Developing Sustainable Geo-information Service in the Context of SDI

(Shaanxi Bureau of Surveying and Mapping)

XU KUN
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By

XU KUN

Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: (Geo-information Management)

Thesis Assessment Board

Chairman: Dr. Ing. P.Y. Georgiadou
External examiner: Prof. Dr. Ir. A.K. Bregt
Supervisor: Dr. J.M. Morales
Second supervisor: Ir. W.T. de Vries

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHENDE, THE NETHERLANDS
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**Abstract**

Geo-information service (GI-service) has been facilitated fast by technology development and increasing customers’ requirement, from service aiming at single requirement, to service being well-described for reusing. Nowadays services supplied by service providers are published in service repository for service retrieving by customers in the geo-information market.

GI service provider decides the quality version of GI-service which affects service status in the market. To be advantaged in competition in the market, GI service provider should optimize their geo-processing, products and services to be more effective and sustainable, which can facilitate the using of service. As to make GI-service to be sustainable is an attempt, we try to find the way to evaluate sustainability of GI-service by using the concept of sustainability and the criteria to evaluate sustainability in general.

To propose a method for GI-service sustainability evaluation, the reviews of GI-service concept, classification of GI-service, and sustainability indicators selection will be taken as the theory foundation to establish the framework of GI-service sustainability evaluation. This framework will be used for further evaluation.

To decide core services to be developed to meet customers’ needs, customers’ requirements and provider’s capability need to be identified and analyzed. It is an efficient and essential way to improve customers’ satisfaction which affects the sustainable existing of service. “Good practice” of service developing and provision could be helpful in deciding core service.

The interaction of these core services could provide functionality for complex service tasks. GI-service architecture needs to be established to specify the interaction between core services. Basing on required core services, the concept of service system and reviews of GI-service provision, a scenario of “to-be” situation of service system will be proposed. The service components and service interactions in the system will be designed according OGC standards, to improve interoperability of service. To evaluate the developed GI-service, the evaluation framework developed before will be utilized. This work provides evidence for improving service to be sustainable.

The main objective of this research is to propose a method for developing sustainable GI-service basing on concept of GI-service, GI-service system and sustainability evaluation, and customers’ requirements. To achieve this objective, a case study will be executed at SBSM and all required work will be implemented.
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1. **Introduction**

This chapter presents needs for sustainable Geo-information service (GI-service), and describes objectives, questions and methodologies of research. This chapter also introduces what will be done in the research, and structure of research and thesis.

This chapter is structured as follows: section 1.1 introduces background of research; section 1.2 is problem definition based on the background; section 1.3 describes objectives of research, which should be achieved to solve problem; section 1.4 lists main questions to be answered in this thesis; section 1.5 provides methodologies which will be used for research; section 1.6 is about thesis structure according the structure of research.

**1.1. Background**

In this section, GI-service development will be generally expatiated first, and following is the description of some organizations which have developed GI-service. The next concept is about “sustainable”, the meaning of sustainable in World Bank. The introduction of SBSM will be given as the last part of background.

**1.1.1. Trends in GI-Service**

Spatial Data Infrastructure (SDI) was designed to share available geo-data and make them broadly accessible and available at the lowest possible cost, where and when they are needed. This type of SDI can be thought of as a network of geo-data service facilities. Nowadays, geo-information is used in diverse areas, simple geo-data sharing does not fulfil the current demand of geo-information, and SDI therefore has to change its role to be an integrated system which can provide customized information and services.

To be useful, a service has to comply with user requirements, which mostly depend on the way geo-data is perceived, expected and used, and on the current forms of projects, markets and technology. A flexible approach can be achieved, for example by identifying core services that may be combined. A GI-service is accordingly defined as a non-persistent collection of elements organized so that they have value for a user(J Morales 2006).

Technically, there are two basic GI-services, data services and processing services:

- Data services, including Web Feature Services (WFS), which allow requests for geographical features across the web, and Web Map Services (WMS), which produce maps of spatially referenced data dynamically from geographic information. It is also possible to make use of the function to obtain get-Capabilities metadata about these data services.
• Processing services, are used to operate on spatial data, they include, for example, Geo-
referencing services and routing services. There are standard interfaces for these services.

There are some good examples of GI-service provision, the service providers are Infrastructure for Spatial Information in Europe Initiative (INSPIRE) and Ordnance Survey (OS). Following two sections will give general introduction to the providers.

1.1.2. The Initiative of the INSPIRE

The initiative of INSPIRE intends to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services. These services allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an interoperable way for a variety of uses. The users of INSPIRE include policy-makers, planners and managers at European, national and local level and the citizens and their organizations. Services are the visualization of information layers, overlay of information from different sources, spatial and temporal analysis, etc. (Commission of the European Communities 2002)

1.1.3. The Situation of the OS

Ordnance Survey is the national mapping agency of Great Britain. It is responsible for collecting, maintaining, managing and distributing the definitive record of the features of the natural, built and planned environment. The definitive record of official boundaries and the record of such other national geographic datasets as required by government and the private sector.

Ordnance Survey concentrates on the collection, management and provision of nationally consistent data and national map series. It encourages partners to add value to Ordnance Survey data and develop applications and value-added products and services that meet a wide range of end-user requirements.

Ordnance Survey works with and consults with others in the geographic information community to help determine and advice upon the standards and quality of its data in relation to present and future national needs. (Ordnance Survey Executive Agency 2004)

1.1.4. Concept of Sustainability Defined in the World Bank

Sustainability in the domain of GI-service is a new topic, and there is no clear definition about it, therefore we start by looking at definitions of sustainability in general in different fields.

In general, “sustainable” means being able to continue into the future and “sustainability” means the ability to provide for the needs of the world's current population without damaging the ability of future generations to provide for them.

As the World Bank is the leader institution on sustainable development, we try to use the concept of sustainability there to explain sustainability of GI-service. In the World Bank, Sustainable development concerns five perspectives, such as financial capital, physical capital, human capital, social capital and natural capital. Sustainability is defined as the following list:(Farmer 2004)
Developing Sustainable GI-service in the Context of SDI (Shaanxi Bureau of Surveying and Mapping)

- Capability to meet human needs (adhere to user requirement)
- Without compromising the ability of future generations’ needs (long term, flexible)
- Using natural resources in balance with nature’s ability to replenish them (recovery)
- Achieves the greatest common good for the most people (large audiences)
- Achieves equitable distribution of resources and access to means of income (affordable)

So sustainable development implies that the natural resource capital must not be exploited more than its capacity and ability to reproduce; the pollution must not be larger than the surroundings’ capacity to absorb; and it is necessary to have a system of production, consumption and distribution that takes due account of other people living locally; in other communities; in other countries; as well as future generations. That is, one continuously has to think and act in terms of a local, regional, national and global context.

We do not claim that the concept provided by the World Bank directly applies to GI-service, and we just use it as a start point to develop a concept of sustainable GI-service.

1.1.5. Shaanxi Bureau of Surveying and Mapping (SBSM)

Shaanxi Bureau of surveying and mapping is one of the most important Bureaus in China. Their main task is to execute basic survey and surveying projects with the order of the national Bureau of surveying and mapping. Their main product is data which covers the whole Shaanxi province and geo-information systems which are used by decision makers and atlas of natural resources producers. Their products are used by clients from land administration, forest management, transportation, resource and environment management, and water management. Nowadays their users not only include the government departments, but also some private companies.

Currently, the SBSM has as its main responsibility of a project to create a geo-database of Shaanxi province. The aim of this project is to supply basic, authoritative geo-information for public. Shaanxi geo-database has to compatible to this project.

In all these situations, the SBSM has not yet developed services as described before. In this thesis, by analyzing and categorizing users and their needs, and capability of the SBSM, we will develop guidelines for the SBSM to develop sustainable GI-service.

1.2. Research Problem

There are some problems between current offered geo-information products/services and customers’ requirements in general, and also in China. In this thesis, GI-service provision at SBSM will be used as a case.

1.2.1. Gap between Product and Consumption

The general situation on spatial information is one of fragmentation of datasets and sources, gaps in availability, lack of harmonization between datasets at different geographical scales and duplication of
information collection. These problems make it difficult to identify, access, and use data that is available. (Commission of the European Communities 2002)

Recently in practical applications, there is an increasing demand of dynamic and multi-dimensional data, because the natural and artificial features are obviously in three dimensions (3D), such features may change in time and appear to be in different shapes, structures and details at different scales. Unfortunately, so far, the dynamic and multi-dimensional real world is usually abstracted as static 2D (or 2.5D) objects by means of orthogonal projection and planar tessellation. In the SBSM, they have the same problem. When customers want to analysis and simulate the features, current situation, and trends about objects, for example, customers want to analysis the trends of population in Shaanxi province, they may want to access the information service which can supply 3 dimensions, including time, position, and index, to support the analysis. (Shaanxi Bureau of Surveying and Mapping 2004)

Integration of data from different sources is a problem in the SBSM. Sometimes customers want to analyze special information based on the geo-information, for example, when customers want to analysis the situation about vegetation along slope of highway, they may need to integrate the data about the vegetation and the data about the slope, which may not be stored in same format.

When customers need information for their projects, they must go to the SBSM to get permission, and then buy the data they need. It causes waste of human resource and finance, and restrains the interoperability between the SBSM and customers.

All these problems make the services provided to the customers unsupported, so there should be some changes to the current GI-service to solve these problems.

1.2.2. Need of GI-service

The way in which SDI is implemented from both technical and organizational perspectives will influence their socioeconomic impacts, and ultimately their sustainability. There is a need to move from a data-centric view to one that encompasses distributed processing, and ultimately a more open and fully service driven model. The real challenge is for a model based on competing services that need to declare their compatibility, robustness, trustworthiness, and effectiveness in a transparent way to end users. (Bernard 2005)

In this research, we will take services of the SBSM as the specific case. Spatial data is necessary to describe location and land information, so the SBSM provides digital maps to customers for management and making more informed decision. For example, digital maps of the roads in cities they provide to local government can be used for the government management of transport, health service and emergency issues; the SBSM however does not supply direct GI-service for these applications.

1.3. Objectives

The main objective of this research is to propose a method for developing sustainable GI-service. In order to achieve the main objective, several sub objectives have to be achieved. They are listed below: (combined with Figure 1)
1.4. Questions

According the description and Figure 1 above, this thesis need to answer following questions:

1) What is GI-service?
2) What are the current criteria to evaluate sustainability of GI-service?
3) What can be considered as the current GI-service of the SBSM, and how can these services be characterized?
4) What is the gap between what is available at the SBSM now and what is required by customers? What type of services at the SBSM can be developed to be sustainable?
5) What are the requirements for the SBSM to implement sustainable GI-service?

1.5. Methodology

Based on the questions, the methodologies which will be used in this research are:

1) Carry out literature review on existing cases about the concept of:
   - GI-service
   - Classification of GI-service
   - GI-service infrastructure
• the existing understand about sustainability
• and the criteria to evaluate sustainability

2) Case study, to collect information about the SBSM, and analysis the services which provided by the SBSM.
3) Do comparison, and explain whether the GI-service of Ordnance Survey and INSPIRE are feasible in the SBSM
4) Evaluate the services of the SBSM by question proposal.
5) Analysis the current services of the SBSM, and answer the question what type of GI-service could become sustainable, and develop criteria to evaluate sustainability of GI-service.
6) Design a model to develop sustainable GI-service.
7) Discuss about making a general development strategies.

1.6. Thesis Structure

Chapter 1 Introduction
Describes the research problem, objectives, questions and methodology

Chapter 2 GI-service and Sustainability of Service
Discusses Literature about criteria for classifying GI-service and sustainability evaluation, and conducts initial criteria for sustainable GI-service evaluation via cases and literature review

Chapter 3 Products and Services in SBSM
Describes objectives, methodologies, and data collection of the fieldwork

Chapter 4 Needs for Sustainable GI-service
Presents data analysis, in this chapter, the required core services at the SBSM are identified, the capability of the SBSM to develop GI-service will be evaluated, and issues of sustainability are discussed

Chapter 5 GI-service System Architecture in the SBSM
Sets a scenario of service which covers all the requirements of the core services at SBSM, the architecture for this service is described from the aspects of components and service interactions. And the sustainability evaluation framework are developed and used for sustainability evaluation of this service.

