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Enhancement of China Land Information Management Systems

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduce no material previously published or written, nor material that has been accepted for the award of any degree or diploma, except where due acknowledgement has been made in the text.

________________________ (Signed)

_______ Wen He________________ (Name of student)

Abstract

Urbanization is a major trend taking place worldwide as well as in China. There are severe social, economical and ecological impacts in association with this rapid urbanization process. Geospatial information has become indispensable for the various aspects of urban development, planning, and management. The challenge for land surveyors is to provide the city managers at all levels with current, citywide, complete, and in timely manner geospatial information to support more proactive decision making which encourages more effective sustainable development. Currently cities manage considerable collections of land related information. But the traditional separation of this information into different component themes leads to a considerable loss in the value of the information as a resource. Efficient and effective management of this information is of particular importance. City-wide land information management system (LIMS) provides the means to technically and institutionally integrate these component themes of land information into a truly corporate information resource.

LIMS is a municipal information infrastructure, including hard infrastructure (hardware, software, and data communication and networking) and soft infrastructure. This study is mainly concentrated on soft infrastructure, i.e., institutional issues and policies, which is more important than hard infrastructure and an urgent need in China environment. The main objective of this research study is to develop the framework, approaches and measures to enhance a city-wide LIMS in China for better servicing the sustainable development and reducing the negative impacts of rapid urbanization, and for promoting geo-economy and spatially enabled society. The research was conducted through a critical review of LIMSs overseas and in China; analysis and identification of the problems of China LIMSs by comparing with the good practices worldwide; discussion with several city LIM managers of their existing systems, problems and potential improvements and solutions; and wide reference to advanced strategy direction in the area of LIMS.

This research study has designed a LIMS model, developed an institutional framework for a LIMS, and proposed the recommendations for various legal and policy issues, including copyright protection, national security of geospatial data, funding model and pricing of geospatial data, and data management policies. A big issue for developing efficient and effective LIMS in China is data sharing and coordination. Duplicated efforts are common everywhere, which not only wastes limited resources provided, but more seriously damages the usefulness of geospatial databases. To better resolve the problems, the vision of a LIMS is developed, a strong governance structure is proposed, and a good partnership among all geospatial data providers and users is discussed. Technically, data sharing also needs addressing the problems in geospatial data transformation. The research conducted an experimental study to identify and analyze the possible errors in the data conversion, which can help reduce the errors.

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Chapter 1
Introduction

1.1 Information society and spatial information for sustainable development

We are living in a so-called information society, where large percentage of the population work in information technology (IT) related sectors and information becomes precious resource, like human resource and capital resource, generating welfare. With the rapid development of information technologies several new concepts appear, like E-commerce, E-government, E-logistics, cyber-city (or digital city), digital earth, and eventually digital life. These concepts not only change the way of our thinking, but also generate significant social and economic benefits. It is well estimated that among all kinds of information 80% are position related information, i.e., each piece of information has a position (or coordinates) attached to it. This position-related information is called geographic information or in more general term geospatial information/data. Geospatial data and information are strategically important to decision makers at all levels as it affects a major part of all human decision-making. To facilitate use of geospatial information a good spatial information infrastructure is needed. Geospatial information (or data) infrastructure, originally called **S**patial **D**ata **I**nfrastructure (SDI), is defined by the United States Federal Geographic Data Committee (FGDC) as the technology, policies, standards, and human resources necessary to acquire, process, store, distribute and improve utilization of geospatial data (refer to www.fgdc.gov). Many countries, in particular the developed countries, have placed the establishment of **N**ational **S**patial **D**ata **I**nfrastructure (NSDI) as their top priority. In 1994 the then President Clinton of the USA issued an executive order on building spatial data infrastructure. Singapore has developed a strategic plan IT 2000 for national information infrastructure (NII) with a vision to transform Singapore into an intelligent island. In 1993 the then President of European Community Delors presented the European Council a major vision. One of the major elements is the development of information society within European Community. Having read a report on the digital earth, which is an informally published speech of the then Vice President of the USA Mr. Al Gore on the concept of digital earth in 1998, by a group of Chinese geoscientists, the then President Jiang of Chinese mainland commented that we should also implement the concept of digital earth. Since then digital China, digital city or other terms have been talked and discussed everywhere in China. It is clear from the above SDI is a strategic direction of the development for a country. The SDI includes both soft and hard infrastructures. The former means institutional structure, policy directions, standards and procedures. The latter includes hardware, software and networking (data communication). Both types of infrastructure are of equal importance. But this study will be concentrated more on soft infrastructure, i.e., institutional structure (coordination mechanisms and directive committees), data sharing mechanism, policy and standards, data intellectual property and pricing.

The word 'development' is a managed process of changes designed to improve the conditions of members of a society. Sustainable development of a society has been a main concern of the governments at various levels and ordinary citizens. Sustainable development implies that this process should balance the exploitation of resources, the direction of investments and the advancement of technology in a manner that affords the same opportunity to future generations. To this end the United Nations (UN) developed the UN Agenda 21 (www.un.org/esa/sustdev), and Habitat Agenda (www.unhabitat.org). To support the above two agendas, International Federation of Surveyors (FIG) also developed FIG Agenda 21 (www.fig.net) . The UN defines a sustainable society as one which 'meets the need of the present without scarifying the ability of future generations to meet their own needs', and the sustainable development is 'the development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. The UN Sustainable Development (UNSD) Agenda 21 Chapter 40 has the following key points about information for decision making:

- In sustainable development, everyone is a user and provider of information considered in the broad sense. That includes data, information, appropriately packaged experience and knowledge. The need for information arises at all levels, from that of senior decision makers to the grass-roots and individual levels;
- More and different types of data need to be collected at all levels, indicating the status and trends of the ecosystem, natural resources, pollution and socio-economic variables. The gap in the availability, quality, coherence, standardization, and accessibility of data between the developed and developing world has been increasing, seriously impairing the capability of countries to make informed decisions concerning environment and development;

- A general lack of capacity, particularly in developing countries, for collection and assessment of data for their transformation into useful information and for their dissemination;
- The means need to be developed of ensuring that planning for sustainable development at all sectors is based on timely, reliable and usable information and of making relevant information accessible in the form and at the time required to facilitate its use;
- Relevant international organizations should develop practical recommendations for coordinated, harmonized collection and assessment of data at all levels;
- There already exists a wealth of data and information that could be used for the management of sustainable development. Finding the appropriate information at the required time and at the relevant scale of aggregation is a difficult task;
- Mechanisms should be strengthened or established for transforming scientific and socio-economic assessments into information suitable for both planning and public information. Electronic and non-electronic formats should be used.

In summary the above points stress that in a sustainable society the information is a critical element for any decision-making; and in developing countries data availability and accessibility, data quality, and data standardization are key issues in developing any information systems.

The Habitat Agenda (www.unhabitat.org) has action plans for sustainable development. Action 76 states: to ensure an adequate supply of serviceable land, Governments at the appropriate levels and in accordance with their legal framework should develop and implement information systems and practices for managing land, including land value assessment, and seek to ensure that such information is readily available. Also the Action 114: to develop and support improved and integrated land management, says that the governments at the appropriate levels, including local authorities should develop integrated land information and mapping systems. These statements clearly indicate the importance of development of land information management system, which should integrate all the related information/data, not piece by piece, and making them available to the relevant parties.

FIG in coordination with UN-Habitat held an international conference on Spatial Information for Sustainable Development in Nairobi Kenya in October 2001 and issued The Nairobi statement (FIG, 2002a). The statement is strongly related to the international community's efforts to advance the implementation of the Habitat Agenda as well as the implementation of important elements of NU Agenda 21.

1.2 City-wide land information management (LIM)

Population, land resources, and environment are three major subjects for human being. Land resources are defined as to be used land by human being under the definite technologies within a definite period (Sivakumar and Ndiangui, 2007). As one can see that land is a precious resource without which humankind cannot survive and is an essential component for the operation of wealth. In recent years we have witnessed an unprecedented growth in world's population and a general move towards urbanization, especially in developing countries and countries with economy in transition. According to UN reports (UN Population Division) (FIG, 2010), the urban population increased from 220 million in 1950 to 732 million in 1990 (29% of world population). By 2007 50% of the world population was living in cities. The latest predictions expect that 4.9 billion people, or 60% of the world population, will be urban dwellers by 2030. Investigations show significant differences in urban population change between the more developed regions and the less developed regions. In 2005 74% of the population (0.9 billion) in the developed regions was living in cities, while 43% population (2.3 billion) in the less developed regions was in cities. By 2030, there will be 1 billion (81%) of population in cities for the developed regions, while 3.9 billion (56%) for the less developed regions. It is estimated that in 2050 47% of China population will live in cities.

In the 21st century the world is facing global issues of climate change, critical fuel and food shortage, environmental degradation and natural disaster related challenges as world population continues to grow and over 60% will be urbanized by 2040. This is placing excessive pressure on the world's natural resources. The eight Millennium Development Goads (MDGs) form a blueprint agreed to by all the world countries to support the mitigation of these global issues. FIG and World Bank jointly issued a declaration on land governance in support of the MDGs (FIG, 2009). Land governance is about the policies, processes and institutions with which land, property and natural resources are managed. This includes decisions on access to land, land rights, land use, and land development. Land governance and management covers all activities with the management of land and natural resources which are required to fulfill political and social objectives and achieve sustainable development. This relates specifically to the legal and institutional framework. Figure 1.1 gives a global land management perspective (FIG, 2009).

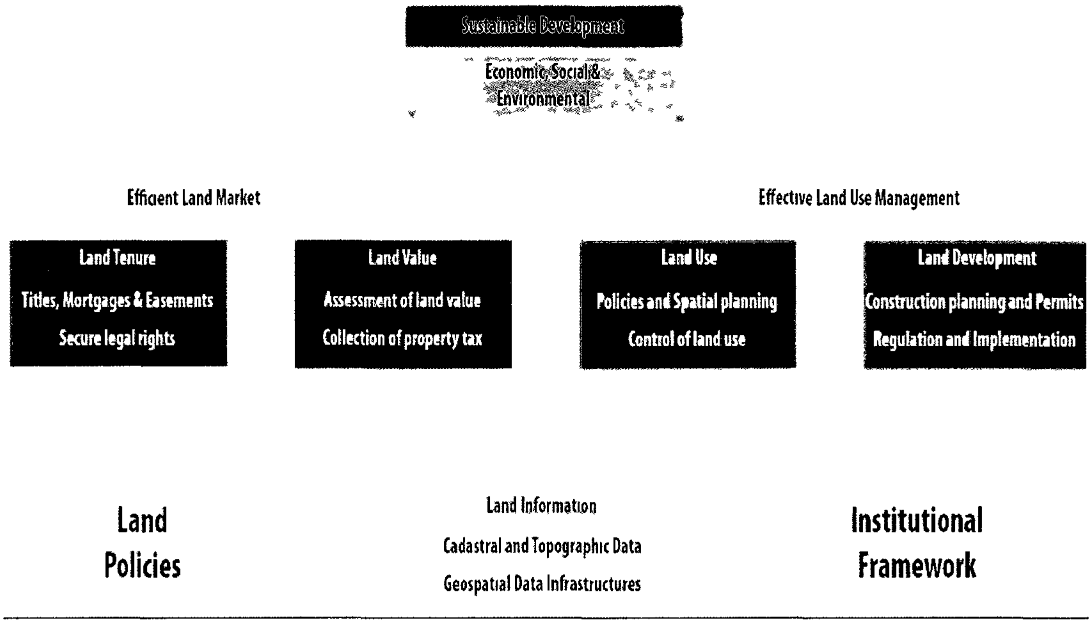


Figure 1.1 A global land management perspective (after FIG, 2009)

Rapid urbanization creates a great pressure on the development and management of cities, in particular transportation, land demand, and pollution. Therefore the mayors of over 1000 major cities gathered together in Berlin in 2000, called City Submit 2000, discussing issues of urban sustainable developments. The Statement of City Submit 2000 particularly mentions that

- It is the first time in human history we have recognized that most of 6 billion human population will live in cities;
- The world is facing a problem of explosive growth of urban population, particularly in developing countries;
- Any city in the world is facing many problems, and no one can claim its developments are sustainable.

The statement also suggests one of the main measures to overcome the problems generated from urbanization be to take full advantage of information technologies and build an intelligent city.

Due to rapid urbanization, urban land becomes much more valuable resource. If we are to improve the quality of life, we must find more efficient and effective ways of managing this valuable resource. To achieve this objective we must understand much more about land, its nature, value, use and the right that exist to exploit. In other words we need to radically improve the ways in which we collect, manage and use land information. Cities currently manage considerable collections of land related information. However, the traditional separation of this information into different component themes leads to a considerable loss in the value of the information as a resource. Efficient and effective management of this information is of particular importance. City-wide land information management system (LIMS) provides the means to technically and institutionally integrate these component themes of land information into a truly corporate information resource.

FIG in cooperation with UN-HABITAT has developed the desirable characteristics of an effective city-wide LIM by analyzing worldwide good and bad practices (FIG, 2002b). These characteristics are summarized below:

- The core data required to support the city's business and to measure performance should be identified. The focus should be on maintaining these core data and temptation to waste time on desirable rather than essential information should be avoided;
- There should be one source for each piece of core data. This source should be known and communicated to everyone who might want to use those data. Repetition of core data across systems should be forbidden;
- Common data definition/standards should be adopted and enforced across the city's departments. This will avoid similar, but not identical, bits of data being spread out across disparate systems. Where relevant, national and international standards should adopted;
- The custodians for core data should be clearly identified. Custodians are stakeholders within the organization who rely on particular pieces of data for their day-to-day operation. It should be their responsibilities to collect and manage the core data assigned to their custodianship. This responsibility should be backed up with service level agreements with users of this core data. A service level agreement is a contract in which an agency agrees to supply data to predetermined standards and at a fixed price;
- The responsibility for keeping data up-to-date must be clear. Where data are provided by contractors, the responsibility to maintain core data may be placed on them. Alternatively the data may be kept up to date using internal sources. Whichever route is

chosen, the responsibilities of all parties should be documented clearly and the processes of updating the data implemented;

- Where appropriate the best commercially available solutions should be applied to avoid costly city-specific solutions being commissioned;
- The connections between the varieties of systems used by different parts of the organization should adhere to an agreed framework. Providing the appropriate connectivity enables the LIM and business processes to operate efficiently.

In summary the above statements stress that core data must be identified and kept current. Data currency is particular critical, otherwise the data become useless. In addition, these core data could be located in different agencies under an agreed framework: responsibility of core data sets, data updating policy, data quality policy, data sharing policy, data pricing policy, and funding models.

1.3 **Motivation and objectives of this study**

As mentioned above, since late 1990s when the concept of digital China was promoted, various information systems in China have been established in each city and different platforms were used. The development levels vary significantly from city to city. The system is mainly centralized databases for their own purposes. However, all the systems in a city lack coordination, interoperation, data sharing or exchange and mainly for internal uses. Effective use of the information to support decision-making process has not yet achieved. Although local (or urban) spatial data infrastructure (LSDI) in China developed very rapidly since then, LIMSs have suffered from several serious practical problems:

(1) The drive for the investment in LIMS is technology-led with technologies rather than management being the evangelists;

(2) There is no corporate vision of city-wide LIMS and how it can effectively support the planning and delivery of services. Hence there is no strategic framework to guide and integrate aid programs and investment in city-wide LIMS;

(3) LIM-based projects are fragmented with minimal co-ordination among the stakeholders and any associated aid agencies;

(4) Data are produced in a one-off process to support a project. The data are not maintained or shared to the benefit of other possible users. The same data are captured several times

with slightly different specifications leading to significant extra cost and inefficiencies. The benefits of any investment in land information are diluted;

(5) Only specialist, technical staffs have access to land information. As a consequence, land information is not accessible by the city officials or citizens, leading to many decisions being made in a spatial vacuum.

The net effect is that land information is not fully used to support sustainable development of a city and hence will jeopardize sustainability.

These problems motivate this study. The objectives of this thesis are to develop a framework based on China environments and in reference to the experience in developed nations, and to develop some measures or techniques to support the framework. Some issues look simple in developed countries which are under legal governance, but not the case in China which is more under "person governing". Take copyright as an example, there are international laws and regulations governing this issue, but information providers still worry of their data being copied and re-sold. Another example is that national security of geospatial data is of main concern in China. The policy is under military control, limiting civilian access to digital maps which hinders wide application of the information. This is the sole issue in China, not in many other countries (except Russia).

To achieve the above-mentioned objectives the following key issues need addressing in this study:

(1) Develop a framework of urban land information systems, including data contents (or sub-systems) and quality, institutional and management issues.
(2) For the above we need to develop: data exchange standards and mechanisms for various information platforms used by different departments; management issues of benefit sharing and responsibility; data quality control mechanism; mechanisms to enforce copyright or data ownership;
(3) Develop mechanisms to promote applications of data, including pricing policy, data security, and copy right issues.

1.4 Organization of the thesis and summary of the contents and contributions

The title of enhancement of China land information management systems is used based on the following considerations. As mentioned above, land information means land related information, but the former is more concise and well understood in the international community. There is another possible term land information management infrastructure, but it is a broader term. According to Wikipedia, "*infrastructure is the basic physical and organization structures needed for the operation of a society or enterprise, or services and facilities necessary for an economy to function. The term typically refers to the technical structures that support a society, such as roads, water supply, sewers, electrical grids, telecommunications, and so forth*". Although there is a term of soft infrastructure, it "*refers to all the institutions which are required to maintain the economic, health and culture/social standards of a country, such as financial system, the education system, and the health care system, the system of government and law enforcement, as well as emergency services*". As one can see from the above, the term of infrastructure is broader than a system. The meaning of land information management systems discussed in this thesis is close to land information management infrastructure, but the author, to be modest, prefers the term of land information management systems (LIMS), for there may be some needed for the infrastructure, which are not addressed in the thesis. Also from the discussions in section 1.3 land information management is a more common term used in international community (also see section 2.2 below). One should also note that this study focuses on city-wide information management aspects, while the general ideas, recommendations, and approaches proposed in this thesis is applicable to a wider region, like a province or even the country.

This thesis consists of 7 chapters. Chapter 1 is an introductory one, where spatial information for sustainable development is emphasized (Section 1.1), city-wide land information management is discussed (Section 1.2), the motivation and the objectives of this research are addressed (Section 1.3), and the organization of the thesis and summary of the contents are given (Section 1.4). The main contribution of the author is to strongly relate building of a good LIMS to the sustainable development of a society, to spatially enabled society, and to information economy.

Chapter 2 critically reviews land information management systems (LIMS) overseas and in mainland China. Some existing problems in Chinese LIMS are identified. China land tenure system differs from that of other countries and regions (like Hong Kong). The concept of freehold land and leasehold land does not exist in China. Instead, there is only the "socialist public ownership", i.e., state-owned or collectively-owned land depending on the location of land. Also its law distinguishes the ownership of land and the right to use land. Land-use rights can be granted by the State to a person for a specified purpose within a specified term. This chapter first summarizes the land tenure system in China (Section 2.1). Review of LIMSs in some selected overseas regions is given (Section 2.2), which gives an overview on the systems and their development history. From this review we can learn their experiences. The selected regions include Singapore who is basically a city size and from whose experience we can learn much; Service New Brunswick (SNB); Geospatial data infrastructure in North Carolina, the USA; and land management information systems (LMIS) in Korea. The first three reviews give ideas on their institutional and management arrangements, while the last review gives the concept on system design and implementation of a LMIS. To understand better the current development level in China, the author selected 3 cities for a detail study (Section 2.3): small-medium size city Sanya (area of about 1900 square kilometers and a population of 536 000); medium size city Haikou (area of some 2300 square kilometers and a population of over 1 million) and large city Guangzhou (area of 7300 square kilometers and population of over 10 millions). By comparing the developments in China with overseas, the main problems in Chinese LIMS are identified (Section 2.4). The main contributions of the author in this chapter are critical review of selected overseas practices and Chinese practices and situations; and from the comparison the major drawbacks in China LIMS are identified, which guide this study.

Chapter 3 discusses the design of a LIMS. Based on the author experience in managing lands department of a city, and in managing the stated owned agriculture land in a province, and in reference to the practices of other cities and also to the new developments in LIMS, a detail design of a LIMS is proposed. The conceptual design of a system is presented (Section 3.1) with 3 layer structures: data layer, application layer, and service layer and by following the state information standards and security protection system. Main components or sub-systems of a LIMS are devised, i.e., surveying and mapping system; land management system; cadastre and real estate system; underground utility system; and mineral resource system. For each sub-system the database contents and management systems (Sections 3.2 - 3.6) in application layer are discussed. The main contributions of the author are (1) design of a comprehensive city-wide LIMS, which is the first model in China and will provide geospatial solution to the problems a city is facing; (2) inclusion of underground utility system as a core sub-system promotes integration of spatial information for efficient city administration, e.g., emergency response to water leakage and fire due to gas leakage; (3) proposal to combine urban cadastre and rural cadastre into a system and combine cadastre system and real estate/housing system into a management block.

Chapter 4 denotes to the development of an institutional framework for a LIMS. A major issue for developing efficient and effective LIMS in China is data sharing. There exists a serious duplication of data collection among various government departments with different data quality and data formats. One of the main reasons is the lack of the vision of a LIMS. In this study a vision is proposed (Section 4.1) as to develop an infrastructure that allows spatial data to be available and accessible to authorized public, government department and individuals and promote proper use of integrated spatial data for effective decision-making process, and development of information economy and spatially enabled society. To achieve this vision a number of management and institutional issues is discussed. They include governance and coordination; partnership and responsibility; data management policies; funding model and data pricing policy; and evaluation framework for a LIMS. In this study 3-layer governance and coordination structure is proposed: coordinating council (governing committee) for policy issues; secretariat (management committee) for operation activities; and technical committees for detail management of technical issues and user committee for feedback (Section 4.2). In terms of partnership and responsibility we propose a partnership arrangement and an assessment framework based on a "good governance principles based tool" (i.e., in terms of direction/strategic vision, performance, accountability, and fairness) (Section 4.3). Section 4.4 is about data management policies, which deal with data standard and quality. Although there exist several sets of the standards for various kinds of data, international standards, state standards, and ministerial standards, Selection of a suite of standards is not a simple task. In this study the criteria to be considered in the adaptation of a core suite of standards are proposed. The data quality is an important indicator and includes data lineage, consistency, completeness, semantic accuracy, temporal accuracy, positional accuracy, and attributes accuracy. For the liability of data providers it is proposed that both data and data quality indicators should be provided to users. Funding model of a LIMS and data pricing policy are crucial for a successful implementation of the system. Having analyzed different funding models, pricing models and Chinese situations, a detail funding model and pricing policy for a LIMS in China is proposed (Section 4.5). For improving the efficiency and performance of the developed system, regular evaluation and assessment must be performed. To this end an evaluation framework is discussed

(Section 4.6), which consists of 4 elements, well-defined objectives, clear strategy, outcomes and measurable indicators, and evaluation of the results.

Chapter 5 contributes to the technical aspects in data sharing. In addition to the soft issues (data sharing policy and institutional arrangements) discussed in Chapter 4, technically data format difference between different software is a major problem. Moreover, data captured in different time or by different organizations may have different thematic definition and this leads to the difficulties for spatial data sharing. This chapter is concentrated on the technical issue. Section 5.1 introduces the concept of geospatial data exchange. Section 5.2 describes three different GIS data models (Arc/Info, ArcView Shape File, and MapInfo Interchange File MIF) and ISO TC/211 model. Section 5.3 gives detailed comparisons among these models. In Section 5.4 the tools for geospatial data transformation are discussed. They are basically two kinds: professional software tool such as FME, and data transformation modules built in GIS, such as Arc/Info Conversion Toolbox and MapGIS data conversion module. Having reviewed and analyzed the various data models in GIS, in particular the thematic differences between different GIS models, an experimental study of data transformation between DWG and Shapefile was conducted by using (a) FME and (b) Arc/Info Conversion Toolbox (Section 5.5). Three data sets were selected for the study: a part of the Florida Land Boundary Information System; a set of vector data of Lufkin, Texas in AutoCAD R14 format; and a map sheet of DWG file of a county in China, including contours, spot elevations, edge of farms, etc. The errors in these data transformation are identified and the reasons for causing these errors are analyzed. These provide a basis for improving the quality of spatial data conversion. The error in the data conversion by understanding the regularity of the possible errors in the data conversion can be reduced, though the error in data conversion is not avoidable due to the fundamental difference in data model and data structure among different GIS software, functions of different data conversion software packages, and quality of source data to be converted. The last section summarizes the findings.

Chapter 6 denotes to two important issues: copyright and security of geospatial data. They affect wide application of city-wide land information systems (LIS). As we know big issue in China LIMS is data sharing. The repeated efforts in data collection are common everywhere, for which lacking copyright protection of and restricting access to geospatial data are partially responsible. Having reviewed the international conventions on intellectual property and copyright as well as China law on copyright, we analyze and discuss the copyright issue of geospatial data, and address their legal protection for China (Section 6.1). Several recommendations are proposed in

Section 6.2 regarding legal protection of geospatial data. These include further development of the culture of geospatial data copyright protection; enactment of the law on the copyright issues for geospatial data. This is because the copyright law of China, like many other developing countries, does not explicitly include geospatial data (digital maps); for the second recommendation a committee at national level should be established to study the legal issues related to geospatial data; and resolving or defining the issues related to copyright and ownership of geospatial data (digital maps). This chapter also summarizes some techniques which have been developed to protect copyright of a work (Section 6.3). But according to the author, they are of secondary and the primary measure is legal protection and actions. Section 6.4 discusses security of maps, which are fundamental to all geospatial information systems, but unfortunately are classified in China. With rapid developments in space positioning and mapping technologies, the policy needs reviewing. For the benefit of country's economy, the author propose that China should: move away from the sole military control model of Russia; learn the mixed government and commercial model of the USA, i.e., release the restriction on public access to geospatial data; and adopt the India model of two types of maps as an intermediate step. The main contributions in this chapter are making a number of recommendations on the copyright protection and security issues of geospatial data after a critical review and analysis of the current situations in China and overseas developments in the area.

Chapter 7 presents conclusions and recommendation. Based on this research study nine important conclusions are summarized and two recommendations for further actions are given.

Chapter 2

Review and Analysis of Land Information Management Systems (LIMSs)

To develop effective and efficient city-wide LIMS in China we must review the current situation in China against the overseas practices. China land tenure system differs from other countries and regions (like Hong Kong), and therefore the first section briefly describe the China land tenure system. In review of overseas practice not only city LIMS, but also regional/local LIMS are included. The second section reviews the practices in Singapore, New Brunswick of Canada, North Carolina of the USA, and South Korea; and the third section reviews and analyzes the current situations in 3 selected cities of China, i.e., Sanya, Haikou, and Guangzhou. The fourth section gives a comparison of the China urban LIMS against the overseas practices, and identifies the areas where China urban LIMS need to be improved.

2.1 China land tenure system

The land tenure system of Chinese mainland is different from that of other countries and regions (like Hong Kong). Private land ownership in China was abolished in the collectivization movement during the 1950s. Since then, the only land ownership has been "socialist public ownership", which is either state-owned land or collectively-owned land depending on the location of land. Most of land in the urban areas of a city or town is generally state-owned, and most of land in the rural areas of a city or town and rural land are, unless otherwise specified by law, collectively-owned. Therefore China has only form of land use right for individuals, but not ownership, i.e., individual or cooperate organizations (like university, institutes, hospitals, and other public service centers) have right to use the pieces of land they are located, but land ownership belongs to the country.

The governments at different levels under laws can allocate state-owned land upon payment of relevant compensation to existing land user(s), to designated users for the land use rights of a period. The users, however, cannot transfer the land to other parties. Although all land is owned by the state or by collectives, private individuals and institutions are permitted to hold, lease and develop land for which they are granted land-use rights (PRC, 2008)

China law distinguishes between the ownership of land and the right to use land. Land-use rights can be granted by the State to a person to entitle him to the exclusive use of a piece of land for a specified purpose within a specified term. A premium (except for specific purpose) is payable on the grant of land use rights. Land use rights are granted for a maximum period of 70 years (PRC, 2008).

Upon expiration of the term, renewal is possible and a new contract for the grant of land-use rights and payment of a premium must be executed. If no renewal, the land-use rights will go back to the State. In this case any individuals or organizations will lose the ownership of the buildings and structures on the land.

Land-use rights may not be transferred, leased, or mortgaged if the provisions of the grant contract, with respect to the prescribed period and conditions of investment, development and use of the land, have not been complied with. In addition, different regions may have some differences in the conditions which must be fulfilled before the respective land-use rights can be transferred, leased, or mortgaged.

Under article 38 of the China law on Administration of the Urban Real Estate (PRC, 1995), real property must not be assigned under the following conditions:

- have not fully complied with the conditions as stipulated in Article 39 (see below) if the land-use rights are acquired by means of grant;
- subject to sequestration or restriction by other means, sentenced or determined by the authorities;
- the land-use rights have been retrieved;
- without written consent by the other parties if the real property is collectively owned;
- with argument on the ownership;
- has not been registered and a title certificate of which has not been obtained; or

- other conditions that may not be assigned as stipulated in Laws.

Under Article 39 of the said law, if land use-rights are acquired by means of grant, the following conditions must have been met:

- the premium of the grant of land-use rights must have been paid in full in accordance with the grant contract and a land-use rights certificate must have been obtained;
- investment or development must have been made or carried out in accordance with terms of the land grant contract;
- more than 25% of the total amount of investment or development must have been made or completed; and
- where the investment or development involves a large tract of land, conditions for use of the land for industrial or other construction purpose have been confirmed.

2.2 Overseas practices and experience

This section intends to provide a critical review of the land information management systems in several selected regions. Selected regions are Singapore, New Brunswick in Canada, North Carolina in the USA, and Korea. Land information system (LIS) is defined with slight difference, but required for a spatially enabled society. Some define it as spatial information, and the others define it narrowly as information related to land management.

2.2.1 Singapore

Although Singapore is a country, its area (710 square kilometers) and population (4 987 600 in 2009) are similar to a city in China. Its development of spatial data infrastructure (SDI) is of particular value and reference to us.

The Singapore Land Data Hub was conceived in mid-1989 and administrated by the Singapore Land Authority (Chua, 1996). The objective of the hub is to create an integrated infrastructure for sharing land data in digital form and to avoid the costly duplication of efforts in geographical data capture across the various government agencies. The hub is a multi-ministry effort to establish a central repository of land digital data. The geographical digital data are contributed by more than 13 public sector agencies/departments and used by more than 30 government departments. The successful implementation of the Singapore Land Data Hub requires both the soft and hard infrastructures.

The soft infrastructure means institutional structure, policy directions, standards and procedures. The institutional structure for supporting the Land Data Hub program consists of two multi-ministry committees chaired by the Ministry of Law. The Land System Committee (LSC) is chaired by the deputy secretary of the Ministry of Law and is to set the policy directions for the program and resolve major issues related to the geographical digital data sharing across the Civil Service. At the working level the Land Data Exchange Committee (LANDEX) identifies and develops the procedures required to implement the policy directed by LSC. The LANDEX committee identifies the common sharable geographical digital data, the custodian for the data, the data exchange standard, and defines data access and security procedure for the geographical data.

The hard infrastructure is hardware, software and network infrastructure. The technical development and operations of the Singapore Land Data Hub is managed by the Land System Support Unit (LSSU) of the Ministry of Law, which is responsible for administering geographical digital data sharing in accordance to the policies, standards and procedures defined by the LSC and LANDEX. The geographical data from various government agencies are in different format and in vendor-proprietary format. LSSU has developed specific software to translate these formats into a standard format acceptable to the various government departments. This avoids the need for the various government departments to develop the same set of software and hardware for data translation. The various government departments can assess remotely the data in the hub and specific applications via the Wide Area Network (WAN). With the popularity of Internet and Intranet, LSSU has also explored the feasibility of delivering digital land data via the Internet and Intranet. LSSU has placed the Data Dictionary (Metadata) in the Intranet for access by the various government departments.

With a strategic plan IT2000 for National Information Infrastructure (NII), Singapore set a vision to transform into an intelligent island. In this vision, Singapore has been establishing an advanced high capacity and high-speed nationwide information infrastructure. This infrastructure will interconnect computers in virtually every home, office, school and factory. Under IT 2000 the Land Data Hub 21 has been worked out with a vision, which involves three strategic plans:

(1) Building Land Information Network Infrastructure for more effective and efficient data sharing via high speed network;

(2) Building Integrated Land Information Service. This system will package digital land data from the various government agencies into integrated information services for the benefit of general public;

(3) Building the land base information layers. This which will integrate commonly used land digital data into a seamless and logical database for ease of access and for facilitating the public administration of land matters.

With the great vision the Singapore Land Data Hub has transformed from the manual data exchange program to an on-line and real time data sharing platform called LandNet. LandNet also facilitates on-line GIS consultation and collaboration among government agencies. The goal of LandNet is to achieve an integrated government vision where agencies not only share data but also share processes and systems (Ng, et al., 2008).

In summary Singapore has a strong administrative structure to promote data sharing; a clear and integrated government vision to develop into a spatially enabled society; and a mechanism in place to provide integrated land information services to public.

