown GIS software products, since 1997 an annual evaluation of such products has been organized by the State Science and Technology Commission (SSTC) and China Association for GIS (Xu, 1998). In the evaluation, major GIS software packages are assessed against a set of nominated parameters (standards). The main items for assessment include software functions, operational speeds, efficiency, user groups, user feed-back, etc. The best products are recommended to users after the evaluation. Technical innovations have also been encouraged to improve the performance, applicability and usability of GIS software products. A number of software companies have also been set up to market GIS products.

There are now a dozen of commercialized homegrown GIS software products. MAPGIS, GEOSTAR, CITYSTAR, MapEngine and Supermap are among the popular pieces of commercial GIS platform software. AF Internet GIS, CD WebGIS, Geobeans and Geosurf are popular pieces of website GIS software. Based on statistical data in 2000, homegrown GIS software has captured about 30% of the domestic market (Zhou and Li, 2002).

4.3 Development of NSDI policies

One of the NSDI policies, the Administrative Regulation on Licenses for Using National Fundamental Geographic Data was formulated and executed by the SBSM at the end of 1999. This regulation classifies users into three categories:

a) Central government agencies and provincial governments;
b) Non-commercial organizations or individuals; and
c) Commercial users or non-commercial organizations using the data for commercial purposes.

The first category of users can get national fundamental geographic data free of charge for the purposes of decision-making and social welfare. Users in the second category get the data at favorable prices for internal or individual use in education, academic research, planning and management; or to provide research results to central government agencies and provincial governments for macro decision-making and social welfare. Users in the third category get the data at market prices. Up to now, SBSM has provided about 20 ministries and 15 provincial governments with newly created geo-spatial data, such as the 1:250,000 scale dataset, the 1:10,000 scale DEM and DOM data for the 340,000km^2 key flood control area covering seven major river catchments. This has promoted the social service aspect of national fundamental geographic information and the geo-spatial data sharing process in China.

5 Network-based geo-spatial information services and clearinghouse

A website for National Fundamental GIS (http://nfgis.nsid.gov.cn) was set up in 2000 and has been in operational use since then. Users can obtain information from the website on the fundamental data sets available by browsing the data catalogs. The 1:4,000,000 vector data can be read and partly downloaded. The catalogue information on map sheets at a scale of 1:50,000 to 1:1,000,000 can be retrieved. Paper maps can be searched for using the database by specifying the name of the map sheet, its scale, reference system, publisher, publishing time, and/or the spatial extent. Digital datasets can be searched for by the name of the dataset, its scale, date of completion, spatial extent, etc. Information on aerial photos can also be accessed from the website. The search can be made by the name of aerial surveying area, resolution, the surveyor, date, spatial extent, etc. Most of them can be searched for using both the graphic and textual interface, as shown in Figure 3.

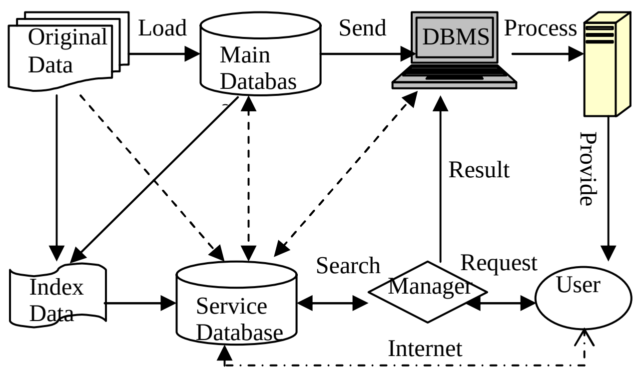

Figure 3 Network-based geospatial information

In 1999, SBSM began to implement a National Surveying and Mapping Infrastructure project. Its main objective is to improve the ability to acquire, process, store, manage, distribute and utilize geo-spatial information. A large number of remote-sensing data processing and GIS software packages have been installed in NGCC, four SBSM production bases and some provincial production units. In these organizations, the LAN bandwidth has been augmented to 1000 Mbps and the network nodes have increased two to five times since 1999. New hardware and equipment, such as the Sun Enterprise server 5500, have been installed. A storage area network was installed in NGCC, including an STK tape library, FC switch and FC disk-array. This has solved the problem of bottleneck between the storage systems and servers. A wide-area network is under construction, which will connect NGCC and the main data production bases, as well as provincial geomatics centers. This will provide the basis for the further development of a national geo-spatial data clearinghouse.