Chapter 6 Conclusions and Recommendations
Presents conclusions according research questions, and discusses the method of sustainable GI-service developing and general development strategies
2. GI-service and Sustainability of Service

This chapter is about definition of GI-service, GI-service classification, state of the art of GI-service in general, GI-service infrastructure, GML encoding and sustainability of GI-service. In this chapter, we have also established criteria for sustainability evaluation.

This chapter is structured as follows: section 2.1 defines GI-service; section 2.2 interprets service chaining; section 2.3 depicts classification of GI-service; section 2.4 describes GI-service infrastructure and relationship among quality of services, quality of service resources, and quality of GI-service system; section 2.5 expatiates reason to use GML encoding for web GI-service; section 2.6 describes services and standards in OS and INSPIRE; section 2.7 extracts criteria to evaluate sustainability of GI-service; section 2.8 generalizes conclusions for next part of research.

2.1. Definition of GI-service and other Relative Concepts

SDI has changed role from simple data providing, to be integrative systems for provision of geo-information and GI-service to customers. As a contribute of the infrastructure, GI-service can be defined in terms of data, operations, processes, value-added products or any combination of them.(J Morales 2004)

GI-service means the provision of functionality (data and functions) of interest to a customer (end-user or software application). It is the result generated, by interactions at the interface between service a provider and a consumer. Interface is a named set of operations that characterize the behaviour of an entity; and operation is a transformation or query that an object may be called to execute.

Service provision is an economic activity that does not result in ownership and this is what differentiates from providing physical goods. Service provider is an (network-addressable) entity that accepts and executes requests from consumers. Each request triggers the supplier internal activities, to meet customer requirements.

2.2. Service Chaining

Service chaining is a trend for development of GI-service. In OGC, service chain is defined to be sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action. Normally, GI-service aims at single requirements which is with low reusability, it’s hard to aggregate this type of GI-service to work for other requirements because lack of description of solutions. GI-service which are with descriptions of function, interaction mechanism, points of composition, and enables interchange and reuse of basic GI-service, enable to create service chains for more complex tasks. The services used for chaining called service resource, including data, operations, processing, etc.
2.3. Classification of GI-service

Before GI-service infrastructure being designed to enable GI-service interaction and service chaining, services classification scheme should be defined to form components of the infrastructure.

2.3.1. Core Services in OpenGIS Specifications

Open GIS Consortium (OGC) is an international industry consortium of 331 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. In OGC, services will be classified by these three classification schemes: (OGC 2003) Semantic classification schemes, Interface classification schemes, and capability classification schemes. According to the classification schemes, in this thesis we will use such service classification to characterize services:

- Catalogue services

Catalogue services enable services provider to publish metadata of their data and services. For customers, it’s easy to search data or services by querying metadata in catalogue services.

The OpenGIS Catalogue Service Implementation Specification defines common interface for conformant browsing, querying data.

- Data services -- provide access to datasets available in databases, include map services and feature services:
  - Web Feature Service (WFS)
    
    WFS provides an interface for the insertion, selection, updating and removal of geographic features.(OGC 2004)
    
    WFS Implementation Specification defines interface to enable customers to read metadata, ask for features, and retrieve these features.
  
  - Web Coverage Service (WCS)
    
    WCS supports interchange of geospatial data as "coverage" containing values or properties of geographic locations. (OGC 2002)
    
    WCS Implementation Specification extends the WMS interface to allow access to coverage.

- Processing services -- provide operations or data processes to spatial data:
  - Web Coordinate Transformation Service (WCTS)
    
    WCTS provides an algorithm that converts coordinates for spatial objects between different spatial reference systems.(OGC 2001)
The OpenGIS Coordinate Transformation Service Implementation Specification defines standard interface for coordinate transformations.

- Portrayal services -- provide visualization of geo-information:

Portrayal services produce rendered outputs, such as cartographically portrayed maps, perspective views of terrain, annotated images, views of dynamically changing features in space and time.

  - Web Map Service (WMS)

WMS is a service for producing and displaying maps of spatially referenced data from geographic information, and enable customers to query and combine maps from any servers. (OGC 2006)

The WMS Implementation Specification defines interface for these operations.

- Get-Capabilities

The Get-Capabilities operation returns an Extensible Markup Language (XML) document describing the GI-service and the data collections from GI-service which clients may request.

### 2.4. GI-service Infrastructure

GI-service infrastructure enables core services being described, accessed, and combined to create service chains for specific requirements. Normally GI-service infrastructure system is constructed by communication of three parts: GI-service Provider (GSP) - nodes, GI-service Register and GI-service requestor. GI-service provider executes the performance of GI-service versioning, which means different service providers produce different quality versions of services because of their different GI-service system infrastructures. Versioning and services trading could be visualized like this: (OGC 2002)

![GI-service Versioning in Publish – Find – Bind Paradigm](image)

**Figure 2-1 GI-service Versioning in Publish – Find – Bind Paradigm**

In this architecture, there are three fundamental roles are defined to actuate the service trading. They are:
- GI-service registry registers service offers from GI-service providers and returns service offers upon request to GI-service requestor according to some criteria.
- GI-service provider registers service offers with a GI-service register and provides GI-service to clients.
- GI-service requestor obtains service offers, satisfying some criteria, from the GI-service registry and binds to discovered services provided by the GI-service provider.

To export, GI-service provider gives the GI-service registry a description of a service, including a description of the interface at which that service instance is available. To import, GI-service requestor asks the GI-service registry for a service that displays certain characteristics. The GI-service registry checks against the required to bind with a service instance. Preferences may be applied to the set of offers matched according to service type, some constraint expression, and various policies. Application of preferences can determine the order used to return matched offers to the requestor.

Taking GI-service classification as an example to illuminate service composition in a service system (J Morales 2006). GI-service infrastructure is composed of core services, registry services, and administration services. Registry services provide a common mechanism to classify, register, describe, maintain, access, and combine information about data, operations, processes, and value-added products. Administration services are needed for the smooth-running of the infrastructure and including: design services used to define combinations of core services to create customized GI-service, workflow services which allow choreographing any service chains defined using design services. Figure 2-2 indicates core services which could interact with each other for required functionality.

![Figure 2-2 GI-service Framework (J Morales 2006)](image)

As complex GI-service are provided by integrating basic services and other functions in a GI-service infrastructure to be compliant with customers’ requirements, the quality of the complex GI-service produced by this infrastructure will depend on quality of service resource and quality of GI-service infrastructure system which affect the processing of services integration.
2.5. **GML Data Encoding**

Geography Markup Language (GML) is an Extensible Markup Language (XML) based encoding standard for geographic information developed by the OpenGIS Consortium (OGC). It is an XML grammar written in XML Schema for the modelling, transport, and storage of geographic information. The benefits of using GML encoding are (Eric Boisvert1 2004):

- Better quality maps. GML encodes information about geographic features or objects, and these can be displayed to as fine a resolution as required. Thus, screen-based maps generated from GML appear crisp and easy-to-read. Such maps can also be saved as local files, emailed, or printed.

- Works on a browser, without the need to purchase client-side software. When a GML file is received at the client, it is converted to a set of drawing objects and rendered as a map on the browser.

- Custom map styling. GML contains map "content" only (e.g., where features are, their geometry, type and attributes), users can invoke different "style-sheets" to display the geographic data according their wishes.

- Editable maps. It is quite straightforward to annotate GML-based maps that have been downloaded and rendered on a browser. Once GML has been converted to Scalable Vector Graphics (SVG), the user can apply graphic editing tools on the client to add text (of any font, size and colour), highlight features, and draw virtually any kind of shape on the map. The annotated map graphic can then be saved as a file, emailed, or printed.

- More sophisticated linking capabilities. One of the benefits of GML is that you can embed links associated with features. These links can be simple Uniform Resource Locator (URL) addresses, or they can be more sophisticated. It means that any Web address associate can be associated with a feature. When a user clicks on a feature, the user is transferred to that address.

- Better query capability. GML enables features easy to be identified, and, by means of turning on and off different feature themes, it's easy to identify features within features (e.g., a house within a lot).

- Control over content. Because GML is feature-based, it is quite easy to provide a filtering function that allows users to download only the feature-types that they want to appear on their maps. This filtering can reduce data transfer time. Map content can also be controlled after the geographic information has been delivered to the client's Web browser. Using a clickable legend, a user can display/hide information themes instantly, and without the need to call the server to generate and deliver a new map. This cannot be done with GIF/JPG maps.

- Animated features. Objects and features that change over time can be accommodated in GML, and can be rendered as animated graphics using SVG.

- There is no need to target just a Web browser. GML is a non-proprietary geographic file format that can encode most types of geographic information. As such, you can use it as a general geospatial data interchange format. In fact, geographic data in GML can be sent to any device with an XML interface.
Service chaining. Geo-data encoding in GML can be used in different sites which are providing discrete services. Because (a) GML is a general format, so sites don't need to support lots of proprietary data formats, and (b) GML is extensible and XML-based, which makes it easy to manipulate, change, and add to its contents.

Because of these benefits, GML encoding facilitates customers’ requirement of internet data exchange and accessing data directly. Accordingly, GML is widely adopted to develop web GI-service.

2.6. Case of GI-service

In this section, we will list GI-service in OS and INSPIRE to demonstrate the status of GI-service and standards to specify geo-information and service interface.

2.6.1. GI-service in Ordnance Survey (OS)

OS have been developing services to meet national requirements from different market. They provide geo-data products directly to the public, and also support their partners to develop products, services and solutions by using their data.

Information from both ground and air survey has been added to database at OS, the electronic map can be updated with an average of 5,000 changes everyday. As a world-leading map resource, the database has been made easier for others to be integrated in to it, held as separate layers, or linked to OS mapping. Main data products in OS are MasterMap, Superplan data, landplan data, and siteplan data:

- OS MasterMap provides data with definitive, consistent and maintained referencing to more than 440 million features, such as forest, roads, rivers and individual houses, covering the whole Britain. In addition to the topographic mapping, address layer, Integrated Transport Network (ITN) layer, and Imagery layer are added to OS MasterMap. With the exception of the Imagery Layer, OS MasterMap is supplied in compressed GML format. (Ordnance Survey 2004)

- GI-service standards

OS provides WFS which enable customers to ask features and retrieve features. They have their own standards to classify GI-service. They have emergency services, services for central government and local government, services for health, services for insurance, services for land and property, services for retail, services for transport, services for utilities, and services for wireless and communications.

2.6.2. GI-service in INSPIRE

INSPIRE is designed to optimize the scope for exploiting the data that are already available. It aims to build European spatial information infrastructure that delivers integrated GI-service to the users which include government, utility and public services, research and development, commercial and professional end users, Non governmental organizations (NGOs) and not-for-profit organizations, and citizens and their organizations.
They provide catalogue services, view service, query service, object access service, generalization services, and geo-processing services. These services allow the users to identify and access spatial or geographical information from a wide range of sources in Europe.

They use some existing standards or specification to ensure the interoperability needed for discovering and sharing of geographic information and services. Such as ISO/TC211 Geographic Information--Geomatics, OpenGIS Abstract Specifications, and OpenGIS Implementation specifications.

2.7. Sustainability Evaluation of GI-service

This is an attempt to evaluate sustainability of GI-service. But in other fields such as economic and water environment, sustainability was well defined, and there are some formed methods to evaluate sustainability.

2.7.1. Definition of Sustainability in World Bank

Nowadays, there are many theories about sustainable development. The most famous definition of sustainable development is- “to meet the needs of the present without compromising the ability of future generations to meet their own need”. (The Brundtland Commission 1987) In the context of this thesis, the concept presented many challenges to development of GI-service.

2.7.2. Definition of Sustainable GI-service

To understand sustainable GI-service, Quality of services (QoS) which will reflect the situation of GI-service should be introduced firstly. QoS is the concept of applying and ensuring specific, quantifiable performance levels on a service. So QoS shows the capability of a service provider to adhere to standard (specific) levels of customer requirements.
According to the explanation of QoS, sustainable GI-service could be defined like this: GI-service that can maintain a desirable level of QoS for a significant period of time without negative economic or architectural (component configuration) impact to the service provider.

2.7.3. Criteria to Evaluate Sustainability of GI-service

It will be easy to understand to evaluate sustainability by criteria. Since the time of the Brundtland Commission, there exists a worldwide effort to develop criteria of sustainable development. Generally, there are three main principal approaches: economic, socio-cultural, and biophysical. Indicators using for indicating quality of development will be chosen according these approaches.(K. Hamilton 2004)

The Organization for Economic Co-operation and Development(OECD) established selection principles for environmental indicators under three broad headings – policy relevance, analytical soundness, and measurability – which are applicable to others indicators as well:(K. Hamilton 2004)

The following principles will be used in order to select indicators to evaluate sustainability of GI-service:

- **Policy relevance:**
  -- Indicators should be easy to interpret.
  -- They should show trends over time.
  -- They should be responsive to changes in underlying conditions.
  -- A threshold or reference value should be established, against which conditions can be measured.