2.2.2 Service New Brunswick (SNB)

In 1970s the government departments in New Brunswick, Canada began developing isolated, project-based electronic databases, and organizational and institutional issues impeded the realization of the centralized database design of LIS. In 1980s the technology had advanced enough to support the concept of land information network (LIN). Databases developed and maintained by different departments and housed at departmental locations, rather than in a centralized data bank, were linked to other databases by common parcel identifier. The concept of LIN means that participating government departments can access to shared information. However, the public still had no convenient access mechanism. Technology advancement in 1990s allows the original concept of centralized land information system model to be materialized. And a single entity – Service New Brunswick (SNB) was set up. The creation of SNB allowed for the amalgamation of all basic land information activities under one umbrella. SNB is headed by a President and governed by a Board of Directors, comprising members from industry, education, and government. The SNB provides basic geo-information to both government departments and agencies, and the public; it also fosters private sector development. SNB operates as in the following manners (GIC, 1989; Groot and McLaughlin, 2000):

- SNB has a business orientation, complete with revenue incentive and flexibility not present in a government department model;
- The requirements to maintain public records continue to be satisfied;
- Corporation structure and control are tailored to SNB own unique requirements;
- Separate budgeting and accounting procedures are in place;
- Government maintains full control over policy and standards;
- Staffs are employed within the public service framework.

In summary the land information management in Province of New Brunswick, Canada went through from an isolated and project-based system in 1970s to a centralized system SNB. The centralized system does not mean all the databases are centralized, but the management arrangements are centralized. The databases were developed, maintained, and housed by various departments, and linked via data communication means. This kind of system structure is quite suitable to China LIMS. SNB is operated as semi-governmental mode and with business orientation and revenue incentive.

2.2.3 Geospatial data infrastructure in North Carolina

In the early 1990s the state embarked on the goal of a true statewide geospatial data infrastructure (Siderelis, 2000). In 1991 the Governor, by executive order, created the Geographic Information Coordinating Council (GICC), designed Centre for Geographic Information and Analysis (CGIA) as a lead agency for coordination of geographic information and placed the Centre within the organization of the Governor's Office of State Planning. Henceforth GICC and associated coordination structure have guided the implementation of a statewide geographic information infrastructure. The GICC is a standing committee of the Information Resources Commission, the state's regulatory body created by the legislature and responsible for all information technology in the state. The council is a policy body consisting of elected and appointed heads of agencies, representatives of users, and representatives of the various public and non-public sectors with an interest in geographic information and technology. The GICC is staffed by CGIA and supported by three user committees and two special advisory committees. Three user committees are state government users committee, affiliated users committee and federal government users committee. Two special advisory committees are state mapping advisory committee and technical advisory committee. There also is a management and operation committee, whose membership includes the Council chair and vice-chair, and each committee chair. The membership of the GICC is designed to be representative of major stakeholders of the geographic information infrastructure and to provide a forum for stakeholders to jointly oversee statewide initiatives.

The vision of statement was developed through consensus of a broad community of stakeholders and can be summarized as follows:

- *It aims to have a statewide framework for geographic information operational by the year 2000. That framework will enable North Carolinians to take the availability of geographic information for granted, in the way that they take good roads and clean water for granted;*
- *The foundation is a comprehensive statewide database whose content, accuracy, and scales have been determined through consensus and in recognition of the critical users to which it will be applied. While any user may have a unique view of the database and it ostensibly may be physically distributed and maintained by a variety of data custodians, it will appear to users as a consolidated, integrated database;*
- *The database will be accessible over a network to all sectors; the network will operate at high speed and support a diversity of information types including voice, data, and video. Access to the database through the network will be priced fairly and economically;*
- *Users will be supported by service centers that provide GIS production and consulting services, technical support, education, training and outreach, and clearinghouse functions.*

CGIA, from its inception, has operated on a cost recovery basis. Its sole source of funds is receipts collected as user fees. The cost of the coordination functions provided by CGIA are treated as overheads and incorporated in the CGIA rates.

In summary there is a strong and clear management structure for geospatial data infrastructure in North Carolina. The Geographic Information Coordinating Council (GICC) is created by the Governor of the state and a standing committee of the Information Resources Commission, the state's regulatory body created by the legislature. It has enough power and authority to policy and to direct the geospatial activities. It has a clear vision to enable North Carolinians to take the availability of geographic information for granted. As the USA implements a data free access model, one can expect the database building and maintaining are funded by the state government. However, centre for geographic information and analysis (CGIA) will charge fee for providing various supports to data users, like consulting services, technical support, education, training and outreach based on cost recovery model.

2.2.4 Land information management systems (LIMS) in Korea

South Korea has worked out a plan for establishing an efficient land information management system (Choe, et al., 2001). The targets for its LIMS development include:

- *Re-engineering of business process and institutional improvement.* Land management business, which is defined in a related acts and ordinances, can be processed by online networking. Many steps that are necessary in the conventional business process could be eliminated through data sharing and networking. For this purpose there might be many institutional factors to be improved. Also land management related laws and regulations need improving;
- *Enhancing data sharing.* The intention of LIMS development is to share land information data through nationwide network for public service and policy making by central government. To this end integrated data model and content standards should be established and maintained.

To achieve the above targets the following issues need to be considered:

(1) *Open system architecture.* Local governments have very diverse computer platforms and also various GIS software systems. Open system architecture could provide interoperability between different computer platforms and different software systems. It can make local governments share existing resources in their computing environment. The LIMS adopted 3-tier open system architecture for interoperability in this computing environment, which is composed of client, database server and middleware. This architecture enables also nationwide data sharing and scaling up.

(2) *Component development.* A LIMS can have various applications in land management business. But each application has similar functions, like map display, printing, zooming in or out, and etc. In object-oriented programming and distributed object technology, a component is reusable program building block that can be combined with other components to form an application. It is an efficient way to decompose business process into common

meaningful units. And these can be developed as components using CORBA or COM technology.

(3) *Distributed computing*. The LIMS will be nationwide network system that connects local governments and central government systems. Each system has its own databases and common applications. For this purpose a distributed computing environment is needed.

(4) *Nationwide networking*. One of the goals of the LIMS is to manage land data from local governments in a real time, to serve zoning information to citizens at any time and any place to improve the efficiency of land management business. This can only accomplished by nationwide online networking.

The Korea LIMS has 5 basic databases and 4 major application systems. The databases include:

(1) *Topographic maps*. Digital topographic maps are essential for a LIMS. They originally were in a CAD format (DXF), and should be converted into GIS format for easy analysis of the data. They are composed in several layers, like road, building, stream, geodetic points, elevation, railways, etc.

(2) *Cadastral maps*. They are important because people regard land as important property. People have great concerns of their areas of land, and therefore the boundary of a land parcel must be accurate.

(3) *Zoning maps*. There are many zoning maps for land use regulation, such as land use planning maps, agriculture promotion zoning maps, forest land use maps, etc.

(4) *Attribute database*. It includes all the information on land, like land properties, ownership, etc.

(5) *Land regulation database*. It includes land policy, land law, and land administration.

The application systems include:

(1) Land management business system, consisting of 6 sub-systems:
  - land transaction;
  - foreigner's land acquisition;
  - land development allotment;
  - real estate agent;
  - public land pricing; and
  - zoning system.

(2) Spatial data management system in local government;

(3) Land use planning support system in provincial government; and
(4) Land policy-making support system in central government.

As mentioned above, the LIMS is developed with a 3-tier architecture regarding heterogeneous computing environments, i.e., open system architecture is necessary for sharing data to service nationwide on various computer platform. Specially, the middleware, which has functions as broker between databases server and clients, can make free from different computing environments. Figure 2.1 shows system architecture. The LIMS middleware is based on OpenGIS CORBA specification for development of standard interface, rational unified process (RUP) for development method, unified modeling language (UML) for system design, VisiBroker, C++ and JAVA for system implementation. The components of open LIMS middleware are data providers that make any kind of servers or software assess SDE and ZEUS as GIS server. MapAgent that displays maps, OpenView that has core functionalities of GIS, MapOCX that provides spatial information to client, and web service that provides citizens to zoning information through internet.

In summary this review of Korea LIMS provides useful reference for the design of an efficient LIMS. The system should be 3-tier structured which allows its operation under various computer environments. The lower layer is databases including necessary core data sources; application layer contains all the information management systems; and upper layer is service systems. The same as the others systems discussed above, the goal of LIMS development is to share land related information through a data link network for public service and decision making at the governments at different levels. To this end integrated data model and content standards should be essential.

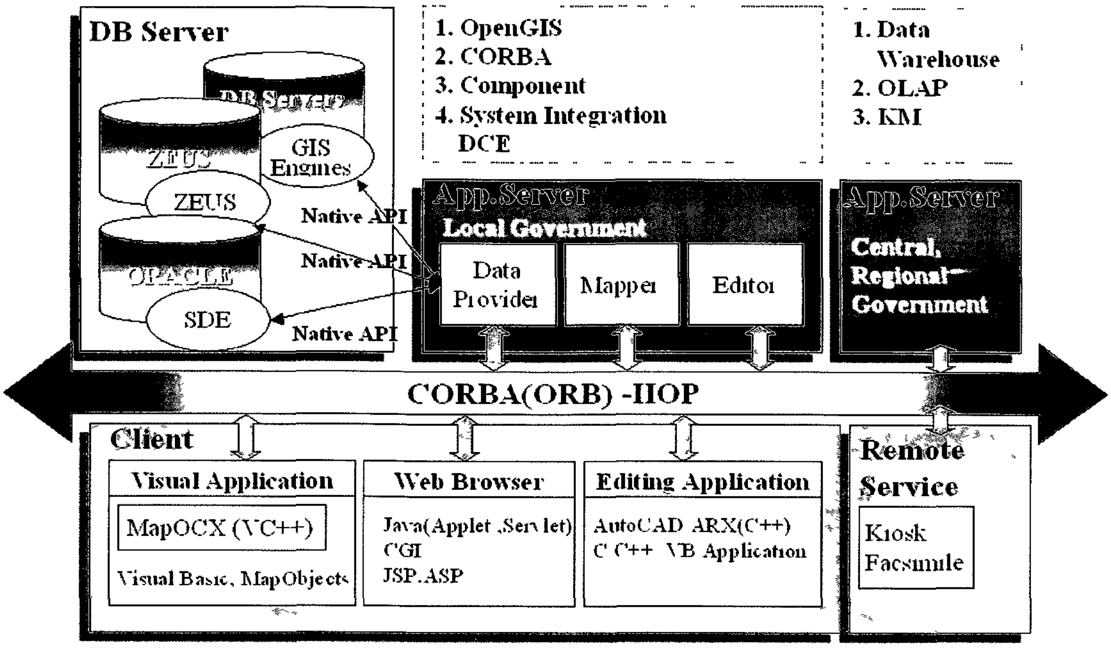


Figure 2.1 Korea LIMS architecture (after Choe, et al., 2001)

2.3 The current practices in China

To understand better the current urban LIM practices and situation in China we selected 3 cities for study: Sanya, Haikou, and Guangzhou. The first two are of medium size, while the third one large city.

2.3.1 The LIMS in city of Haikou

Haikou situated at the north cost of Hainan Island, is the capital of Hainan Province with an area of 2304 square kilometers and population of over 1 million. The city has four administrative districts with each district having both urban and rural areas. Geospatial information is mainly collected and maintained by Haikou Bureau of Lands and Resources and Haikou Bureau of Planning.

According to Tsai (2010), a senior engineer of the information center of Haikou Bureau of Lands and Resources, the bureau has 4 sub-bureaus with one in each administrative district. The information center has following databases:

- 1:50 000 topographic maps updated in 2004, covering the whole city;
- Cadastre maps showing the outlines of each land parcel. The maps are frequently updated;
- Land use maps;
- Maps for agriculture land; and
- Land planning.

The last three databases are updated in the recent second run of nation-wide land surveys. China completed the second run of land use surveys recently with an aim to understand the nation-wide land use situation. All the provinces, cities and counties did the surveys according to specified working procedures and standards. Their cadastre maps do not contain real estate information, which is kept in Building and Construction Bureau. The database for basic land price is also not in the center, but located in the department of land marketing of the Bureau. The Bureau has an institute of surveying and mapping. It is a semi-commercial organization, meaning under a government bureau, but mainly supported by themselves through its commercial activities in surveying and mapping market. They do cadastre surveys with the support from the Bureau, but also conduct large scale mapping and engineering surveys for other industry sectors. Except the cadastre survey data, the data of all other surveys, which are not financially supported by the Bureau, are not given to the information center. Therefore the center does not have any data on large scale mapping. Even large scale mapping did not completely cover an area, for it was done piece by piece depending on market demands. The center has developed its own application systems for office automation purposes. They preferred home-developed software systems, for they believe this kind of software systems are easier to modify if necessary. These systems include land monitoring management system; land use management system; and the management system for land requisition.

According to Mr. Huo (2010), Head of Information Section, Center for Surveying and Mapping, Haikou Bureau of Planning, the information section mainly serves for city planning. They have following databases:

- Maps with scale 1:1000 – 1:2000, covering main urban area of 600 square kilometers. The data used in the system are the 1994 products. Although the computer systems were upgraded in 2004, but the data is still old;
- Incomplete underground utility information; and
- Incomplete coverage of large scale maps of 1:500.

Incomplete information/coverage means they updated the last two databases project by project. If there is an internal need for planning or external contracts from construction companies for a particular area, they will map the area with scale 1:500 and do underground utility surveys if required. When the project is completed they require the construction company to submit as-built surveys with which the databases are updated. During the visit Mr. Huo and his colleagues repeated many times they cannot have a good system as they wish to have because of very poor funding situation. The Bureau has a survey team of over 100 staff members, but their works mainly for external commercial activities.

The municipal government also has an information office, responsible for office automation programs. They have intention to promote data sharing among governmental bureaus and departments. But no much progress in this aspect according to Huo (2010) and Tsai (2010).

It is clear from my visits to these two bureaus that:

(1) The city authorities concerned do not have a vision and even an idea to develop a spatially enabled society. They do not know much about the importance of geospatial information to their decision-making;

(2) Each bureau the author visited does not have plans in establishing a LIMS. They work on an isolate and project-based manners, like above-mentioned New Brunswick in 1970s;

(3) Funding is a critical issue, which is much related to the first point above-mentioned. This is because the authorities did not concern the matter and the relevant staff did not actively promote their activities and importance of geospatial data for decision making to the top city managers.

2.3.2 The LIMS in city of Sanya

Sanya is the southernmost city in Hainan Province with an area of 1919.6 square kilometers and a population of 536 000 (year 2006 data). Sanya is renowned for its tropical climate and is a popular tourist destination, called the "oriental Hawaii". It has two direct jurisdiction township-level districts and six towns and five state-owned farms. Township-level districts include Hexi District and Hedong District and six towns are: Tianya Town, Yacheng Town, Haitangwan Town, Tiandu Town, Fenghuang Twon, and Yucai Town. The city extends 91.6 km in west-east direction and 50 km in north-south direction. It has 209 km coastline and planned urban area of 37 square kilometers.

Two government departments collect and manage geospatial data: Bureau of Lands, Environment Protection, and Resources (LERD); and Bureau of Planning (PD). Bureau of Planning mainly collect and manage topographic data of various scales; while Bureau of Lands, Environment Protection and Resources collect and manage information/data related to its functions (land management, environment, and mineral). The data are not shared between these two bureaus. Both PD and LERD have its information center and survey team. The survey team in PD is responsible for large scale topographic maps and the survey team of LERD mainly does cadastre surveys. LERD have three types of data: basic data, specific data and files. The basic data include:

- 1:10000 maps covering the whole city produced by Hainan Bureau of Surveying and Mapping as national basic maps with updating in 2004;
- 1:1000 maps covering the urban area dated in 1999;
- 1:500 maps, which were produced between 2002 and 2008 and does not cover the entire urban areas, but surveyed piece by piece;
- Photos covering the whole city and obtained in 2006;
- Spot 5 images acquired in 2003.

The specific data include:

- Land use maps of 1990, 1996, and 2004, covering the whole city area;
- Rural cadastre;
- Urban cadastre covering 50 square kilometers with updating from time to time;
- Basic cultivated land.

The information system of lands and resources has two sub-systems, according to Ms. Ye, the director of the information center of Sanya LERD (Ye, 2010):

- Office automation for cadastre and housing managements, developed by a Shenzhen company in 2003;
- Market information system for housing, developed by a Shanghai company in 2008

The existing systems suffer from several problems due to its lack of a general plan and vision. The systems were developed piece by piece, and each system was for a particular purpose and for solving an individual task without proper integration. The main problems in database construction include (DIST, 2009)

(1) Poor data sharing mechanisms even within the LERD system;
(2) Lack of data updating and management mechanisms;
(3) Incomplete data standards; and
(4) Delay in database building.

The main drawbacks in the development of management system are (DIST, 2009):

(1) Several needed management systems do not exist. There are only two management systems, as mentioned above, office automation for cadastre and housing managements and market information system for housing/real estate;
(2) Supports for geospatial decision-making is at low level;
(3) Not much data integration and sharing among various systems/sub-systems;
(4) Not much adaptation of new developments and technologies – the system design and techniques used are not up-to-day;
(5) Low automation of the systems; and
(6) Low data service capability.

The Sanya LERD invited Digital Intelligence System Technology (DIST) to design the second version of information management system and the project started. It should be mentioned that with newly designed implementation plan they also budget 600 million RMB for updating the basic topographic data. This suggests they will collect topographic data by themselves rather than use the data from PD through data sharing among government departments.

The LIMS in Sanya suffers from the similar problems as in Haikou: no planning, no data sharing, and isolate project-based system. Fortunately, Bureau of Lands, Environment Protection and Resources started its second generation of LIMS. Although the system will be still for internal uses, it will be upgraded. Establishment of a city-wide LIMS is still long way to go, which involves lots of changes, including changes in culture and concept. The major change must come from top-down direction.

2.3.3 The LIMS in city of Guangzhou

Guangzhou is classified as a mega city according to an international standard with population of over 10 millions. There are 8 urban districts, 2 rural districts, and two counties. The total area is more than 7300 square kilometers. There are several government departments which involve the collection and use of geospatial data. Among them Bureau of Planning and Bureau of Lands, Resources, and Housing are the two main players.

Bureau of Planning produces topographic data at various scales from 1/5000 to 1/500. From an internet search by Boos and Muller (2009) the city authority of Guangzhou in 2004 initiated the Digital Municipality of Guangzhou (DigiM,GZ) project which is scheduled to be completed by 2010 (Guangzhou will hold Asia Games in Oct. 2010). The project aims to represent the Guangzhou metropolitan area as digitalized virtual municipality by using a wide range of up-to-date GIS and telecommunications technologies. When in use it will provide a universal platform to deal with all digital data relevant for city planning, management and maintenance, including water, gas and power supplies, transport networks, drainage and telecommunications. According to an internet investigation from FIG, which collected the information about the use of spatial data infrastructures in the world's largest metropolitan areas (Boos and Muller, 2009), a metropolitan area in this context is defined as an urban agglomeration with more than 10 million inhabitants, which by now is true for 26 cities in the world. China has 3 such cities, Beijing, Guangzhou, and Shanghai. Their evaluation of the availability of spatial data is classified into SDI master plan available, primary spatial data available, secondary spatial data available and spatial data accessibility available. Guangzhou belongs to the third and other two China cities to fourth category. According to their definition, primary geospatial data are original data, like survey data, data with limited interpretation like water bodies or boundaries, which are obtained without analysis or even less interpretation. Secondary data are thematic data which are derived from analysis of primary data, statistical data collection and/or image interpretation.

Urban Planning and Survey Institute under Bureau of Planning has 4 surveying teams, underground utility surveying team (now renamed as institute of underground space surveys), geospatial information center, and institute for application of new geomatics technologies (Zhang R, 2010). The survey teams collect geographic data at various scales and all the information/data are managed by geospatial information center. Underground utility survey team collects data related to utilities. The utility information is managed by the Office Atomization of Urban

Planning and Survey Institute. Two basic information systems are managed by two different units in the same institute. Based on the information collected in my recent visit they have completed the database for basic geographic data, and developing service information systems, like hotel information, transportation information, 3D city models, and etc. The institute has set up a mechanism for updating the databases of its information systems. 1/500 digital maps in the built-up urban area of 800 km^2 is updated every year and for the other area of 300 km^2 every two years; 1/2000 maps for the area of 4300 km^2 is updated every 3 years; and 1/5000 maps covering the whole city is updated every 5 years. This updating scheme is called the 1-2-3-5 scheme. It involves lots of work and resources. The institute is investigating the methodology for rapid map revision.

Bureau of Lands, Resources and Housing has several separate information systems, which are managed by different offices (Zhang HF, 2010): the survey office manages its survey and GIS data; the housing office manages housing databases; cadastre office established its cadastre system; the information center of the bureau is developing land planning and land-use information systems; the mineral resources office keeps the related information. Even for the same information system different districts have their own systems with different platforms. Take cadastre information system as an example each district of the city contracted out the system development to different companies. The system platform and standards may vary among the districts, and the central office of cadastre management cannot access the information of its districts. The current situation of isolated systems seems working, for the systems have a limited usage. But it is definitely far away from an ideal. The Bureau has established a good management structure: the Head of Bureau also act as Director of the IT office with help of office manager and several deputy managers. The office manager is the Head of Bureau office, and deputy managers are the Heads of Financial Office, Human Resource Office, and Information Office. But to the author's opinion it does not work properly, which is responsible for the above unfavorable situation.

It seems Bureau of Planning has a concrete plan and is doing well in building and maintaining topographic databases, located at the information center. Funding mainly comes from government. However, they have a separate underground utility database, which is located at different office and make data integration inefficient. In response to my questions during the visit, they said that data is accessible by other government departments free of charge. But it may not be true when Bureau of Lands and Resources was asked of the topographic data during my visit.

As one can see from the above surveys, Bureau of Lands, Resources and Housing has done poorly in their LIMS. No data sharing within the Bureau; no data standards; and no long term plan for innovative uses of spatial information.

In relation to the review of a LIMS in megacity Guangzhou, several points need stressing here. According to FIG (2010), administrations of large cities are often confronted with a multitude of key problems: high urban density, traffic congestion, energy inadequacy, unbalanced development and lack of basic services, illegal construction both within the city and in the periphery, informal real estate markets, creation of slums, poor natural hazards management in overpopulated areas, crime, water, soil and air pollution leading to environmental degradation, climate change and poor governance arrangements. Spatial information has become indispensable for numerous aspects of urban development, planning, and management. Compared with the megacities in developed countries (e.g., New York and Paris), Guangzhou, like other megacities in developing countries, is generally incapable of providing a comprehensive citywide SDI. Missing capabilities included no spatial data policies, common metadata, formal data sharing arrangements between unities and agencies, or shared data access mechanisms. It could be many years before mature and fully populated SDI emerge. It therefore is an urgent task for China cities, especially megacities to accelerate their building of efficient LIMSs.

2.4 Analysis of China LIMSs

As mentioned in the introduction, since late 1990s various information systems have been established in each city and different platforms used. The development levels vary significantly from city to city. Compared with the advanced systems as described in Section 2.2, China urban land information management systems suffered from the following problems:

(1) Lack of a powerful inter-department governmental committee. All the information systems are basically sole department owned or isolate and project-based systems. Municipal governments lack general plan and vision for city-wide spatial information system. There is no legal framework to give an institution full authority to manage the urban SDI. Other government departments may set up their own systems of specific purposes;

(2) No consideration was given to the requirements of other governmental agencies, which arises from the above problem. In the design of spatial information systems other interested parties

were less involved. Therefore the system is only used by the department. The data format, standards, and accuracy are based on the requirement of a particular department;

(3) No Internet access capability among various systems. Although there is Intranet to connect different offices in a department, there is no Internet communication for data. The above problem (2) suggests no data sharing among various departments, no need for internet data communication, and no technical standards necessary;

(4) The system is not fully utilized. The above reasons are responsible for it. In addition public unawareness of the existing SDI is another important reason. A considerable number of the systems have not been fully utilized with a few laid aside, despite a huge financial investment to get it up and running. They are basically a simple conversion from traditional paper information to digital form. Effective use of the information to support decision-making process has not yet achieved.

(5) Data/information is not updated. Data are the most critical factor for a system to be fully utilized. Maintaining of updated data/information is very expensive. Currently many cities in China created GIS database by digitizing the existing maps, many of which may be out of date. The quality of spatial data is therefore one of the most important factors that limit the use of GIS technology.

(6) No proper funding mechanism and not enough support from the city top managers. The municipal government has not recognized that a good LIMS is an important infrastructure (like highways). .

Fortunately, the China central government stressed the importance of building digital China. In 2003 President Hu directed the State Bureau of Surveying and Mapping (SBSM) to actively promote national spatial data infrastructure (NSDI) for digital China, and accelerate the construction of the so called “informationized geomatics” for better services to national economy. Recently, other state leaders repeated similar directions to SBSM. Under these directions SBSM and the Information Office of the State Council jointly enacted several policy documents, like “Guidelines for SDI construction and applications”, “Regulations on SDI construction”, “Regulations on Database” and “Regulations on Common Geographic Information Platform”. A new wave of digital city, digital China started rolling. SBSM have set digital China as their mission. According to deputy director Mr. Li (Li, 2009), SBSM have following six main tasks:

(1) Rich geographic information (GI) sources. SDI is the core of digital China. SBSM will work with other relevant central government ministries/departments to enhance data

collection of geodetic controls, ortho-images, land cover, DEM, transport systems, hydrological systems, place names, cadastre, and boundaries, etc;

(2) Strengthen services of SDI in the areas, like e-government, geospatial decision-making, management of resources, eco-systems, urban planning, environment protection, emergency response systems, etc;

(3) Promote the development of geo-industry;

(4) Modernization of survey datum;

(5) Enrich the regulations and standards related to SDI, in particular management responsibility of the governments at different levels, rights of data usage, updating, copy right, exchange and data sharing, etc

(6) Start digital city model projects

Li (2009) also said that building a digital city is the responsibility of municipal government. Due to historical reason, urban surveying and mapping activities are under the administration of Ministry of Construction and Housing, and therefore Ministry of Construction and Housing listed the construction of urban information platform as one of its priorities in urban development, which is included in the state medium and long term development plan (2006-2020). Ministry of Construction and Housing also issued a number of regulations and guidelines, such as "Policy on Data Sharing in Construction Industry", "Policy on Data Updating in Construction Industry", "Policy on Management of Information in Construction Industry", "Policy on Information Services to Public in Construction Industry", "Guidelines for Digital City Model Project", and etc. However, digital city is a complicated matter involving all the aspects in the management of a city and needs strong supports and long term commitments from all the sectors involved. As pointed by Tian and Wang (2009), China is facing serious problems in the construction of digital city. They are mainly so called "strong in vertical direction and weak in horizontal direction" and "separation between blocks". The first problem means that information systems link strong under the same administrative system (like lands or planning), but week between different administrative systems (like lands and planning). The second problem means that various information systems do not communicate to each other. These problems not only generate serious repetition in data collection and greatly waste resources, but also hinder sustainable development of informationized urbans and cities.

Chapter 3

Design of a Land Information Management System

This chapter on the design of a land information management system (LIMS) is based on my 8-year experience in managing Bureau of Lands and Resources for city of Sanya in Hainan province and on 3-year experience in managing the state-own firming land for Hainan province, which is about 25% of the provincial agricultural land, and in reference to the practices of other cities in China and also to the new developments in LIMS worldwide. Nowadays the administrative scope of a city in China is not the same as that overseas, where municipal government administrates only its urban area. But a municipal government in China administrates not only its urban area, but also rural region (agriculture area), like counties or towns. Therefore the design of a LIMS should also consider agricultural land and mineral resources. In addition underground utilities, particularly in urban areas become more and more important infrastructures of a city, and therefore a LIMS should also include the management of underground utilities. This chapter has six sections. Section 1 describes the conceptual design of a LIMS, followed by five sections, each of which is devoted to each sub-system, including its databases and management systems.

3.1 Conceptual design and the components/sub-systems of a LIMS

A LIMS can be developed with 3-tier architecture. Open system architecture is necessarily adopted to share data and to service clients on various computer platform. Specifically the middleware, which functions as a broker between database (DB) server and client, can make free from different computing environments. The conceptual design of a LISM is presented in Figure 3.1. The data layer includes components of DBs and data updating systems. There are various sub-DBs (hereafter we do not distinguish between the principal DB and sub-DB, for the readers can understand from the text), which contain all types of information for different land-related applications. The DBs need regularly updating through updating systems, and should be connected to the DBs at higher levels (like provincial or state DBs) for necessary data exchanges. The application layer includes various management systems, like land use planning management system, cadastre management system, map management system, and etc., which will be discussed below. All the management systems should be built on an e-government platform. The service layer includes various service elements, like spatial data visualization, output systems, and etc. A LIMS should follow the national standards as much as possible and be properly protected. The DBs can be in centralized or distributed version. But the distributed system is recommended. This can give the incentive and responsibility to different government departments and agencies. For the distributed systems the information service systems of each basic sub-system in a LIMS also provide data and information for other sub-systems. For instance land management sub-system needs digital maps from surveying and mapping sub-system. The latter will provide the needed data through its information services system to the former.

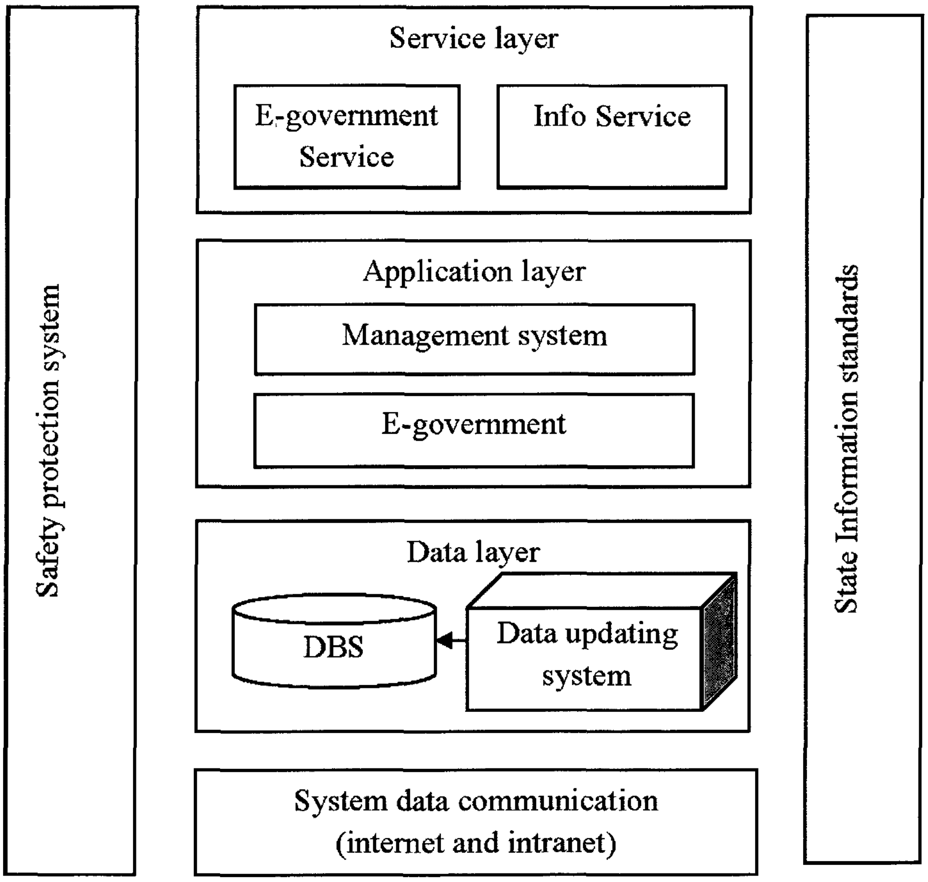


Figure 3.1 Conceptual design of a LIMS

A typical and good land information system for a city would consist of at least the following basic sub-systems:

(1) Surveying and mapping system;

(2) Land management system;

(3) Cadastre and real estate system;

(4) Underground utility system; and

(5) Mineral resource system.

A brief description of each sub-system is given below.

The surveying and mapping system provides spatial data or topographic maps, which is the fundamental information for all the other systems. Other types of information can be overlaid on topographic maps. In addition to digital maps the system should include the information for monitoring and management of surveying and mapping projects. Figure 3.2 shows the structure of the system. The system has various DBs, including geographic information (geodetic control stations and reference systems, digital maps of various scales, and photographs and images); registered surveyors and companies; surveying and mapping projects; surveying and mapping files. The system also has various application/management systems to support quality control of surveying mapping products and to provide needed data/information. They are management system (MS) for surveying and mapping products, MS for qualified surveyors or surveying companies; MS for survey files; MS for survey and mapping projects; and legal monitoring system.

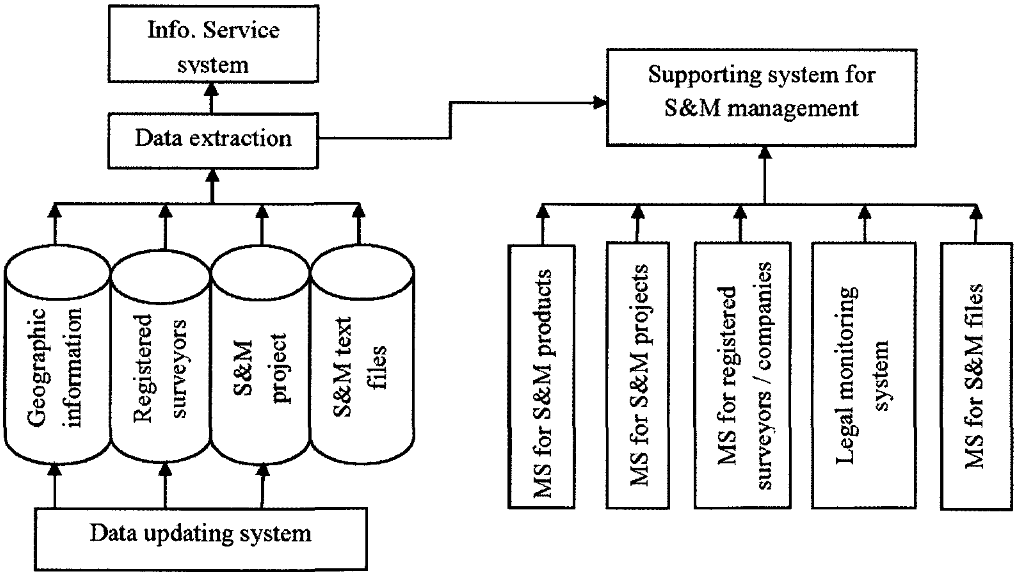


Figure 3.2 The structure of surveying and mapping system

Land management system provides the information on the current status and planning of land use. The information should be current, so that any change in land use can be monitored, cultivated land can be properly protected, and the implementation of land use policies can be monitored and assessed. It provides critical information for decision making and for the management of land use planning, land use and construction-use land. Figure 3.3 shows the structure of land management system. The system includes DBs for land planning, land use, land development, and also land policy, laws, and relevant regulations. There are several application/management systems (MS) in the land management system: MS for land planning, MS for land development, MS for enforcement of land policy/regulations, and MS for approving the request for land use change.