The 1:1,000,000 data will be put on the website in the very near future. A dynamic national atlas program has been initiated to provide the public with access to more geo-spatial information.

6 Applications

The NSDI has come to play significant roles in China's national economic construction and social development by providing governments of all levels and professional institutions with a unified spatial platform for their space-referenced systems for planning and administration or systems in support of decision-making.

6.1 Applications in government administration

In order to get timely information on the spatial distribution of national economic construction and social development, governments of all levels have set up various types of space-referenced systems to support decision-making. For instance, a Comprehensive Situation Information System has been established in the State Council and in the headquarters of more than twenty provincial governments. A variety of socio-economic, environmental and resource data are integrated on the basis of multi-scale fundamental spatial data (Zhang, 2001). This system has been playing an important role in strategic planning and spatial decision-making. Another example is the 1:250,000 data sets that are being used by the Ministry of Finance to compute the average elevation of provincial highways over sea level and the distance regulation coefficient for road transportation, which serves as the basis for collecting reasonable taxes on automobile fuel and for regulating the distribution of relevant financial subsidies.

6.2 Applications in professional organizations

Many professional organizations engaged in city planning, land management, water conservancy, environment protection, agriculture and mobile telecommunications have actively taken advantage of the fundamental geo-spatial information for urban construction, the management of natural resources, the mitigation of hazards and ecological protection. For example, Shanghai has established its information systems for the management of land and real estate tenure and land use planning. Also, the Shenzhen and Changzhou Municipal Planning and Land Bureaus have set up administrative information systems incorporating GIS and other automated administration solutions, which provide functions of documentation, inquiry, statistics, analysis, and the making graphics and maps through the computer network. All of these efforts have led to remarkable social and economic benefits.

6.3 Applications in scientific research

Among the 62 priority projects listed in China's Agenda 21, about 40 need to establish or apply GIS. Fundamental geo-spatial data is essential for research projects such as Landslide Monitoring of the Three Gorges, Moving Southern Water to the North, Assessment of Crop Yields and the Sustainable Development of County-level Agriculture in the Huanghuai Region, and the Remote Sensing Monitoring of the Vulnerable Ecological Environment in the Shanxi Inner-Mongolia Region. For example, to determine the distribution of cultivated lands with a slope of over 25 degrees, we overlaid the 1:250,000 DEM on the land cover data and analyzed it comprehensively. We also used the 1:250,000 database to investigate the optimal central and western routes for moving southern waters to the north.

6.4 Public applications

In recent years, the electronic cartographic products for public use are constantly being produced. The China Cartographic Publishing House has presented the National General Atlas of China, Electronic Map of Beijing 2000, and the Tourist Attractions of Beijing on CD-ROMs. At the same time, on-line services based on electronic maps have also appeared. For instance, Getting Around on Maps provides the public with the latest information about cities, by opening such columns as transportation, tourism, shopping, dining, real estate, recreation, finance, education and training on the electronic maps of 34 large cities. The To Know about Beijing online provides information in both pictures and texts of about 3,400 place-names, 1,400 blocks, 300 tourist attractions, 10,000 organizations, 1,000 real estate projects and 400 bus lines in Beijing.

7 Summary

In this paper, the development of NSDI in China has been reviewed. The review covers the development of the institutional framework, the establishment of multi-scale fundamental geo-spatial databases at the national, provincial and municipal levels, progress in technical standards and systems, and the network-based geo-spatial information service. Applications of NSDI in government administration, professional organizations, scientific research and among the general public have also been briefly discussed. It can be said that the NSDI in China has achieved significant progress and many applications. However, many issues in the development and application of vertically and horizontally integrated geo-spatial databases and communication networks still remain to be tackled, as well as necessary institutional arrangements for the effective flow and exchange of geo-spatial information. For instance, great effort needs to be devoted to the continuous updating and refinement of multi-scale fundamental geo-spatial databases, the establishment of a nation-wide geo-spatial data clearinghouse, the development of long-term and productivity-enhancing application programs, the promotion of geo-spatial data sharing, as well as the development of the geomatics industry.

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