- **analytical soundness**
  -- Indicators should be well-founded in technical and scientific terms.

- **Measurability**
  -- Indicators should be calculated from data that are readily available.
  -- Data should be documented and of known quality.

Evaluating ‘sustainability’ of GI-service is important to enable GI-service providers to develop GI-service which can fulfil customers’ requirements in a specific period. To evaluate sustainability of GI-service, we can try to use the normal method of sustainability evaluation. The following steps will be taken:

- Firstly, it’s efficient to structure indicators for GI-service under approaches. Relating to the understanding of GI-service (chapter 1), we choose economic, technology, and socio-culture as approaches.

- Secondly, choosing indicators with the selected approaches. After analysis (section 2.4), we know that the quality of the GI-service depends on quality of service resource and quality of GI-service infrastructure system. Therefore, it must be an efficient way to use service resource quality characters and service system quality characters as the indicators, as quality characters can be proved by the three principles, and belong to these approaches.

- Finally, perform evaluation.
Using the Conceptual framework of “Sustainability Assessment” to assess criteria for sustainability, (Gregor Ochsenbein, Daniel Wachter et al. 2004) we develop the framework for sustainability evaluation of GI-service, as shown in table 2-1:

**Table 2-1 Framework for Evaluating Sustainability of GI-service**

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Service Resource Quality characters</th>
<th>Service System Quality characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service (x)</td>
<td>Value x1 of service resource quality character1</td>
<td>Value x2 of service resource quality character2</td>
</tr>
<tr>
<td>Service (y)</td>
<td>Value y1 of service resource quality character1</td>
<td>Value y2 of service resource quality character1</td>
</tr>
<tr>
<td></td>
<td>Value y1 of service system quality character1</td>
<td>Value y2 of service system quality character2</td>
</tr>
</tbody>
</table>

According to this framework, values of services for each indicator will be calculated. Then it’s possible to evaluate sustainability, as shown in table 2-2:

**Table 2-2 Sustainability Evaluation of GI-service**

<table>
<thead>
<tr>
<th>Evaluation of Sustainability</th>
<th>Indicators</th>
<th>Desired Level of Quality</th>
<th>Quality of GI-service (x)</th>
<th>Quality of GI-service (y)</th>
<th>Quality of GI-service (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Resource Quality Character 1</td>
<td>Specific value1</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Service Resource Quality Character 2</td>
<td>Specific value2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Service System Quality Character 1</td>
<td>Specific value3</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Service System Quality Character 2</td>
<td>Specific value4</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>2</td>
<td>-2</td>
<td>-2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each indicator, a specific value will be given. By comparing this given value with the values in the above table, we can score for each service. If the total score is plus, the service is sustainable, or else is not. Then we can get the “total score” which indicates the sustainability of the services. For example, we can conclude from table 2-2 that GI-service (x) is sustainable, GI-service (y) and GI-service (k) is not.
2.8. Conclusions

GI-service means the alignment in the provision of geo-data products and GI-service with the demands from customers. GI-service are implemented as self-contained, self-describing, and can be published, located and accessed via a GI-service infrastructure.

The initial purpose of a GI-service infrastructure is to establish a framework for delivering geospatial solutions, products and services that meet constantly changing user requirements.

Sustainable GI-service is services which can be combined to provide GI-service for more complex tasks, can be interoperated, and do not have a continuous impact on the resources of the provider due to requirement changes. Also there is a need for a good framework for sustainable GI-service.

To evaluate sustainability of GI-service, quality of GI-service will be evaluate firstly according quality of service resource and quality of GI-service system. Then, with the evaluation framework, we can evaluate sustainability of GI-service.
3. Products and Services in SBSM

This chapter describes objectives, methodologies, and results of data collection of the fieldwork. In the fieldwork, interviews, questionnaires, and observations are used together to get a more clear picture of the current situation. These methods aim at describing for each organization the following issues: Hard-/software, data, and services.

This chapter is structured as follows: section 3.1 introduces objectives of fieldwork, explains why the fieldwork should be done; section 3.2 illustrates which organizations will be include in the fieldwork; section 3.3 describes methods which will be used to collect data; section 3.4 describes data acquired from fieldwork, which was arranged in the same sequence with objectives to show how extend the objectives were achieved; section 3.5 also represents information from fieldwork, which introduces SBSM technical capability with regards to services; section 3.6 points out the pitfalls in the fieldwork; section 3.7 concludes how are the fieldwork objectives achieved.

3.1. Objectives of Fieldwork

- **Main objectives**
  - To evaluate sustainability of current geo-information (GI) services at SBSM
  - To understand differences between customers’ requirements and GI-service provided by SBSM

- **Sub-objectives**
  - To find how people understand GI-service in China.
  - To collect information about GI-service and GI-service needed.
  - To find relationship between existing providers and customers.
  - To evaluate sustainability of current GI-service in SBSM.
  - To collect information about capabilities of SBSM to develop sustainable GI-service.

3.2. Target of Fieldwork

In this fieldwork, SBSM and other organizations which have data relationship with SBSM were contacted, they are:

- SBSM and other 15 organizations involved (see annex 1 and 2, there is information about name of organizations)

- In SBSM, 3 persons were interviewed, and 30 responses were obtained from 30 persons working in the Shaanxi Provincial Geomatics Centre by questionnaires

- For the 24 persons from 15 organizations, some of them were interviewed directly, some of them were interviewed by people from SBSM (SBSM have investigated customers’ requirements in 2005)
3.2.1. **Institutional Introduction of SBSM**

Section chief of SBSM (Ms. Shi Xuemei) provided a brochure introducing SBSM, proving information such as department setting, tasks of each department, which is for people to get general impression of SBSM.

3.2.1.1. **Main Organizational Framework of SBSM**

There are eight main institutions which constitute SBSM:

- The first Topographic Surveying Brigade – SBSM, executes photogrammetry, remote sensing, topographic surveying, cadastral surveying, building surveying, engineering survey and city planning survey.

- The second Topographic Surveying Brigade – SBSM, has the same tasks with the first Institute of Topographic Survey.

- The first Geodetic Brigade – SBSM, executes geodetic surveying and GPS surveying.

- Geodetic Data Processing Centre – SBSM, execute processing such as adjustment and mapping, to data of triangulation, gravity measurement, engineering survey, deformation measurement, and so on.

- The first Institute of Photogrammetry and Remote Sensing – SBSM, executes engineering photogrammetry, industrial photogrammetry, architectural photogrammetry, archaeological photogrammetry, and so on.

- The Institute of Quality Control, executes quality control of surveying data according national quality control regulations.

- The Map Publishing Company executes map designing and decoration, compiles national atlas, regional atlas, thematic atlas, comprehensive atlas, and publishes civil maps for the public.

- The Shaanxi Provincial Geomatics Centre provides data products and services to customers.

3.2.1.2. **Function of the Shaanxi Provincial Geomatics Centre**

In the website of the Shaanxi Provincial Geomatics Centre, there is general information about functions of this Centre. The Shaanxi Provincial Geomatics Centre takes responsibility of storing foundation geo-data of Shaanxi province, constructing geo-database, maintaining geo-database, and data dissemination. Also, the Geomatics Centre develops foundation geo-data products and Geo-information systems about different subjects.

There are six departments in the Geomatics Centre: Internet management office, Market office, Research office, Product development office, Database office, and Product archives office, as following figure 3-1 shown: (Shaanxi Provincial Geomatics Center 2006)
There are about 60 staff in the Geomatics Centre, 90% of them have education from junior college or college, including 5 senior engineers, and 5 masters.

### 3.3. Methodology of Fieldwork

Data collected during fieldwork can be categorized as: (Kumar 2005)

- Primary data: is data collected by observation, interviewing and questionnaire.
- Secondary data: is data already exist and only need be extracted from existing sources.

In this fieldwork, both types of data were collected.

- Primary data, by interview, questionnaire, and observation, first-hand information were acquired, such as understanding of GI-service, GI-service requiring, and the Bureau capabilities to develop GI-service.

- From documents of SBSM earlier research, secondary data about customer’s requirements were acquired, and the situation of industrialization of geo-information in Shaanxi province were found in article of deputy director general of SBSM, which is about ideas to improve geo-information providing and using in China.(Li Pengde 2006)

Methodologies used in the fieldwork:

- Interviews
  The interviews were conducted orderly. Interviews are effective way to collect information, and it’s easy to communicate with interviewees, both interviewer and interviewee have enough chances to provide new ideas besides questions listed before, to complete the interview.

- Questionnaires
  Because of working conditions at the Bureau, time slots for interviews were not available; therefore data collection at the Geomatics Centre was also done by means of questionnaires. The questionnaires were structured based on the order of sub-objectives. In this way, money and time was saved, and enough responses of the questions were got, even one person was not willing to be interviewed. From the 32 questionnaires sent, 30 responses were received which accounts for about 94%.
Observation

Observations are also used as a method to evaluate capability of SBSM. Because it was easy to see how the Geomatics Centre was equipped when I was there, and I thought that results of observations can be used as complement of information which were acquired by interviews and questionnaires. Observations were conducted in natural situations.

There are some methods, which including avoiding personal factors and creating active situation with responders, were used to reduce the negative affects to the results of data collection. And other methods, such as constructing questions according statistical principle and reconfirming data to responders, are used for validity of data collection.

3.4. Data from Fieldwork

In this section, data about service provision, such as understanding of GI-service, geo-information products, customers’ requirements of geo-information products/services, and some policy issues in SBSM will be retrieved from fieldwork.

3.4.1. Understanding of GI-service in China

On the side of data/services provider, SBSM provides paper maps, digital datasets to customers, and they build thematic geo-information systems for customers from different fields, then they think that it means they are providing GI-service.

On the other side of customers, they think GI-service means providing paper maps, geo-datasets, developing thematic GIS, and data processing.

According all description above, it can be included that, in China, GI-service means: Providing paper maps and geo-data, data processing, and development of geo-information systems.

3.4.2. Products Provided by SBSM

Because the Shaanxi Provincial Geomatics Centre is as the part of managing and disseminating data in SBSM, we can find types of data provided by SBSM according the types of database at the Shaanxi Provincial Geomatics Centre. The figure 3-2 below shows these types and management of database.
Figure 3-2 Key Database and Management System at the Shaanxi Provincial Geomatics Centre

We also find types of data of the province and some services which the Shaanxi Provincial Geomatics Centre provide in their website:

- Topographic maps and topographic data: features of topographic maps include geodetic control point, residential area, construction of mining, transport and affiliate establishment, pipe and barrier, water system and affiliate establishment, administrative boundary, physiognomy and terrene factors, and vegetation. The period for data updating is about 3 to 5 years. As people said in the interview with SBSM staff, topographic maps and data are suited for many professional works, and required by most of the customers of SBSM.

- Thematic data and maps, which are extracted from topographic maps and satellite images, normally refer to special subject of construction, transportation, and land use.

- Cadastral maps and land cadastral maps

- Digital urban maps about Xi’an city in the scale of 1:10,000

- Satellite image and aerial photography: TM, SPOT images are available at SBSM. They bought aerial photography which cover 100,000 sq. km. areas of Xi’an, Tongchuan, Hancheng, Suide, Hongjianzhuo, Wuqi, Qianyang, Shanyang; and satellite images which cover the whole Shaanxi province at resolution of 1 meter. But because there is lack of professional data extraction, data precise still need to be improved.

- Geodetic and geodesy products, is well-produced and available at SBSM.

- Digital Elevation Model (DEM) is available at SBSM, they have 5577 in the scale of 1:10,000; 596 in the scale of 1:50,000; and 30 in the scale of 1:250,000. DEM can be applied for disaster analysis and urban planning.

- Digital Orthophoto Map (DOM), can be used for updating of vector data, and normally be requested for city planning, land management, and transportation. SBSM has 2048 in the scale of 1:10,000, and the resolution is 1 meter; 281 in the scale of 1:50,000, the resolution is 1 meter.
Digital Line Graphic (DLG): features of DLG include geodetic control point, physiognomy and terrene factors, transportation and affiliated establishment, water system and affiliated establishment, administrative boundary, and construction. DLG can be used to analyze overlaying data; data query; and establish thematic attributes. It’s always applied for the base of location for transportation, population, natural resource, and water conservancy. SBSM has 5577 in the scale of 1:10,000; 596 in the scale of 1:50,000; and 30 in the scale of 1:250,000.