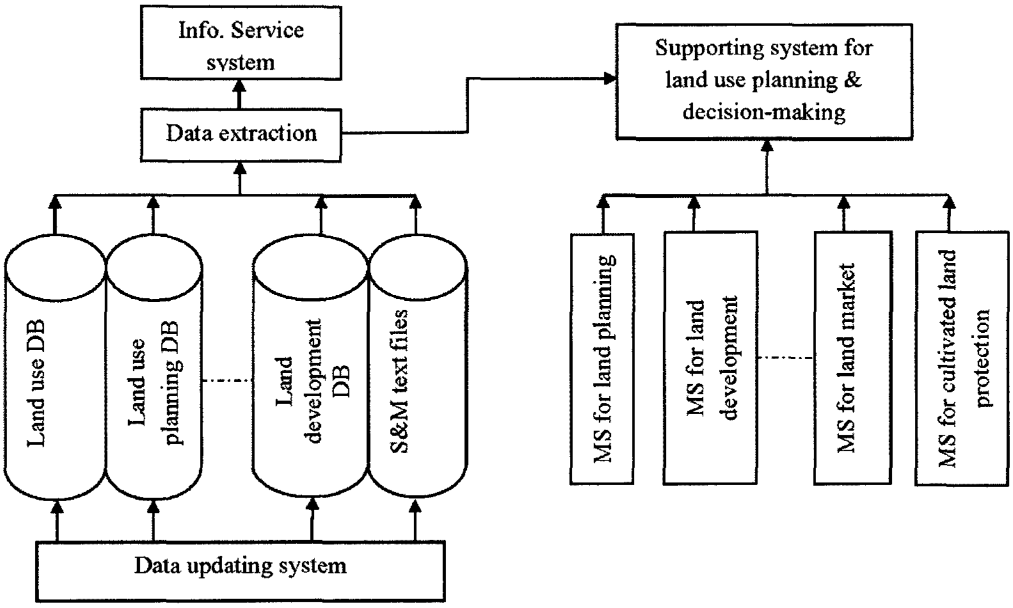


Figure 3.3 Structure of land management system

Cadastre and real estate management system The purpose of the cadastre is to ascertain the location, size, and use of real property and to record data pertaining to value and ownership rights (Blachut, et. al., 1979). Real property may consist of a land parcel either with or without a building on it or an apartment in a building. In the latter case the property is easy to define by specifying the building, the floor, and the location of the apartment on the floor. The size of the apartment can be obtained from existing drawings of buildings or it can be measured. Definition of a land parcel is a much more intricate matter. Its boundaries are either defined by physical features, like roads, walls, buildings, rivers, or mathematically by the coordinates in a permanent coordinate system. The physical features may be destroyed. Therefore in modern cadastre system the boundaries of a land parcel are defined by surveyed coordinates. In the developed world the basic functions of an urban cadastre system are moving from the financial (taxation purpose) and juridical (legal record of the ownership of a land parcel) in the earlier date towards a multipurpose character nowadays.

Compared with the cadastre system in the developed world, the cadastre system in China is relatively new, only since 1980s. The land ownership differs also from other countries and regions (like Hong Kong). Section 2.1 has described Chinese land tenure system. In addition, as above-mentioned, a city in China now normally consists of rural area (countryside) and urban area (built-up area). Therefore there are so-called rural cadastre and urban cadastre. Urban cadastre started implementation earlier than rural cadastre. There is a move for China to enhance her rural cadastre with an aim of protecting farming rights and enhancing food security. The Chinese central government understand that once arable land is converted from farming to another use, it is probably lost forever as a source of agricultural production. To make matters worse, for every land parcel removed from agriculture, a family loses its livelihood and joins the rank of the rural poor. To protect arable lands and foster sustainable agricultural practices, China has adopted policies and laws aiming at strengthening the land rights of individual farmers. Nearly all arable lands are owned by collectives and released to the farmers by the local collective in a contractual lease arrangement that sometimes dated back decades. When land disputes arise it is difficult or impossible for farmers to prove what rights they have to specific pieces of property without adequate documentation. As a result, China established the rural land registration and certification pilot program through the China Agricultural University with funding from the UN FAO and World Bank, which grew directly from the 2005 collaboration between the World Bank and the China Development Research Center of the State Council (Robley and Yuen, 2009). The objective of this program is to explore and test legal, technical and organizational solutions for sustainable rural land registration and certification. The long-term goal is to register every rural land parcel and document its correct boundaries and to formally recognize the land tenure of every farming household in the nation. This indicates cadastre is becoming more and more important, though the Chinese land tenure system is different from that in the developed world. Currently the China cadastre system is divided into urban cadastre and rural cadastre. This separation is mainly due to the historical reason in cadastre management. The urban cadastre system was set up by following “regulations for urban cadastre surveys” issued by then Ministry of Construction, while rural cadastre system was built based on “regulations for land use surveys” issued by Ministry of Lands and Resources. The former mainly deals with the ownership/use right of a land parcel and properties on it, while the latter manages resources and land use. This separation has caused many problems, which are summarized below.

(1) As mentioned above, the both systems have different focuses. Therefore the urban cadastre system cannot efficiently manage urban land, and the rural cadastre system cannot properly manage the ownership/use right of developed land and properties on it;

(2) With rapid economic developments and urbanization, the boundary between urban and rural areas becomes vague, and also changes with time. Thus, this separation cannot properly manage the cadastre in the rural-urban boundary region;

(3) Arising from (2), the maintenance of the both systems become difficult;

(4) The current separate systems do not support well the applications of E-government.

In this study the author proposes an integrated cadastre system, i.e., integration of urban cadastre and rural cadastre systems. Moreover, the current management mode separates urban land cadastre and real estate cadastre. This is mainly due to institutional reason: land cadastre managed by lands department, while real estate managed by housing department. Actually, a building is located on a land parcel with certain period of use right. We should integrate real estate cadastre and land cadastre through a link between them. Figure 3.4 shows the structure of cadastre and real estate management system. In the figure land use regulation DB and land base price DB are not in the system, but obtained from land management system. But these DBs are needed in the cadastre and real estate management system.

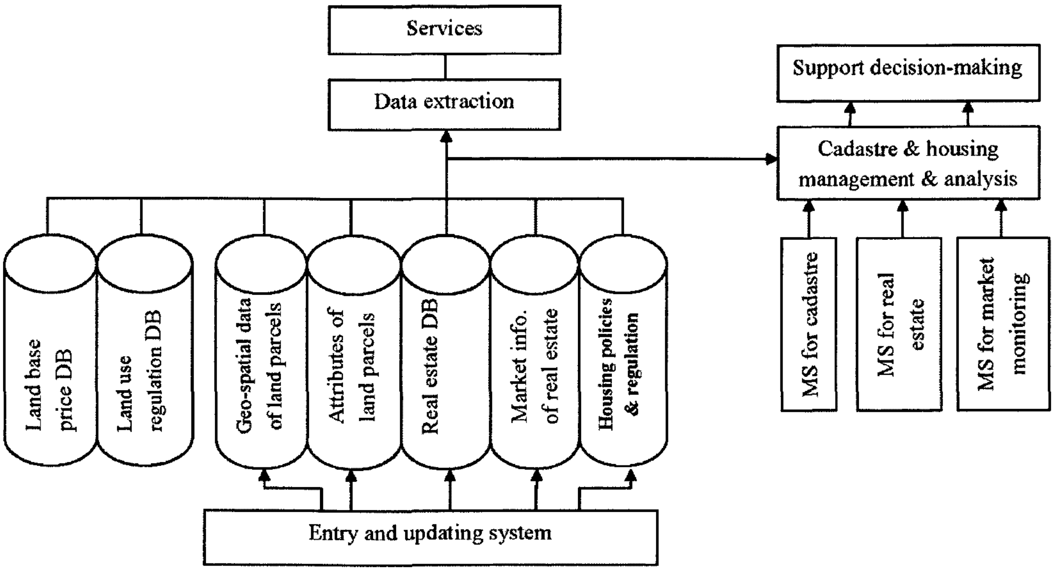


Figure 3.4 Cadastre and real estate management system

Underground utility management system The term utility encompasses the city water and sewer system and all installations connected with gas, heating, electricity, and telecommunication. Underground utility survey deals with the mapping and description of underground servicing lines such as ducts, cables, pipes, and associated elements such as manholes, poles, catch basins, transformers, and hydrants. As the utilities of modern cities become not only more complex and costly, but also more essential, the need for a complete, accurate, and up-to-date integrated information is becoming apparent. Need for a systematic documentation of underground utilities has been recognized worldwide. China has established a professional association for utility surveying, and published technical specification (MOC, 2003). Utility investigations and surveys in many cities started in early 2000s. Hong Kong also has Hong Kong Institute of Underground Utility Specialists since 2002, studying the techniques for surveying and management of underground utilities and also conducting projects. The Department of Land Surveying and Geo-Informatics at Hong Kong Polytechnic University has created a stream under its Bachelor of Science Program in Geomatics, called Utility Surveying and Management. These are some evidences to show the importance of mapping and management of urban underground utilities. Management of underground utilities is becoming a major activity of a modern city. The main characteristics of underground utilities includes invisible (underground), complex (i.e., various types of utility, network form), and dynamic (i.e., new utilities continuously installed with rapid urban developments, and old utilities are continuously replaced). The information related to underground utilities is of large volume, and includes utility graphic and attribute data, topographic data, and all man-made buildings and infrastructures (like roads, recreation facilities, and etc). Although these three types of data are different, utility data must be overlaid on the other two for any decision-making analysis. A good management system of underground utilities must be able to perform various functions, like data entry and checking, management of graphic data and attribute data, inquiry, statistics, spatial analysis, aided design, and decision-making. Figure 3.5 shows the structure of underground utility management system.

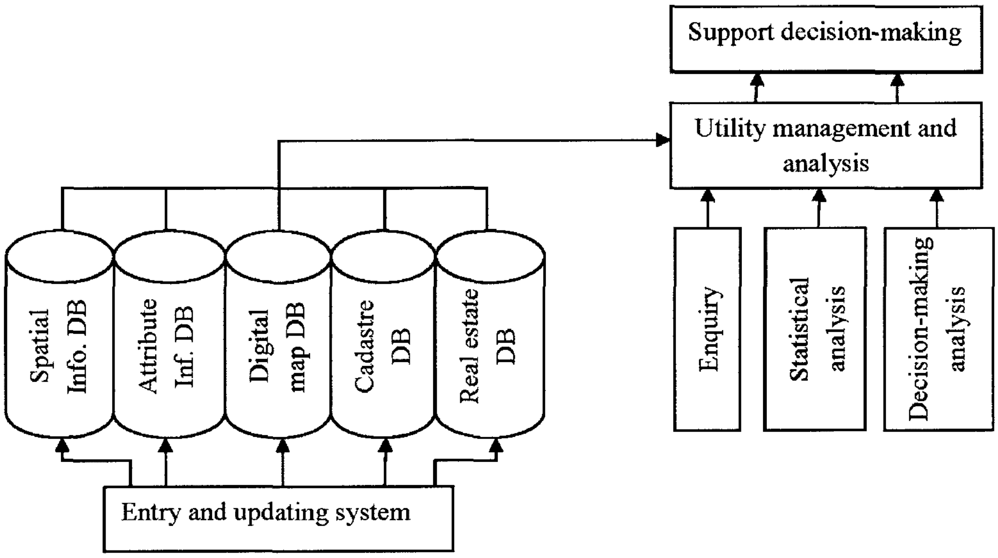


Figure 3.5 Structure of underground utility management system

Mineral resource management system provides the information on the mineral resources and their distribution in the region, the geological conditions, and also mining activities. This information is used for planning of resource exploration, monitoring safety conditions for each mine, and providing information services to mining corporations and the public. In China mineral resources are under central government control (GDLR, 2006). Therefore the mineral resource management system at city level is to support the provincial system. Figure 3.6 shows the structure of mineral resource management system.

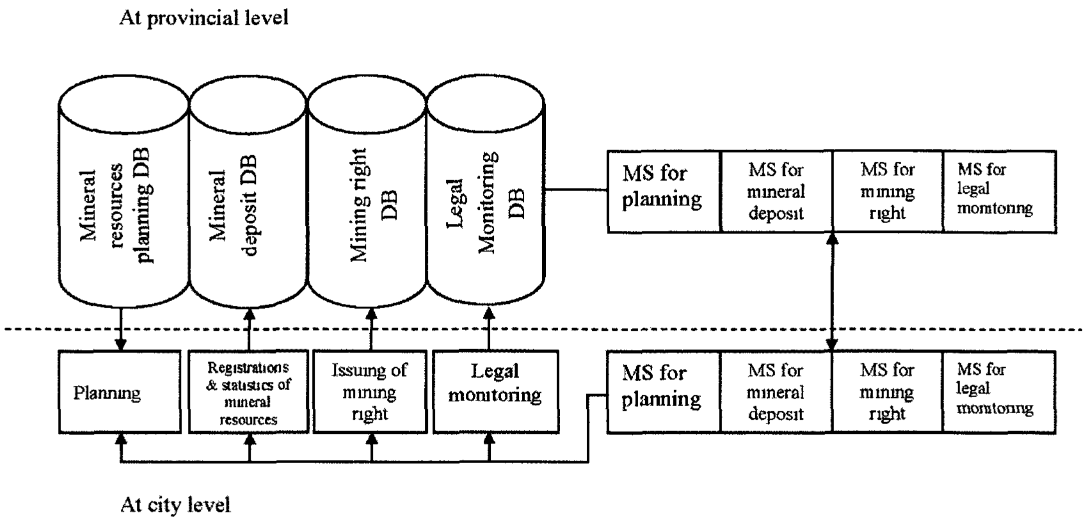


Figure 3.6 Structure of mineral resource management system

These are the core elements (sub-systems) that a city-wide LIMS should have. There are other data/information, like transportation information or navigation maps, which is needed for the management of a city. But these data or information are based on the core data, digital maps with added information (traffic signals, traffic regulating signs, etc.). Therefore transportation information system is not included as a core sub-system. Integration of these core data can help efficient city administration. For example, for public safety one can use comprehensive data about roads, properties and hazards to produce dispatch system; for land planning one can use spatial extent of allowable land uses, soil property, and topographic information to produce land zoning maps.

3.2 Surveying and mapping management system

3.2.1 Databases

Geographic information DB includes several components (or sub-DBs). They are geodetic control stations (horizontal and vertical; coordinate systems and their transformation parameters), digital maps at various scales, zoning (administrative regions), place names, images, and etc.

DB of registered surveyors and survey companies contains the information on all the survey companies registered in a city and registered surveyors. The information for each registered survey company should include its office address, the class of qualification (A, B or C), list of the survey equipment and facilities, list of the staff with their qualifications and experience, and major accomplishments (awards, major projects completed, etc.).

DB of survey projects contains the information on the basic surveying projects (like geodetic surveys, basic topographic surveys) and special surveying projects (like engineering projects, the projects with special requirements). The information should include the project duration, location, nature, scope, and the quality of final products as well as the undertaking survey company.

DB of surveying and mapping files contains all the surveying and mapping regulations, specifications, and standards; list of all survey products and maps. The DB should be assessable to outsiders in order to avoid any duplicated work.

3.2.2 Management systems

MS of surveying and mapping products is a major management system. It accesses geographic information DB and should be able to perform the following main functions:

- datum and coordinate transformation;
- extraction of geographic information or digital maps for a particular need (e.g., transportation network, hydrology system etc);
- generation of DTM; and
- image overlaying..

MS of surveying and mapping projects mainly functions the planning of basic surveying and mapping projects, monitoring the implementation of planned project, publishing the project for tendering, and quality assessment.

Legal monitoring system is a system for any legal actions. The qualification of survey companies, quality of survey products, survey market, and map market need monitoring; and survey monuments and targets need protecting. Any conflicts and illegal activities should be settled by the authorities concerned. All these actions and information will be recorded in the system. The system is an automatic process and open to relevant parties for their information and decision making.

MS of surveying and mapping files functions rapid entry, management, inquiry and output of survey files and makes them available to relevant parties and the public. It can enhance the service capability of survey products to community. It uses the information in various DBs.

MS of registered surveyors and survey companies allows a company to register or to make any changes in its particulars through internet access, and allows the authorities concerned to check the changes or to approve the applications.

3.3 Land management system

3.3.1 Databases

Land use database contains the spatial data of land, i.e., geometric information (point, line or polygon) and images, and their attributes, including zoning information (e.g., boundary of a district or a county), ownership (state-owned or collective-owned), use right, and classification of land use types. Land use is classified into 3 levels based on the Land Classification Guidelines by Ministry of Lands and Resources. The first level has 3 types of land: agricultural land, developed land or construction-use land, and unused land; each land type of land at the first level (e.g., agricultural land) has several sub-types of land at its second level (e.g., forestry, cultivated land, etc.); and so on. Land type is also classified into 9 classes based on terrain slope, i.e. flat land if surface slope smaller <0.035; 4 slope land types at different slope rates; and 4 terrace land types on different slope rates.

Land use planning database contains the information on future land use, which is compiled according to national, provincial and local plans for a particular period of time. The current plan is for a 5-year period 1996-2010 and the next two periods are 10 years each, from 2011to 2020 and from 2021 to 2030.

Primary cultivated land database contains important information. With rapid urbanization and economic developments more and more cultivated land has been converted to construction-use land, generating a great threat for the food supply to the increasing population of China. The central government have paid particular attention to this kind of conversion and issued a number of policy papers to protect cultivated land, in particular primary and good quality land. This database should contain the related documents for cultivated land protection, quality assessment criteria of cultivated land, and the information on primary cultivated land (location, types, right of use etc.).

New construction-use land database includes mainly the information on users who request for new construction-use land, means to acquiring, i.e., direct allocation (normally for public purposes, like schools and hospitals) or through land auction (normally for commercial purposes, like residential buildings), the original ownership/use right of the land, area, land type, location, price, period of use right, and approving authorities, etc..

Land provision database records all the information related to the released land, including its location, area, land type, etc.

DB of land development planning contains the plans for land development and consolidation, and related information and documents.

DB of land development projects contains all the information on land development and consolidation project: the investors, project location, area, project duration (starting and ending date), cost, and final outputs.

DB of agricultural land classification contains the quality of each lot of agricultural land according to the nationwide common classification standards. This information is used for land consolidation, protection of agricultural land, assessment of land, and compensation for converted cultivated land. To maintain enough agricultural land there is a policy, called the compensation for converted cultivated land. This means that an organization or a company if occupying a piece of cultivated land for construction-use purpose has a responsibility to create a piece of new cultivated land with similar area as compensation.

DB of the implementation of land law and regulations contains all the process and information used in monitoring and execution of those land users, who do not follow the laws and regulations.

DB of remote sensing images, which is used for monitoring land use and land-use changes. Remotely-sensed satellite images are used more and more for monitoring land use, land-use changes and land degradation. There are images at different spatial and temporal resolutions. This kind of data is needed more and more and volume of the data will become huge.

DB of land base price includes the base price for urban developed land and for agricultural land. This information is important for rational land development, regulating land market, and enhancing the transparency of land management. It is a basis for the government to control land market, tax land, manage land consolidation, and compensate for the occupation of land.

DB of land policies contains all the policy papers, laws and regulations related to land use.

3.3.2 Management systems

Management system (MS) for land use planning is a major MS for land management. It uses the information in the various DBs to produce land use maps, analyze land use pattern, and evaluate capability and potential productivity of land. Based on the policies governing land use and the above information generated, the system produces land use planning maps, plan for the protection of primary cultivated land, and plan for land development.

MS for granting construction-use land uses the information on land use, land use planning, annual plan for land conversion to assess the requests for new construction-use land and approve them if appropriate. The system should provide an on-line process from the acceptance of an application, checking the completeness of the needed information in the application, approving the application, finally to fee collection. The system also links via internet all the governmental departments/offices involved in the process, namely cadastre, lands, and planning.

MS for land development and consolidation manages the whole process of land development and consolidation, from approving of the plan, project formulation, operation, to final evaluation.

MS for land policy execution manages the whole process of monitoring, enforcing and executing the implementation of land laws, regulations and policies.

MS for land market should have two main functions: management of land market and land trading. The system uses the information in DB of land market and DB of land base price to support land marketing.

MS for the files on lands functions data entry, categorization, inquiry, statistics, and browse. It supports several government actions, like approving land use, protecting cultivated land.

Supporting system for cultivated land protection provides statistical analysis, data mining and prediction modeling for land use and land use changes, land use planning, protection of cultivated land, and land development.

3.4 Cadastre and real estate management system

3.4.1 Database

DB for cadastre management includes two types of data: spatial data and non-spatial data. The former records the sizes and locations of all land parcels. In modern cadastre system the coordinates of the boundary of each parcel are determined with survey techniques. The area and location of each land parcel can be easily derived from the boundary coordinates. The latter records land tenure, land use and its historical transaction. Also any restriction on the use of a land parcel should be included.

DB of land base price is useful for taxation cadastre and can be obtained from the above (refer to section 3.3.1). This information is becoming importance for transparency in land auctioning.

DB for laws and regulations, which governing land use, can be obtained from the above (refer to section 3.3.1).

DB for real estate management includes the information for each estate and for each flat in the building. For each estate there are two types of information: spatial data and non-spatial data. The spatial data include its location, facilities (such as swimming pool, gardens, and club), and building height; while the non-spatial data include information on developer, construction companies, construction history from land acquisition to the completion of the project. For each flat the DB should have its geometry, area (both construction area and usable area), usage and ownership.

DB for market value of each flat should be included, which will be used for taxation of real estate, although China has not yet implemented it. But it is important to control and monitor real estate market. Recently, with a rapid rise in the price of a property, the Chinese government is considering levying property tax as a measure to regulate the market. The market value of real estate changes with time and therefore the DB should be updated more frequently.

DB for housing policies and regulations should include the approval papers for the development of a real estate and all the regulations governing real estate industry and market. This information will be used for monitoring and regulating real estate industry.

3.4.2 Management system

MS for cadastre should have following functionalities: spatial, temporal, and spatiotemporal queries, statistics, analysis, and registration and change of users. The system provides the information not only for the management by the government at different levels, but also for supporting the solution for any conflict in the ownership of a land parcel.

MS for real estate should have two sub-systems: one for an estate, and the other for housing. When the estate is completed the estate sub-system provides not only the historical information, but minor change in the estate. The sub-system for housing should have following functions: registration, change of ownership, query, and statistics.

MS for market monitoring is to tax the change in ownership based on market value assessment and related regulations, like stamp duty, taxation of value-added.

3.5 Underground utility system

3.5.1 Databases

DB of underground utility spatial information There are many types of underground utilities, such as water supply system, drainage system, gas pipes, electricity cables, communication cables, heating pipes, and industrial pipes. Each type of utility can be stored on one layer or a separate system. Mainland China currently classifies underground utilities into 7 types (Li and

Chen, 2008): electricity, communication, water supply, sewage, gas, heating, and industrial systems. A 4-digit coding system (i.e., xxxx) is used. The first digit represents the type (category) of pipe (1-7 corresponding the above 7 types); the second digit is for sub-category of each type (take communication as an example, 0 for ordinary communication cable; 1 for broadcast cable; 2 for military cable; 3 for security cable; and 4 for associated facilities); the last two digits distinguish pipe points and types of facilities. For the detail refer to "technical specification for detecting and surveying underground pipelines and cables in city" (MOC, 2003). This DB should include 3 sub-systems: spatial information of underground utilities (e.g., the 3D coordinates of each pipeline, the position of each facility); graphic information; and topological information (topological relation among pipelines, between a point and a pipeline, etc.).

DB of underground utility attributes information should include two sub-systems: one for pipeline and the other for points of pipeline. The basic elements of an underground pipeline include points of pipeline and sections of a pipeline. The former means pipeline facilities, connecting points or points where the direction of pipeline changes, and points where the diameter of pipe changes. The latter means the pipe connecting the same type of pipeline points. The attribute information includes their characteristics: like materials, diameters, and any others.

DB of digital map includes topography and surface buildings and infrastructures. This is the same as that in section 3.2.1 and can be obtained from surveying and mapping management system (geographic information). This information is of importance in the management of underground utilities by relating them to surface features.

DB of cadastre includes the data on land and surface infrastructure ownership. This is the same as that in section 3.4.1 DB for cadastre management and can be obtained from cadastre and real estate management system. The information is needed for the operation (like digging, construction), maintenance, planning and design of new underground utilities.

DB of housing is the same as that in section 3.4.1 and can be obtained from cadastre and real estate system. It is needed for decision making analysis related to any emergency response.

3.5.2 Management system

The management system of underground utility should have the following basic modules or sub-system:

(1) Data entry: input spatial data and attribute data into the DBs from various data sources, like field survey data, existing data in other systems, paper maps, and other sources. For the existing data in other systems managed by different platforms, data format transformation must be done before input to the DBs.

(2) Data editing: edit graphic information and attribute data under a GIS environment.

(3) Data integrity checking: perform various checks to ensure data consistency and integrity. The checks include numbering of points and lines, feature points, the attributes of a pipeline, the depth and floor elevation of a drainage system, crossing and topologic relations of pipe networks, and etc.

(4) Inquiry: perform various inquiries, including conditional inquiry (also called structured query language SQL inquiry). Inquiry should be performed in two directions: from attributes to graphs and from graphs to attributes.

(5) Statistical analysis: provide the statistics data for a number of interests. Typical data required are: the length of a pipeline or a type of pipe for a given condition; the total feature points of a pipeline or a type of pipe; all the utility information in a given region; and conditional statistics (or called SQL statistics)

(6) Decision-making analysis: this is important function group, includes

- Sectioning which provides the information on the geometric relations among various types of pipes. The geometric information includes the depth of each pipe and horizontal intervals among them.
- Profiling, which provides the information on the relation between a pipeline with surface features
- Clearance analysis, which provides the vertical separation between two pipelines at their closing point
- Depth checking, which provides the depth of a pipeline against the value specified in its design documents.

- Action plan for emergency response to leakage: upon finding of leakage place for any kinds of pressured pipe (like water supply, gas, etc), the system analyzes the affected area and then select the manholes, which should be closed
- Action plan for fire: upon knowing the place of fire, the system determines the locations of nearest waterhole to be used for fire fighting
- 3D analysis, which displays the 3D information of the utilities in a selected area, and analyzes their geometric information among various pipelines in the area. This function is needed for the design of new utilities.
- Analysis for construction operation. When a road or an area need reconstructing the information on the affected utilities needs to be provided for the design of relevant operations.

3.6 Mineral resource management system

3.6.1 Databases

DB for mineral resource planning consists of multi-source and multi-epoch spatial data and their attributes, namely the texts, figures and relevant attributes, and planning indicators in the plans for different periods. Textual documents include the master plans, the reports on special resource planning, and the report on environment assessment. The figure and attributes include the distribution of mineral resources, plan for mineral exploration and protection, the current situation of resource exploration, investigation of resources and prospecting plan. The planning indicators include the current situation, exploration and protection of resources.

DB for mineral deposits contains the registered deposits of various mineral resources based on geological surveys, and the spatial data and attributes of resources.

DB for mining rights contains two sub-databases: database for mining right and database for prospecting right. The former includes the information on application, change, extension, cessation and fee of mining right. The latter includes the information similar to the former, but regarding to the right for mineral resource prospecting.

DB of mining area contains spatial data and attributes of a mine, including its geographic and geological information, ore characteristics, deposit, exploitation, and years of mining.

DB of geological information contains geological data and relevant plots.

3.6.2 Management system

MS for mineral resource planning should have the following functions: compiling and checking a plan, managing the implementation and the outcomes of the plan. To function as the above it needs the data/information on the mineral resources, geological setting, land use, economic development, and planning criteria in the area.

MS for mineral deposit performs the functions of deposit registration, inquiry, and statistics by employing techniques of GIS, computing and DB.

MS for mining rights is to manage the rights of prospecting and mining.

Chapter 4

Development of an Institutional Framework for a LIMS

Institutional framework for a LIMS is also called the soft infrastructure (policies, organization, management arrangement, and funding). In Chapter 1, the desirable characteristics of an effective city-wide LIMS, which were derived from the good practices worldwide, were discussed. We here summarize the main points as an introduction to this chapter. The main desirable characteristics of a LIMS and our approaches are as below.

(1) Provision of necessary core data to support the management of a city and any decision-making related to geospatial solution. This is addressed in Chapter 3 by designing a LIMS based on China environment. However, maintenance of these core data is a key issue, and should be discussed in this chapter;

(2) There should be one source for each piece of core data, which should be known and communicated to everyone who might want to use those data. Repetition of core data across systems should be forbidden. This suggests databases designed in chapter 3 can be distributed databases. However, duplication of data collection is a phenomenon everywhere in China. This involves institutional issue and some management issues which should be focused on in this chapter. Data sharing is a main issue in building spatial information systems in China and is complex. In addition to what discussed in this chapter, chapter 5 will addresses a technical problem – data conversion between different GIS.

(3) Common data definition/standards should be adopted and enforced. This has been mentioned in Chapter 3 system design where common standards are used in the design. China has state GIS standards, developed by State Bureau of Surveying and Mapping, similar to ISO-TC211, and also various regulations and guidelines issued by different ministries of the central government, like ministry of construction and housing, ministry of lands and resources, and etc. For designers and developers of geospatial information systems, the question is not

whether standards should be adopted, the challenge is to choose suitable standards and sensible approach for their implementation, to facilitate sharing of information and to make systems easier to support and maintain. This will also be discussed in this chapter.

(4) The custodians for core data should be clearly identified. It should be their responsibilities to collect and manage the core data assigned to their custodianship. This issue will be discussed in this chapter as one of institutional and management issues – partnership and responsibility.

This chapter contributes to the policies and institutional arrangements, which are to facilitate the availability of and access to spatial information. There are 6 sections in this chapter. The first section contributes to the development of a LIMS vision, followed by the second section governance and coordination. Section 3 is devoted to partnership and responsibility. Section 4 addresses data management policies, i.e., data standards and quality. Section 5 discusses the funding model for a LIMS. The last section is about the evaluation framework for a LIMS.

4.1 Development of a LIMS vision

Over the last two decades, governments at various levels and industries in China have invested a lot of money in the development of some kinds of geospatial information systems, which were designed mainly to serve specific communities (like forestry, urban planning, land record management, business, geographic, etc.) within a local or its respective community structure. Many of them just followed the wave of the so called digital China, digital city or e-government without any community vision. Therefore many systems have not been fully utilized, and their information is not current due to poor maintenance. Nowadays the focus on geospatial information systems is increasingly shifting to the challenges associated with integrating these systems, building what has come to be called geospatial data infrastructure. Such infrastructures have been described as information highways, linking environmental, socio-economic and institutional databases ("horizontal highways"), and providing for the flow of information from local to provincial levels and eventually to the national level ("vertical highways") (Coleman and McLaughlin, 1997).

Based on the current developments in the area of geospatial information systems in China and the world good practices, as summarized above and discussed in detail in Chapter 1, we propose that *the vision to build the LIMS for a city is to develop an infrastructure that allows geospatial data to be available and accessible to authorized public, government departments and* *individuals and promote proper use of integrated geospatial data for effective decision-making process, and development of information economy and spatially enabled society.* This vision involves several key words: core geospatial data, availability and accessibility, infrastructure, spatially enabled society and information economy.

Regarding *core geospatial data*, they include fundamental data (e.g., digital topographic maps), cadastre and real estate information, land use and planning data, mineral resources, and underground utilities. The common barriers confronting the development of a LIMS in China are on the process of maintenance. First, many city administrations followed the tide of automation and e-government, applied a budget for the creation of digital map data converting from paper maps, soon saw the increased user requirements and hence faced imminent requests for updating. In the views of officials at the mayor level, fair and just, a huge budget was just given out for the digital mapping project and no sooner it is reported that another budget for updating is required. It is always neglected that when the mapping data was first converted a lot of the data might not be able to reflect rapidly changing paces of the city. In a busy city like Hong Kong, there are in average 2000 spots of construction every day. Guangzhou Department of Planning has proposed an updating plan of the so called "1, 2, 3, and 5-year scheme", i.e., different updating intervals for different areas of the city (refer to Chapter 2). There must be a systematic and efficient updating mechanism to support a valid city LIMS. This is a budget as well as a planning problem. A LIMS which have been built without a detailed consideration on the continuous updating mechanism will soon become obsolete. In the past decade the most obvious change in developed counties in LIMS was from "Design and Build" to "Sustain and Maintain" (Dale, 2007). What has changed there has been the focus on customers' services and a greater awareness of the need for public accountability. Land information systems (LIS) have turned to land information services (LIS), administered not out of altruism but for the tangible benefit of the economy. I am sure Chinese governments at various levels will soon recognize this trend of change. To better serve the people the data must be current and reliable.