Digital Raster Graphic (DRG) is one of products which are from digitalization of paper maps. The SASM has 2028 in the scale of 1:10,000; 596 in the scale of 1:50,000.

GIS systems, which are developed for projects or government decision making.

They provide services for government decision. For example, in 2003 they developed a simulation of flooding system based on topographic data, to provide an efficient way for government to analysis trends, and decide measurement for prevention of flood.

They also developed many GIS system for some projects, such as:

- Zhujiangkou 3D maritime geo-information system
- Shaanxi highway services information system
- Yinchuan information system for management of wireless
- Shanghai information system for management of building surveying

Most of the time, these systems are used to support government decision making and provide information for construction.

3.4.3. Requirements from the 15 Organizations

By asking questions to customers in the 15 organizations, listing questions in the questionnaire to employees in SBSM, and collecting information from the report of SBSM’s earlier research, some requirements are concluded:

By asking questions to customers in the 15 organizations, listing questions in the questionnaire to employees in SBSM, and collecting information from the report of SBSM’s earlier research, some requirements are concluded:

1) National Statistic Bureau
   - Visualization of statistic data
   - Data analysis based on geo-data

2) State Forestry Administration, P. R. China
   - Paper maps and digital datasets
   - Need forest geo-database which supports monitoring and evaluation of forest and the environment in the area of forest, digital maps such as DLG to support research about the relationship between tree species and landform.
3) Chinese Oil Company
   o Paper maps and digital datasets
   o Information system which can support their management of oil-mine, route of transportation, and support their address choosing of sales.

4) Coal-mine department
   o Information for saving cost and construction of coal-mine
   o Location of mine disaster

5) National Electricity Company
   o Choose location of electricity station
   o Design routes for electricity transportation

6) Ministry of communication, highway department
   o Paper maps and digital datasets

7) National Railway Department
   o Paper maps of the area which the railway passes and digital datasets
   o And system where can analyze data of human distribution, economic, environment along railway route, which can support their designing and management.

8) Ministry of Water resource
   o Paper maps and digital datasets
   o Need to analysis invalidation of water supply system, and exploit water resource, so they need information system to support planning and management of Water resource Conservancy project.

9) Geographic Institution, in Chinese academy of sciences
   o Topographic data
   o Species calculation
   o Land cover
   o Location for people in fieldwork

10) Earthquake Forecast Centre, National Seismology Bureau
    o Paper maps and digital datasets
    o Need information system which provide historic data of earthquake, to analyze trends of earthquake, and fast evaluation of losing in economic and evaluate risk of earthquake, such as territorial historic earthquake information system, earthquake environment and potential epicentre information system.
11) National Land Use Department
   - Paper maps and digital datasets
   - Information system to support their management of land resource and mineral resource, and geological environment. For example, land use planning management information system on web.

12) Institute of Remote Sensing Applications, Chinese academy of sciences
   - Topographic data for aerial images rectification
   - Information about land resource and agriculture, based on topographic data

13) Institute of Geographic Sciences and Natural Resource, in Chinese academy of sciences
   - Paper maps and digital datasets
   - Need services to integrate thematic data of natural resource with environment data, to provide a platform for data sharing, to support research about optimum usage of natural resource, protection of environment, sustainable area development.

14) Remote Sensing Centre, Chinese Geological University
   - Topographic data for aerial images rectification

15) Mine resource Centre, in Institution of geology and Geophysics, Chinese academy of sciences
   - Topographic data as the foundation data for thematic information
   - Topographic data and aerial images for modelling spatio-temporal objects and processes for monitoring the environmental influences caused by deep hard coal mining

3.4.4. Needs for Data Sharing and Existing Relationships between SBSM and Other Organizations

As there are data collection at SBSM, and data requirements outside of SBSM, data sharing will be needed to connect two sides of this situation, and a mechanism of data sharing need to be established to make data available for data users.

3.4.4.1. Needs for Data Sharing

SBSM still has problems to provide GI-service: (Li Pengde 2006)

- Because there are many differences in different areas, such as ability of data collecting, the frequencies of data updating are different
- Sometimes customers need thematic data which is not available at SBSM
- Because of secrecy policies, presently SBSM doesn’t provide services to citizens.

The 15 organizations have also collected topographic data and some thematic data which should be shared to reduce data redundancy, decrease cost of data collection, and complete construction of SDI.
3.4.4.2. Existing Relationships between SBSM and Other Organizations

SBSM has such types of relationships with other organizations:

1) Face-to-face communication
   - SBSM provides foundation data to customers when they need occasionally.
   - SBSM develops GIS system for customers. For example, Shaanxi highway information services system, which based on integration of geographic data and thematic data from the Bureau of Highway. It is divided into six sub-system, they are highway attribute management system, GIS inquiring and analysis system, users management system, spatial data management system, decision making assistant system, operation management system.

2) Institutional relationship

SBSM executes surveying projects for these departments and organizations

3) Other organizations hand in data to SBSM

   - When these organizations do foundation surveying, they must send copies or catalogues of productions to the Geomatics Centre.
   - When these organizations do the professional surveying, they must send catalogues which generally describe the data to the Geomatics Centre, provide information such as control points, name of maps, reference frame, and department which keeps the productions.

4) Creditability contract

When they do these data exchange, they will sign contracts to insure secrecy of data.

3.4.5. Other Findings

We also find some information about data dissemination and data producing in the way of documents and browsing electronic documents in their website.

3.4.5.1. Flow of Data Dissemination

There are two types of processes of data dissemination which are concluded from the regulation of providing and applying for usage of surveying products in Shaanxi Province: (Shaanxi Geomatics Center 2006)

   - not via Internet, the process is:
Figure 3-3 Data Dissemination

This diagram shows that customers have to submit application for data, and most of the past time data was disseminated in this way because data provider thought it was difficult to keep secrecy to transmit data in internet.

- via Internet, the process is:

Figure 3-4 Data Dissemination via Internet

SBSM publishes data via internet. But still, when customers request data in internet, they must apply for the data and sign contract to get data.

3.4.5.2. The industrialization of Geo-information in Shaanxi province

In China, there are three modes of geo-information: foundation geo-information, public geo-information, and value-added geo-information. As shown in Figure 3-5: (Li Pengde 2006)
As a kind of resource, geo-information has value to be developed. From original geo-information to product which can be used, then to be commodity in circulate domain, finally can make benefit to support further development in GI-service. So there is a chain which consisted of foundation surveying, data process, geo-information industry, and GI-service, to develop geo-information industry.

There are some policy files used in SBSM for data producing and data dissemination.

- Specifications for inspection, acceptance and quality assessment of digital surveying and mapping products

In the specifications, glossary is given, and we can also find the detailed rules and procedures to implement quality assessment, which ensures the quality of DLG, DRG, DOM, and DEM.

- Policy about providing surveying products
This policy provides the application form, and the flow of application of surveying products. We can find that, with the permission from SBSM, people can only use data after subscribing contract of data use.

Every year the Geomatics Centre must provide the information about data use to SBSM.

- Policy about management of publication of geo-data

There are such regulations for publication of geo-data:

  o Before publication of geo-data, the publisher should apply to the State Department, and provide the general specification about the data
  o Geo-data should be published by special publisher with license from the State Department

3.4.5.4. Other Organizations Competing to Provide GI-service

There are some other organizations and private companies are competing to provide GI-service:

- Xi’an Academe of Coal-mine
- Xi’an Academe of Surveying and Mapping
- Institute of Shaanxi Highway Survey and Design
- The First Institute of Railway Survey and Design
- Shaanxi Forestry department
- Institute of Shaanxi Geological Surveying and Mapping
- Shanghai Changxing Computer corporation
- SuperMap company in Beijing

The predominance of these competitors is:

- Have flexible mechanism and can deal with sudden changes in market
- Would like to use new technology
- Have money and dare to invest
- Lower price of products

3.5. Study of SBSM Situation with Regard to Services

In this section, we describe a general vision of services at SBSM and hardware/software ability. The purpose is to review the possibility to develop GI-service.

3.5.1. Status of Services at SBSM

Currently in SBSM, they have such items of services:

- Providing paper maps
- Digital maps
- Constructing spatial database for customers
- Data processing
- Develop thematic GIS
3.5.2. Capabilities of SBSM to Provide Services

- **Hardware**

In SBSM, they have some advanced devices:
- Data storing devices (STK L180 tape warehouse, Sun T3 tape array, Lec tape array),
- Switch (Vixcel, Cisco6500),
- Server (SUN Enterprise5500, Dell4600),
- Graph workstation (Sun, Dell, HP)
- Image scanner (ULTRAN scan)
- Output equipment with high precision (HP5500)
- And internet transport system (1000M)

From the picture above, we can see that SBSM is well-appointed.

- **Software**

They have some software to support their data providing:
- To construct database, they use geo-database model, oracle and ArcSDE
- For data processing, they have AutoCAD, ArcInfo, MapInfo, ArcMap

3.6. Pitfalls and Disadvantages of Each Method

There are still some pitfalls which will affect the results of data collection:

- **Interviews:** It’s difficult to interview people without any bias and to keep interview in control; all these must have influenced the quality of data. Also it need much time to interview people, 2 persons one day at most.

- **Questionnaires:** Because people just answer questions in questionnaire, they have no opportunity to clarify issues, and their response to questions may be influenced by others’. So the veracity of these responses should be considered when using them for analysis.

- **Observations:** Because personal opinion and method of recording will affect results, as problems of observation as a method of data collection described in research methodology (Kumar 2005), the interpretations drawn from observations are only use for reference.
According methods described in the Research Methodology (Kumar 2005), such works were conducted to decrease influence:

Interviews were composed of successive meetings in order to clarify certain details. For example, in the first meeting with director of the Geomatics Centre, information of status and ability of the Centre were acquired. Then, to get more information about data dissemination and relationships between SBSM and customers, another meeting was conducted. In addition, after being written down to prepare fieldwork report, this part of content was send to him by email, to be validated.

Questionnaire had been structured many times before using. Then it was sent almost at the end of Friday, and collected in the morning of the next Monday. It means that people have enough time to consider about the questions, but have few chances to use others’ answer for reference.

3.7. Conclusions

In this fieldwork, primary data was collected by interview, questionnaire and observation, and secondary data was also gathered in forms of existing documents. Beside the disadvantages of the method, this fieldwork provides sufficient material for understanding situations of GI-service in China.

In this chapter, status of GI-service at SBSM is depicted in detail. The understanding of GI-service in China is different from normal understanding, and the definition of data is not clear, when they talking about data, they, most of the time, mean maps.

Commonly customers request maps, digital geo-data, and/or system development. But because of secrecy policy, the way they apply for data is special, they sign contract before receiving data.

In SBSM, they have advanced hardware, and use new technology for construction of database and data processing. Although currently they don’t have GI-service in general meaning, they have willing and capability to develop GI-service.
4. Needs for Sustainable GI-service

This chapter presents an overview of current set of customer requirements, the available products at SBSM. Next, this chapter illustrates gaps between customers’ requirements and available products, GI-service which should be established, and discusses about sustainable issues. With this data analysis, development of GI-service architecture will be conduct in the next chapter.

This chapter is organized as follows: Section 4.1 describes customer communities and their specific requirements, Section 4.2 enumerates products available at SBSM; Section 4.3 presents gap analysis and proposed solving, with respects to data sharing, GI-service standards; Section 4.4 portrays a comparative analysis of customers’ requirements and devises similarities; Section 4.5 lists GI-service which should be developed; Section 4.6 describes sustainable issues; and Section 4.7 draws some conclusions.

4.1. Customers and Requirements

Based on data collected in the field, we can group the 15 organizations that are customers of SBSM into 9 customer communities. Such communities are as follows: statistics, forest, mining, water, utilities, transportation, disaster forecast and management, land use, and scientific research.