Another maintenance problem is seen from the rapid advancement of technology. Certain trends are clear. Computerization will continue, resulting in the regular replacement of technology that is currently "state of the arts". Every four years or so both hardware and software will need to be replaced (Dale, 2007). The multiplied cost of software and hardware renewal, the cost of technical personnel training and the increasing demand on data accuracy and integrity pose heavy burden on proper maintenance. Yet, these pressures should have been envisaged in the planning stage.

Regarding *infrastructure* it includes hard infrastructure (like hardware, software, and data communication network) and soft infrastructure, which is policies, institutional structure and organization arrangement, and funding. To make data available and accessible to users the policy on data sharing, availability to different kinds of users and data pricing should be developed. To this end a powerful committee and related legal aspects must be established. This in particular important in China, for China is in its primary development stage and still under a transition from so called the "person governing" society to "legal governing" society. The governments still see their roles as governing rather than servicing.

Regarding the *promotion of data applications*, several factors affect wide application of spatial data, like pricing and benefits, copyright protection and ownership, and issue of national security of geospatial data. They are mainly policy issues. Big issue in China in a LIMS is data sharing. This is completely unresolved so that the repeated efforts are common everywhere, like two organizations map the same city, two geoid models established for the same region; two sets of GPS permanent stations in a city, etc. The most serious is that these phenomena have been "recognized" (theoretically not, but practically yes) by central government departments. Take a mega city as an example. Two sets of GPS Continuous Tracking Reference Systems (CORS) established by two municipal departments were assessed as reaching the national advanced level by a similar group of scholars/scientists and got government awards at national level. Currently data sharing is very limited due to not only culture but several factors like copy right (frequently the shared data are copied for other uses), pricing (not regulations governing the cost recovery and benefit), data security, in particular, digital maps are classified in China, which significantly affect public access to the data. Proper solution to these can significantly enhance the application of spatial data.

Spatially enabled government/society is a new concept. The aim to develop spatially enabled governments was a key outcome of the 17th United Nations Cartographic Conference for Asia and the Pacific and the 12th meeting of the UN-supported Permanent Committee for GIS infrastructure for Asia and the Pacific (PCGIAP) in September 2006. These movements promoted Working Group 3 (formerly cadastre) of the PCGIAP to refocus its activities on spatially enabled government as part of developing national spatial data infrastructure

(Rajabifard, 2007). A society or a government can be regarded as spatially enabled when spatial information is regarded as common goods made available to citizens and businesses to encourage creativity and product development. According to the results of a survey on spatial enablement of Australian government conducted by Geoscience Australia in 2007, the vision for spatial enablement leads to improved decision making; reduction of administrative costs; and enhanced industry development opportunities. However, this requires data and services to be accessible and accurate, well-maintained and sufficiently reliable for use by the majority of a society which is not spatially aware. As we can see from the above statement, development of a spatially enabled society should be the goal of a LIMS.

4.2 Governance and coordination

Sharing of information is a key for a LIMS. According to SDI Cookbook (Nebert, 2004), a spatial data infrastructure is defined as the technology, policies and people necessary to promote sharing for geospatial data through all levels of government, private and non-profit sectors, and the academic community". Currently, the data/information discussed in Chapter 3 is in different organizations, though not complete, and each organization has its own program areas, which make co-ordination of an overall program problematic. One of the foremost and key hurdles is resolving the question of data ownership. The need to have a consistent product maintained by common standards and specifications requires the product to be manipulated and maintained under central control. This requires a strong governance structure.

Based on overseas experiences (refer to Chapter 2) and China environments we propose the following management structure.

(1) Establishment of a coordinating council (or governing committee) – the council should have enough authority to determine the policies and affect all the parties concerned (refer to Chapter 2, Section 2.2.1: Singapore and Section 2.2.3: North Carolina). The council chairman should be a deputy Mayor of a city and the council members should include all the heads of those departments who use or collect spatial data. According to China political and administrative structure each city has several deputy/vice mayors and each is responsible for a certain areas, i.e., overseeing a number of departments. My surveys tell that a deputy mayor sometimes may not have enough authority to some departments which are under the administration of other deputy mayors. Also the deputy mayors may change from time to time. All these weaken the authority of this council. We therefore further

propose that this council and its chairmanship should be legally powered by the Municipal People Congress (refer to Chapter 2, Section 2.2.3: North Carolina). At its annual meeting, the progress in the LIMS should be reported and annual budget should be set aside (refer to Section 4.5 – funding model). The main functions of this council are to determine data policies on standards, quality, ownership, and sharing; approve the funding related to geo-spatial data collection and systems; and approve the plan for the implementation of a LIMS. The first function should be clear, for common data standards and data sharing is a must to achieve the vision. But more deliberations should be given for other two. Some departments or their district branches may have money to spend and therefore wish to establish their systems with less coordination among different branches and with their administrative authority, like Guangzhou Department of Lands, which leads to inconsistent systems and may cause unnecessary duplications. Therefore government funding of projects related to spatial data system must be approved by the council independent of source of funding. The last function arises from the recent surveys of system development. Each department applies funding on annual base and funding level received varies and may not be the required amount depending on government financial situation. It is therefore important to have a detail plan for system development to ensure system consistency and complete, rather than piece by piece.

(2) Set up council secretariat (or management committee). A LIMS typically involves many government departments. Take Guangzhou as an example, users mainly include

- Municipal Administration Bureau
- Planning Bureau
- Water Supply and Drainage Bureau
- Fire Bureau
- Public Security Bureau
- Pricing Bureau
- Forestry Bureau
- Agriculture Bureau
- Public Health Bureau
- Transportation Bureau
- Harbor and Waterway Bureau
- Industry and Commerce Administration Bureau
- Product Quality Monitoring Bureau

- Lands, Resources and Housing Bureau
- Power and Light Cooperation
- Communication Cooperation
- Construction Bureau
- Development and Reform Commission
- Governments of Districts

Among all these government users, some are not only data users, but also data providers. These departments are: Bureau of Planning, Bureau of Lands, Resources and Housing, Bureau of Water Supply and Drainage, Bureau of Transportation, Bureau of Harbor and Waterway, Power and Light Cooperation, and Communication Cooperation. Having analyzed the nationwide municipal administrative structure, we found Department of Planning and Department of Lands and Resources (some cities include Housing) are two main data providers. The former provides topographic data (digital maps), which are the fundamental for all the users. The latter produces and manages the land related data (e.g., land use, land planning, mineral resources and cadastre). Since the system is land information management system, we therefore prefer the council secretariat be located in Department of Lands and Resources. In this arrangement a deputy head of Department of Lands and Resources should serve as council secretary and operation manager of project LIMS.

(3) Under the secretariat there are several working groups (WG) or technical committees. Their main responsibility is to manage their tasks (technical issues, operation issue, and policy related issues) and provide proposals to the council for consideration and approval. Upon council approval of an issue, it becomes regulations and should be followed by all the parties concerned. Technical issues include data quality, data contents, data standards, data communication techniques and network, system platforms and data exchange format and techniques to ensure data consistence among different systems. Operation issues are for instance funding of the secretariat and its staff, and any major day-to-day operation problems which need the council attention or solution. Policy issues include data sharing policy, data access policy, data security policy, data updating policy, data ownership, funding model, commercialization of public information, privacy and protection of personal data, liability of data provision, and etc.

(4) Set up a user group committee. In addition to the users mentioned above (i.e., public sector users) there are other industrial and commercial user groups. They will use geospatial data

for many new initiatives. Location-based service (LBS) is a new development in the application of geospatial data for personal activities and has huge market. Most of LBS developers are commercial and private companies and will be large user group in near future. Therefore the user group committee should include not only government departments, state-owned companies, social organizations, but also private commercial companies. We suggest this user group committee should be open to everyone who is interested in geospatial information. This committee is an important for the development of an efficient LIMS. They provide the feedback on the existing system and suggest its further improvements.

4.3 Partnership and responsibility

A LIMS involves several key databases (see Chapter 3), which may be established by various government departments. Originally different database is used to support the managements of a department. It is a wise approach that a LIMS should be distributed systems rather than a centralized system. Each department is responsible for some sub-systems based on its current functions, including the system building and maintenance. For instance, Department of Planning is responsible for topographic database (digital maps, images, etc.); Department of Lands, Resources and Housing is responsible for cadastre data, real estate data, land use and planning data, and mineral resource data; Department of Construction is responsible for underground utilities (some cities underground utilities are under responsibility of Department of Planning); Department of Transportation is responsible for transportation facility data on land; while Department of Waterway is responsible for transportation facility data in water body; and Power and Light Cooperation and Communication Cooperation are responsible for their data. Various sources of information are collected and maintained by different organizations. To achieve a successful LIMS, sound partnership (i.e., good coordination among and within all relevant responsible sectors) is essential. Partnership should be dynamic, reflecting the dynamic relationship among LIMS components. In China the government administrative structure changes from time to time during the whole course of reform. Take city of Shenzhen as an example, lands and housing were two separate departments a few years ago, they were merged into a same department till recently the government structural reformation; lands and planning were in the same department a few years ago, and they were then two separate departments till recently reformation – merging several departments into a commission. Sound partnerships facilitate the data exchange and sharing, therefore reducing effort and production cost. Partnerships can be assessed using a 'good governance principals' based tool (Magel and Franke, 2007) as follows.

(1) In terms of direction/strategic vision:

- All parties share the vision as defined in section 4.1. The first step in building a LIMS is to define the partnership – how many institutions should be in the partnership. This varies from city to city. Those who collect geospatial related information, and land, resources, facility/utility related information, and those who use those information for their managements should be in the partnership;
- Each party to the partnership sees how their organization can contribute to the vision. It is of particular importance at outset that each party at a joint meeting expresses their potential contributions in the area of data collection, modeling and updating, data sharing, system construction and maintenance, funding commitment, and etc. The meeting coordinates the potential contributions of each party and then defines the roles and responsibilities for each party;
- Roles and responsibilities are clearly defined. These are formulated at the above-mentioned meeting and approved by the council. As mentioned in section 4.1, over the last decade the most obvious change in LIMS has been from "design and build" to "sustain and maintain". Design and build a LIMS with one-off financial support from a government department is easier, but sustain and maintain the system by continuously updating is not an easy task. Certain trends should be made clear to all parties involved. As mentioned in 4.1, computerization will continue, resulting in the regular replacement of the "state of art" technology, requiring enough resources to be able to afford to do so; and
- The parties have adequately adjusted to any changes to the vision that have occurred over time, and to any changes in the organization structure. In China organization structure changes from time to time. This makes partnership difficult. A good partnership should be formulated in such a way that any changes in organization structure will not affect the functions of the system and sub-systems.

(2) In terms of performance:

- There is a clear idea among participants as to what constitutes success. A successful LIMS is characterized by state of art hard infrastructure in place, a powerful coordinating council, sound institutional arrangement, up-to-date core data following national and international standards, good data policies developed to share data, to make data available to users, and to promote information economy;
- Performance is monitored and reported. The framework for performance measurement and reporting is developed jointly. However, there are no accepted frameworks and methodologies to compare and evaluate a LIMS. Part of the difficulty is that LIMSs are in constant reform and more importantly, they have strong social and culture links. But it needs developing, for comparison and assessment is important for leaning and for identifying strength and weakness. This will be further discussed in Section 4.6;
- There are sufficient resources to build and maintain the partnership; and
- The different context in which the parties work is understood and accepted. Each party has its own business model and internal management data/information. The partnerships will not affect or interference their internal matters. Data sharing only refers to those data useful to other parties.

(3) In terms of accountability:

- The accountabilities of all the parties are clear. Some parties are information/data providers. They should follow the agreed common standards (data format and quality) to collect and update data. Some parties are data users and they must follow an agreed funding model and data security policy;
- There is an open, transparent and accountable relationship between the parties;
- The accountability relationship of the parties to their respective organizations is recognized and respected; and
- The effectiveness of the partnership is reported publically. This should be reviewed annually.

(4) In terms of fairness:

- All parties believe they receive sufficient values from the partnership. The benefits should be defined at the outset;
- The clients of the parties, and the public more broadly, benefit from the partnership; and

- The laws which govern each party are recognized and respected. In China each party may belong to different organizations, like Bureau of Planning and Bureau of Lands and Resources, though under the same municipal administration, follow the technically guidelines of different central governmental administrations: the former follows Ministry of Construction and Housing, the latter follows the Ministry of Lands and Resources. The policies and visions and partnership relations of a LIMS should be well communicated to their heads and their internal policies and regulations should be respected unless these are against the agreed vision.

4.4 Data management policies

Data management policies deal with the data standards and data quality. As pointed out by Nebert et al. (2007), an SDI may be defined in broad social terms as a framework for collaboration. To facilitate good and efficient collaboration institutional and culture issues as well as technical issues need solving. The former has been discussed in section 4.2 governance and coordination, and section 4.3 partnerships and responsibility, and the latter will be discussed in this section. Also some technical issues to facilitate data exchange will be addressed in Chapter 5. The technical framework of an SDI enables interoperability for the access and exchange of geospatial resources (Nebert et al. 2007). Interoperability of geospatial information or integration of spatial databases is one of the key issues in the development of a LIMS. The problem is that, as mentioned in Chapter 2, most current SDI activities operate as independent application "silos" with little interoperability between them. Each activity develops its own best practices with regard to what standards are used, what version of a given standard is used, and so forth. The result is that, while given a SDI may be interoperable within its own community/institutions; it might not interoperate with its internet neighbors. The obvious reasons are that various organizations produce their data in different systems, with different accuracy and standards, which would lead to the problems of integrating databases. Within a LIMS the policies and standards will be implemented so as to foster the integration of various data sources.

The standardization of the information and data is critical for the construction of a LIMS, which can ensure integration of various data sources. Application of a common set of standards may reduce life cycle costs, enhance interoperability, decrease implementation risk, and improve services. Many efforts and developments have been made internationally. Geospatial standards are primarily developed by the International Organization for Standardization (ISO) Technical Committee 211 (TC 211) and Open Geospatial Consortium (OGC) and are often dependent on other industry standards, such as those of the World Wide Web Consortium (W3C) and OASIS, which develop e-business standards. International Cartography Association (ICA) has a special committee for data standards (refer to www.nol.sbs.ohio-state.edu/ica/home.html#/). In China State Bureau of Surveying and Mapping, Ministry of Lands and Resources, Ministry of Information Technology, and several other government agencies and organizations have developed relevant standards. The national standards normally align with international standards, for China is a member of ISO TC-211 committee and ICA Data Standard Committee. But we should identify if there are any discrepancies between the international standards and national/regional/local standards. If this happens, the technical committee should make recommendations and get approval from the coordinating council regarding which set of standards should be used.

There are many standards which directly or indirectly support the deployment of geospatial solutions, including various standards in information technology. The selection of appropriate standards can be daunting. In addition, standards will change version numbers on a regular basic, but there are rarely coordinated with changes in other standards. Identification of a specific set of standards and their version numbers is of great benefit to implementers and adopters. Adapting to frequent changes in standards is expensive and prone to issues of incompatibility. Adaptation of a core suite of standards must consider the following criteria.

(1) Evidence of implementation. Nowadays, many Chinese software developers (universities, research institutes, and companies) claimed they produce various digital city software packages. The standards they used may not be consistent with international or national standards, and must be carefully assessed. Commercial and noncommercial software solutions and documentation are useful matrices in identifying mature standards. For instance the OGC (Open Geographic Committee) lists providers which have implemented OGC standards.

(2) Dependencies. Standards rarely are stand-along and frequently have implicit and explicit dependencies on other standards. The latest version of a standard is not necessarily the one which will work well with a selected set of other standards. Successful application of standards must clearly define the type, context, and version of related standards and their

usage. Dependency on other immature standards or as widely adopted may cause the problem of interoperability.

(3) Stability and conformance. The implementation of technical standards to ensure interoperability requires that the standards have some means of being assessed or tested for conformance or compliance.

(4) Core or supplemental status. Whereas several geospatial standards appear to be common, a number of other standards may be optional. The core standards should be viewed as the most widely implemented standards which provide baseline functionality in an SDI. Supplemental standards may not be required for SDI implementation.

Standards of importance to geospatial information users range from the detail of computer hardware and networks to the design of databases and map products. They can be summarized as follows.

- Hardware and physical connection standards, which address important concerns relating to the basic architecture, physical connection, and cabling of hardware devices;
- Communication and network management standards, which address the provision of the physical infrastructure for sharing information;
- Operating system software standards. This includes selection of operating system, adaptation of sound standards and procedures for system and network administration, and standards to allow geospatial objects (like a map feature with its associated attributes and rules guiding its interaction with an application) to be exchanged between computer systems and to be used by multiple software packages;
- Data format, exchange and access, which covers the logical and physical structure of geospatial data and capabilities for access and exchange of geospatial data among multiple computer platforms and applications;
- Application development standards, which allow for the customization of applications;
- User design standards include the standards for databases schemas, geospatial metadata, map compilation and map accuracy, and map presentation.

The standardization of a LIMS must be based on existing international standards and national standards and regulations on information collection, data quality management, and data bases. If no standards and regulations at state level to be followed, the technical committee should develop them by itself and get approval from the coordinating council before implementation. In the development international standards should be referred as much as possible. It is recommended that the technical committee prepares a document on the geospatial data standards to be used in its LIMS at outset to guide its LIMS implementation. The following is the proposed standards, some of which are already in place (at state level), but some needs further development.

(1) Basic set of standards, where E stands for existing standards at state level (issued by a corresponding ministerial administration)
  - Guide for the standardization of lands and resources information (E);
  - Standards for core elements of lands and resources information (E);
  - Standard reference models for lands and resources information (E);
  - Data models for lands information (E);
  - Metadata for lands information (E);
  - Standard reference models for lands information (E);
  - Guidelines for coding lands information (E);
  - Standardized terminologies for lands and resources information;
  - Rules for specialized standards for lands and resources information;
  - Classification and coding of lands information;
  - Legends for lands information.

(2) The standards for data acquisition
  - Standards and specifications for digitalization of geological information (E);
  - Rules for storing and processing of lands information (E);
  - Specifications for cadastre surveys (E).

(3) Data quality management
  - Quality control (QC) rules for the acquisition of lands information (E);
  - QC rules of the data for building land use database and land planning database.

(4) Standards for various databases
  - Urban cadastre database (E)

- Specifications for building urban cadastre system;
- Land-use planning database at county/town level (E);
- Land use database at county/town level (E);
- Technical specification for building land use database at county/town level (E);
- Mineral resource exploration planning database (E);
- Mineral deposit database (E);
- Database for dynamic monitoring of land use with remote sensing;
- Land classification and evaluation databases;
- Database for land related files;
- Land development project database;
- Land development plan database;
- Developed land database;
- Basic cultivated land database;
- Land pricing database

(5) Standards for data exchange

- Regulations for the classification and coding, and file naming of lands and resources information (E);
- Operational specifications for lands information sharing (E);
- Standards for lands and resources data exchange (E);
- Regulations for land information sharing;
- Specifications for the data submission from land surveys.

(6) Regulations for system building

- Guidelines for building of land use and planning management systems at county/town level (E);
- Guidelines for designing E-government system (E);
- Specifications for national LIMS network (E);
- Specifications for design of a LIMS (E);
- Specification for evaluation of a LIMS;
- Specification for monitoring of land use with remote sensing

(7) For information services

- Specifications for lands information services;
- Catalogue and fee schedule for products/services;
- Procedures for responding to and tracking requests;
- Map symbology standards (E);
- Map design and layout standards (E).

(8) For system security

- Rules for security management of a LIMS (E).

(9) Hardware and network standards

- Computer operating system standards;
- Computer hardware standards and specification;
- Physical network and protocol standards;
- Network interface requirements.

(10) System administration standards

- File and directory naming standards;
- System access and security.

(11) Software and application standards

- Application development standards;
- Application design and documentation standards.

The fundamental components of a LIMS are data related activities: production of data, use of data, and technological and institutional environment for data access and application Data are the most expensive resources in a LIMS. Therefore data quality/integrity is the single and most important concept in LIMS quality management (Doucette and Paresi, 2003). The data quality is usually defined by factors such as data lineage, consistency, completeness, semantic accuracy, temporal accuracy, positional accuracy, and attributes accuracy.

- Lineage includes information such as descriptions of source data, method of derivation, and data transformation and also dates for all relevant activities;
- Consistency describes the fidelity of relationships in a data set, like topological relation in networks and polygons;

- Completeness of data set is usually defined as including information about the selection criteria, definitions used and other relevant mapping rules. Completeness measures of quality must typically be made against some standard or data set of higher accuracy, i.e., this data set is complete when compared to a data set of equal or higher accuracy;
- Semantic accuracy refers to the quality with which spatial objects are described according to a selected model. It describes the number of features, relationships or attributes that have been correctly encoded in accordance with a set of feature representation rules.
- Temporal information describes the date of observation, type of update, creation, modification, deletion, and the validity periods for geospatial data records. Typically temporal accuracy is thought of a time frame or a time of year;
- Positional accuracy is easy to understand by data users;
- Attribute accuracy describes how attributes are positioned, and how they are measured. Reports on attribute accuracy include the date of the test, and the date of the materials used in the tests.

The data management policy should include the requirements for providing data quality indicators. Some indicators, like positional accuracy and temporal accuracy can be obtained from field surveys at data collection stage, but for the others sampling tests on the data set should be conducted. In the test reports the methodology/techniques used, numbers of samples, date of tests and the results should be clearly described. In the current practices a LIMS normally provides users with the data required, but no data quality indicators. This may introduce liability for providing incomplete or inaccurate data, which could give rise to compensation for any damages if decisions are taken based on that information. Therefore it is the author's opinion that both data and data quality indicators should be provided to users. Also when metadata is published on web, the corresponding quality indicators should be included to give users a clear picture on the data available.

To ensure the data quality and integrity the collection of data and the establishment of databases should follow strictly the adopted standards. ISO 15046 is a multi-part International Standards for Geographic Information/Geomatics. The standard contains 21 parts, among which parts 13, 14, and 15 are related to data quality. The following is a list for easy reference:

15046-1	reference model
15046-2	Overview

15046-3	Conceptual schema
15046-4	Terminology
15046-5	Conformance and testing
15046-6	Profiles
15046-7	Spatial subschema
15046-8	Temporal subschema
15046-9	Rules for application schema
15046-10	Feature cataloguing methodology
15046-11	Spatial referencing by coordinates
15046-12	Spatial referencing by geographic identifiers
15046-13	Quality principles
15046-14	Quality evaluation procedures
15046-15	Metadata
15046-16	Positioning services
15046-17	Portrayal of geographic information
15046-18	Encoding
15046-19	Services
15046-20	Spatial operator
15046-21	Functional standards

4.5 Funding model and data pricing policy

Building and maintaining a LIMS are costly. The former is one-off investment, while the latter is a long term commitment. The cost of a LIMS includes: the cost of data capture and maintenance which is of large percentage of the total cost; the cost of physical infrastructure, including hardware, software and data communication facilities; the cost of people, including their salary and the cost of training new staff members and continuous professional development for existing staff members; and the cost of other factors, such as regulation, development of standards, publication, etc., which is probably modest in comparison with the above. The questions that who pay the cost and how the money is raised should be addressed.

4.5.1 Different funding models

We must discuss different data pricing models before funding model for a LIMS. According to Harris (2000), there is a variety of pricing models for earth observation data: free data for all users; marginal cost price for all users; market driven, realizable prices for all users; full cost pricing; two-tier pricing, and etc. They are briefly described below.

(1) Free data for all users. The term free of charge is defined as no charge to the recipient at the point of delivery. No charge is made for the data themselves, not for the medium on which the data are distributed. This policy encourages data sharing, but there may be no discipline in the demands by users for the data and no sufficient recognition of the value and economic impact of the data.

(2) Marginal cost price to all users. The price which recovers the cost incurred in providing data beyond the costs of basic infrastructure is the marginal cost price. The marginal cost price is impossible to define accurately because it is the result of administrative decision. The merits of this model include encouraging discipline in the selection of and request for the data, and avoiding budget deficits by recovery of marginal costs. The same problem as (1) is some users can make commercial gains from the use of the data without making a commensurate contribution to the costs;

(3) Full cost pricing. Prices set at the full price or competitive price capture the investment costs of building and maintaining the system and the marketing activities. This model of course can provide better services to all users, for the money recovered can be re-invested into the system. But the data may be too expensive and the policy is likely to restrict the use of the data;

(4) Market driven or realizable price for all users. This is in between the second and third models;

(5) Two tier pricing. The two tiers of pricing are normally market driven price for all users except for the users in the categories given preferential treatment who receive data at the marginal cost price. Normally the users in the preferential treatment are researchers and educators.

For funding SDI there are two basic models: dissemination of data at zero or coping cost by public bodies using the first data pricing model; and cost recovery by public bodies using the third data pricing model. The first model is used in the USA. The governments believe that taxpayers fund the collection and updating of data. Any subsequent charge to citizen is a second charge and is not fair to them. In addition, there is a little gain by selling the data when compared with the tax levied on the geo-information related industries. Several counties have adopted this funding model, like Australia, New Zealand, etc. The arguments against this model are: there are generally many more taxpayers than users; and the revenues gained from selling the information/data could off-set public spending. The second model is used in UK. They believe that any revenue collected is a profit to the taxpayers. Since the number of data users is small compared to the number of taxpayers, the cost recovery can also minimize the problem of subsidy of some individuals at the expense of the populace as a whole. It can be used for public and to subsidize the maintenance cost of the data. The criticisms for this model are: commercialization of public sector information can be in conflict with the public tasks of these public bodies, and unfair with respect to private competitors because it has advantages, such as tax-exemptions and other facilities, inherent in its function as a public body. It is the author's view of point that a good balance must be sought to develop a charge model if the second model is in favor, i.e., a government wishes to charge for the access to the data. Access to data and charge for the access to data is two contradictory matters. Higher the price of data is, fewer users will be. This contradicts with the role of a government in the promotion of IT industry and information economy.

4.5.2 A proposal on pricing and funding models for a LIMS in China

China has no pricing policy for geospatial data, and no clear funding model, because China is still in early development stage of information economy and spatially enabled society, and most of information systems are owned by individual public body and have less data sharing capability. But for an efficient city-wide LIMS funding model and data pricing model need developing. Having analyzed the above approaches/models, it is author's view that both the USA approach and the British approach are not suitable with the following justifications:

- China is a developing country and needs additional resources to collect and update the system. In this regard the British approach is reasonable;
- China, however, is much less developed in the area of IT industries and information economy. Therefore, the governments at different levels have responsibilities to actively promote GIS/IT industries. The USA approach facilitates the boost of GIS applications and GIS industry. Moreover, GIS industry can generate large revenue for the government. In this regard the USA approach is reasonable to China;
- China has a system of doubling taxes on commerce and industries. Unlike developed countries where taxes are levied only on the profits of a company, China levy tax both on

the company profits and on its revenue. Take city Guangzhou as an example, the government levy about 5% on the gross income of a company, and then about 30% on the final profit. With this taxation system it is quite reasonable for the government to provide GIS data with minimum charge (administration charge).

My proposed the pricing model for geospatial data is a combination of the pricing models discussed above:

(1) Free data for educators. As defined above, only handling fee and medium charge are collected. However a declaration by the user must be signed to ensure the data is used only for education purposes;

(2) Marginal cost price to researcher and public bodies. Any research projects in research institutes and universities do allow including budget for purchasing data, and it is quite reasonable to charge them. We can distinguish two kinds of projects: one is funded by government research funding agencies; and the others funded by government departments at various levels and commercial companies. The former (also called the "vertical funding" in China) is mainly of academic value, while the latter (also called the "horizontal funding") is of more economic benefits. As mentioned above, the marginal cost price is the result of administrative decision; we may wish to differentiate these two kinds of projects in the determination of price. Government departments and public bodies, in addition to their day-to-day management activities, do have funding provision if they need the data for new projects and additional activities. Therefore we can charge them. Since all these activities do have public dimension, and therefore marginal cost model is adopted. The marginal cost is determined by data volume requested and annual maintenance cost. For the second kind of research project we can charge twice of the first kind, because they have commercial element, but should not exceed the next model.

(3) Market driven or realizable price for commercial users. Commercial companies request the data for their business activities and the data can generate financial gains. Therefore it is reasonable to charge them with higher price. However, full cost pricing model is not recommended because it will jeopardize the development of information economy. The data price is determined by the volume of the data and system cost.

(4) All the users must sign an agreement and get a license with the data providers regarding the data usage, the period, and the penalty in abuse of the data, disclose to other parties. Based on the following ways to calculate data cost price, the license is valid for one year. If one wish to continue use the data, the license renewal is required.

The traditional way to price the geospatial data (mainly maps) is by sheets and by scale. With digital information there is a need to consider the way to charge. One approach is to adopt the traditional area approach, i.e., the data is counted on sheet basis and in terms of area. The merit of this approach is that the value of the data does not change after digital conversion. The other approach is to count in terms of the volume of the data. The merit of this approach is that the volume of data reflects the efforts made to collect the data. However, unlike the material stored in paper form, the volume of digital data differs when converting from one form to another. Having analyzed both approaches, the author prefers the second approach, for volume of the data is easy to count in digital technology.

The marginal cost price can be calculated as the marginal cost rate * the volume of the data requested for. The marginal cost rate is defined as 10% the annual maintenance cost of a system (or sub-system) divided by the total volume of the data in the system. The 10% is an objective figure, which means the same data are used annually by 10 times/users. If the data set is used less than 10 times per year, they do not need updating annually. The annual maintenance cost includes hardware/software updating cost and data updating cost. If the hardware and software are updated, for instance, every five years, the annual maintenance cost for this part is the total cost divided by 5. Similarly for data updating annual maintenance cost. Take Guangzhou as an example where the 1-2-3-5 year updating scheme is adopted. If the data requested is in the area where data are updated annually, then it is annual maintenance cost; if in the area where data are updated every three years, the annual maintenance cost is the updating cost divided by 3. In similar, market driven or realizable price is calculated as the cost rate * the volume of the data requested for. The market driven or realizable cost rate is defined as 10% the annual maintenance cost of a system (or sub-system) plus annual sharing cost of the system building divided by the total volume of the data in the system. The annual sharing cost of system building is the total cost in building a system divided by life time span of the system, normally 5 years.

Several situations may occur when a commercial company uses the data to produce a new product, like production of navigation maps based on basic maps. The map provider (government department) will have two ways to calculate its share: one from the above and charge year by year, and the other is from the share of benefit in terms of the percentage of ownership. Because two values are usually different, it is proposed that the smaller amount should apply. Assume, for instance, that A and B share the ownership of a new product with percentage A% and B%, respectively. A is provider of basic data (maps or GIS data) and B is new product producer, normally a commercial company. Since B manages the production and market the products, it should get 50% of the total income. Then two owners will share the rest of 50%, i.e., A gets 0.5*A% of total revenue and B gets the rest. A digital product may not be for sale, but for users to visit. For example, a company has produced a traffic map and put in web for users to use. The company generates revenue for the product through user visits or commercial advertisements in the product. They used digital maps as their base for the new product. A negotiation may be needed in a case by case.

This data pricing model has several advantages:

- Use of an annual cost rate can reduce the burden of users, because the cost is divided by the years of updating cycle and most of projects can be finished in less than one year;
- In addition, use of annual cost rate can encourage users more effectively use the data;
- For popular data bases the data providers will recover more than the maintenance cost. Additional funds can be used to improve the services.

For funding model we propose the government wholly fund the system building because it is an information infrastructure, and 80% of annual maintenance cost. The percentage of 80% is based on the following considerations: the system or its sub-systems are most used by government departments to perform their management functions; and the cost recovery can off-set the shortage of maintenance cost and improve services. Of course 80% is a subjective figure and must be regularly reviewed by the management committee.

4.5.3. Ownership and benefits

As mentioned above, a LIMS is a distributed system with its databases managed by different departments and agencies. Each unit builds a sub-system or systems according to the agreed common standards and policies. It is the responsibility of each unit to keep its system current. The updating cycles are determined by the coordinating council. Therefore the corresponding unit owns the system. Each unit management is required to fund the system based on the proposed funding model. Funding level should be approved by the coordinating council. The benefit generated from the above-mentioned cost recovery should go to the unit.

4.6 Evaluation framework for a LIMS

A good LIMS contributes to the sustainable use of land and resources, and therefore sustainable development of a society. To deploy this benefit a LIMS must be regularly evaluated to learn its strength and weakness. Evaluation is concerned with questions such as: are we doing the right thing, are we doing things right, and what lesions can we learn from the experiences. Evaluating and measuring the performance of the system is a basic prerequisite for improving the efficiency and performance of the system. To this end performance indicators must be developed. Baird (1998) in a World Bank seminar about "Public Sector Performance – the Critical Role of Evaluation" emphasized four elements which are essential for evaluating the performance of an organization or system. They are:

- Well-defined objectives – to know where to go to;
- Clear strategy – to know how to get there;
- Outcomes and measurable indicators – to know if on track; and
- The evaluation of results – to gain input for improvements

he first three elements are linked with organizational levels. The first element defines the targets of a LIMS, which are clearly identified in the vision of the system (refer to section 4.1). The targets include data sharing, good coordination and partnership, promotion of geospatial enabled society and information economy. This element is at policy level and should be the responsibility of governing body, i.e., coordinating council or governing committee. The second element – the strategies – defines the way forward in how to reach and satisfy the objectives. It is at management level and should be the responsibility of management committee. In the proposed governance and coordination (refer to section 4.2), the secretariat or management committee should develop the strategies under the above-mentioned vision and submit to the coordinating council for approval. After the approval of the strategies, the management committee implement, monitor, and evaluate the developed strategies. In a LIMS the second element includes strategy to enhance partnership, data quality management (data standards and quality issues), development of a LIMS funding scheme, and day-to-day management of the secretariat. Increasingly, partnerships are considered essential for the development of a LIMS because they provide the mechanism to allow different organizations to work together to achieve LIMS goals and to share the implementation responsibilities. Another important issue which should be considered at management level is the relevance of spatial data, data quality and currency, and the ability for data to be combined and integrated to improve decision making. The third element is outcomes, which is the results of activities arising from the objectives and strategies. The set of resulting indicators must be developed at outset, which provides a basis to evaluate them. It is at operational level and should be the responsibility of operational units. The standards and quality management policy are developed by technical committee (refer to section 4.4). This committee should also monitor its implementations in the establishment of a LIMS, from data acquisition, building various databases and to building information management systems. But each partner is also an operational unit and they should take the responsibility of the compliance of their databases and management systems with the established standards and guidelines. The forth element – the evaluation of the results – is the actual process, which take the outcomes and indicators into consideration to review and evaluate the objectives and strategies. This process has to be done on a regular basis and looks at performance and reliability of the system as a whole and how the initial objectives and strategies are satisfied. The four elements should be treated as a cyclical process (see Figure 4.1). The developed strategies should be reviewed annually based on the performance outcome and indicator. However, the objectives can be assessed every few years, say 3-5 years.

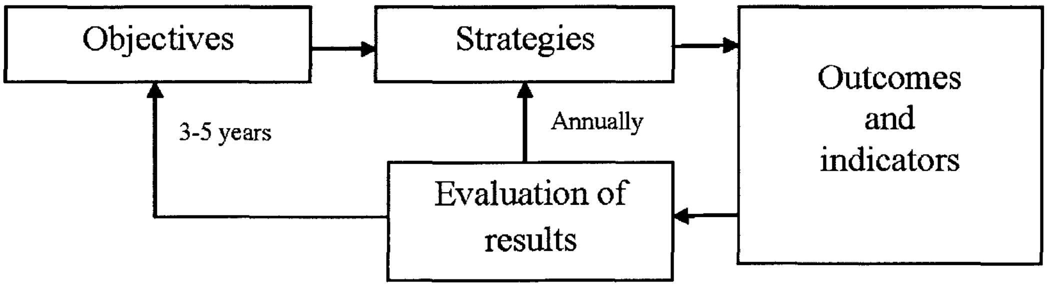


Figure 4.1 Basic evaluation elements and cycle of assessment (after Selhofer and Steudler, 1998)

During the evaluation process the identification of performance gaps is the most crucial step. It identifies the gaps between the actual performance of the system and good practices elsewhere. The gaps will give an indication of where the weaknesses and strengths of the system lie. Williamson (2001) proposed a range of "best practices", which can be summarized by Schuelder

(2007) as land policy principles; land tenure principles; land administration and cadastral principles; institutional principles; spatial data infrastructure principles; technical principles; and human resource development and capacity building principles. Based on these principles The author proposes the following aspects (toolboxes), which provide a suitable basis for the evaluation framework of a LIMS.

- In terms of land policy – if a LIMS is able to support: national land use policy; land reform and development; cultivated land protection; and proper management of land and resources.
- In terms of land administration – if a LIMS is able to support land/real estate registration and ownership, market and trading, and implementation of land policy; and to manage urban and rural land and resources, and the system in accordance with the standards..
- In terms of institutional arrangement – if a LIMS is able to coordinate efficiently partners, to integrate all land related information for an activity, and to develop good partnership between governmental and private sectors.
- In terms of technical aspect – if a LIMS provides user-driven best technical solutions with an advanced level of computerization.

Chapter 5

Technical Aspect of Data Sharing – Data Conversion between Different GIS

As mentioned above, data sharing is a major issue in building a LIMS, in particular in China. There are a number of impediments: lack of data access policy and a proper institutional arrangement (soft infrastructure); difference in data format between different software; and different thematic definitions by different organizations and in different time in data capture. For the first issue we have discussed in Chapter 4. This chapter is concentrated on the technical issues. From technical view of point data sharing techniques go through three development stages, from file oriented to database oriented and eventually to service oriented data sharing (SuperMap, 2009). But the file oriented is simpler and fundamental, and therefore is the main focus of this research.

This chapter reviews and analyzes the various data models in GIS, especially the thematic differences between different GIS models. This forms a foundation for understanding the errors that may be generated in the data conversion from one GIS to another. This chapter has 5 sections. After an introduction to data exchange, GIS data models are discussed, followed by their comparisons. Section 4 addresses data transfer methods. The last section introduces an experimental study of data transformation between DWG and Shapefile by using (a) FME and (b) Arc/Info Conversion Toolbox. The errors in these data transformation are identified and the reasons for causing these errors are analyzed. These provide a basis for improving the quality of spatial data conversion.

5.1 Introduction to geographic data exchange

Geographic data exchange is a key element for geographic data sharing and interoperability. There are three aspects in data exchange: syntactic, semantic and software (Yuan, 1997). The exchange of syntax can be achieved through the transfer of data organization descriptions such as meta-data. The exchange of semantics must preserve the meaning of data. The exchange of software from one platform to another should address the problems of software compatibility. Among these three aspects, the preservation of semantics is the most fundamental and also the most difficult.

Translations among commercial GIS data models are successful in terms of geometric aspects. However, without considering the meaning of geospatial data they can lead to logical inconsistencies within the translated data (Gahegan, 1999). Thus, semantic interoperability among commercial GIS data models is essential and the identification of semantic commonalties and differences among the models is the first step for the semantic interoperability (Harvey, 1999). We first identifies the semantic differences among geometrical types (i.e. point, line and area) used by three typical commercial GIS software packages: ESRI's Arc/Info, ArcView, and MapInfo. The methodology adopted is to translate those data models into a common data model, semantically rich geographic data model. The reference model of ISO TC/211 is adopted as the common model here. With the reference model, semantic differences among these geographic data models are distinguished. According to the findings, a document of possible errors during data exchange among commercial geographic data models can be prepared. Moreover, a common standardized model, which guarantees semantics compatibility during data exchange, can be developed based on the reference model of ISOTC/211.

Data conversion between the different data format is a solution for geospatial data sharing. We should discuss following two methods for spatial data conversion: (a) direct transformation, (b) indirect transformation and then introduce two related concepts of direct data access and geospatial data interoperability.

Direct transformation: spatial data in a file is directly transformed from one data format into another data format by a translator. For example, the data transformation by using the data conversion toolbox in ArcInfo belongs to direct transformation, which for instance can transfer data in Shapefile format to DGN format directly.

Indirect transformation: spatial data in a file is firstly transformed into an intermediate data format, and then this intermediate format is further transformed into the final data format needed. Here two translators are used for the data transformation. Usually, the intermediate format is the interchange format or a geospatial data format of international standard, such as ISO TC/211 geospatial data format. Each GIS software package holds its own internal and open interchange data formats. Internal format is for the design of particular GIS software, while the open interchange format is for sharing with other data format. For example, the followings are the open interchange formats: E00 of ArcGIS, MIF of MapInfo, DXF of AutoCAD and the exchange format of MapGIS. The spatial data transformation based on the interchange formats is illustrated in Figure 5.1.

There are several standards for spatial transfer developed in many countries, such as the Spatial Data Transfer Specification (STDS) developed by the Digital Cartographic Data Standards Task Force in the USA, and Geo-Spatial Data Transfer Format (CNSDTF) developed in China. The process of spatial data transformation by using the spatial transfer standards is illustrated in Figure 5.2. However, the developed standards for spatial data transfer suffer from flaws. Many of them ignore the possibility of taking geospatial data exchange as a specialization of general electronic data exchange.

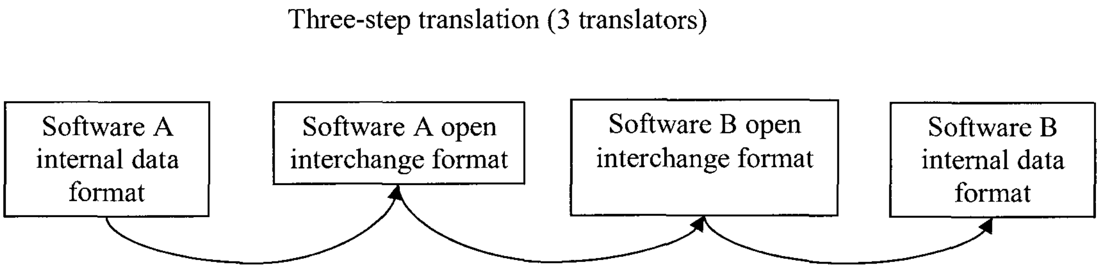


Figure 5.1 Transformation by open interchange format

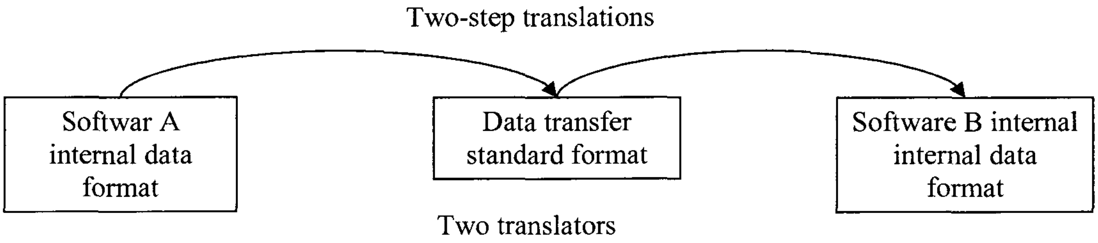


Figure 5.2 Transformation by a spatial data transfer standard format

Direct access refers to the realization of a GIS software package reading other format data directly. Then users can use the GIS software to access a variety of data formats.

Spatial data interoperability means users can access to the necessary information in the case of the heterogeneous databases and distributed computing. For this purpose, Open GIS Committee (OGC) has developed a series of specifications on spatial data interoperability.

5.2 GIS data models

In this section, three different GIS data models are introduced and compared with the ISO TC/211 model. The differences among different GIS models are presented, which serves a base for understanding the potential problems in data transformation between different GIS data models.

5.2.1 Data model of ISO/TC211

The spatial schema (ISO/TC211, 1999) is suggested by the Technical Committee 211 of the International Organization for Standardization (ISO/TC 211). The schema is based on a standard conceptual model for representing and handling spatial properties of objects on Earth's surface. The standard also serves as the foundation for all other standards of geographic information suggested by the ISO/TC 211. Semantics of geometric objects defined by the standard are rich enough to capture different meanings of geometric objects.

The spatial schema represents geometric and topologic properties of geographic features by the classes GM_Object and TP_Object, respectively. Here we focus on the geometric properties and the representation of point, line and areal features in the spatial schema as shown in Figure 5.3. All classes with prefix GM_ are inherited from GM_Primitive which is a sub-class of GM_Object. DirectPosition indicates a location and is not considered as a geometric object

Both classes GM_Curve and GM_Surface share LiesOn association with GM_Point. The association shows that these GM_Point objects coincide with GM_Curve and GM_Surface objects. At the same time, GM_Surface has the other LiesOn association with GM_Curve which shows that these GM_Curve objects coincide with the GM_Surface object. On the other hand, boundary operation of GM_Curve returns a set of GM_Point objects that are the start and end points of the curve. The StartPoint() and EndPoint() operations return the first and last point of the curve. Similar to GM_Curve, boundary operation of GM_Surface returns a set of GM_Curve objects that define the extent of the GM_Surface object.

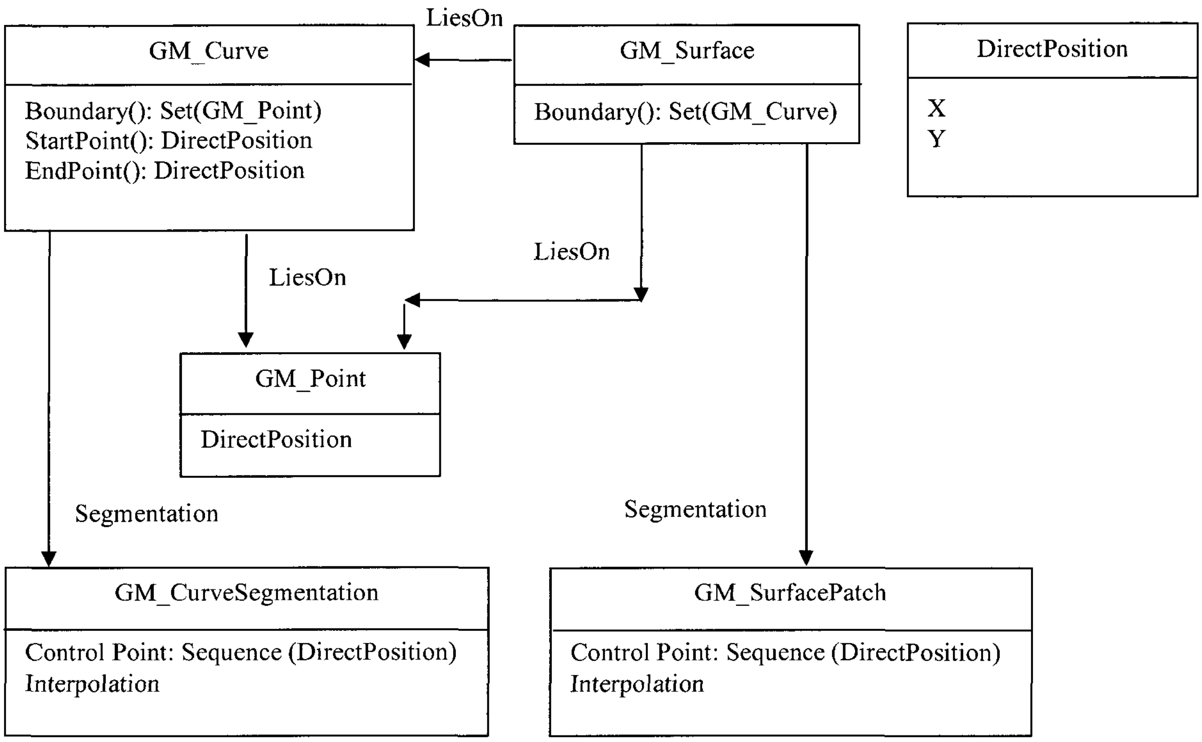


Figure 5.3 Data model of ISO/TC 211

Both GM_Curve and GM_Surface can be decomposed into smaller parts (i.e. GM_CurveSegment and GM_Patch, respectively) with their corresponding segmentation associations. GM_CurveSegment and GM_Patch are defined by a set of DirectPosition as control points. The Interpolation attributes of both classes define the actual constructing mechanism of the corresponding GM_CurveSegment and GM_Patch objects.

5.2.2 Data model of Arc/Info

Figure 5.4 shows data model of Arc/Info (ESRI, 1993), which is self explanatory. Point is a 0-dimensional feature. Arc is the core element in the data model and acts as the topological linkage among nodes and polygons. The node-arc-polygon structure is used in Arc/Info where arc is bounded by starting (i.e. Fnode) and ending (i.e. Tnode) nodes, whereas polygon is defined as a series of arcs through the contiguity between the arc and the polygon. Each polygon is associated with a point as user label

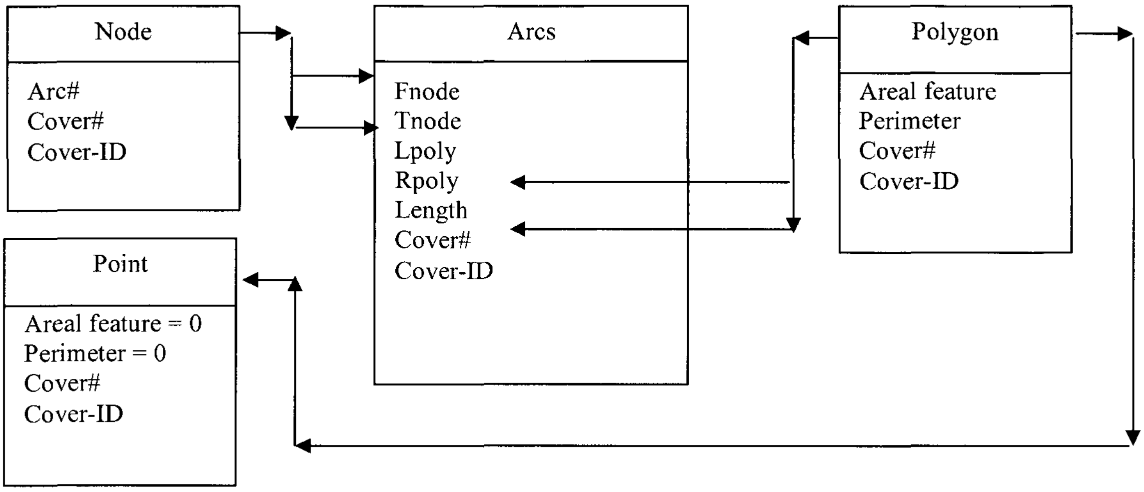


Figure 5.4 Data model of Arc/Info

5.2.3 Data model of ArcView Shape File

An ArcView shape file (ESRI, 1998) defines geometric objects using part-whole relationships and arrays of points. Hence, point is a pair of x, y coordinates forming the most fundamental object in the model. For example, MultiPoint is a class of logical group of point objects and these related points are arranged into an array of points. The Polyline class represents linear feature in a shape file. Each Polyline object consists of two components: Parts and Points. The Polyline class records the total number of parts (NumParts) and points (NumPoints) contained in a linear feature. Each Part contains a list of point objects and represents a constructing component of the linear feature. The points in each of the constructing component (i.e. Part) are sequentially maintained in array Parts. All points of the linear feature are maintained in array Points. In other words, a linear feature is constructed by joining Points to line segments (i.e. Part) according to the array Parts and Points. The line segments are then joined to form a linear feature.

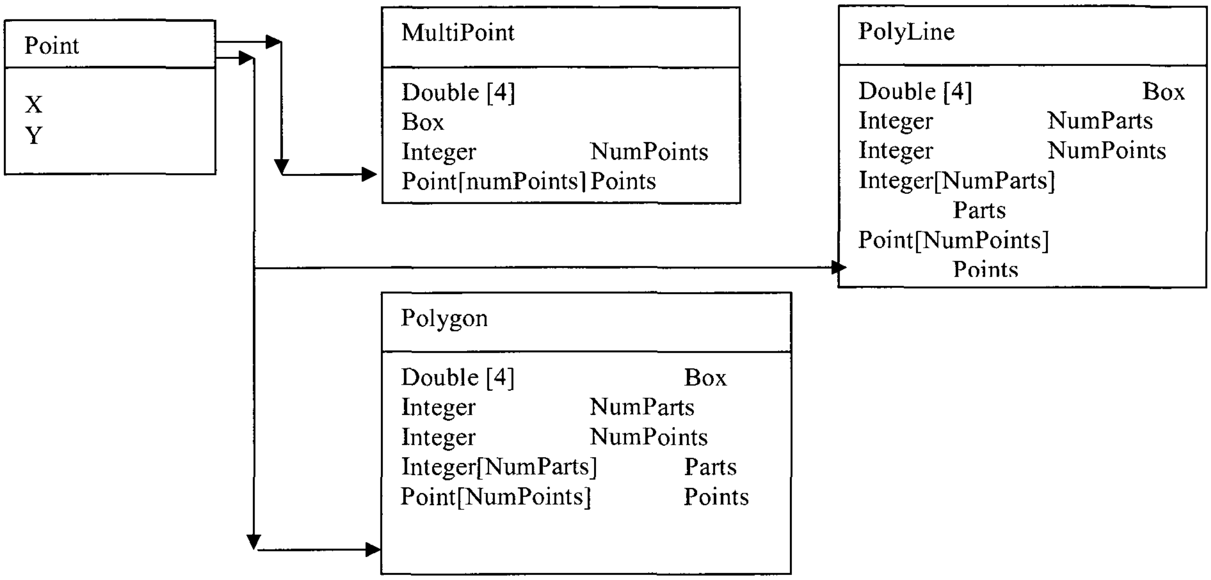


Figure 5.5 Data model of Shape file

A polygon is constructed using a method similar to that of a linear feature. A Polygon object can consist of a number of self-enclosed loops. Each of the loops is considered as Part of the Polygon, and a loop consists of a series of Points as its vertexes. NumParts and NumPoints contain the total number of loops and Points contained in a Polygon respectively. According to information stored in arrays Parts and Points, a Polygon is constructed by joining Points stored in array Points into Parts and then the loops are formed into polygons.

5.2.4 Data model of MapInfo Interchange File (MIF)

The MapInfo Interchange File (MIF) is designed mainly for exchanging spatial information among GIS software packages (MapInfo, 1995). Hence, the MIF data model is simple and straightforward. The data model is known as the spaghetti model in which point, line and areal feature are not interrelated.

Similar to all other models (see Figure 5.6), a point feature is represented as a pair of x, y coordinates. At the same time, class Line represents a linear feature containing two pairs of x, y coordinates. The first represents the starting point and the other represents the ending point. For a linear feature contain more than two vertexes, it is depicted by class Polyline. The Polyline class contains a series of x, y coordinates, each pair being one vertex. Class Region represents areal feature, which is the combination of one or more Polygons. Each Polygon in the Region is a list of coordinate pairs and each pair is a vertex of the Polygon.

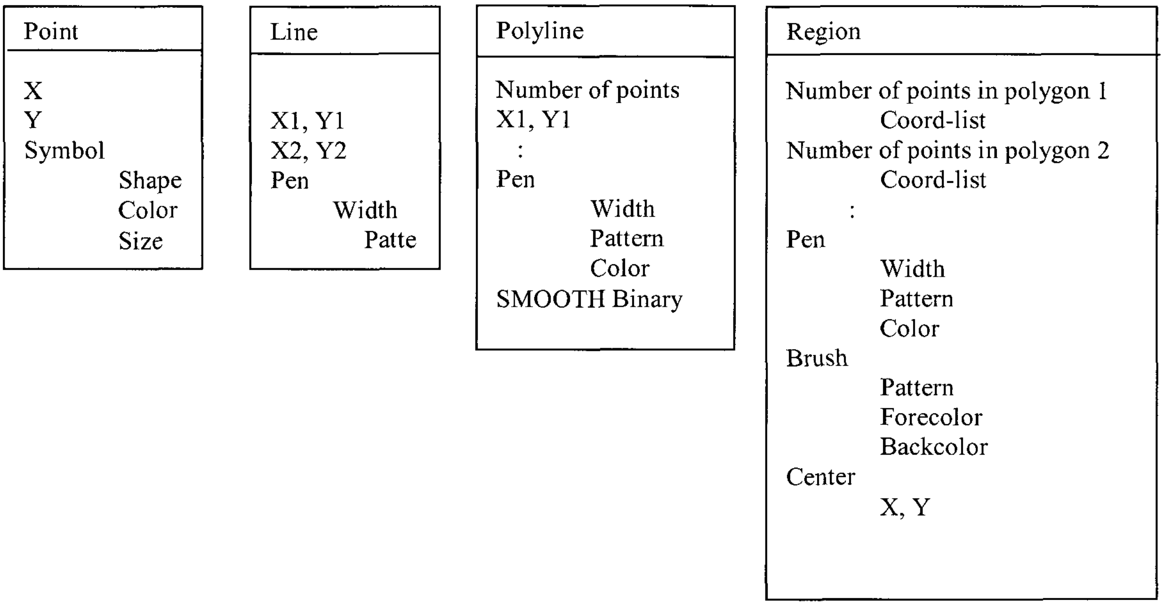


Figure 5.6 Data model of MIF

5.3 Comparison among various data models

5.3.1 A comparison between GIS data models with ISO TC/211 data model

From the above descriptions of various data models, one can see the differences among them. We summarize their differences and analyze the possible mapping relation of these GIS models with the ISO TC/211 model.

Arc/info data model versus ISO TC/211 data model

If Point is considered as a geometric feature in Arc/Info, it will be mapped to GM_Point in the ISO TC/211 data model. On the other hand, if the Point is considered as a location (e.g. Lable point of polygon), it is mapped to DirectLocation. Node, in the definition of Arc/Info, must be the starting or ending of an Arc. This constraint restricts the mapping of Node and Arc to ISO/TC 211. Arc is mapped to GM_Curve, and the GM_Curve associates with one and only one GM_CurveSegment. Nodes are mapped as the first and the last DirectPositions in the ControlPoint list of the GM_CurveSegment respectively. This is because GM_CurveSegment is the only class in the ISO/TC 211 model that consists of a sequence of DirectPosition in the ControlPoint list. The ControlPoint list contains the definition of starting and ending nodes.

Class Polygon is mapped to GM_Surface with no GM_SurfacePatch as its segmentation. The class Polygon cannot refer to GM_SurfacePatch because its position is defined as a series of DirectPositons instead of GM_Curve,.This definition is in contrast to the definition in Arc/Info. On the other hand, the relationship between Arc and Polygon is represented by the LiesOn association between GM_Curve and GM_Surface. Moreover, each Polygon is associated with a label point in Arc/Info, thus, a DirectPosition which represents the label should be attached to the GM_Surface.

Table 5.1. Mapping the Arc/Info Model to ISO/TC 211 Model

Arc/info	• TC/211
Point	• DirectLocation / GM_Point
Node	• A Direct_position which is either the first or the last point in the ContorlPoint sequence of the GM_CurveSegment
Arc	• A GM_Curve which associates with only one GM_CurveSegment. The GM_CurveSegment consists of DirectPosition in ControlPoint list using Linear segmentation.
Polygon	• A DirectPosition plus s a GM_Surface. • A DirectPosition shows the users label. (Remark: the inside relation is missing)

	• A GM_Surface consists of a set of GM_Curve as boundary but have no GM_SurfacePatch as its segmentation.

MapInfo's MIF data model and ISO TC/211 data model

In MIF, a Point object is standalone and is not related to linear and areal features. Thus, it is represented as an independent GM_Point object. For a Line object, two pairs of XY coordinates represent two ends of a line. The Line object is mapped to GM_CurveSegement of ISO/TC 211 with the constraint that the GM_CurveSegement consists only 2 DirectPosition objects in the ControlPoint list. Polyline of MIF is mapped to GM_Curve with constrains that the GM_Curve consists of GM_CurveSegment contains two DirectPoistion only. Since MIF's Polygon is composed of XY-coordinates, it is mapped to GM_SurfacePatch and the pairs of XY-coordinates are mapped to DirectPosition in the ControlPoint list. MIF's Region, which consists of a series of polygons, is mapped to GM_Curve. Similar to Polygon, each Sub-Polygon in Region is mapped to GM_SurfacePatchs with Segmentation relation to the GM_Surface.

Table 5.2 Mapping the MIF Model to the ISO/TC 211 Model

MapInfo	TC/211
Point	GM_Point
Line	A specific type of GM_CurveSegment which consists only two DirectPosition in the ControlPoint list using Linear interpolation.
Pline	A specific type of GM_Curve which consist a series of GM_CurveSegment with each has two DirectPosition only.
Polygon	A specific type of GM_SurfacePatch which consists a series of DirectPosition as coincident point in the ControlPoint sequence using Planar interpolation.

Region	A GM_Surface which consists a series of GM_SurfacePatch. The GM_Surface does not posses LiesOn association to GM_Curve.

Data model of ArcView's Shape File verus ISO TC211 data model

Point in Shape file is directly mapped to GM_Point object with no semantics conversion if it is considered as apositional feature. On the other hand, the class Point is mapped to DirectPosition if it constitute of linear or areal features. Polyline in Shape file supports the concept of part-whole relation. This relation is mapped to the Segmentation relation between GM_Curve and GM_CurveSegment. The whole of the Polyline is mapped to a GM_Curve, and it does not posses 'LiesOn' association with GM_Point. The part, which is an Array of Point object (i.e. Point[NumPoints]), is mapped to a set of GM_CurveSegment. With Reference to the array NumPart in the Shape file, Points that correspond to a line segment are mapped to ControlPoint list of the GM_CurveSegment. Moreover, the sequence of Point in the array Point[NumPoints] implies the order of points in the ControlPoint list.

Similarly, Polygon contains part-whole relation and the relation is mapped to the Segmentation relation between GM_Surface and GM_SurfacePatch. The Polygon is mapped to a GM_Surface which does not contain any geometric information. The mapped GM_Surface associates with a set of GM_SurfacePatch with Segmentations relation. Corresponding to the array of Part[NumPart] and Point[NumPoints], each associated GM_SurfacePatch contains a list of DirectPositions in the ControlPoint sequence. The mapped GM_SurfacePatch is constrained as a self-enclosed loop according to the definition of Polygon in a Shape file.

Table 5.3 Mapping of the Shape file Model to the ISO/TC 211 Model

ArcView	TC 211
Point	GM_Point / DriectPosition
Polyline	● Whole: A GM_Curve object which consists of an ordered set of associated GM_CurveSegments (i.e. part). ● Part: GM_CurveSegment with each pair of XY-coordinates are mapped to DirectPosition in the list of ControlPoint
Polygon	● A GM_Surface object which geometric information is defined by Segment only (i.e. no definition on GM_Curve with LiesOn association) ● Ring (or part): A GM_SurfacePatch which is connceted by 4 or more DirectPosition objects in the ControlPoint sequence. This specific type of GM_SurfacePatch must be closed (i.e. the first and last vertices must identical) and do not contain self-intersection loops.

5.3.2 A comparison of the differences between GIS data models

Differences between Arc/Info and MIF

First of all, both the Point object of Arc/Info and MIF are mapped directly to GM_Point without lost of semantic. Node in Arc/Info is mapped to DirectPosition with the constraint that it is a starting or ending of a GM_CurveSegment. The Point object of MIF does not contain association with linear features. Consequently, the association between Nodes and Arcs in Arc/Info is lost in the transformation of linear features from Arc/Info to MIF.

For linear features, Arc in Arc/Info is mapped to GM_Curve. In MIF, linear feature can be modeled with either class Line or Pline. Line and Pline are mapped to GM_CurveSegment and GM_Curve respectively. According to the definition of linear features in the Arc/Info data model, Arc is not constrained as linear feature with only 2 ends and, therefore, Arc in Arc/Info should be mapped to Pline in MIF. Although the both Arc and Pline are mapped to GM_Curve, they are different in semantics. Arc corresponds to a GM_Curve, which associates with only one GM_CurveSegment. On the other hand, Pline is mapped to a GM_Curve, which is made up of a series of GM_CurveSegments that contains only two DirectPositons. Thus, the meaning of the GM_CurveSegment of Arc and the GM_CurveSegment of Pline are different and direct mapping between Arc and Pline is impossible. Exchange from the Arc object to the Pline object can only be accomplished by decomposing the unique GM_CurveSegment of arc into a series of GM_CurveSegments corresponding to the Pline. However, this decomposition destroys the semantics meaning of Arc of Arc/Info. In the reversed transformation, the series of GM_CurveSegments of the Pline are grouped into one unique GM_CurveSegment of the Arc. Another approach is to transfer each GM_CurveSegment of the Pline into an Arc (i.e.GM_Curve) of Arc/Info. The transferred GM_Curve contains one GM_CurveSegment only. In the both cases, part-whole relationship between Pline and its constituents is lost.

For areal features or polygons, unfortunately, both models adopt different semantics. A Polygon in Arc/Info is mapped to GM_Surface with no GM_SurfacePatch as its segmentation in order to preserve the relationship between polygon and arc in Arc/Info. In MIF, similar to linear features, areal features can be represented by either Polygon or Region. Since a Polygon in Arc/Info and a Region in MIF are both mapped to GM_Surface, both types of features seem to be match each other. However, a Polygon in Arc/Info contains a series of arcs whereas a Region in MIF contains a series XY-coordinate pairs. The Arc-Polygon relationship is lost during spatial data exchange from Arc/Info to MIF. Moreover, a Label point associates with each polygon will also be lost in MIF. On the other hand, when transferring areal feature from MIF to Arc/Info, the problem of semantics incompatible is more obvious. The Polygon object of MIF is mapped into GM_SurfacePatch, however, there is no suitable class of features in Arc/Info match the semantics of the Polygon class. The Region of the MIF should transfer to the Arc/Info's Polygon, since both of them correspond to GM_Surface. However, the GM_Surface corresponds to Region is constructed from GM_SurfacePatch whereas the GM_Surface corresponds to the Arc/Info's Polygon is constructed from GM_Curve. There is no method to retain the semantics during transformations in both directions. Moreover, the part-whole relation in Region and its constituents are lost when the Region is transferred into the Polygon of Arc/Info.

Differences between Arc/Info and Shape file

In order to presevere the association between point and linear features, both Node in Arc/Info and Point in Shape file are mapped to DirectPosition or GM_Point. Node-arc relationship is preserved during transformation in this case.

Part-whole relationship is the major factor that causes the semantic mismatch between the Polyline of Shape file and the Arc of Arc/Info. In a Shape file, the Part-whole relation is essential to Polyline. It is obvious to map the whole to GM_Curve and the parts to a series of GM_CurveSegments. However, as previously mentioned, Arc in Arc/Info does not support the concept of part-whole relation,. and therefore Arc is mapped to GM_Curve that associates with only one GM_CurveSegment. While transferring the Arc into the Polyline, each Arc is mapped to a Polyline (i.e. GM_Curve) containingt one Part (i.e. GM_CurveSegment) only. In the reversed direction of transformation, each of the Part of the Polyline is transferred into the Arc of Arc/Info and the Part-whole relationship of Shape file is lost.