4.1.1. Customer Communities’ Requirements

All the customers expressed the interests on some specific services by the information they needed. After analysis fieldwork data and studying specialty of these areas, below we present the specific requirements for each of these Customer communities:
<table>
<thead>
<tr>
<th>Domains</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statistics</strong></td>
<td>- Visualization of statistical data</td>
</tr>
<tr>
<td></td>
<td>- Population distribution</td>
</tr>
<tr>
<td></td>
<td>- Enterprises distribution</td>
</tr>
<tr>
<td></td>
<td>- Transportation routes</td>
</tr>
<tr>
<td><strong>Forest</strong></td>
<td>- Aerial photographs</td>
</tr>
<tr>
<td></td>
<td>- Landform data</td>
</tr>
<tr>
<td></td>
<td>- Road data within forest areas</td>
</tr>
<tr>
<td></td>
<td>- Shortest path calculation for emergency</td>
</tr>
<tr>
<td></td>
<td>- Distribution of vegetation</td>
</tr>
<tr>
<td></td>
<td>- Visualization of differences of species in specific period</td>
</tr>
<tr>
<td><strong>Mining</strong></td>
<td>- Distribution of mines</td>
</tr>
<tr>
<td></td>
<td>- Roads data within mining areas</td>
</tr>
<tr>
<td></td>
<td>- Optimal path calculation for transportation</td>
</tr>
<tr>
<td></td>
<td>- Customers’ distribution</td>
</tr>
<tr>
<td></td>
<td>- Routes to location of mine disaster</td>
</tr>
<tr>
<td></td>
<td>- Topographic data and aerial images for modelling spatio-temporal objects</td>
</tr>
<tr>
<td></td>
<td>and processes for monitoring the environmental influences caused by deep</td>
</tr>
<tr>
<td></td>
<td>hard coal mining</td>
</tr>
<tr>
<td><strong>Water management</strong></td>
<td>- Distribution of water systems</td>
</tr>
<tr>
<td></td>
<td>- Water quality modelling</td>
</tr>
<tr>
<td></td>
<td>- Pollution area statistics</td>
</tr>
<tr>
<td></td>
<td>- Visualize changes of water resource, such as water level, water area</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td>- Customers’ distribution</td>
</tr>
<tr>
<td></td>
<td>- Road data</td>
</tr>
<tr>
<td></td>
<td>- Selecting routes</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>- Topographic data of area around road and railway</td>
</tr>
<tr>
<td></td>
<td>- Address data in relation to roads and railways</td>
</tr>
<tr>
<td></td>
<td>- Shortest path calculation</td>
</tr>
<tr>
<td></td>
<td>- Route selecting</td>
</tr>
<tr>
<td></td>
<td>- Location of accidents</td>
</tr>
<tr>
<td></td>
<td>- Combining digital maps of the entire network of road or railway with</td>
</tr>
<tr>
<td></td>
<td>passenger information, emergency access or asset management</td>
</tr>
<tr>
<td>**Disaster forecast and</td>
<td>- Visualization of historical data of disaster</td>
</tr>
<tr>
<td>management**</td>
<td>- Location of disaster</td>
</tr>
<tr>
<td></td>
<td>- Traffic data</td>
</tr>
<tr>
<td></td>
<td>- Adaptive routing</td>
</tr>
<tr>
<td></td>
<td>- Topographic data for disaster surveying and assessment</td>
</tr>
<tr>
<td><strong>Land Use</strong></td>
<td>- Categories of land use</td>
</tr>
<tr>
<td></td>
<td>- Topographic data</td>
</tr>
<tr>
<td></td>
<td>- Aerial photographs</td>
</tr>
<tr>
<td></td>
<td>- Overlaying land parcel data on topographic data or aerial images</td>
</tr>
<tr>
<td></td>
<td>- Visualization of differences of land use in specific period</td>
</tr>
<tr>
<td><strong>Scientific Research</strong></td>
<td>- Topographic data</td>
</tr>
<tr>
<td></td>
<td>- Land cover and land use information</td>
</tr>
<tr>
<td></td>
<td>- Location services for people in fieldwork</td>
</tr>
</tbody>
</table>
Some of these requirements can be fulfilled by data providing, and others need data analysis and processing at the user interface based on geo-data. The impact of these diversified requirements is that SBSM needs to improve their abilities to provide such types of services, as customers always try to find geo-information providers which can provide such types of services efficiently to support their professional tasks.

4.2. Products Available at SBSM

According to the list of products at SBSM (in section 3.5.2.), available information can be discriminated in following table 4-2:

<table>
<thead>
<tr>
<th>Information content</th>
<th>Type</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geodetic reference system</td>
<td>REF</td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td>Place names</td>
<td></td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thematic data and maps</td>
</tr>
<tr>
<td>Administrative units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrative units</td>
<td>REF</td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Digital urban maps</td>
</tr>
<tr>
<td>Administrative boundaries</td>
<td></td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• DLG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Digital urban maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thematic data and maps</td>
</tr>
<tr>
<td>Blocks and census districts</td>
<td>REF</td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Digital urban maps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thematic data and maps</td>
</tr>
<tr>
<td>Properties, buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>properties</td>
<td>REF</td>
<td>• Cadastral maps and land cadastral maps</td>
</tr>
<tr>
<td>Cadastre</td>
<td></td>
<td>• Cadastral maps and land cadastral maps</td>
</tr>
<tr>
<td>Buildings</td>
<td>REF</td>
<td>• Topographic data and maps,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• DLG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Cadastral maps and land cadastral maps</td>
</tr>
<tr>
<td>Building and other facilities</td>
<td></td>
<td>• Cadastral maps and land cadastral maps</td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
<td>• Topographic data and maps</td>
</tr>
<tr>
<td>Elevation</td>
<td>REF</td>
<td>• DEM</td>
</tr>
<tr>
<td>Relief</td>
<td></td>
<td>• Topographic data and maps</td>
</tr>
</tbody>
</table>
### Altimetry
- Topographic data and maps
- DEM

### Hydrography
- **Hydrography, river, lake**
  - REF
  - Topographic data and maps
  - DLG
- **Water**
  - Topographic data and maps
  - DLG
  - Thematic data and maps

### Land surface
- **Ortho-images**
  - REF
  - Ortho-images
  - DOM
- **Aerial photos**
  - Aerial photos
- **Satellite images**
  - Satellite images

### Natural resource
- **Soil**
  - THE
  - Thematic data and maps
- **Geology**
  - THE
  - Thematic data and maps
- **Vegetation**
  - THE
  - Topographic data and maps
  - Thematic data and maps
- **Land cover**
  - THE
  - Topographic data and maps
  - Thematic data and maps

### Transport
- **Transport networks**
  - REF
  - Topographic data and maps
  - DLG
- **Road lines**
  - Topographic data and maps
  - DLG
- **Railroads**
  - Topographic data and maps
  - DLG
- **Transport facilities**
  - REF
  - Topographic data and maps
  - DLG

### Facilities
- **Location of utilities**
  - THE
  - Topographic data and maps
  - DLG
  - Thematic data and maps
- **Communication lines**
  - Topographic data and maps
  - DLG

### Demography
- **Demographic attribute data**
  - THE
  - Thematic data and maps

---

Note: Reference data (REF) and thematic data (THE)

The information providing at SBSM could be converted to services, the types of services include: data services, processing services. But currently they don’t provide these services.
4.3. Gap Analysis

By comparing customers’ requirements and products available at SBSM, we can find some gaps. Take “routes to location of mine disaster” for example, what the Mining Bureau need is optimal routes to the mine disaster for emergency services, but currently SBSM only provides spatial data of road. The Mining Bureau can provide coordinates of mines. To produce the needed information, SBSM should overlay the coordinates data and spatial data to find routes information to mine, and then conduct optimal routes analysis according instant traffic data. Other requirements can be deduced in the similar way, and then we can get a general overview of geo-information and basic GI-service which are needed and gaps between requirements and current formats of products.

Another issue is that of the format. Regarding to the benefits of GML for GI-service (chapter 2), GML is used as an open standard, which is accepted by both data providers and customers in internet applications. Data format would need to be transformed to GML for example. In SBSM, most data is provided in ArcInfo E00 format. The transferring from ArcInfo E00 to GML would allow greater degree of interoperability. There is a proposed way for generating GML data, the procedure is shown in Figure 4-1:

![Figure 4-1 Overview of Making Vector Maps on Web with GML](image)

The E00 files are format of ArcInfo coverage. They are first decompressed to ArcInfo coverage and then converted to shapefile format. The reason is that many free tools are available to convert shapefile to GML. By using free converter, shapefile format data can be converted to GML data. But it could be a problem to transfer data at SBSM, as they have a mass of geo-data. It will cause great deal of financial source, human resource and material resources cost. Besides these problems, there are still some gaps with data sharing and GI-service standards.

4.3.1. Gaps of Data Sharing

As described in section 4.2, at SBSM, they have many types of geo-data which can be used for GI-service, but there are still some problems with data sharing:

1) Lack of culture for data sharing and the supporting regulations and policies

The degree of inter-organizational data sharing is low. Many procedures must be followed to get data from SBSM, it’s not efficient. The most common data which are shared are digital topographic maps, and the data transferring is only one way (not both ways), from SBSM to customers.

SBSM only provides data to government departments and few private agencies because of secrecy policy in China. It disables data sharing publicly, and delays construction of national SDI in China.

2) Lack of mechanism to advertise data in a standard form
There are some formats of data catalogue for different data at SBSM, but customers can only get this information when they request. It’s not available on SBSM website.

3) Lack of standards for data exchange

There is no standard geo-data exchange format at SBSM, a new format should be written in GML. This language is both useful and popular in all kinds of Internet applications, where exchange of data takes place. Considering these problems with data sharing at SBSM, there are some standardization work should be done to data formats. Also if an interoperable web-based framework can be developed, data sharing could potentially be improved.

4.3.2. Gaps of GI-service Standards

As standards being one of these important issues for GI-service, it’s necessary to conform to standards, such as OpenGIS standards mentioned in chapter 2, to provide GI-service. As shown in the following figure 4-2, there are 3 aspects of SDI standards:

![Figure 4-2 SDI and standards](image)

Normally these standards would be:

- Software interfaces (Implementation Specifications) – OGC, W3C (World Wide Web Consortium)
- Foundations for implementation (Abstract standards) – ISO TC 211
- Content standards, Authority for data – National Standards

As being discussed before, to develop GI-service, data should be in GML format which could be understood by both client and server. This work has not been done at SBSM.

GI standards developed by ISO/TC 211 and OGC define service interfaces for simple geo-processing tasks like mapping, metadata and feature access. Currently SBSM don’t have GI-service in general meaning. For the sake of developing web GI-service, OpenGIS Implementation Specification and ISO/TC 211 standards should be considered at SBSM.
In addition, National Geomatics Centre quotes standards which are defined by ISO/TC 211 as the national technical standards for geo-information applications and services. (National Geomatics Centre of China 2006) The standards include:

- **Geographic information – Positioning services**: This standard specifies the data structure and content of an interface of geographic information with position.

- **Geographic information – Portrayal**: This standard defines a schema to describe the portrayal of geographic data for integrating geographic information with information technology.

- **Geographic information – Encoding**: Encoding rules to be used for interchange of geographic data based on Unified Modelling Language (UML) schemas.

- **Geographic information – Services**: This standard defines the architecture patterns for service interface, which will allow a variety of applications with different levels of functionality to access and use geographic information.

- **Geographic information – Simple feature access – Part 1: Common architecture**: This standard establishes a common architecture and defines terms to use within the architecture.

- **Geographic information – Simple feature access – Part 2: Structured Query Language (SQL) option**: This standard specifies an SQL schema that supports storage, retrieval, query and update of simple geospatial feature collections via the SQL Call Level Interface (SQL/CLI).

- **Geographic information – Web Map server interface**: This standard describes a Web Map Server. Producing a map, querying the content of the map, and to ask a map server about its holding can be executed by submitting requests in the form of URL.

- **Geographic information – GML**: This standard defines the XML Schema syntax, mechanisms, and conventions. Implementers should decide to store geographic application schemas and information in GML.

- **Geographic information – Web Feature Service**: This standard describes the OGC Web Feature Service (WFS) operations. The WFS operations support INSERT, UPDATE, DELETE, LOCK, QUERY AND DISCOVERY operations on geographic features using Hypertext Transfer Protocol (HTTP) as the distributed computing platform.

- **Geographic information – Filter encoding**: This standard describes an XML encoding of the OGC Common Catalogue Query Language (CQL) as a system neutral representation of a query predicate. The XML filter encoding can be used by a number of OGC web services.

As the requirement of consistency in national area, SBSM need to confirm these standards when they develop GI-service, which will cause needs of software and hardware technologies. For example, they are expected to develop a user interface based on ArcIMS, then they have software requirement of ArcIMS.

SBSM already have a number of software, such as ArcInfo, MapInfo, ArcMap, AutoCAD, Oracle and ArcSDE (in section 3.5.2), for management and production of geo-information. But the available software does not support for XML/GML. They have also software requirement of XML.
After analysis in this section, we can find that there are many gaps between customers’ requirements and current products at SBSM. It is not a sustainable situation at SBSM, which need to be improved either by developing new services, or by changing the way its current products are created, or by both of these two ways.

### 4.4. Similarities in Requirements

As customers’ requirements are identified above, some customers express similar interesting in services by their similar requirements, as shown in the following table 4-3:

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Domain of customers</th>
<th>Similarities</th>
</tr>
</thead>
</table>
| - Landform data  
- Road data within the forest area | Forest |  |
| - Topographic data for modelling spatio-temporal objects and processes for monitoring the environmental influences caused by deep hard coal mining | Mine | Topographic data |
| - Distribution of water systems | Water management |  |
| - Road data | Utilities |  |
| - Topographic data of area along road and railway | Transportation |  |
| - Topographic data for disaster surveying and assessment | Disaster forecast and management |  |
| - Topographic data | Land Use |  |
| - Topographic data  
- Land cover and land use information | Scientific Research |  |
| - Aerial photographs | Forest | Aerial images |
| - Aerial photographs | Land Use |  |
| - Land cover and land use information | Scientific |  |
| - Visualization of statistical data | Statistic |  |
| - Visualization of differences of species in specific period | Forest | Visualization |
| - Visualization of historical data of disaster | Disaster forecast and management |  |
| - Visualize changes of water resource | Water management |  |
### 4.5. Types of Required GI-service

From the similarities of customers’ requirements and gap analysis, it can be concluded that there are five types of web-based GI-services required, like:

- Data services
- Location services
- Routing services
- Visualization services, and
- Integration services
The following table 4-4 shows part functionality of these required services which are obtained by analysis basing on these services requirements.

### Table 4-4 Functionality and required services

<table>
<thead>
<tr>
<th>Required services</th>
<th>Functionality</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data services</td>
<td>Geographic data provision</td>
<td>Discovery and provide geographic data</td>
</tr>
<tr>
<td></td>
<td>Metadata search</td>
<td>Provide metadata</td>
</tr>
<tr>
<td></td>
<td>Map presentation</td>
<td>Display raster and vector map</td>
</tr>
<tr>
<td>Visualization services</td>
<td>Visualization</td>
<td>Provide visualization functions to be applied to information</td>
</tr>
<tr>
<td>Location services</td>
<td>Get geo-coder</td>
<td>Find position of an address</td>
</tr>
<tr>
<td></td>
<td>Reverse Geo-coder</td>
<td>Find address of a position</td>
</tr>
<tr>
<td></td>
<td>Retrieve location</td>
<td>Describe location of a position</td>
</tr>
<tr>
<td>Routing services</td>
<td>Determine route</td>
<td>Determine and store a route</td>
</tr>
<tr>
<td></td>
<td>Choose path</td>
<td>Shortest path calculation</td>
</tr>
<tr>
<td>Integration services</td>
<td>Integration, modelling and statistic</td>
<td>Integrating for data analysis</td>
</tr>
</tbody>
</table>

Taking the Ordnance Survey (OS) services as a reference, we can find the trends of required functionality which are discovery, retrieval, presenting, processing, manipulation, integration, analysis, or visualization of geographic data. The functions should also be considered as we tend to develop sustainable GI-service system.

### 4.6. Issues of Sustainability

Such required types of GI-service system should be developed at SBSM. However, currently SBSM is in the situation as figure 4-3 showing:

![Figure 4-3 Status of SBSM](image)

In figure 4-3, we can find that SBSM only provide spatial data products, as there are many requirements of GI-service. It’s an inconsistent situation. Normally, as description in figure 4-4, to develop some static GI-service which can fulfil currently requirements is a feasible way to change this situation. But it will be a coming problem that requirements do not keep the same, and static pre-defined services may not be able to fulfil the dynamic requirements of services. It means that SBSM
need to re-engineer the geo-information system, when new customers’ requirements appear. So they should develop a flexible system which can deliver sustainable services in a specific period.

![Figure 4-4 Possible solution at SBSM](image)

Geo-information Systems are information systems which produce proper functionality based on a number of parameters which are system quality characters. Functionality means the ability of the system to do the work for which it was intended. It states system’s capabilities, services, and behaviours. (Felix Bachmann and Klein 2003) So system quality characters which indicate quality of the geo-information system will also show quality of functionalities.

Therefore to have a good quality geo-information system which is available to provide functionality to fulfil customers’ requirements, SBSM must consider the system quality characters when they establish system. As shown in figure 4-5, in this situation, we will say that they have developed a flexible system to provide GI-services to fulfil requirements.

![Figure 4-5 Proposed Sustainable Situation at SBSM](image)
Here service means the basic GI-service which can be used as service resources in the geo-information system, and functionality means data and the functions combination which is combined by basic GI-services interaction to fulfil requirements. The functionality also could be registered, and reused for further requirements. Taking pedestrian navigation requirement for example, propose the required five services have been developed as the basic services in the geo-information system. Navigation needs road data service, weather data service, and traffic data service; location service which provides location data for routing service; then by visualization service, we can present routes for pedestrians. In this case, these service resources are combined to provide navigation functionality which could be further used as one function of mobile GI-service.

To achieve functionality, many or most of the system’s components (e.g., data, operations, and resources) are required to work together with a number of possible structures which assign responsibilities or facilities to each component. However, functionality is largely independent of structures, because if only for functionality, there is no need to decompose system into modules with internal structure. Software architecture constrains allocation of functionality to structure when ‘other quality’ attributes are important. The interest of functionality is how architecture interacts with, and constrains, those ‘other qualities’. (Felix Bachmann and Klein 2003)

Architecture aims to provide an abstract framework to enable services interoperability. It provides foundation for achieving quality, and it’s critical to the realization of many qualities of interest in a system. These qualities should be designed in and can be evaluated at the architecture level. To evaluate the effects of architecture to ‘other qualities’, system quality characters can be characterize by citing system quality characters scenarios. The figure 4-6 shows that there are six elements of scenario: source of stimulus, stimulus, artefact, and environment, response, and response measure.

![Figure 4-6 System Quality characters Parts](image)

We will consider such system quality characters (non-function) as following to evaluate quality of geo-information system. (Felix Bachmann and Klein 2003)

- Availability, concerns system failure and associated consequences.
- Modifiability concerns the cost of change. It concerns portions and time for changing
- Performance concerns timing. It concerns time for the system to respond to changing requirements.
- Security is a measure of the system’s ability to resist unauthorized usage while still providing its services to legitimate users.
- Testability refers to the ease with which software can be made to demonstrate its faults through testing.
Usability, concerns extent of easiness for the user to accomplish a desired task and the kind of user support the system providers.
Interoperability, concerns the capability of service system to interoperate with other systems.

Moreover functionality quality characteristics also should be considered to estimate quality of service.

Based on the concept of Quality of Service (QoS), sustainable GI-service are defined (in chapter 2) as GI-service with functionality which can fulfil customers’ requirements for a significant amount of time without much change or negative economic impact. By evaluating these quality characters, we can find geo-information system which is in good quality, has the capability to provide functionality with the characters of sustainability. Then we can extract the conclusion that functionality which is provided by this geo-information system is sustainable. It means that GI-service with the functionality is sustainable.

4.7. Conclusions

In this chapter, we can find that there are many gaps between customers’ requirements and current products. A gap analysis is conducted on three aspects: data itself, data sharing, and GI-service standards. Firstly, there is a gap between data provided by SBSM and that needed by customers. SBSM should combine data and do some added value to produce useful products/services for customers’ application. Secondly, there is a gap of data sharing. There is no standard data format for data interchange, and there is lack of mechanism to advertise data to customers in a standard form. Thirdly, there is a gap of standards, SBSM do not use any international standards which are quoted as national standards of GI-service in China, they do not have standard software interface for GI-service.

With the gap analysis and the similarities study of requirements which was executed by comparing customers’ requirements, we can argue that data services, integration services, location services, routing service and visualization services need to be developed to adapt SBSM to current requirements of customers in terms of GI-service. To make the GI-service to be sustainable, we should develop a geo-information system with flexible architecture being able to provide GI-service without much architecture changes in a specific period, and accordingly sustainability of GI-service also can be evaluated by evaluation of quality characters.
5. GI-service System Architecture in the SBSM

In this chapter the research question 6 will be addressed: “What are the requirements for the SBSM to implement sustainable GI-service?”

This chapter deals with the design of the architecture of GI-service system, according customers’ requirements, trends of requirements, and needs of sustainability. This chapter lists elements of the GI-service system before gives conceptual description of the GI-service system.

This chapter is structured as follows: section 5.1 describes the scenario of services provision; section 5.2 presents the service produce line, to indicate what will affect the quality of basic service and the aspects should be concentrated on service designing; 5.3 describes conceptual designing and components designing of the architecture, evaluates how these quality characters will be affected; section 5.4 evaluates sustainability of services according the evaluation of sustainability of GI-service in chapter 2; section 5.5 draws conclusion of developing sustainable GI-service in the SBSM.

5.1. Scenario of GI-service System

In this section, a scenario of transportation information system will be established to explore the way to develop a method for development of sustainable GI-service. In following sections, we mean GI-service system to be the GI-service system of the SBSM.

5.1.1. GI-service System Conceptualization

To set a scenario of GI-service system, the system components and structure should be formulated clearly. Figure 5-1 indicates that, GI-service infrastructure in Shaanxi province will be constructed with three main parties, data providers, GI-service Provider (GSP) - nodes, and services users. SBSM is one of the GSP-nodes of the GI-service system. Users interact with GSP-nodes to request services, these interactions are shown in dot-lines in figure 5-1; The GSP-nodes may interact with other GSP-nodes to achieve complex tasks, these interactions are shown in solid-lines; And sometimes the service providers need to access data from external data providers, by utilizing data discovery functionality of the clearinghouse server, these interactions are shown in dashed-lines.

![Figure 5-1 GI-service Infrastructure in Shaanxi Province](image-url)
The GI-service system enables GSP to make use of functionality (data and functions) offered by the others to supply a wide range of services to comply with various customers’ requirements. Figure 5-2 shows that, as one of GSP-nodes, the SBSM has same internal structure as normal GSP, and is able to make use of architectural elements available in other GSP in Shaanxi Province of this GI-service system to realize a particular service.

![Figure 5-2 GSP-node Internal Structure](J Morales 2006)

- The service repository component contains descriptions of data definitions, process definitions and previously assembled service chains.
- The geo-processing units are responsible for execution of node functions. These units use data and applications as specified by definitions in the service repository.
- The service-design component defines how services are created and communicates with other GSP-nodes.

### 5.1.2. Scenario of Sustainable GI-service System

Take one of the requirements -- transportation information services as an example. In context of this thesis, we aim to establish such a GI-service system as being described in figure 5-1 to provide sustainable GI-service with interaction of service resources. Therefore we should considerate current required functionality of road network data, find location of courier centre and optimum route selection for haulage. Moreover, we should take account of further possible requirements of fare calculation for transportation.

It can be found that further possible requirements from technology development and GI-service provided by other GI-service providers. For example, technology development such as mobile will cause requirement of instant route selection services; in OS, they have developed transportation information services, such as giving instant access of delivery routes to transportation sector, and enabling re-routing when incidents occur. These services are possibly needed in future of China.

Here propose the main objective of the transportation information service is to provide users with an application which enables fare calculation based on routes data of transport. The users could be the
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transportation organizations, and individuals. And we will establish an optimized service system to provide service which can be used to fulfil this objective.

A large number of data resources will be required for transportation information service with functionality of location, routing, visualization and fare calculation:

- Location finds location of destination and provides instant location for re-routing when accidents happen.
- Routing selects optimum location for courier centre, which affects routes to other courier centre.
- Visualization enables to show location of the destination and routes between original centre and destination in users’ interface.
- Fare calculation calculates haulage fare

For these functions, the data requirements are:

- Place name, used for locating specific area based on geographic name input
- Courier centre distribution data affect routes selection as the internal courier centres in between original centre and destination.
- Road network data provides potential route information for haulage which is used as an element for data analysis, and also is base for visualization
- Instant traffic data, acquired from Traffic Management Organization, it’s important for routing, and need to combine with location for re-routing service when meet traffic accident
- Price data, the prices for different transportation for haulage

Besides data services, such geo-processing service will be needed as:

- Location service with these core services:
  - Directory service provides access to an online directory to find the location of courier centre.
  - Location utility service, used to provides a Geo-coder/Reverse Geo-coder; the Geo-coder transforms a description of a location, such as a place name, street address or courier centre, into a normalized description of the location with point geometry.