Both Polygon of Arc/Info and Shape file are mapped to GM_Surface. However, GM_Surface mapped from Arc/Info and Shape files are semantically difference. The GM_Surface, which mapped from Arc/Info is constituted from GM_Curve. However, the GM_Surface mapped from Shape file is constituted from its parts (i.e. GM_SurfacePatch). These GM_SurfacePatch are made up of DirectPositons. Hence, there is no direct mapping in either direction of transformation.

Differences between Shape file and MIF

Transformation between Shape file and MIF causes relatively fewer problems in retaining semantic information of spatial features. For positional objects, Point of Shape file corresponds to DirectPosition or GM_Point, whereas Point of MIF corresponds to GM_Point. Association of positional feature to linear feature cannot be retained in MIF.

There are many similarities between the Shape file and MIF in the modeling of linear and areal features. Both data models adopt the concept of part-whole relation, and they represent 1D and 2D objects by a series of 0D objects or XY-coordinates. As a result, direct mappings can be achieved between MIF's Pline and Shape file's Polyline (i.e. GM_Curve), MIF's Region and Shape file's Polygon (i.e. GM_Surface). MIF's Line can be mapped to Shape file's Polyline (i.e. GM_CurveSegment) with the constraint that the mapped Polyline (i.e. GM_Curve) contains only one part. Similarly, MIF's Polygon (i.e. GM_SurfacePatch) is mapped to Shape file's Polygon (i.e. GM_Surface) with constraint that the mapped Polygon contains one part only.

5.3.3 A summary - analysis of differences in data model

By transferring data models of different software to a semantically rich data model, we can observe that data models of different GIS software adopt different semantics for positional, linear and areal features. The Arc-node-polygon structure and part-whole relation are the major sources of the semantic differences. The loss of semantics of spatial features can limit the performance spatial analysis and lead to misuse of spatial data. Although the reference model of TC211 is found to be rich enough to represent the semantic meanings of spatial data adopted by the three studied models, both the TC211 and the Open GIS Specification (OpenGIS Consortium, 1996) are short in addressing the issues of semantics interoperability (Gahegan, 1999). This is known that a workable approach towards interoperability GIS is to consider fundamental semantic issues in the design of the GIS (Harvey, 1999). Findings of this paper can be used in developing a conceptual model for semantic interoperability and to extend the reference model of TC211 and the Open GIS.

5.4 Tools for geospatial data transformation

The tools for geospatial data transformation can be classified into the following two categories: (a) professional software tool for spatial data transformation, such as FME, and (b) data transformation modules built in GIS, such as Arc/Info Conversion Toolbox and MapGIS data conversion module.

After an introduction to the various GIS data models and analysis of their differences and mapping relations, we now introduce the tools which have been developed for data transformation among different GIS data models.

5.4.1 Feature Manipulation Engine

The Feature Manipulation Engine (FME) is an integrated collection of spatial Extract, Transform and Load (ETL) tools for data transformation and data translation produced by Safe Software Inc. (see Figure 5.7). FME is a semantic translator. It can process data during a translation to produce a destination dataset that is greater than the sum of its source components. FME uses the semantic mapping file to control the entire conversion process. One can custom the process of data conversion by editing the semantic mapping files.

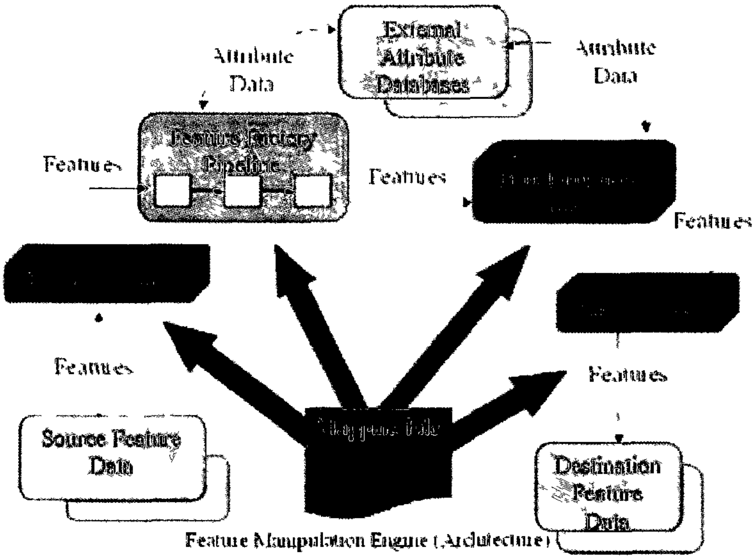


Figure 5.7 The Structure of FME (from: http://www.antu.com.cn/fmeanli-web/fme.htm)

FME contains three core components:

- *FME Universal Translator*: is the fastest way to perform translations, simply by dragging and dropping files, and using the supplied defaults. It is does not involve any customization.
- *FME Workbench*: offers transformation and translation capabilities traditionally reserved for custom software solutions. It has an intuitive point-and-click graphic interface to enable translations to be graphically described as a flow of data.
- *FME Universal Viewer*: allows quick viewing of data in any of the FME supported formats.

5.4.2 Arc/Info Conversion Tools

Arc/Info Conversion Tools can directly transfer spatial data between a number of spatial data models/formats, such as CAD data sources, coverage, raster datasets, shapefile and others. Table 5.4 lists all conversion tools in Arc/Info. Besides, Arc/Info contains ArcView 8x Tools which can exchange between SHP and AGF, input E00 data, translate MIF to SHP, translate SDTS to Coverage and others.

The advantages of Arc/Info Conversion Tools are: (a) the Tools are very easy to use, (b) the time cost for data conversion is very low, and (c) the input and output data sets can be viewed in ArcMAP. However, errors may be generated during the spatial data conversion, and the data formats supported by the Tools are limited and users can't customized the translation Tools.

Table 5.4 Arc/Info Conversion Tools (from ArcGIS Document)

Toolset	Description
From Raster toolset	Contains tools that convert raster data to other formats
Metadata toolset	Contains tools to validate the metadata content according to a specific metadata standard or export the metadata content to standalone metadata files that can be used with other metadata
To CAD toolset	Contain tools that prepare and convert features to a native computer-aided design(CAD) format
To coverage toolset	Contains tools that convert feature classes to the coverage format

To dbase toolset	Contains tools that convert tables to dBase format
To Geodatabase toolset	Contains tools that convert features and CAD files to geodatabase feature classes
To Raster toolset	Contains tools that convert data to rasters
To Shapefile toolset	Contains tools that convert features to shapefiles

5.5. Experiments of data conversion from DWG to Shapefile format

In order to identify and analyze the problems in geospatial data transformation, we design this experimental study.

5.5.1 DWG data format

DWG is the native format of AutoCAD which consists of many objects. Objects include entities that can be drawn, such as line, circle, polyline, and also includes entities that can't be drawn, such as dictionary, tables. The objects which have the same line style, line weight, color and belong to the same type of features are put in a layer. A layer includes various types of objects, such as examples illustrated in Figure 5.8

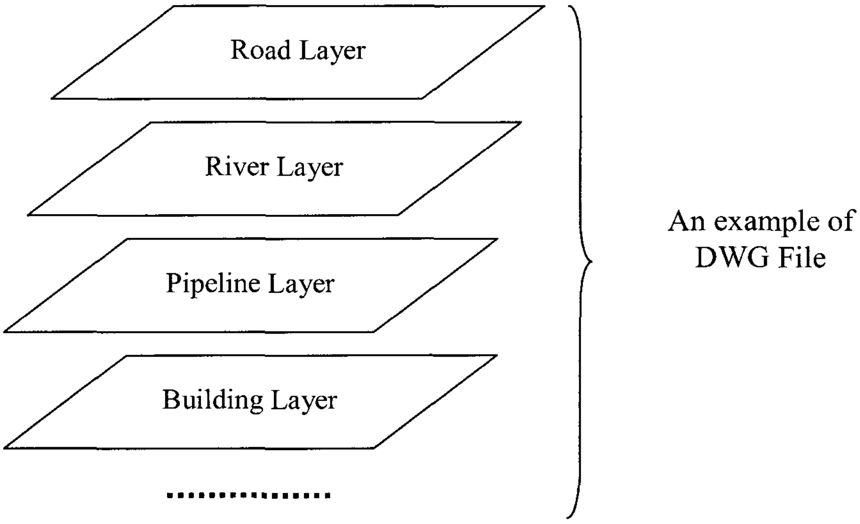


Figure 5.8 A DWG File with many layers

5.5.2 SHP data format

The data model of SHP was introduced in section 5.2.3. A shapefile does not store topological relations and attribute information for the spatial feature in a dataset. Geographic features in a shapefile can be represented by points, lines or polygons. A Shapefile only contains a single type of geometry. Thus, a drawing file often consists of many shapefiles (Figure 5.9). In shapefiles, there are five entity types (Table 5.5). A shapefile consists a main file (*.shp), an index file (*.shx), a dBase table (*.dbf).

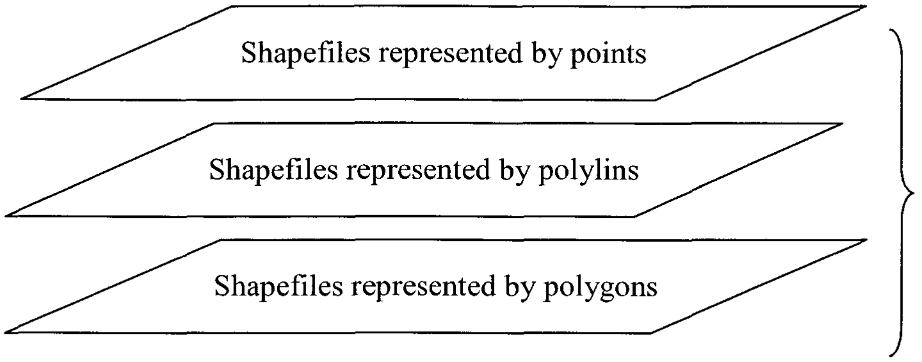


Figure 5.9 A data file that consists of several Shapefiles

Table 5.5 Shapefile Entity Types

Type	Instruction
Point	Used to represent control points, elevation points. point-like features
Polyline	Used to represent linear features, such as roads, pipelines, etc
Polygon	Used to represent area features, such as housed, lakes, etc
Multipoint	Used to represent a number of scattered points
Multipatch	Used to represent TIN

5.5.3 The datasets for experiments

In this experiment, we selected three data sets in DWG format as described below.

- Data set 1: a part of the Florida Land Boundary Information System (http://data.labins.org/2003/). The DWG files were obtained by project the USGS 1:24000 DLGs files into the State Plane Coordinate Zones (NAD83). The DWG files are originally for AutoCAD users without attribute information. Related metadata are as the follows: Projection: State Plane; Datum: NAD83; Units: Feet. The file names are comprised of the DEP quad number plus the first letter of the State Plane Zone they that the data are projected into. Each DWG file has several layers, including administrative boundaries, hydrography, hypsography, pipelines, roads, railroads, public land surveys, etc. This set of DWG file contains 15 drawings, which were converted into Shapefile format. The errors in this data conversion is counted and analyzed.

- Data set 2: a set of vector data of Lufkin, Texas in AutoCAD R14 format. This data was produced by aerial photogrammetry method in 1996 and the data set includes contours, streams, building footprints, dense vegetation, edge of curb, and spot elevations. These files are in the coordinate system of *State Plane NAD83，Texas Central Zone，US Survey Feet。* The data set include a total of 15 map sheets.

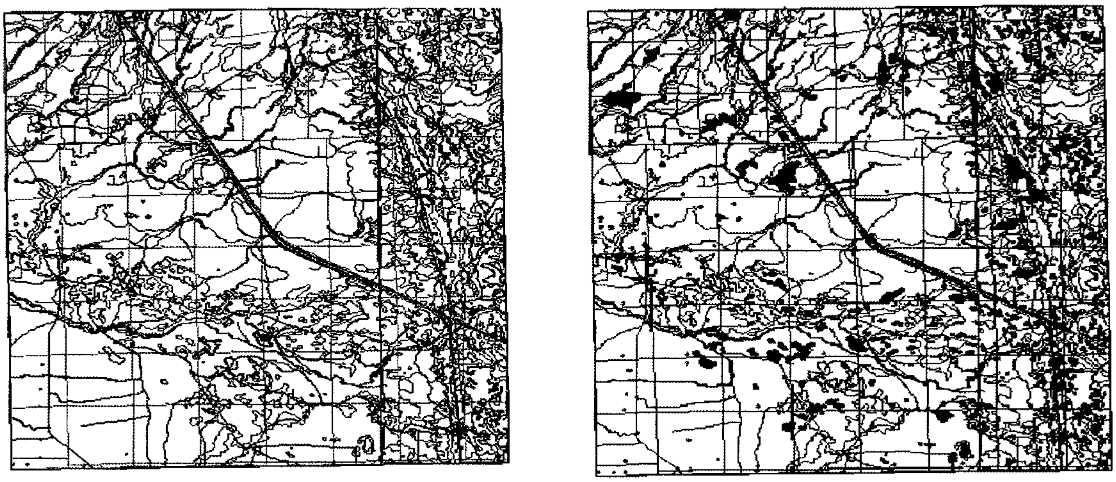
- Data set 3: a map sheet of DWG file of a county in China, including contours, spot elevations, edge of farms, etc. Due to data confidentiality policy in China, no detail description of the data set is given here.

5.5.4 Data conversion by ArcGIS

Data set 1

This data set consists mainly of linear features without attribute data and annotation. Feature Class to Shapefile (multiple) that is a tool of Arc/Info Conversion Tools was used to convert the 15 map sheets from DWG format into Shapefile format. After the conversion, almost all the geometry and location of the entities' are the same as the entities before the data conversion. However, there exist errors in the data conversion as the following.

(1) In ArcGIS, a DWG file is composed of the classes of point, line, polygon, annotation, and nultipach feature classes. When *Arc/Info Conversion Tools* is used to convert DWG data format into Shapefile format, the conversion tool translates each of the feature class into Shapefile, respectively. An original DWG file typically has many layers, each of which represents a different type of geographic feature. For example, there may be different line layers for streets, water mains, and parcel boundaries. Each layer has its own defined line style, line weight and color. While after the conversion, a shapefile, resulted from the line feature class, for example, represents all the line features in all the layers in a DWG file. All entities in a Shapefile have the same appearance, e.g. they are in the same color, line weight, line style as illustrated in Figure 5.10, where A is the original file and B is the converted result.



A B

Figure 5.10 Visualization differences of the entities before and after the data conversion

(2) In the original DWG file in AutoCAD, a line is attached with length and angle information and a polyline is attached with area and length information. However, these attached information is lost after the data format conversion from DWG into shapefile.

In the data conversion, the polylines with the start and end node coordinates being identical, are converted as polygons. There are a number of problem in the polyline to polygon conversion. For example, a number of contours are converted as polygons (see

Figure 5.11A), and there are many overlapped polygons that are generated (see Figure 5.11B).

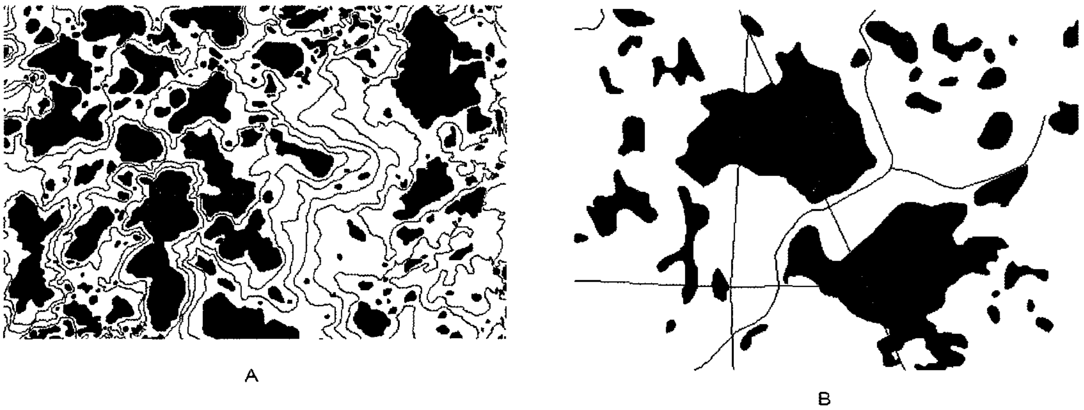


Figure 5.11 Problems in converting polylines into polygons

Closed polylines are stored as polygons in the polygon Shapefile. However, these closed polylines are stored again as polylines in the polyline Shapefile. This results in data redundancy in the converted Shapefile.

(3) In this data set, the same type of theme features for the same location as one represents a layer. After the data conversion, insert point of the block is translated as a point, and the block is translated as an entity stored in the polyline Shapefile. In Figure 5.12, the green entity is the conversion result of a block. The entity contains all the road features. This makes it difficult for the data users to further process single a specific road feature of the block.

Due to the quality of the original data set, the converted results have many duplicated entities.

Figure 5.12 The Conversion result of a block object

Data set 2

The data set 2 has a better quality than the data set 1. It contains geometric information of buildings, and commonly used symbols are represented in blocks. A total of 15 map sheets in DWG format were chosen to translate into Shapefile by the Arc/Info Conversion Tools. After the conversion, the geometry and location of most of the entities are the same with the original entities. In ArcGIS, DWG files are converted to Shapefiles with the file name "*_DWG_<feature classes>", where "*" is the name of original DWG file. To accord with the Shapefile naming standards, sometimes users may have to change the DWG file names. In addition to the five problems mentioned above of the data set 1, the conversion result of the data set 2 has the following additional problems.

(1) After the data conversion, the entity of map grid of the map sheet was lost.

(2) Blocks are used to represent some of the symbols in the map sheets. For example, in Figure 5.13, "×" indicated a bock entity of point symbol. The blocks are converted into Shapefiles, a block is translated to be the following two: a) the location of the inserted point entity, and b) the overall block. This leads data redundancy. Because,

Shapefiles just store geometry and attribute data, but not symbols. Users need to further process the symbols in ArcMap.

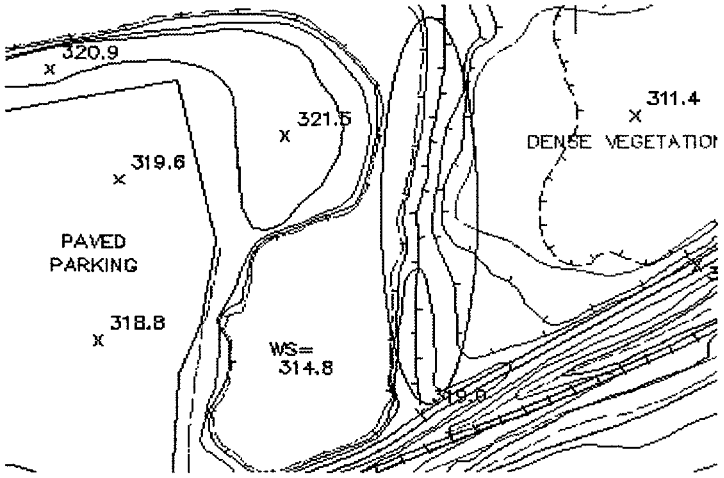


Figure 5.13 The symbols of the entities are stored as blocks

(3) In Figure 5.13, entities within the red ellipse are represented by a number of linear features in a DWG file. DWG file stores each of the sections as a line segment and symbolized as different features. While in a Shapefile, only the position of lines is stored, and symbolization of the lines needs to be processed separately in ArcMAP.

Data set 3

The data set 3 is a map that covers a village area in China. There is an Excel table that stores information about the village (see Figure 5.14). Original DWG file could not be converted by ArcGIS Tool until the Excel table was deleted. However, deleting the table means lost the attribute information in the table. In addition to the data conversion problems 1), 2), 4) and 5) we encountered for the data set 1, the following additional conversion problems appeared.

(1) Arc/Info conversion tools can't read the Excel tables, until the Excel tables were removed. This led losing of attribute information stored in the Excel tables.

(2) In the origin DWG file, there is an image entity, which represents number of the map. This image entity was lost after data conversion.

(3) There were three hatch objects in the original data file. After data conversion, the hatch objects were lost and three points were generated. The coordinates of three points are (0, 0) which were wrong information.

(4) Elevation points with height annotations in the original data file were represented as text objects. The text objects were translated as annotation points in Shapefile. One of the attributes of the elevation points is height. After the file was converted to be Shapefile, the height information was stored in the attribute database. Therefore, text objects of elevation annotation were redundant information.

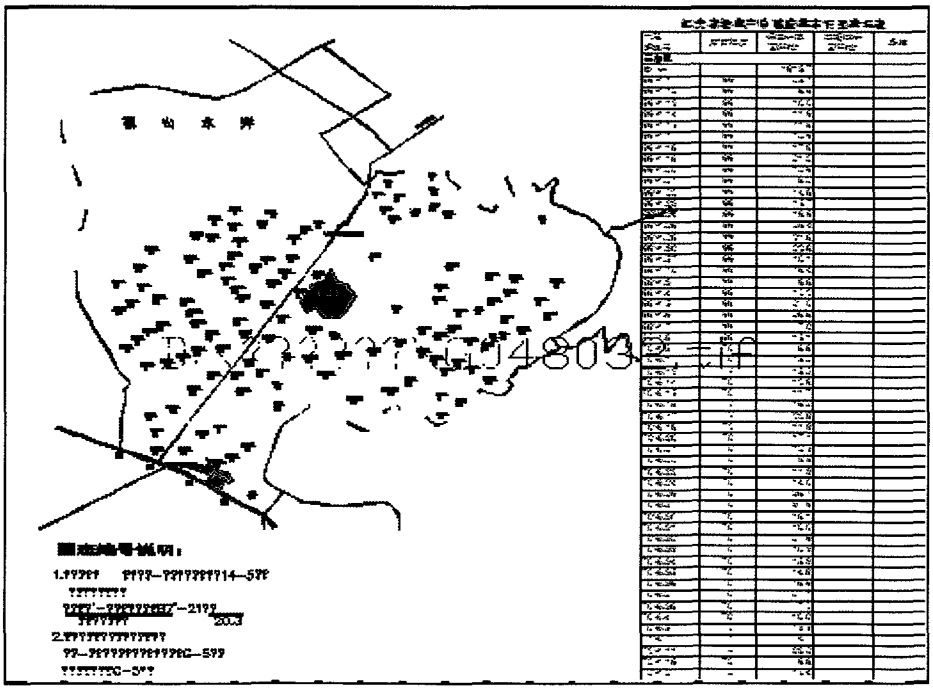


Figure 5.14 The data set 3 in DWG format

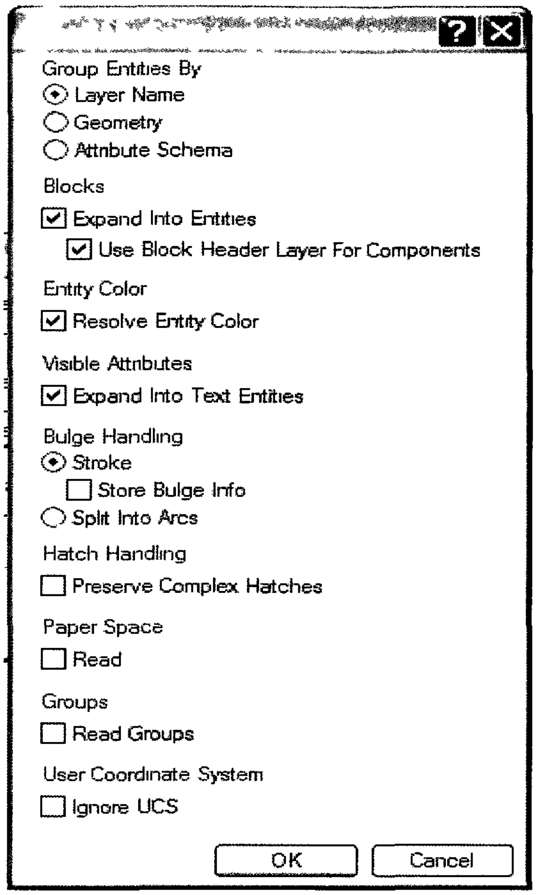
5.5.5 Data conversion by FME

The results for data set 1

By using Workbentch in FME, the data set 1 was translated from DWG format into Shapefile format. From this data conversion experiment, we have the following findings.

(1) The geometric position and shape of the original entities in the data set 1 remained the same after the data conversion. There is no entity lose in this data conversion. This might due to the reason that there is no attribute information in original data set 1.

(2) In FME, the entities in a DWG format can be grouped in the following three methods: a) by layer name, b) by geometric type of entity or c) by attribute schema (see Figure 5.15). The commonly used grouping method is by layer name. The FME thus translates each of the layers in DWG files into Shapefile, respectively. After the conversion, each of the layers is in different color, however, the color for each layer in the Shapefile is different from the original color of the corresponding layer in the original DWG file. This causes a visualization error.



Group Entities By

● Layer Name

○ Geometry

○ Attribute Schema

Blocks

☑ Expand Into Entities

  ☑ Use Block Header Layer For Components

Entity Color

☑ Resolve Entity Color

Visible Attributes

☑ Expand Into Text Entities

Bulge Handling

● Stroke

  ☐ Store Bulge Info

○ Split Into Arcs

Hatch Handling

☐ Preserve Complex Hatches

Paper Space

☐ Read

Groups

☐ Read Groups

User Coordinate System

☐ Ignore UCS

Figure 5.15 DWG parameter settings in FME

(3) In a FME data conversion, if the value of "closed" attribute is "Yes", the polyline is converted into polygon, and if the value if "No", the polyline will not be converted as polygon. In this experimental data set, "closed" attribute of all the polyline is with the value of "No", these polyline entities are not converted as polygon.

(4) In some DWG files of this data set, entities of some of the themes are represented as a block. In DWG Setting (Figure 5.15), we choose "expand into entities" in the Block section. A block is then translated into many entities that compose of the block. Thus, in the Shapefile, users can process every entity of the blocks interpedently.

(5) In FME Workbentch, one can custom the conversion process. For example, one can determine which attributes of original data are added to attributes of the destination data.

(6) Due to the bad quality of the original data, there are quite many duplicated features.

The results for data set 2

By using FME for converting data set 2, we have the following findings.

(1) The polylines can be converted as polygons, however area and length information of the polylines are lost in the data conversion.

(2) In DWG file, the elevation points have (X, Y, Z) coordinate and are marked as the symbole“×”. By using the FME software, the coordinates are converted from DWG into Shapefile, the elevation points become two-dimensional coordinate: (X, Y) from its original three-dimensional coordinates (X, Y, Z). This means that elevation information of the elevation points is lost in the data conversion.

(3) In this set of DWG file, some symbols are represented as blocks. In FME, if we separate these blocks into entities, the appearance of the symbols will be different from the original blocks after the data conversion. For example, in Figure 5.16, a block is consist of a circle and a text entity in DWG file; while after the data conversion, the circle is translated into a polygon, and the text entity translated into a point. Thus, if we do not separate the blocks which represent symbols, the blocks will be translated into points located at the position of insert points of the blocks. One can choose appropriate symbols for the points in ArcMAP later.

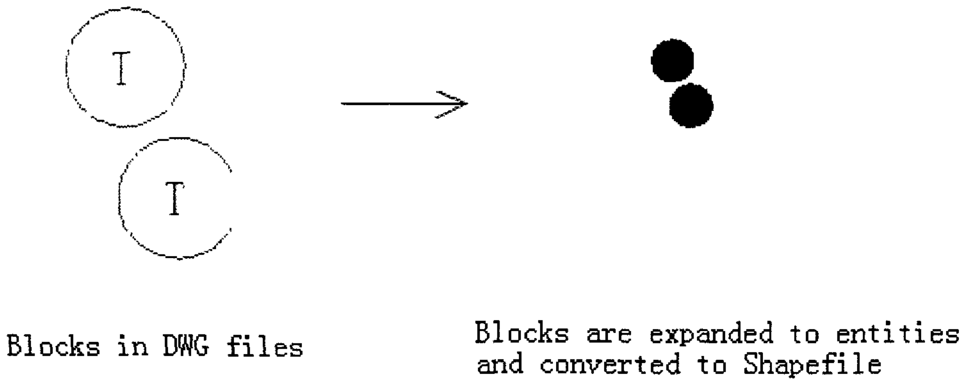


Figure 5.16 Comparison of blocks before and after the conversion

(4) In AutoCAD, most of attributes are expressed as annotations. The geometry data and attribute data are stored as two different entities. While in GIS, an entity contain both geometric and attribute information. And an entity can be annotated based on its attributes.

The results for data set 3

After conversion of the data set 3 by using FME, geometry and location of almost all the entities are the same as the original entities. However, there are some problems were identified.

(1) In this DWG file, two object types are not supported by FME: AcDbRasterImage 、AcdbOle2Frame. Therefore, after the data conversion, these two types of entities are lost. FME translation log has warning information when there is features lose like these.

(2) All text annotation objects in DWG file are translated into points object in Shapefile. Some display information of text objects is lost in the data conversion.

(3) In DWG file, hatch entities are used to represent filling drawings of the closed areas. By using FME to convert DWG to Shapefile, hatch entities are translated into polygons which overlap with hatches' bounds.

Due to some errors in the original source data, the conversion result contains some unknown wrong points and unclosed polylines.

5.5.6 Analysis of the experimental results

5.5.6.1 Characteristics and problems in data conversion

In the experiments, 31 tiles of DWG files were converted to Shapefiles by both Arc/Info Conversion Tools and FME. Many problems arose in the data conversion experiments. We analyze the characteristics of the data conversion and the problems, which are summarized in Table 5.6.

Table 5.6 The analysis of data conversion by FME and Arc/Info

	FME	**ArcGIS**
Error on Completeness	1) Some of the object types in DWG cannot be read by FME. If a DWG file contain objects that cannot be read by FME, these objects cannot be converted, or will be lost in the data conversion. The translation log warns users which objects are missing. 2) Length and area information about polylines are contained in DWG file. These information is missing after the data conversion. 3) The three-dimensional coordinates of elevation points become two-dimensional coordinates after data conversion. This means that is height information is lost in the data conversion.	1) If DWG files contain objects that ArcGIS cannot be read. These objects can't be converted. That is to say that objects are missing after data conversion. There is no any warning on potential missing of the objects. 2) In DWG file, there is length and area information for polylines. These information is missing after data conversion.
Classification	According different situations, one can group DWG entities by layer name, by geometry or by attribute schema.	The DWG entities are divided into five feature classes: point, polyline, polygon, multipatch and annotation
Polylines to polygons conversion	Convert those polylines with attribute of "closed" is "Yes" into polygons.	ArcGIS Tool converts all those polylines with identical start node and end node into

		polygons. This leads many wrong polygons in the Shapefiles. For example, it may convert the closed contours as polygons.
Block entities	It is optional whether the blocks are separated as individual entities. If the blocks are separated, the blocks are translated into the entities that compose of the blocks. If the blocks are not separated as blocks, the blocks are translated as the points at the position of the insert points of the blocks.	Block entities are converted to a point and a whole line entity and a polygon entity when the line is closed.
Hatch	The hatch entity is converted to polygon which consists of the bound of the hatch entity. The pattern of the hatch is missing.	The hatch entity is converted to a point.
Errors in original data	Due to the quality problems of the source data, after the data conversion, there are some errors in the Shapefiles, such as repeated entities, bound of polygons are not closed, etc.	Due to quality problems of the source data, there are some errors in the Shapefiles after the data conversion.
Customization	Users can custom the conversion process.	Users can't adjust the conversion process.

5.5.6.2 Reasons for causing the conversion problems

There are several reasons which cause the above-mentioned data conversion problems. These are summarized below.

(1) Classification error: AutoCAD is a software package for computer aided design, which focuses on the facility of graphics editing and visualization. AutoCAD organizes objects by layers (see Figure 5.8). Arc/Info is GIS software and focuses on the spatial query and analysis. It organizes entities by points, polylines and polygons. The mapping relations between layers and points, polylins and polygons are different in different conversion methods. One can access DWG data of AutoCAD directly in ArcGIS. The relation between DWG layers and Shapefiles are showing in Figure 5.17. For each DWG file, it is converted to 5 layers of entities in ArcGIS. The feature layers contains point, line, polygon, annotation and multipatch feature classes. The line feature class, for example, represents all line features in all the layers in the DWG file. AutoCAD drawing datasets are denoted by a white compass icon. They contain all contents of the AutoCAD drawing and rendered using the original colors of the AutoCAD entities. However, one cannot change their symbols, or use them as a snapping layer. Converting DWG file to Shapefile by Arc/Info actually convert each of feature classes independently.

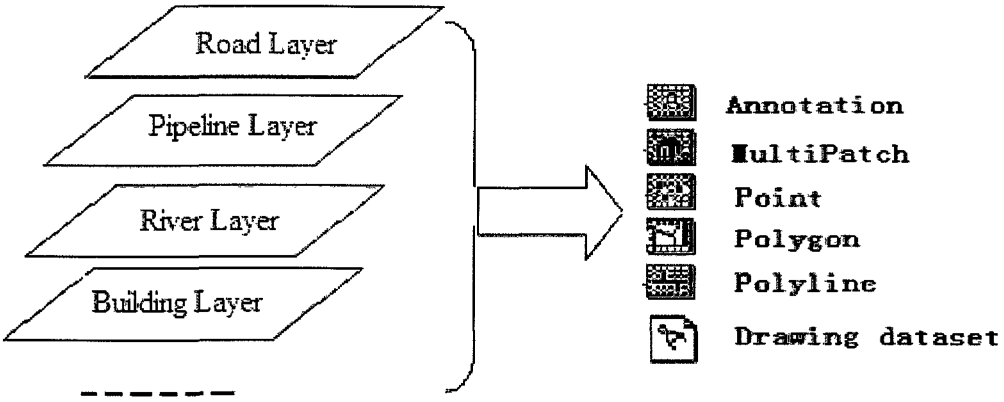


Figure 5.17 A DWG file is converted as five layers of entities in Arc/Info

In FME, it is optional to group entities in DWG file in either the following three methods: a) by layer name, b) by geometric type of entity or c) by attribute schema. It normally organizes the file by layer name and the then map and the relations with layers. FME groups entities in DWG based on their geometry types, i.e. to classify the objects as point, line and polygon. By using a filter transformer in the data conversion, all entities in each layer are generated as point, line, polygon or annotation in Shapefile (Figure 5.18).