- Routing service takes responsibility of find routes between the original centre and the destination.
- Integration service will be taken to integrate routes, instant traffic data for choosing optimum route to destination.
- Visualization service shows location of courier centres, road network, courier centre distribution and optimum routes between the selected courier centres in base map.
- Distance statistic service will be applied to calculate the distance from the original centre to destination.

The steps of transportation information service can be identified:

- Acquiring the input address data
- Find the optimum routes by executing a series of services, such as location service, and routing service
- Calculate distance along the selected routes
- Find price information for variable transportation for haulage
- Fare calculation
Figure 5-3 shows the general process flow of the services identified above in the service chain for fare calculation:

![Figure 5-3 Flow of Service Chain](image)

Figure 5-4 shows the behaviour definition of all the service elements identified in figure 5-3 and their interconnections. It depicts the relationships between elements and the service handler. The service handler takes responsibility of connecting and controlling the relationships between these elements. In the figure, client is allowed to have control on the whole process of service chaining:

![Figure 5-4 Fare Calculation Process Design](image)

With the concept of GI-service system (in chapter 2), the SBSM is defined as the GI-service provider, and in this scenario of Transportation Information Service, SBSM is also GI-service handler/mediator who realize the service chain. Some data services are not the specialty of the SBSM, they are available at other expert services providers. We propose that these data service can be utilized by the SBSM to complete and supply the transportation information services, because the precondition to make service sustainable is to make service exist.

5.2. GI-service Produce Line

As we know that GI-service provider determines the quality version of GI-service. (See section 2.4) The procedure they established to produce GI-service is a produce line of GI-service. Figure 5-5 UML class diagram is used to model the structure associations between GI-service, GI-service version, GI-service produce line, and quality constrains. GI-service version means that each GI-service have a
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quality version, and quality constrains govern the quality of each GI-service version by constrains on operation.

![Diagram](image1)

**Figure 5-5 Quality Constraints of GI-service**

(Adam Sliwinski 2004)

From this figure, we can conclude that the quality of basic services produced in such process (without service combination) depends on the quality of data and quality of operations. Each GI-service has an interface, in order to satisfy heterogeneous requirements GI-service providers will advertise the GI-service to a broker in the service system.

After being advertised, the basic GI-service produced in the above produce line becomes service resource for further service produce in the service system. To make GI-service be discovered and utilized efficiently by service user, GI-service must be advertised properly, and have the ability to response to service requests. It means that we should pay attention to both service sequence designing and components designing in the next part of this chapter, which concerns architecture construction for transportation information service.

The following figure 5-6 is the sequence of service invoking for complex service produce/service chain. (WPL=Web Produce Line, WPLS=Web Produce Line service) (Adam Sliwinski 2004)

![Diagram](image2)

**Figure 5-6 Service Resource Responding to Invoking**
This UML sequence diagram shows the validation mechanism within service invoking process in service chain sequence:

- Validation mechanism: this mechanism is used to distinguish different service request, and allows the service resource provider to prove whether the service invoking can be fulfilled with the capability of the existing basic service. It will be implemented in our architecture designing.

This mechanism will be applied in later service sequence design of the transportation information service.

5.3. Architecture of GI-service System

As being analyzed (in chapter 4), quality of GI-service system depends on the architecture of the system. In the section, we will propose architecture for GI-service in the scenario depicted above.

5.3.1. Service Framework

As being depicted in figure 5-7, service framework is composed of core services, registry services, and administration services. Core services are registered and published in repository via registry service; administration services need to invoke registered core services from the repository; service clients will utilize administration services to find the services to fulfil their requirements, and administration services provide the required functionality by services interactions; requirements from clients affect the types and quality of required core services in service system. In the following parts of section 5.3, the actors, activities of actors, services interactions, and required core services of transportation information service will be discussed.

![Figure 5-7 Service Framework (J Morales 2006)]
5.3.2. Use Case Model of Transportation Information Service System

UML use case diagram can be used to overview the usage requirements for a system, figure 5-8 presents the general view of the transportation information service system.

![UML Use Case Diagram](image)

Figure 5-8 Use-case Diagram of the Service System

This UML use case diagram mainly depicts actors and use-cases:

**Actors:**

- Transportation organizations/Individuals: as the users of the service, the people or organization which requests the transportation information service.
- Requestor identification system: the system which can identify the requestors with ID numbers to check whether they have license to receive the transportation information service.
- Data creators: the entity which creates data to support the transportation information service, it could be the SBSM, or organizations mentioned above which provide thematic data, such as transportation organizations, weather Bureau, and so on.
- Policy advisor: the people who can give advices for policy problems caused in the procedure of service delivery.
- Expert organizations: the organizations which can provide expertise on information classification.
Technology supporter: the people who can advise for spatial data management and data processing.

Data processing system: the system executes data processes which are required by transportation information service.

Service designer: takes responsibility of service designing, in this scenario. In this service system, SBSM is the service designer, also the service handler.

**Use-cases:**

- Request registration: when the requestors want to get access of transportation information service, registration will happen.
- Data retrieval and acquisition: data provided by the data creator should be acquirable for the service. It can be facilitated by catalogue service.
- Information classification: it classifies data into two kinds — data for direct data service and data supporting processing service.
- Data processing: if required, it will be executed by the data processing system.
- Service design: executed by service designer to provide service specification.
- Service delivery: delivering transportation service to identified requestors.

The `<extends>` relationship — this type of relationship means that the source use case extends the behaviour of the target use case.

The `<uses>` relationship — this type of relationship between use cases means that there is a shared activity between the connected use cases.

### 5.3.3. Sequence Model of Transportation Information Service System

Figure 5-9 shows the interactions in more details to state the relationship between actors and use-cases in the service system.
- Service request is identified and registered before being executed.
- Request causes service design activity which will need to invoke data for data processing from different data creators.
- After classification, data will be retrieved and send to service delivery or data processing, which depends on service requirements.
- The service handler will get the required service after data processing and service interaction.
- At last the service handler delivers service to the service requestor, and the service produced in this process will be registered for reusing.

5.3.4. Components of Architecture

According the depiction of the scenario, the main application functions of transportation information service are composed of location, routing, and fare calculation. For each application, we need data and service components of the system being available for combining. Figure 5-10 shows a UML component diagram of the high level architecture.
The services components in this service system will be found as data services, processing services and catalogue service. Here data will be accessed by web map service (WMS), web feature service (WFS), and Gazetteer service. The reason are that WMS provides base maps and road network data; WFS offers access to attributes which are useful for further applications, such as distance statistic; Gazetteer service is needed for location by place name. Therefore data services are categorized into WMS, WFS, and Gazetteer service. In additional, catalogue service is required to provide metadata of data and service resources which describe resource characteristics that can be queried and presented for further processing by both humans and software.

It can be seen that in this system, interface will be designed for each service to enable service chaining. And in the whole process of service designing, the quality of service will be used as the criteria for geo-information/service quality control.

5.3.5. Services Interaction

Figure 5-11 states the interactions between the services in more details. It can be seen that the client request map for visualization firstly, and then they select the destination to get the input data for service. By catalogue service, the addresses of services and data will be searched. According these addresses information, location service will be invoked to locate the destination, which needs to invoke WFS to get address information of destination by place name. Then routing service will be used to find routes from original centre to destination. Courtier centre distribution data which can be provided by WMS will be used to integrate with routes data by integration service, the purpose is to
select optimum route. The routes will be visualized, and can be used as one parameter combined with haulage price data to calculate haulage fare by the client.

5.3.6. Component Design

In the architecture, the main components are: WMS/WFS/Gazetteer service, location service, routing service, integrating service, visualization service, distance statistic service, and catalogue service. In this section, these functions will be designed and presented. As being analyzed (chapter 4), when we want to develop GI-service at SBSM, we need to be compliant to OGC web service specifications in order to keep consistent in national level which benefits durative of the service.

5.3.6.1. Location Service/Routing Service/Visualization Service

Location service provides the function of finding the geographic location of courier centre; routing service has functions of selecting routes for transportation; visualization service is used for presenting the routes on base map. Location service in OGC has core services of location service, routing service, and visualization service. (OGC 2005) So here we will implement Open Location Service for these three required services. Figure 5-12 shows the Location Server infrastructure.
Location Content Databases are accessed through OGC Interfaces (Web Feature Server, Web Map Server), depending on implementation requirements. Location services conform to http/1.1 transaction protocol, support XML request. Figure 5-13 shows the Usage Pattern for Request/Response Pairs. (OGC 2005)

The interactions between client application and location service are in forms of request and response. The process of information transmission is: Clients request → XML request (after encoding) → getservice request (by generation) → response (after request processing) → XML response → visualized information (after decoding). The important point for service implementation is that both client application and core services understand the semantic of XML encoding.

5.3.6.2. Distance Statistic Service

Distance statistic service is a kind of processing service, provides client access to distance calculation operating on spatially referenced data. The required data can be retrieved from WFS in GML format. The interface of distance statistic service follows the WPS specification discussion paper (version 0.4.0). The WPS interface specifies three operations that can be requested by a client and performed by a WPS server: GetCapabilities allows client to retrieve service metadata documents; DescribeProcess allows client to request and receive back detailed information about one or more
processes that can be executed by an execute operation; and execute, allows the operation request to be implemented by the WPS. (OGC 2005)

Figure 5-14 shows conceptual model of distance statistic service. Execute operation takes responsibility of carrying out the operation request. In this model, parameters to request are specified by as: service is a processing service; version states the service version; Processname is distance statistic; the mask is the http address for the mask data and masktypename is road; the bbox is bounding box in which the statistic will be calculated; the status specifies if execute operation response should be returned with status information.

![Class Diagram of Distance Statistic Service](image)

**Figure 5-14 Class Diagram of Distance Statistic Service**

### 5.3.6.3. Integration Service

Integrating Service provides function of integrating routes information and instant traffic data for choosing optimum route to destination. It’s a processing service, and has the common three operations of WPS: getCapabilities, describeProcess, and execute. The operation request of integration service is encoding in XML, and execute response is also a XML document.

### 5.3.6.4. WMS, WFS, Gazetteer Service

To mapping and feature services, the standard OGC WMS 1.3.0 and WFS 1.1.0 implementation specification will be used as the direction. There are three operations of WMS: GetCapabilities, GetMap, and GetFeatureInfo. Figure 5-15 shows the WMS interface (OGC 2006)
In transportation information service, we use WMS `getCapability` and `getMap` operation to get base map for visualization, and road network for routing. XML encoding will be used for `getCapability` and `getMap` request using HTTP POST.

Figure 5-16 is a UML diagram describing the WFS interface. As seen that `WebFeatureService` class inherits the `getCapabilities` operation from the abstract `OGCWebService` class, which is common to all OGC Web Services. The Web Feature Service class adds the `describeFeatureType`, `GetFeature`, `GetFeatureWithLock`, “transaction”, and `lockFeature` operations. WFS request will be in XML encoding with HTTP POST. In transportation information service, WFS provides the operation of `getCapability`, `describeFeatureType` and `getFeature`, for gazetteer service and providing spatially reference data to distance calculation. (OGC 2004)

The Gazetteer Service is developed basing on WFS. To support query processing, a gazetteer service has the following operations: `GetCapabilities`, describe feature types it can service; `DescribeFeatureType`, describe the structure of any feature type it can service; `GetFeature`, service a request to retrieve feature instances.
5.3.6.5. Catalogue Service

As catalogue OGC web catalogue service will be implemented for storing and retrieving of resource (data and service). Figure 5-17 shows that catalogue service has functionality of storing resource, discovering resource, and managing resource. The client application interfaces invoke catalogue service via catalogue service interface. Catalogue service request will be encoding in XML, and will response by generating a SOAP message which is platform independent, language independent and encoded using XML.

Figure 5-17 Catalogue Service Application

5.3.7. Quality Characters

The quality of complex service is decided by quality of basic services and quality of service system (Being analyzed in section 2.4): the quality of basic service depends on data quality and quality of operations (Being analyzed in section 5.2); and quality of service system depends on characters of functionality, performance, availability, usability, interoperability, testability, modifiability, and security (Being indicated in section 4.6). So all these quality character will be taken as quality characters of GI-service in this research. In this section, we expatiate on each quality character and analyze some of system quality characters by quality character parts, to indicate the range of value they can take. The purpose is to find how these quality characters can be estimated.