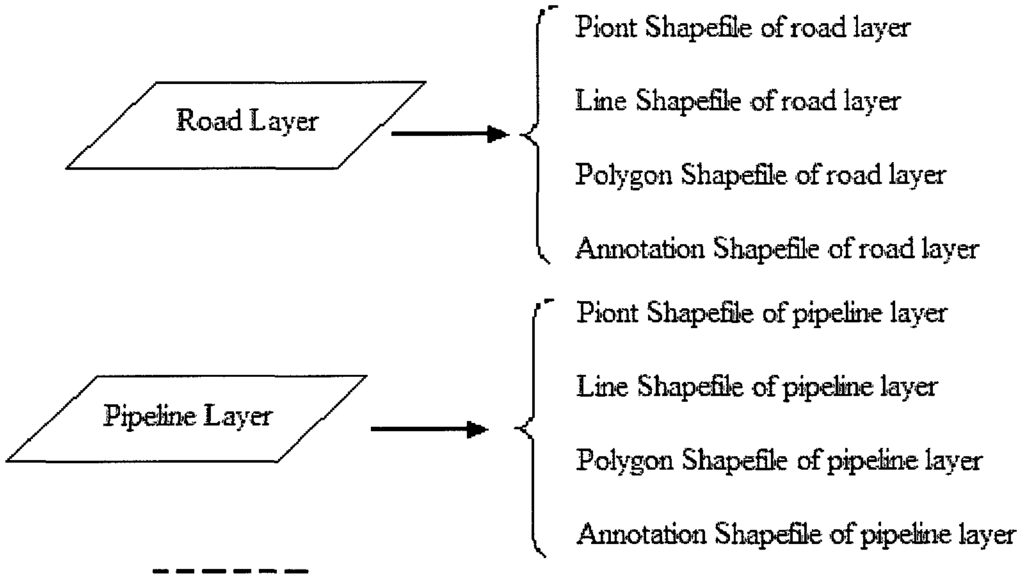


Figure 5.18 DWG file is converted by FME based on the layers

After the conversion by FME, the resulted Shapefiles contain the same type features. Features of the same type have the same attributes and appearance. It is therefore convenient to edit the converted Shapefile. While by using Arc/Info to convert DWG to Shapefile, a Shapefile contains many type features, as illustrated in Figure 5.17. This leads to classification errors and makes it inconvenient for graphic editing.

(2) Entity missing error: The relationship between Arc/Info feature type and the AuroCAD entity types is illustrated in Table 1.4. AutoCAD has more entity types than the feature types in Arc/Info. Various objects are converted to certain feature classes. Arc/Info cannot read all the entity types in AutoCAD. Some entities in AutoCAD are not supported by Arc/Info, such as hatch, image and other. As a result,

these entities will be lost in the data conversion from DWG format to Shapefile format.

Table 5.7 The mapping relationship between AutoCAD entities and Arc/Info feature types

Arc/Info Feature Type	AutoCAD Entity
annotation	Mtext
	Text
multipatch	3DFace
	Solid
	Insert
	Lwpolyline(closed)
	Mline(closed)
	Polyline(closed)
point	Insert
	Point
polygon	3DFace
	Solid
	Circle
	Ellipse
	Insert
	Lwpolyline(closed)
	Mline(closed)
	Polyline(closed)
polyline	3DFace
	Solid
	Arc
	Circle
	Ellipse
	Insert
	line
	Lwpolyline
	Mline
	Polyline
	Trace
null	Attdef
	Attrib
	Body
	Dimension
	Seqend
	Hatch
	Image

	Leader
	Ray
	Shape
	3DSolid
	Spline
	tolerance
	Wipeout
	Vertex
	Viewport
	Xline

Table 5.8 lists the entities in AutoCAD that are supported by FME. If the second column is null, then the entity in AutoCAD is not supported by FME. These entities will be lost when we use FME to convert these entities into other formats.

(3) Error on displayed information: In AutoCAD, a DWG file stores the parameters on the entity display, such as color, line style, line width, and various unique parameters about the entity appearance. While Shapefile will not store these information on display, rather on entities' geometry and attribute information. When an Shapefile is opened for display, the default display parameters will be used. As a result, what displayed based on the default value in Shapefile is different from the original specified displaying information in the original DWG file. For example, in AutoCAD the text annotation is represented by Text type entities. Table 5.9 describes the text entity in the DWG file. By converting DWG file to Shapefile, the text entity is translated to a point. The geometry data of the point record the coordinate of annotation's insert point. The annotation contents are stored in the corresponding attribute table.

Table 5.8 AutoCAD Entities Supported by FME (From FME Document)

AutoCAD Object Type (R14)	FME AutoCAD_entity
3DFace	Autocad_face
3DSolid	Autocad_solid
Arc	Autocad_arc
Attdef	Autocad_attr_def
Attrib	
Body	
Circle	Autocad_ellipse
Dimension	
Ellipse	Autocad_ellipse
Seqend	
Hatch	Autocad_hatch
Image	
Insert	Autocad_insert
Leader	Autocad_leader
line	Autocad_line
Lwpolyline	Autocad_line, autocad_polygon
Mline	Autocad_multi_line
Mtext	Autocad_multi_text
Point	Autocad_point
Polyline	Autocad_line, autocad_polygon
Ray	Autocad_ray
Shape	Aucad_shape
Solid	Autocad_solid
Spline	Autocad_spline
Text	Autocad_text
tolerance	
Trace	Autocad_trace

Wipeout	
Vertex	
Viewport	
Xline	Autocad_xline

(4) Error on displayed information: In AutoCAD, a DWG file stores the parameters on the entity display, such as color, line style, line width, and various unique parameters about the entity appearance. While Shapefile will not store these information on display, rather on entities' geometry and attribute information. When an Shapefile is opened for display, the default display parameters will be used. As a result, what displayed based on the default value in Shapefile is different from the original specified displaying information in the original DWG file. For example, in AutoCAD the text annotation is represented by Text type entities. Table 5.9 describes the text entity in the DWG file. By converting DWG file to Shapefile, the text entity is translated to a point. The geometry data of the point record the coordinate of annotation's insert point. The annotation contents are stored in the corresponding attribute table.

Table 5.9 Description of text entity in DWG (From: http://www.opendwg.org)

Item	**Description**
Length	Entity length
Type	1 (DWG internal type code)
Handle	Code 0, length followed by the handle bytes
EED size	Size of extended entity data, if any
EED	Extended entity data, if any
Graphic present Flag	1 if a graphic is present
Graphics	If graphicpresentflag is 1, the graphic goes here
Obj size	Size of object in bit
Entmode	Entity mode

Numreactors	Number of persistent reactors attached to this object
ISbylayerlt	1 if bylayer linetype, else 0
Nolinks	1 if major links are assumed +1, -1, else 0
Color	Color number
Ltype scale	Linetype scale
Invisibility	Object visibility (optional): 0=visible; 1=invisible
Elevation	Elevation
Insertion pt	First alignment point
Alignment pt	Second alignment point
Extrusion	Extrusion direction(optional)
Thickness	Thickness (optional; default=0)
Oblique ang	Oblique angle (optional; default=0)
Rotation ang	Text rotation (optional; default=0)
Height	Text height
Width factor	Reletive X scale factor-width (optional; default=1)
Text value	Default value (the string itselt)
Generation	Text generation flags
Horiz align.	Horizontal text justification type
Vert align.	Vertical text justification type

(5) Error in converting polyline to polygon: AutoCAD focuses on graphic display, and there is no specific entity type of polygon for representing surfaces. We can define a polyline is "closed" or not. If the polyline is closed, it represents an area object. This polyline is converted as a polygon by a data conversion from DWG to Shapefile by FME. In AutoCAD, some polylines are not specified to be closed although they have identical start and end nodes. These polylines are represented as line features. However, these polylines are translated to polygons when the file in DWG is converted to Shapefile by Arc/Info. For example, sometimes, Arc/Info conversion tools even convert contours and roads to be polygons.

5.5.7 Solutions to the problems

The key issue of converting DWG file to Shapefile is to build the mapping relations between DWG entities and Shapefile object types. Figure 5.13 and Figure 5.12 indicate that FME can support more types of AutoCAD entities than Arc/Info. If there is any entity missing, FME can give a warning during the data conversion. Besides, Arc/Info may convert some polylines that are not area object as polygons. On the other hand, FME only converts the polylines that are specified to be "closed" as polygons. FME converts DWG files by layers. And users can custom translations in FME. In general, FME can reach a better result of converting DWG files to Shapefiles than that converted by Arc/Info.

In the section on experiments, we mentioned that height information of the elevation points is lost in the data conversion by FME. In fact FME provides many translators. Using the "NeighborFinder" translator, FME can get the height information from elevation point's annotation and furthermore transfer the height information to the attribute table of the elevation point. This problem of missing height information can thus be solved. The translation process is shown in Figure 5.19.

In geospatial data conversion, the quality of source data will directly affect the quality of the data conversion result. Therefore, data preprocessing is very important, to clear data and remove unnecessary error information in the source data as much as we can before a data conversion. As a result we can have a better data conversion result.

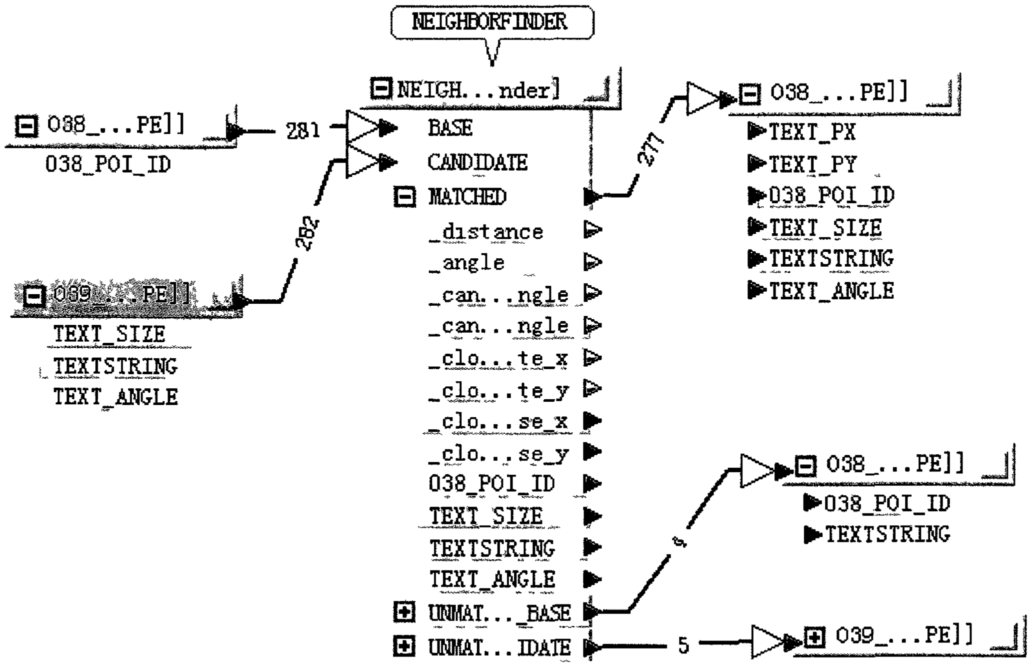


Figure 5.19 Elevation Point Get Height Information From the Elevation Annotation

5.6 Summary

Data conversion is a very important issue in spatial data sharing and interoperability. There are two solutions for spatial data conversion: (a) based on the built in data conversion tool in a GIS, such as the data conversion tools in ArcInfo, or (b) professional data conversion software, such as FME. Any data conversion is not error free. This is due to the following reasons: (a) fundamental difference in data model and data structure among different GIS software, and (b) functions of different data conversion software packages, and (c) quality of source data to be converted. Although the error in data conversion is not avoidable, we can reduce the error in the data conversion by understanding the regularity of the possible errors in the data conversion, as presented in this chapter.

Chapter 6

Copyright and Security of Geo-spatial Information

Several factors affect wide application of city-wide land information systems (LIS), like pricing, copyright, and security/confidentiality of geospatial data. They are mainly policy issues, but involve some technological components. As mentioned before, big issue in China LIMSs is data sharing. This is completely unresolved issue so that the repeated efforts in data collection are common everywhere. This phenomenon is due to not only the culture but also several factors, such as copyright (frequently the shared data are copied for other uses), pricing (not regulations governing the cost recovery and benefit), data security or confidentiality, in particular, digital maps are classified information in China, which significantly affect public access to the data. In Chapter 4 we discussed institutional arrangements and cost model (data pricing and benefit sharing). This chapter is focused on intellectual property of data or copyright issue and confidentiality of geospatial information. They are legal or policy issues. There are four sections in this chapter. We first discuss copyright of geospatial data in Section 6.1, where copyright convention and criteria for a work to be qualified for copyright protection are summarized. Also the copyright of geospatial data is analyzed and discussed. Then legal protection of geospatial data for China is addressed in Section 6.2, resulting in some recommendations regarding legal protection of spatial data. There are some technologies developed to protect copyright of a work. Section 6.3 summarizes some of them. To promote wide applications of geospatial data for the development of geo-economy and geospatially enabled society of a country we also discuss and analyze the issue of geospatial data security/confidentiality, mainly national security of geospatial data, in Section 6.4, which is one of the main problems in China, for China treats digital maps as classified data. This is mainly policy issue.

6.1 Copyright and ownership of geospatial data

6.1.1 Intellectual property (IP) and its protection mechanisms

As defined by World Trade Organization (WTO), Intellectual property (IP) is any product of human creativity in industry, science, or art. Intellectual property rights (IPR) are granted by laws and cover two main categories (Longhorn, et al., 2002):

(1) copyright and right related to copyright, which protect literary and artistic works;

(2) industrial property, including patents, industrial designs and trade secrets, which are protected to foster innovation and the design and creation of new technology, and trademarks and geographical designations, protected for economic reasons.

Other mechanisms for protecting data and software include legislated protection of databases, trade secrets, and trademarks, as summarized in Table 6.1.

Patents grant an inventor a temporary monopoly to exploit an invention, typically 15 to 20 years. This is done with the expectation that society will benefit if new inventions are publicly disclosed, but the inventors require a reward for making their findings publicly known. However, database protection laws are enacted only in some countries, like European Union (EU), by recognizing such databases form a significant economic and scientific contribution to society. In the USA only databases with their creation requiring an intellectual input can be copyrighted, while databases produced only through large efforts could not be copyrighted. A trademark is any sign, represented graphically, which is capable of distinguishing goods or services of an organization or business. To obtain protection a trademark owner must register the name in an appropriate jurisdiction. Trade secrets and confidential information can be granted under Protection of Unclosed Information in the WTO Agreement. By relying solely on trade secrete to protect IP, an inventor may run into a risk that another person will produce the same or similar product, potentially obtaining a stronger IP protection, like patent. The inventor will then lose his IPR.

Table 6.1 Basic features of different mechanisms for protecting IP (after Longhorn, et al., 2002)

mechanism	data	database	software	geographic coverage	comments
copyright	no	yes	yes	registered across jurisdictions	only protect forms of expression, not ideas or data
patent	no	no	yes	require application in each country	not all countries allow patents on algorithms
database protection	yes	yes	no	only available in certain countries	concepts of fair use remain to be established
written license	yes	yes	yes	terms used in licenses vary from country to country	especially useful when dealing with agreements among diverse organizations
trademarks	no	no	no	require application in each country	used only for name and logo
trade secret	yes	yes	yes	laws protecting secrets vary greatly among countries	requires that deliberation efforts be made to keep information or product secrete

Copyright assigns certain rights to the creators of literary and artistic works, including books, drawings and paintings. Copyright, as a right, is protected by law. The purpose of setting up a copyright is to let the inventor to enjoy the benefits of the mental invention, so as to promote creativity, innovation and the spread of knowledge. The concept has been extended to cover computer programs, maps, imagery and databases. Copyright protects the forms of expression of an idea, concept, method or formula, but not the ideal itself. Copyrights are enforced by national laws. Scientists and educators can generally "fairly" use copyrighted materials (called "fair use", of course the definition of "fair" is rather subjective), which is specifically allowed in the copyright laws of many nations. Of course the fair use cannot be transferred to the third party or used for any commercial purposes. Electronic media have additional protections, such as those granted in the USA by the 1988 Digital Millennium Copyright Act (DMCA). The DMCA signed by then the President Clinton accomplishes four things (http://www.loc.gov/copyright): implements the World Intellectual Property Organization (WIPO) treaties; establishes "safe harbor" for online service providers who unknowingly transmit copyrighted works; permits the copying of software during computer maintenance; and facilitates internet broadcasting. Quite commonly, infringement of copyright is difficult to prosecute in other legal jurisdictions. Although there are some high technologies developed (see Section 6.3 below) to detect or prevent pirate copies, effective legal means to exercise copyrights are the most important.

6.1.2 Copyright Conventions

The protection of intellectual rights reached an international level of attention over a century. It was the protection of artistic works first came into the scene. There are two major international treaties on copyright (Chan, 2001): the Berne Convention, or called the Protection of Literary and Artistic Works, and the Universal Copyright Convention (UCC). The Berne Convention was signed in 1886 in Berne, Switzerland, and updated and signed in Paris in 1971. China signed the Berne Convention of the later version in 1992. After that, the attentions were shifted to the protection of commercial audio products. In 1967, the Convention Establishing the World Intellectual Property Organization (WIPO) promoted and developed procedures covering all types of intellectual rights (Law Reform Commission, 1994). It set up a model to protect the computer software in 1977. This has not received much attention in many countries. At present copyright is employed to protect computer software in many countries. The UCC was originally drafted in 1952, signed in 1955, and revised in 1971 in Paris. China is a signatory country for the UCC. One important aspect for these international conventions is that each revision is considered as a separate treaty. It binds only those countries who signed on that revision. Therefore the copyright acts in different countries may be slightly different even if they are signatory countries for a same treaty.

Based on the international treaties many countries have developed their own copyright acts. Although these acts may vary from country to country, as the above-mentioned reasons, the basic principles and spirits are similar. China enacted the laws on copyright and computer programs in 1991. They were drafted with reference to the Berne

Convention and the various laws on intellectual property in different countries as well as the legal principles of China.

For a work to be qualified for copyright protection following criteria should be met:

- *Originality* The word 'original' is a key word to qualify copyrightable data. For copyright protection the work must be recorded in writing or otherwise. According to this criterion, ideas are not protected but the expressions are. Facts and data are not protected because they cannot be created;
- *Compilation* of data from one source to form a new data set is part of the literal work under copyright laws. In the Berne Convention compilation is considered as a form of creation because the selection and arrangement of their contents constitute intellectual creation;
- *The sweat of the brow ("Unfair Extraction Right")*. To protect the works, which are created merely from the sweat of the brow, i.e., through large amounts of effort or money, the "Unfair Extraction Right" has been proposed by European Community. This can be assigned through license of sale. However, this right has not been accepted by all countries, like the USA does not accept the sweat of the brow as a criterion. Each country has its own interpretation and acts.
- *Registration* In the Berne Convention, registration or copyright notice is not required for copyrighting a work. It exists immediately when the work is created, or expression is recorded in any media (like paper, books, computers or any electronic storage media). For the UCC, it permits member countries to have copyright notices and registration as a formality to obtain copyright protection. In the UCC, the copyright notice of a copyright protected work is a mark with a letter C inside a circle (i.e., ©). In China, registration of copyrighted works such as computer software is required.

6.1.3 Analysis of copyright issues related to geospatial data

Anyone who creates, uses, or disseminates spatial information, tools, or services based on the data and tools, faces certain legal responsibilities. Cho (1998) highlighted the following legal risks related to geospatial data or GIS:

- Failure to secure IP right;
- Liability for infringement of IP rights, whether intended or not, resulting in illegal use of the data or tools by others;
- Failure to secure accountability for defective data or GIS tools (i.e., models, methods and services based on the data and tools);
- Liability for breaching privacy or confidentiality obligations;
- Legal uncertainties involved in outsourcing data collection, processing, and dissemination.

All these aspects need particular attention when geospatial data are used for any purposes.

The field of legal issues in geospatial data is complex and evolving rapidly, and various international agreements and national laws are under discussion which will affect use of geospatial data and software. From the nature of IP, it is clear that protection of geospatial data as such, must be sought in copyright protection. In this respect it must be noted that copyright does not extend to raw data, but only to enriched data. A map is a collection of information. The information is facts or the true position of a feature on, above or below the ground at the time of collection. With the criterion of originality it cannot be protected. However, in map production the graphical data are so selected, arranged, and presented in a suitable scale (i.e., some information is simplified and others are shown to a scale or even exaggeratedly) that the purpose of a certain work can be met. In addition, a map is also designed to produce artistic and aesthetic effect. Therefore, according to the criterion of compilation, a map should be within the realm of copyright protection.

Geospatial data (or digital maps) are digital data stored in computer. Although a map is copyright-protected based on the criterion of compilation, the argument against copyrighting digital maps is strong: the data is just a collection of information through a given or standard procedure. The data, both graphic and textual, are facts in the time of collection. This contradicts with the criterion of originality. Moreover, the data are stored and collected with little or no selection or arrangement. This conflicts with the concept of creativity. Therefore there is a doubt on its copyright protection. However, with the criterion of Unfair Extraction Rights the collection of geospatial data is labor-intensive work and costly, and the data can be protected through compulsory license. But this is only valid for some countries (like EU), who accept the concept of sweat of the brow. Regarding geospatial databases there is no universal laws or regulations to protect them as one can see from the above discussion (Section 6.1.1) on two treatments (i.e., EU versus the USA). This is an important issue China must settle.

Copyright is also much related to ownership. Copyright is given to a piece of work and not to a person or organization. There may be cases where two or more individuals or organizations completed a piece of work, i.e. they jointly own the work. This results in joint copyright. One should note that joint copyright can be a dangerous trap for business. Disputes over joint copyright issues are often expensive, fact-intensive and it is difficult to prove ownership. The related parties must settle the percentage of copyright at outset. In geospatial industry there exist many cases of joint copyright as discussed below.

One of typical examples is that an institution has produced a digital map and sold it to another institution, and the institution that has bought this digital map adds new data to the map to makes it more marketable in a certain field, like navigating maps by adding a lot of traffic information. The new product enjoys copyright protection. Now the question is who should be the owner of the new product, or who should get benefits from the new product. To avoid any later dispute it would be beneficial to all if a joint copyright is to be established. In essence, it is a contract of profit and duty sharing agreement. This method is in vogue in the developed countries. Another example is up-dating database. If a work is copyright protected on its creation, the updated database will earn copyright protection every time when it is produced. That means all the new updated databases are given copyrights. As the data of a LIMS have to be updated frequently, there may be a situation that copyright is given to a piece of work with only minor updating. This does not cause any problem if updating is done by the same organization, but generates joint copyright (ownership) if done by another organization. For a copyrighted material, it should be original. However, if the work is a copy of the previous edition with only a small alteration, it is debatable whether it is copyright protected under the originality and compilation. Copyright of an updated database is given to work, which is substantially different from the previous edition. The definition of substantial is not just on quantity but also the quality. Quality means that the updated data effectively affect the users in deriving the information for their management activities.

6.2 Legal protection of geospatial data for China

China has had the law of copyright since 1991. It protects maps, but has not included (at least not clearly specify) geospatial data or digital maps. To promote geospatial economy or spatially enabled society geospatial data protection and liability must be defined. This section first reviews the practice in Hong Kong, who maintains a good international trading stance. The purpose of this review is to give a good example. Some recommendations on legal protection of geospatial data in China are then proposed.

6.2.1 Legal protection of digital mapping products in Hong Kong

Hong Kong maintains a good international trading stance. In the 1970's Hong Kong had two laws: the Copyright Ordinance [Cap. 39 – chapter 39] and the United Kingdom Designs (Protection) Ordinance [Cap 44] to protect intellectual rights. After the repatriation in 1997, Hong Kong Special Administrative Region (SAR) enacted one comprehensive law to protect intellectual property rights. The Copyright Ordinance [Cap 528] is now in force. Its section 2, copyright and copyright works, defines that copyright is a property right which includes many forms of works and one of them is the artistic works. In its section 5, artistic works includes a graphic work for which it includes map, chart or plan. This is the law which specifies the legal protection of digital or paper maps. In Section 119, penalties for offences, an infringement of copyright is liable to a maximum fine of $500,000 and 8 years of imprisonment. The court has the right to award extra damages on the flagrancy of the infringement and on the extra benefits accruing from the infringement (Section 108, provisions as to damages in infringement action).

In *Secretary for Justice v. Crown Publishing (HK) Limited and Leung Shing Sang* (HCA 428/2008), the Hong Kong government claimed the copyright relating to a set of digital mapping products, for which the defendants had published road maps in 2003 and 2004. The government has proved to the court about the art design of the B10000 maps. The first defendant claimed innocence on the business but the court refused and cited the authority of *Copinger and Skone James* on Copyright such that innocence or ignorance is not a defense. The government sought additional damages under Section 108(2) of the Copyright Ordinance [Cap 528] from the 2nd defendant who was the consultant of the map books. A publisher bought some digital data from the mapping authority of the government. It is intuitive that the publisher intends to use the digital data to make products for profit – in this case – the road map. The publisher, Crown Publication (HK) Ltd, hired a consultant, the second defendant, to make a road map based on the B10000 digital maps purchased from the mapping authority. Obviously, the sale agreement was for the sole use of the purchaser but not for publishing purpose. The consultant did not negotiate for the commercial license for the reproduction of mapping data. The mapping authority did not warn the map purchaser that the purchase price did not include a publication license. This more or less reflects that bureaucratic arrangement of the government office. A proactive contact with the 1st defendant would have solved the problem. Although the 1st defendant claimed innocence in running this new business, the court did not accept that as a proper excuse. The second defendant, having received a fee of HK$170,000, is considered the culprit of the case, who tried to take advantage on the slack monitoring of the mapping authority.

Hong Kong has a good and working system to protect digital mapping products. The government, not the mapping authority itself, has a monitoring mechanism on the violation of copyright. In this case, Custom and Excise Department takes the action of charging the copyright violator.

6.2.2 Recommendations for legal protection of geospatial data in Chinese mainland

Since the Peoples Republic of China entered the United Nations as a member and a permanent member of the Security Council in 1975, China has committed herself to international treaties including intellectual property enforcement. With the increasing economic power in recent decades, China has to keep up with prevailing international standards, so as to keep good standing in copyright protection and enforcement under an international trading environment. The commercial products like software, video and music records are popular items of protection. China protects intellectual rights. The Standing Committee of the National People's Congress (SCNPC) has set up policy and signed several international treaties on the protection of intellectual rights. The State Intellectual Property Office of the Ministry of Commerce administers the tasks with the major attentions on international trades.

As mentioned above, the first national copyright law was passed in 1991. The current Copyright Law of the People's Republic of China was amended and adopted by the Standing Committee of the National People's Congress in 2001. The law has a wide coverage of intellectual works. In Article 3, Section (7), maps are included as drawings of engineering designs. This is a general form of copyright protection to maps. However, this is not an advanced form of digital mapping data protection where special attention and specifications on digital data are delineated. The only interpretation of digital map protection is implicitly under Article 47 (7) as follows: "intentionally deleting or altering the electronic right management information of a work, sound recording or video recording, without the permission of the copyright owner or the owner of a copyright-related right, unless otherwise provided in law or in administrative regulations". The law also sets up an institution for the implementation of copyright law. In Article 7, the Copyright Administration Department under the State Council is established for the nationwide administration of copyright. In each province, autonomous region and municipality under the Central Government, a similar copyright department is set under the local administration. Article 46 states that an infringement shall bear a civil liability. That means anyone who commits any acts of infringement shall bear civil liability for such remedies as ceasing the infringing act, eliminating the effects of the act, making an apology or paying compensation for damage, depending on the circumstance. The Civil Procedure Law should be applied if any dispute occurs. The violation of the intellectual rights on digital mapping data from private business sector could be easily dealt with. Yet, the violation of the intellectual rights on digital mapping data from the private business sectors which are supported by other government departments could make the situation difficult. This is a long existed institutional problem.

Like many other developing countries, the copyright law of China has included maps as artistic work and protected, but not clear for geospatial data (digital maps), as discussed above. As GIS/LIMS services and products are advancing at an unprecedented speed, the existing law may not be comprehensive in providing protection to geospatial data owners. This problem exists elsewhere in the world. For developed states, lawsuits on copyrights are frequent. In developing states, although mostly are protected by a general copyright law, many complaints of the lack of geospatial data copyright protection are made (Moyo, 2005). Moyo (2005) described that the lack of "specific mapping law for interdepartmental data access and exchange has led to pressure amongst geospatial data producers to recover their operational costs and protect their creativity." The consequence of the lack of such a protection leads to a number of risks and implications. And, it calls for a mechanism to protect individual organization and the ways to reward the spatial data owners. These risks and implications, if intellectual property rights of geospatial data are not acknowledged and defined, include:

- No commitment for data sharing discussed in Chapter 4;
- Difficulty in the implementation of the funding and data pricing models as discussed in Chapter 4;
- Damage in the culture on copyright; and
- Negative effect on quality assurance.

It is clear from the above discussion that China still lacks geospatial data copyright protection and liability. Therefore there is an urgent need to develop or supplement a lawsuit for geospatial data and databases. The author therefore has the following recommendations.

(1) Further develop the culture of copyright protection of geospatial data among government officers, company managers, educators, scientists and engineers in geoscience. China is a developing country and concept of copyright is relative new to them. They do not regard infringement of copyright as serious as thieving goods and money. There are complaints from Chinese geospatial data community that the software cost and license fee are too high and data security is threatened by pirate copies. On one hard it is easily felt that the copyright fee paying for software developers are too much whereas users may also feel the data costs are too high. Therefore copying or decoding of commercial software and pirate copy of data often happen and also give a good name called "Ai Guo Ban 爱国版" software. Data owners do not feel secure about their products. In this regard the government departments of copyright at various levels have a lot of roles and duties to perform. On one hand they must actively promote their existence (i.e., many people do not know there is such a government department) and good culture of copyright with various means, like through different kinds of media (newspapers, TV, posters, etc.), and publicly punishment of offenders to educate people. On the other hand they should check frequently and randomly the users to sure the society that copyright protection is of importance. As the first step they should seriously check and punish government users if offended. This is to make sure the government users will set a good example. Each institution, in particular governmental departments, education institutions, research institutes, and other public-funded agencies should have internal auditing system to regularly self-check their data and software. The Hong Kong practices in this aspect can be leant.

(2) Law on the copyright issues for geospatial data should be worked out (see (4) below for detail analysis). Although China adopts the Berne Convention and has law of copyright, it is not explicit, as discussed above, how geospatial data can be protected. Different person can interpret differently. Data protection and ownership

are important legal issues to the IT industry. To promote IT industry in China it is the high time the Chinese authority should enact a separate set of laws on geospatial data related copyright. Collection of geospatial data is very expensive. With the digital technology the data is much easier to be copied. If the data cannot be protected, no one will invest in establishing a GIS. There is a typical example in China: one municipal government spent a large amount of money to update the digital maps of the city, but is afraid of selling digital data to other organizations. In my visit the director of the institute (data owner) explained the reason that because there were no strict regulations and laws enforced and the organizations who bought the digital map data may copy or even re-sale them to others. I am sure there are many similar cases in the country. This will not only limit the usage of geospatial data, but also generate a situation that each organization has to collect information by itself. The author therefore strongly recommends that geospatial data should be copyright-protected. There may be an argument that China is not in such an urgent need because all the geospatial data are under the control by government. The collection of spatial data is generally open in many countries, yet China is one jurisdiction which has controls over the collection of spatial data. Traditionally speaking, mapping data in China are the sole product of the government institutions. The copyright naturally belongs to the surveying or mapping institutions. Therefore it explains there is relatively little legal protection to mapping data. In other advanced counties, they protect not the spatial data but the way the data are selected, coordinated, and arranged. This is the effort of the mapping institute which makes the technological and artistic input into the data. This is seen as an intellectual property. Unlike commercial intellectual products, Geo-spatial dataset and mapping data are controlled by the National Survey Law where the State Survey Bureau controls the copyrights of the national products and local provincial authorities control regional mapping products. With rapid development of geospatial economy, the situation that governments control geospatial data will soon be changed. Private companies and corporate agencies have entered the market of geospatial data collection. They need copyright protection. Also most of copyrights of geospatial data belong to public bodies, and geospatial data copyright law can protect their damages and loss. Moreover, there are arguments from many land bureau directors that the high-tech copyright protection devise should be developed and used so that it would allow an easy proof of infringement from other pirate copies. The needs come from the background that different government institutions or departments would produce similar mapping data. Vast investments have been made on some basic spatial data plus some particular applications. The holders of the data would like to market their data but easily it would be pirated because the production of general mapping data can be done from variable sources. Although there are some technical means to protect copyright (see Section 6.3), all of them do have limitations and can be decoded. The best way for copyright protection is through legal protection.

(3) A committee at national level should be formed to study the legal issues related to geospatial data. The committee should consist of the representatives from legal, information and administration sectors. National Bureau of Surveying and Mapping should be a key member in this committee. The main duty of the committee is to draft regulations/laws on the intellectual property of geospatial data after a wide consultation process. The regulations must be approved by the National People Congress. Having had the law of geospatial data copyright protection, its implementation and enforcement are critical. This is particularly true in China. To have legal protection on the violation of digital map copyrights in China, the legal prosecution unit should be done by specified departments which have the legal authority to exercise proper legal action, like in Hong Kong where Custom and Excise Department takes the action of charging the copyright violator, rather than Department of Lands (Surveying and Mapping Office is in this department).

(4) Resolving the issues related to copyright of geospatial data (digital maps), which are unclear. From the above reasoning (see Section 6.1.3) paper maps are copyright protected based on the criterion of compilation, and their digital form should also enjoy the same protection. Production of digital maps is not just collection of facts/information through given standard procedures, as argued by many others, but involves the selection of information/facts, as analyzed in (Chan, 2001). If digital

maps are produced by ground surveys, selection of features and points of a feature (like a road) to be surveyed and accuracy of survey is required. If they are produced by photogrammetric techniques, selection of technical specifications, instrumentation, ground controls, and other technical details involve intellectual work. In the case digital maps are produced from the digitization of paper maps, there are two operation modes. One is through scanning. Selection and preparation of layers of features are needed before scanning. The other is manual digitization. Design of operation procedures, specification, and quality-checking method is required. Thus, the production of digital maps/databases is not just mechanically (without any intellective work) collect/record facts, but needs intellective involvement, like design of survey procedures, analysis of the results, and quality checking of the results. Moreover, the production of digital maps is labor-intensive. Under the Unfair Extraction Rights the digital maps/GIS should have some kind of protection (through an agreement). In the view of the author digital maps are qualified for copyright protection. Regarding the Unfair Extraction Right, it was proposed by European Community and mainly used by the European countries. China should adopt it in her laws to protect those works which involve intensive labor or money.

A LIMS involves several kinds of geospatial data and databases, and several organizations. As discussed and proposed in Chapters 3 and 4, each sub-system of a LIMS is responsible by one single institution. One sub-system sometimes uses databases which are from other sub-systems. The copyright should be assigned to individual database and the ownership is to the organization that creates and maintains the database. For example, the basic layer of geodetic control and detailed mapping layers should be held by planning department/survey department, the cadastral land parcel layer should be held by the lands bureau and the sub-surface utility layer should be held by the construction bureau. These designated departments should have the legal authority on the particular type of data. They can grant license for production or use, and these data holders have the political duty to promote the use and the maintenance of updating of the data. An unauthorized use of spatial data on the market can be easily spotted.

(5) Clearly define the ownership of geospatial data. It is clear that producer of paper maps is the owner, but it is sometimes not clear about the ownership of digital maps if they are converted from paper maps by digitization. The ownership should be clear if paper maps are owned and their digitization is done by a same organization or through outsourcing. However, if company A owns paper maps and company B performs their digital conversion based on an agreement; both companies should share the ownership of the final products (digital maps). The percentage of ownership can be computed based on the cost each party has paid. There may be a case that digital maps are produced by an organization other than the paper map producer and by selective digitization, i.e., no all the features are digitized, but only those interested objects are selected. An example is digital street maps where the buildings along a street are not interested and replaced by blocks. The new products are copyright protected under the criterion of compilation. The percentage of ownership cannot be determined using the above method, but larger percentage should go to the organization of the new products.

In the case of updating of GIS database, an updated work will qualify for copyright protection if it is substantially different from its previous version. How to define word substantial? In the view of the author, over 25% of information updated can be considered as a new version. This is based on the similar principle for map revision. In the old time maps need regular revision. The revision is determined in terms of age of maps or the change of their contents. According to a survey by an ISPRS WG, many countries revised their base maps on average every 10 years or if the change is larger than 25% (Chan, 2001). Updated digital maps have their own independent copyright. But if the updating is done by different company, the question is who owns the product. In similar to the above two organizations (original owner and updating company) should share the ownership. The percentage of the ownership can be calculated based on the percentage of updated or revision. As the data of a GIS must be frequently updated, there may be many cases where updating is not large (or less than 25%). Each updated database cannot be treated as a new version for independent copyright, but should be provided to the users who purchased the original version of data. The data provider may wish to charge fee for the updated database.

In the case of value-added GIS product, many organizations/companies use digital maps as a base for their IT developments. They add specific information and generate new IT products. The new products definitely earn independent copyright and are copyright-protected. The question here is the ownership of the new products. In the view of the author the digital map provider should also share the ownership of the new products. The percentage of the ownership should be negotiated based on the amount of information added and the amount of original information useful. Take as an example a traffic information database. A company adds all the relevant traffic information into a digital street map. The information includes traffic signals, signs, gas stations, number of lanes, traffic direction (one way or two ways), etc. However, the information in original digital map, which is useful in this database, is only street positions and their names. The sharing of the ownership should be determined based on the above, not all the data in a digital map.

In the case of compiled information: the cases may arise, for instance, that digital maps may be simplified or re-compiled to generate new products to satisfy specific requirements by another organizations. According to the criterion of compilation the new ones have their own independent copyright. But the ownership needs negotiating.

6.3 Technical protection of digital map copyrights

A common and simple technique to technically protect digital maps is to convert original coordinates of each map feature to false ones. This is done through a transformation (also called encryption):

$$X = F_1(x, y)$$

$$Y = F_2(x, y),$$

where x, y are the coordinates of a point in the original (undistorted maps), and X,Y are the coordinates of transformed maps (distorted maps), and F_1 and F_2 are suitable functions designed by map owners. The distorted digital maps are then sent to users. The authorized users also receive a recovery functions and hardware device, i.e., F_1^{-1}, and F_2^{-1}, so that they can transform the distorted maps back to the original ones (also called decryption):

$$x = F_1^{-1}(X, Y)$$

$$y = F_2^{-1}(X, Y)$$

The recovered maps can only display and worked on in a specified computer. Any unauthorized map users can be discovered easier.

There are many other techniques used. Zheng et al, (2009) reports on the digital map copyright protection in China using the watermarking technology. The technology of watermarking and steganology of electronic signals are used to thwart counterfeiting (Cox, et al., 2007). Watermarking here refers to the technology which imperceptibly alters GIS datasets to embed a message and to detect such a signal in a dataset. Steganology here refers to the technology which undetectably alters GIS datasets to embed a message and to detect such a signal in a dataset.

Watermarking. Cox, et al. (2007) expounds on the two methods. Paper watermarks appear in cash notes. The watermark will not be seen unless the cash note is deliberately viewed by holding against a light source. The watermark thus has a function of proving the authenticity of the money note. The idea of electronic (or digital) watermarking is to embed a small amount of secret information, i.e., watermark, into the host media to achieve goals like copyright assertion, authentication, and content integrity verification, etc.. They imperceptibly alter the signal which allows the identification or another other message that the original owner want to express. Digital watermarking schemes can be classified into three categories: robust watermarking, semi-fragile watermarking and fragile watermarking according to (Si and Li, www.dcs.warwick/ac/uk/). The first one is indented for the applications of copyright protection and digital rights management (DRM) wherein the watermark containing copyright information should be detectable after attacks that aim at erasing the watermarks but maintaining the value of the host media. While the latter two have been developed for the purposes of authentication and content integrity verification, in which the embedded watermark is expected to be destroyed when the attacks are mounted, so that the alarm will be raised by the detector when it fails to extract the watermarks.

Steganography. Another slightly different method is steganography. A classical example is to write invisible message using milk instead of common ink. When the paper is heated above a candle the message is visible again. The term staganalysis, which is the opposite of steganography, is the method to detect hidden message. It is more important than steganography from the perspective of e-national security. Both terms are combined as steganology (Cox, et al., 2007).

Cryptography. The progress of the electronic watermarking technology reflects the increasing concerns on the copyright protection of electronic merchandise. The well developed technological solution first came up was cryptography. Cryptography is commonly used to protect an initial unauthorized use of a digital product. In a digital product, the content is encrypted. A lawful user has to apply the decryption key, then the encrypted file be made available and usable. To meticulously encrypt a digital map is one of the solutions. The fallacy of the protection is that a purchaser, after using the decryption key to obtain an unprotected copy of the map, proceeds to make pirate copies or unauthorized uses. There is a technical need to ensure copyright even after the digital product is decrypted.

Watermarking or Steganography. Watermarking is usually applied to images. A watermark algorithm generates a reference pattern which is superimposed on an original image (See Figure 6.1). The watermark can be imperceptible to human eyes. The image has a robust security that can survive normal image processing because the watermark is an inseparable part of the image content. A digital detector gives high reliability in discovering a watermark. Of course, the watermarking action can be reversed if the exact algorithm is used. The technology can be applied to all map data with selected regions and different embedding algorithms.

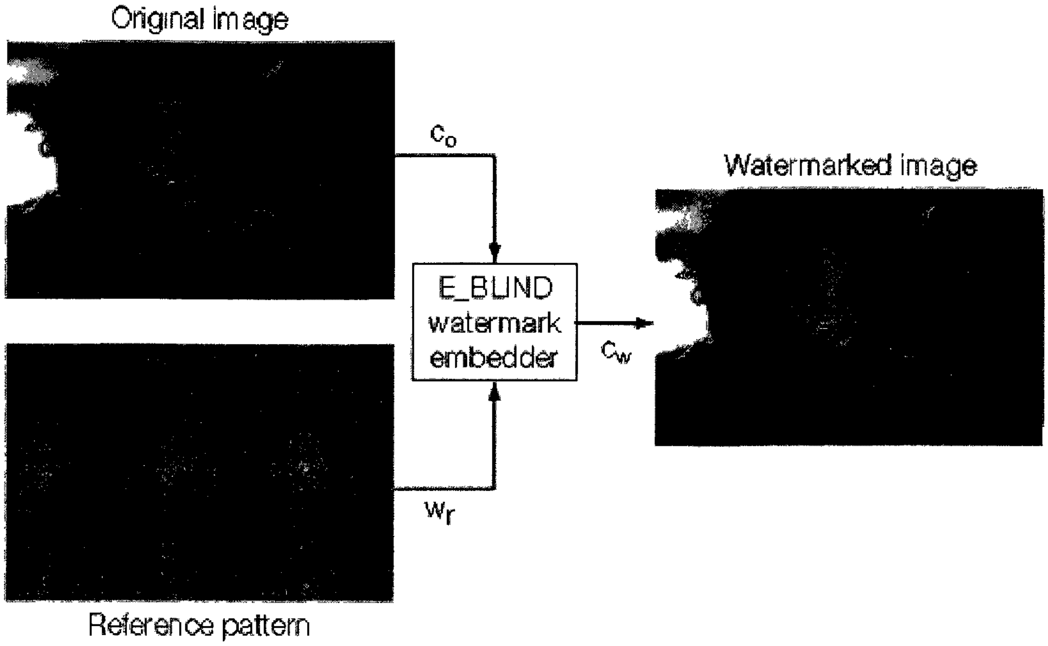


Figure 6.1 Results of a blind embedding algorithm with a reference pattern constructed from uniformly distributed noise (after Cox (2007))

Steganography is another mature technology which writes an undetectable message (e.g. the ownership message) onto the innocuous body content (e.g. GIS data). Even without using the steganographic algorithms, the insertion of typical codes or digits to prove ownership is a method used for hundreds. For example, in the Seven Figure Logarithmic table, a publisher who spent much effort in crunching out the correct figures deliberately put a few many mistakes in the digits. If another publisher infringed his copyright and declared that the publication was done by another publisher, these little errors were used to prove ownership. There are numerous possibilities for a GIS dataset owner to plant as many secret codes into the dataset.

Automatic copy control. It is reckoned that many currently market available technology assists only the detection of violation of digital copyrights. It is a deterrent against any copyright tortfeasor. As it is mentioned earlier that copyright legal enforcement in China is in its early stage, it is practically preferable to have a digital copyright technology, which actually prevents the illegal or undesirable copyright infringement. One successful control is the signal decryption device of the satellite television channels.

Another once successful application was the implementation of digital watermarking on audio products by the Secure Digital Music Initiative (SDMI) in 1998. Large electronic companies would produce digital record players which can only work on audio products with the SDMI watermark. The technology was soon deciphered and a US research had opened the secret to the public. The SDMI was not continued after 2001 (Wikipedia on SDMI). Similar video watermarking technology (Video Encoded Invisible Light VEIL) can be used on DVD recorders. The well known international name-brand DVD recorders will not record a video if it is watermarked. This is a strong disincentive to purchasers. Many Chinese new DVD recorders are known to be 'robust'. One can indiscriminately play and record licensed or pirate DVD, attracts bigger market share.

Even one could prove the authenticity of the original digital product with the above-mentioned technology; a tortfeasor may perform a subsequent digitization upon the analog signal which easily creates a high-quality illegal digital copy. There are limited ways to protect intellectual property but numerous ways to violate them.

Restricting illegal or unauthorized use of digital product pays great efforts and receives short success. The new copyright device is like antibiotics whereas copyright tortfeasors are like bacteria - bacteria always get stronger. The technology is matured in imbedding electronic signals in any forms of electronic products.

Under the above analysis, even when reliable and imperceptible electronic watermark is installed in a GIS dataset, no GIS software will automatically apply the restriction on viewing, reading, recording, copying and any other functions on the pirate GIS data. Hardware restriction is also impracticable. The best use of the technology is to prove authenticity and legal ownership of the GIS dataset. It has to work under proper legal and institutional arrangement.

6.4 Issue of security/confidentiality of geospatial data

Digital maps are the fundamental information/data for all kinds of geospatial information systems. However, all maps at scales smaller than 1: 1 million are classified in China. Some of them are treated as confidential products, while the others strictly confidential. This is true for the maps not only at national coordinate systems, but also at local coordinate systems. Most of cities in China use local coordinate systems. A local coordinate system is defined by its northern axis as a central meridian passing through the center of a city and a false origin. The security control of geospatial data in China is very strong due to military involvement. Although most of digital maps are produced by State Bureau of Surveying and Mapping and many other civil mapping organizations, the security issues of digital maps are mainly controlled by PLA Military Bureau of Surveying and Mapping. They claim geospatial data affect nation security and must be kept confidentially. This policy has followed the policy of the former Soviet Union since the foundation of PRC in 1949. Even today Russia has the national security law on limiting geospatial data gathering and dispatching. In short, using a GPS locator in a portable phone may constitute a violation of national security law. National security protection is of high priority for the country. Therefore all the mapping agencies have an office of security control of digital maps and no one would like to challenge this policy because he/she may face a political risk, though many professionals think it is not a wise policy. Due to this policy many map agencies cannot provide data to private companies, limiting the development of new industries, like location based services (LBS) of huge potential market, intelligent transport system (ITS), and geospatial economy. Undoubtedly, limiting access to geospatial information is handy for government security purpose. Yet, it also blocks the healthy commercial interactions which is stipulated the protection of freedom of information access.

The United States of America has much less control of digital maps. She has the first world-leading Presidential Executive Order 12906 which stipulates public access to geospatial data. There are federal laws – Freedom of Information Act and State Public Record Act – to protect the freedom of public access to information. The control of public access to some geospatial data after the 9/11 terrorist attack has been tightened. However, complaints on the limiting access to geospatial data by government homeland security measures surfaced. Tomb (2005) discloses the conflict of nondisclosure of public geospatial records, and censures government departments which remiss the security orders and blocks the flow of public geospatial information. The Federal Geographic Data Committee issued guidelines in May 2004 for geospatial data access, for which the principle of informed citizenry is upheld.

India is a developing country and used to tightly control maps. Nowadays, she has much relaxer policy on national maps. India has two series of maps (www.dst.in/scientific_services/nationalmappolicy.pdf) : defense series maps and open series maps. The defense series maps are classified and mainly cater for defense and national security requirements. The open series maps are issued by Survey of India for supporting development activities in the country. It will become unrestricted after obtaining a one-line clearance of the Ministry of Defense. These maps contain almost all the detail information except civil (like government buildings) and military establishments. But those public establishments which have interesting to public, like police stations, post office, etc remain.

In this research, for the promotion of city-wide geospatial database/LIMS, it is of interests to investigate if the limitation of surveying/geospatial data acquisition, dispatching, access and use serves the purpose of national security. Space programs are always related to global geospatial images. Needless to say, the USA and Russia are the leading powers in space programs. One major difference between the two is that in the USA, besides the research and development efforts of the military, the private commercial sectors also actively participate, unlike the sole involvement of national military efforts in Russia. Indeed, the USA economy has long been supported by military investment and development. The interactions and multiple effects of military research and development have made the USA the strongest power on earth. But, as evidenced from (Tomb, 2005), when there is a conflict between national security and free access to information, there should be a guideline on the access of geospatial information.

Nowadays, space programs can provide accurate and detail mapping of earth surface with satellite imagery, DigitalGlobe and GeoEye are two world leading and private satellite geospatial data providers. Both are listed in New York Stock Exchange. DigitalGlobe supplies Quickbird, WorldView I & II imagery. WorldView I & II has a resolution of 0.5m, as listed in Table 6.2, which is the highest resolution that the USA government allows for commercial dealings. GeoEye supplies Ikonos and GeoEyeI imagery. For best resolution, Ikonos is 0.8m and GeoEyeI 0.5m. Other major satellite imagery providers include SPOT and RapidEye. SPOT, a Franch company, provides best resolution at 2.5m. RapidEye, a Germany company, provides best resolution at 6.5m.

There is a chain of geospatial data related companies adhere to the every satellite data provider. For example, DigitalGlobe lists ESRI, Microsoft, NAVTEQ and Oracle as its strategic alliances for which the satellite imagery is used in their products. There are selling agents as global resellers around the world. These commercial satellite imagery companies are also seen to be supported by their governmental agencies. For example, the National Mapping and Imagery Agency, NIMA, has contracted with DigitalGlobe and GeoEye to acquire high resolution satellite imagery. These government-commercial sector interactions have vitalized and supported thriving geospatial business.

There are many international consultants who specific in the supply of geospatial data including satellite and aerial imagery, surveying maps and digital models, like SpatialEnergy and INTERMAP Technologies. SpatialEnergy is a USA based company providing integrated solutions for geospatial information to the energy industry. These are international consultants for the acquisition and building-up of geospatial data for specific institutional and commercial use. These commercial activities have further contributed in the economy cycle.

Restriction for the acquisition of location data under national security reason is unsustainable. Commercial satellite imagery nowadays has reached 0.5 m resolution; not to mention military capabilities. A sample of WorldViewI imagery is shown below

(Figure 6.2). Modern space programs not only provide high resolution images, but accurate orientation parameters for 3D mapping at a world coordinate system. Overlapping satellite images can generate 3D model of earth surface. With orientation parameters provided 3D model can be located (like software PCI orbit model) to an absolute coordinate system with accuracy of a few meters even without ground control points (GCP). Nevertheless, as for the national policy on the development of spatial data infrastructure, and the growing of the geospatial industry so as to underpin national economy, I propose:

(1) China should choose a direction moving away from the sole military control model of Russia towards the mixed government and commercial model of the USA, i.e., release the restriction on public access to geospatial data.

(2) The USA model could further be scrutinized and gleaned for the suitable parts for China;

(3) The India model of defense series maps and open series maps could be adopted. China produces a civilian series maps removing all the military facilities and approved by Ministry of Defense. The maps and all city maps at local coordinate systems should be unrestricted. The un-restriction here does not mean free of charge, but pricing policy would be followed.

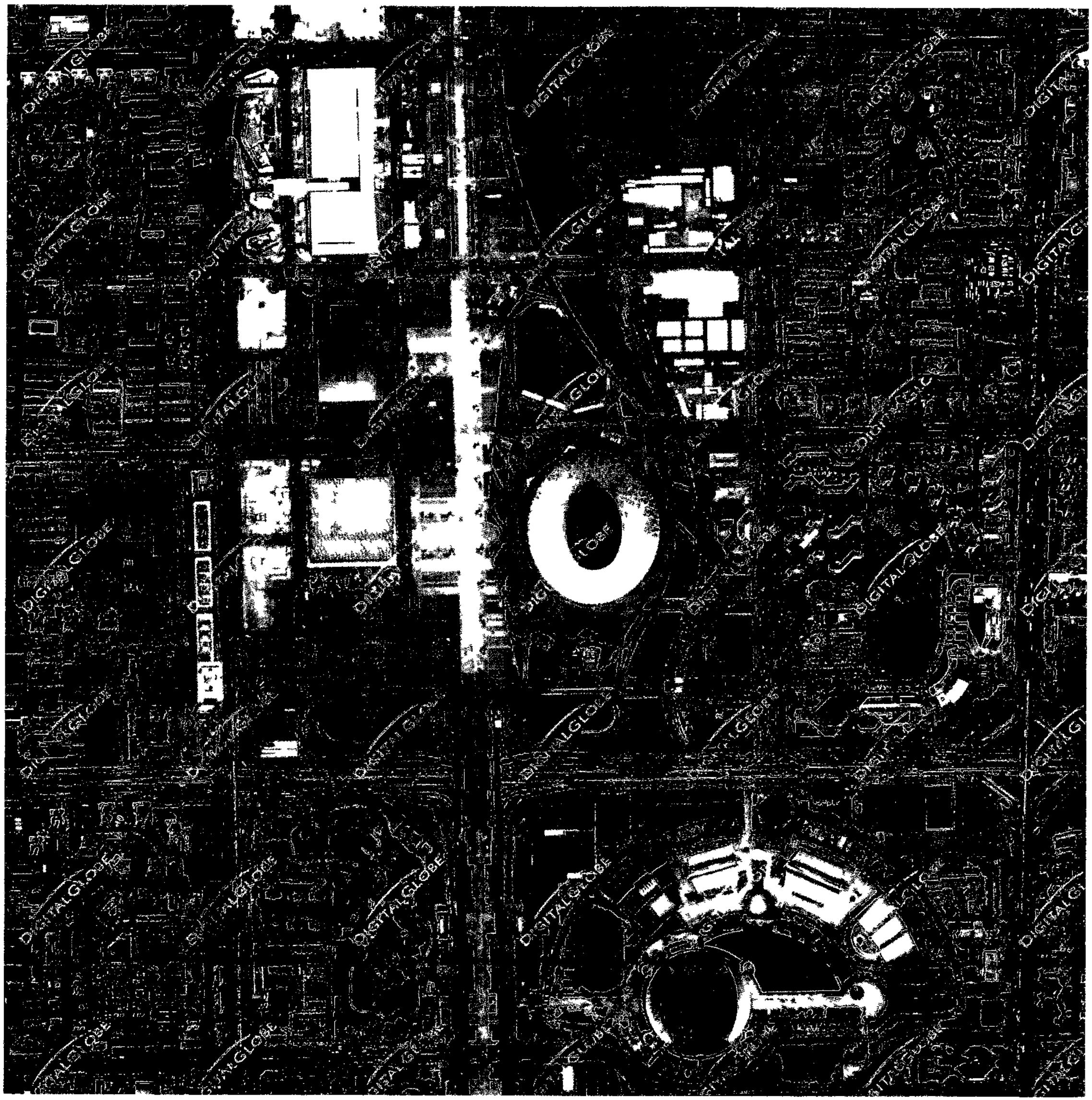


Figure 6.2 DigitalGlobe satellite imagery with Sub-meter accuracy – sample on Beijing.

Table 6.2 Examples of high resolution satellite imagery (after SpaceEnergy, 2010)

	QuickBird	**IKONOS**	**GeoEye-1**	**WorldView-1**	**WorldView-2**
Resolution	0.6m	0.8m	0.5m	0.5m	0.5m
Swath Width	16.5 km	11 km	15 km	15 km	16.4 km
Multi-Spectral	yes	yes	yes	no	yes 8 bands
DEM Accuracy	20 meter	20 meter	3 meter	3 meter	3 meter
Average Revisit Time	3-4 days	2-3 days	2-3 days	3-4 days	2- 3 days
Mapping Accuracy (w/out GCPs)	20-meter	10-meter	2-meter	3-meter	6.5 meter
Agility	Limited Single Scan	Very/Stereo Multi-scan	Very/Stereo Multi-scan	Very/Stereo Multi-scan	Very/Stereo Multi-scan
Days to Collect 1° x 1°	25	8	5	8	1.1

Chapter 7

Conclusions and Recommendations

7.1 Conclusions

Urbanization is a major trend taking place worldwide as well as in China. There are severe social, economical and ecological impacts in association with this rapid urbanization process. Geospatial information has become indispensable for the various aspects of urban development, planning, and management. The challenge for land surveyors (nowadays also called land professionals) is to provide the city managers with up-to-day, citywide and in timely manner geospatial information (also called land related information) to support more proactive decision making which encourages more effective sustainable development.

The main objective of this research study, as stated in Section 1.3, is to develop the framework, approaches and measures to enhance city-wide land information management system (LIMS) in China, for which three key issues need addressing, for better servicing the sustainable development of a city and reducing the negative impacts of rapid urbanization. This research was conducted through a critical review of LIMSs overseas and in China; analysis and identification of the problems of China LIMSs by comparing them against the good practices worldwide; discussion with several city LIM managers of their existing systems, problems and potential improvements and solutions; and wide reference to advanced strategy direction in the area of LIMS. A number of conclusions have been derived from this study, which are summarized below.

(1) Need to actively promote the role of the geospatial information in sustainable development of a city to the city top managers (at mayor level) and develop a clear vision to build the LIMS for a city. In China most of cities have established information offices, basically responsible for government office automation (OA).

But geospatial information, 80% of information is under this category, is in various government departments. Land professionals should make the city top managers well understand the role of geospatial information systems and get their strong support. Each city should have a vision of LIMS, which, as the author suggested, is to develop an infrastructure that make geospatial data to be current and complete, to be available and accessible to authorized public, government department and individuals and promote proper use of integrated spatial data for effective decision-making process, and development of information economy and spatially enabled society. A society or a government can be regarded as spatially enabled when spatial information is regarded as common goods made available to citizens and businesses to encourage creativity and product development. The infrastructure here refers to information highway, including hard infrastructure (hardware, software, and data communication and networking) and soft infrastructure. The soft infrastructure refers to policies and institutional issues. It is as important as hard infrastructure in general, but most important than hard infrastructure in China environment.

(2) Big issue in China is data sharing. This is completely unresolved so that the duplicated efforts are common everywhere. Due to sever duplication in data collection and system building the total resources provided by government become insufficient to keep geospatial data current and complete, making the geospatial databases less useful. Each government department has set up its own GIS system for internal uses without considering the requirements of others, and their horizontal (different departments and different kinds of data sources), even vertical (different levels of government departments) data sharing and integration are weak even missing. This is the problems of geospatial data soft infrastructure, meaning lack of an accepted community vision for a LIMS, no authorized governing committee and proper organization structure, and without appropriate policies on data management, geospatial data copyright protection and ownership, data pricing and funding model, and national security of geospatial data, etc. Technically, design of an efficient and open LIMS and data format transformation also contribute to data sharing and integration. One should recognize that design and build an efficient system is of

course the first and important step, but sustain and maintain the system is much critical.

(3) Sharing of information requires a strong governance structure. A coordinating council (or governing committee) should be established, which have enough authority to determine the policies and affect all the parties concerned. The council chairman should be a deputy Mayor of a city and the council members should include all the heads of those departments who use or collect geospatial data. The council and its chairmanship should be legally powered by the Municipal People Congress, and at its annual meeting the progress in the LIMS should be reported. The council has a secretariat (or management committee), which is proposed to be located in Department of Lands and Resources. In this arrangement a deputy Head of Department should serve as council secretary and operation manager of project LIMS. Under the secretariat there are several working groups (WGs) or technical committees, responsible for the tasks, like technical issues, operation issues, and policy related issues. It is useful to set up a user group committee to provide feedback on the quality and operation of the LIMS.

(4) A LIMS should be developed with open system architecture to better share data and service clients on various computer platforms. The system should be built with 3-tier structures of data layer, application layer, and service layer, and following the national/international standards. Data layer contains various databases with all types of information for land-related applications. Application layer includes various management systems. They should be built on an e-government platform. Service layer has a number of service elements, like data extraction and information service components. The author suggests the DBs be distributed, giving the incentive and responsibility to different government departments. A typical and good land information management system for a city would consist of at least the following basic sub-systems: Surveying and mapping system providing geospatial data or topographic maps, the fundamental information for all the other systems; land management system supplying the information on the current status and planning of land use; cadastre and real estate system in which the author proposed an integration

of urban cadastre and rural cadastre and an integration of real estate cadastre and land cadastre; underground utility management system, which is becoming a major activity of a modern city and should be included as a core system; and mineral resource system providing the information on the mineral resources and their distribution in the region, the geological conditions, and also mining activities.

(5) Good partnership among all geospatial data providers and users are essential and should be developed. A LIMS involves a number of key databases and management systems, which are established by various government departments and agencies. Each organization is responsible for some sub-systems based on its current functions and decision of the governing committee (GC), including the system building and maintenance. The data quality and standards, system construction and maintenance must follow the decision of GC. All parties must share the vision and follow the regulations and policies established.

(6) China has no pricing policy for geospatial data, and no clear funding model. This is because China is still in early development stage of information economy and spatially enabled society, and most of information systems are owned by individual public body and have less data sharing capability. But for an efficient city-wide LIMS funding model and data pricing model need developing. Building and maintaining a LIMS are costly and need a long term commitment. Having analyzed the merits and demerits of different approaches, a mixed pricing model is therefore proposed, including free data for educators; marginal cost price to researcher and public bodies; market driven or realizable price for commercial users (but no full cost pricing model). All the users must sign an agreement and get a license with the data providers regarding the data usage, the period, and the penalty in abuse of the data, disclose to other parties. This research also concludes the municipal government should wholly fund the system building because it is an information infrastructure, and 80% of annual maintenance cost. The cost recovery with the developed pricing policy can off-set the shortage of maintenance cost and can improve services.

(7) Law on the copyright issues for geospatial data should be enacted. Like many other developing countries, the copyright law of China has included maps as artistic work and protected, but not clear for geospatial data (digital maps). Data protection and ownership are important legal issues for the IT industry. A committee at national level should be formed to study the legal issues related to geospatial data. Most importantly, development of the culture of geospatial data copyright protection is much needed among government officers, company managers, educators, scientists and engineers in geosciences, for China is a developing country and concept of copyright is relative new to them. Although some technologies have been and will be further developed for the purpose of copyright protection, they can only work well under proper legal and institutional arrangement. It is the author's opinion that copyright is a legal issue and must be better solved with legal actions.

(8) Digital maps are the fundamental information/data for all kinds of geospatial information systems. However, all maps at scale larger than 1: 1 million and in any coordinate system are classified in China. The security control of geospatial data in China is very strong due to national security consideration. However, this policy starting from the foundation of PRC in 1949 is handy for government security purpose, but greatly blocks the healthy development of new industries (like location based services, intelligent transport system), geospatial economy, and spatially enabled society. With rapid development of space technologies, GNSS and satellite imaging, this policy does not look right. Although many officers and professionals in both government and military organizations know the facts, no one wishes to propose a change due to their political interests. This study suggests China should choose a direction moving away from the sole military control model (former Soviet Union/Russia model) towards a mixed government and commercial model (the USA model), i.e., release the restriction on public access to geospatial data. As intermediate step, China can adopt the India model, producing two types of map series: defense series maps and open series maps. The civilian series maps remove all the military facilities/establishments and get one-line clearance by Ministry of Defense.

(9) Geospatial data may have different format in different software, and different thematic definitions by different organizations and in different time of data capture. Geospatial data exchange is an important technical issue for data sharing, integration, and interoperability. Three aspects of syntactic, semantic and software exchanges are involved. The first one can be achieved through the transfer of data organization descriptions such as meta-data. The third one deals with the problem of software compatibility. The semantic exchange must preserve the meaning of data, and is the most fundamental and difficult. Geospatial data conversion can be resolved by using the data conversion tool built in a GIS or with professional data conversion software. However, any data conversion is not error free. This is due to the fundamental difference in data model and data structure among different GIS software, the functions of different data conversion software packages, or the quality of source data to be converted. In order to identify and analyze the problems in geospatial data transformation, this research conducted an experimental study with three different data sets. The study observed that different GIS software adopt different semantic models for positional, linear and areal features and main differences lie in the arc-node-polygon structure and part-whole relation. Although the errors in data conversion is not avoidable, this study help reduce errors by understanding the regularity of the possible errors in the data conversion.

7.2 Recommendations

(1) This research has developed a framework for city-wide land information management systems, including institutional issues, policy issues and some technical issues. It also provided a number of recommendations for the implementation of the developments. However, all these developments are new in China in terms of concepts or culture change. A great effort is needed for geospatial community to promote the concepts of city-wide LIMS, geo-spatial economy and enabled society to municipal governments. Without a strong support from city top managers an efficient LIMS would never be in place. They

must be made know an efficient LIMS is strategically important to geospatially based decision making at all levels.

(2) State Bureau of Surveying and Mapping (SBSM) is actively promoting digital China and digital city. Some pilot projects of digital city were conducted. But few of them are really city-wide and multi-departmental efforts. They know well building a digital city is the responsibility of municipal government and SBSM has less influence on digital city, for urban surveying and mapping activities are under the administration of Ministry of Construction and Housing due to historical reason. Therefore the author also recommend that pilot study in some cites be conducted to test the developed framework and policy issues. The central government (like though Ministry of Science and Technology) should fund a few pilot study projects with matching fund from corresponding municipal governments to set example LIMSs.

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