5.3.7.1. Data Quality

Data quality indicates quality of data content, data updating frequency, and data. But it’s difficult to evaluate data quality only depending on these properties. As data which can satisfy customers’ requirement will be considered as good quality data, we will use customers’ satisfaction as the measure of data quality. Customers’ satisfaction will be calculated as percentage between number of satisfied customers and number of customers.

5.3.7.2. Operation Quality

Each service will have getCapability and other operations. To estimate quality of these operations developed by service provider, we will use rate of operation using as measurement indirectly. (Glen Dobson 2004) The data of times that the operation being used and service being invoked can only be
acquired by observation during the implementation of services, then take the proportion of these two
data to measure operation quality.

5.3.7.3. Functionality

Functionality is the ability of the system or application to satisfy the purpose for which it was
designed. In the transportation information service chain, the service is decomposed into some basic
service based on functionality. So we just need to evaluate the functionality of each basic service,
which can be represented by the times of reuse for complex applications.

5.3.7.4. Interoperability

Interoperability reflects system capability to interoperate to other system. It is stimulated by a
request of interoperation; the response might be that the system develop new interface for this
interoperation; and the response measure is the number of interfaces to be modified.

For the transportation information service system, we will use the proportion between the
number of interfaces being modified and the number the service being interoperated as the
interoperability measure.

5.3.7.5. Performance

Performance character refers to system’s ability of response. When the service request occurs, the
system must respond to them. Performance is concerned with how long it will take the system for this
response. Six parts can characterize performance like (A sample scenario is shown in the following
figure 5-18):

- **Source**: the service user.
- **Stimulus**: represents the service request arrivals. It can be characterized as periodic, stochastic, or
  sporadic.
- **Artefact**: the systems’ service.
- **Environment**: the system operational situation. It will cause different states of operation executing,
such as waiting or servicing, because of overload and normal operation modes.
- **Response**: the system environment may be changed because of processing the arriving events. For
  example from normal mode to overload mode.
- **Response measure**: the response measures are the time it takes to process the arriving events
  (latency or deadline), throughput, and data loss.

Normally performance will be measured in time aspect. There are two measures:

1) **Throughput**: server-oriented measurement of the amount of work done in a unit of time,
   fast throughput will cause fast response time.

2) **Response time**: amount of time between sending service request and receiving a
   response, it will be affected by server processing time, network time, and client
   processing time.
In transportation information service, response time can be divided into two types: time for transmission (relay the request from client to service and relay the generated response back to the client) which depends on the network speed; and time for service processing.

The transmission time can be acquired from observing transmission time of the service over different times of the day and then generating the latency by average. It can be affected by speed of network.

In the processing stage, we need to combine some services together, and different services are provided by different servers. When the system receives fare calculation request, the first time slice of processing will be the time used to register the request. The second time slice will be used for catalogue service which executed to find service address. The third time slice will be spent on retrieving data services from different data servers which depending on theme of data. Then the following time slices will be utilized to invoke location service, integration service, routing service, and distance statistic service in turn, to calculate the distance between the original centre and destination. The final time slice will be consumed for fare calculation. In this situation, processing time will spend on sending invoking request to these servers, waiting for data and processing resource from the servers, and serving the request. The processing time of performance can be estimated by plus the average time for executing each specified operation. It can be affected by the speed of servers’ components, and the ordering of requests which will be arranged by workflow management.

5.3.7.6. Availability

Availability demonstrates system’s capability to enable service accessible and be executed correctly for the duration it’s required. It can be revealed by system capability to recover from failure. Failure happens when the system no longer delivers a service consistent with its specified service level. The level could be required by service users, or defined by service provider.

An availability scenario is shown in following figure 5-19. In this case, six parts can characterize availability like:
- Source: an unexpected response, such as no result, or results seems abnormal. It can be found from the network, data for processing, and the servers.
- Stimulus: the failure causes unexpected results.
- Artefact: specifies the resource which must be available, such as processor, communication, and process of each server and the system.
- Environment: the state of the system when the failure happens.

![Figure 5-18 Performance Scenario](image-url)
- Response: the possible reaction to the system failure. It depends on service independency and service sequence
- Response measure: the extent that the system keeps availability.

For each component of service system, availability is estimated by the capability of the component keeping available, which can be calculated by the Meantime to Failure (MTTF) and the Meantime to Restore Services (MTTR) in a fixed period:
Availability = MTTF / (MTTF + MTTR)

MTTF means the average time slice from the last state of repaired to the state of failure; and MTTR means the average time slice from the state of failure to the state of having been repaired. The value of MTBF and MTTR will be obtained from observations on the service by the service provider. Propose that each component of the system are independent, the system availability will be calculated by multiplying the availability of each component.

Availability (system) = Availability (network) \times Availability (server) \times Availability (data)

![Figure 5-19 Availability Scenario](image)

In traffic information service system, availability of all the required data and the different servers need to be considered when calculating the availability of the system:
Availability (server) = \prod Availability (each required server)
Availability (data) = \prod Availability (each required data)

Availability (each required server), Availability (each required data), and Availability (network) can be estimated from observation on each component of the system in a fixed period. Availability relates to component designing in the architecture.

### 5.3.7.7. Usability

The usability indicates how easy it is for the user to accomplish a desired task with the service system. A usability scenario is shown in following figure 5-20. In this case, six parts are:
- Source: the service user
- Stimulus: user wishes to use the system efficiently
- Artefact: the service system
- Environment: the states of the system. When the user actions concerned by usability such as cancellation take place, the system is always at runtime or configuration time
Response: the system will take some actions according the user’s wishes or possible further needs, to support “use system efficiently”

Response measure: the response can be measured by task time, number of errors, number of solved problems, users’ satisfaction, ratio of successful operations to total operations

To transportation information service system, we will adopt task time and users’ satisfaction as the usability measurements. Because task time can represent the capability of the system to response to customers’ requirements; and users’ satisfaction can reflect how the capability is. Two of these measurements can generally represent system’s usability. Task time can be estimated by the average time to execute a task; and users’ satisfaction can be indicated by the proportion between number of satisfied users and number of investigated users.

5.3.7.8. Testability

Testability character refers to probability of the system to demonstrate its faults through testing. The six parts of the testability scenarios are:

- Source: testing performers
- Stimulus: perform test
- Artefact: the service system or part of the system
- Environment: different time periods of testing, at design time, development time, compile time, or deployment time.
- Response: the system can be controlled to perform the desired tests, and the response can be observed
- Response measure: the response to each test can be measured by percentage executable statements executed, time to perform tests, probability of failure if fault exists, and length of time to prepare test environment
For transportation information service system, we will use the probability of failure if fault exists as the measurements. The probability will be proposed to be calculated as:

\[
\text{Probability} = \frac{n}{N} \quad (\text{“} n \text{” means times of failure because of fault, “} N \text{” is the fixed testing times})
\]

The value of \( n, N \) can be observed in the implement of test. To be fair and representative, tests will be arranged in different environments. Besides the probability of failure to the transportation information service, probability of failure to each server, and network will also need to be estimated separately as services are invoked from different servers.

### 5.3.7.9. Modifiability

Modifiability concerns the cost of change, especially time and money need to be consumed for system redesigning, implementation, and test when there is a need to modify some part of the system.

In the following scenario, possible values of elements are used to characterize performance.

- **Source:** who makes the changes
- **Stimulus:** wishes to change
- **Artefact:** what is to be changed, such as functionality, platform, user interface, or another system with which it interoperates
- **Environment:** time periods of the change
- **Response:** understand of the change, such as locating places in architecture
- **Response measure:** time, cost money for response, and extent to affect other functions

Modification measure will relate to how much efforts are made which can be observed when the system is modified, and how much it will change to the architecture of the system which can be evaluated by the changed components in the system and other functions be affected.

![Figure 5-22 Modifiability Scenarios](image)

To transportation information service system, we will use time and cost money for modification as the measure. When customers’ requirements change, modification may occur. Then we can get the data of time and cost money by observing the whole process of modification.
5.3.7.10. Security

Security is a measure of how the system can resist user to acquire or modify data and service without being authorized while providing service to users with licence.

In the following scenario, possible values of elements are used to characterize performance.
- Source: the individual or system try to make unauthorized access to data/service, or modify data/service
- Stimulus: an attempt to access system without licence
- Artefact: the target of the attempt such as services and data within system
- Environment: system in different operation modes.
- Response: grant permission or blocks access to data/service. It’s a way for the system to maintain audit trail for recovery.
- Response measure: measures of a system’s response include the difficulty of recovering from and surviving attack. It can be generated from the times of successfully data/service restoring and times of attack.

![Figure 5-23 Security Scenario](image)

To transportation information service system, security will be affect by the mechanism of request registry, secure transactions, licensing to data and services, and the security protocols. We adopt the response measure, to use the proportion between the times of successfully data/service restoring and times of attack as the measure of security.

5.4. Sustainability Evaluation

We choose these quality characters as the indicators for sustainability evaluation (Being stated in section 2.7). In the analysis of the previous section, all of the quality characters can be estimated in certain forms of number. According the sustainability evaluation framework, the sustainability of this transportation service system can be evaluated as the following tables. But the data used here can only be obtained in implementation of service, so now we have not actual data. The data in the following table is just an example:
### Table 5-1 Sustainability Indicators Calculation

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Transportation Information Service</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Resource Quality Characters</strong></td>
<td></td>
</tr>
<tr>
<td>Data quality</td>
<td>90%</td>
</tr>
<tr>
<td>Operation quality</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Service System Quality Characters</strong></td>
<td></td>
</tr>
<tr>
<td>Functionality</td>
<td>20</td>
</tr>
<tr>
<td>Interoperability</td>
<td>4%</td>
</tr>
<tr>
<td>Performance</td>
<td>6 hours</td>
</tr>
<tr>
<td>Availability</td>
<td>90%</td>
</tr>
<tr>
<td>Usability</td>
<td>1 sec, 70%</td>
</tr>
<tr>
<td>Testability</td>
<td>98%</td>
</tr>
<tr>
<td>Modifiability</td>
<td>2 mon, 120000</td>
</tr>
<tr>
<td>Security</td>
<td>95%</td>
</tr>
</tbody>
</table>

### Table 5-2 Sustainability Evaluation

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Desired Level of Quality</th>
<th>Quality of Transportation Information Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data quality</td>
<td>80%</td>
<td>+</td>
</tr>
<tr>
<td>Operation quality</td>
<td>85%</td>
<td>+</td>
</tr>
<tr>
<td>Functionality</td>
<td>15</td>
<td>+</td>
</tr>
<tr>
<td>Interoperability</td>
<td>5%</td>
<td>+</td>
</tr>
<tr>
<td>Performance</td>
<td>5 hours</td>
<td>-</td>
</tr>
<tr>
<td>Availability</td>
<td>80%</td>
<td>+</td>
</tr>
<tr>
<td>Usability</td>
<td>2 sec, 80%</td>
<td>+, -</td>
</tr>
<tr>
<td>Testability</td>
<td>95%</td>
<td>+</td>
</tr>
<tr>
<td>Modifiability</td>
<td>1 mon, 100000</td>
<td>-,-</td>
</tr>
<tr>
<td>Security</td>
<td>90%</td>
<td>+</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td></td>
<td>+4</td>
</tr>
</tbody>
</table>

Note: For the indicator with more than one value, if one of them is scored as ‘-’, the indicator will be scored as ‘-’. As shown in this evaluation, this service is sustainable.
5.5. Conclusions

In this chapter, a scenario of transportation information service is used to guide the system architecture design and component design. The basic services in this service system cover all the core services currently required at the SBSM. Then a service-oriented architecture is established to provide required functionality of fare calculation.

The basic services are: WMS, WFS, and Gazetteer services which provide data for data processing; processing services of location services, integration services, routing services, distance statistic service and visualization services; and catalogue service. All these services are categorized in OGC specifications. To make services easy to be understood and utilized by customers, we use the OGC standard interfaces as the interfaces of the relevant basic services.

To achieve functionality of fare calculation, these basic services will interact in interface for service chaining. The interactions between these services are depicted via UML sequence diagram, which shows data/service invoking and response clearly by linear relations.

The architecture of transportation information service system is defined as a service-oriented architecture. This style of system architecture allows interoperable services chaining to provide the required functionality. In this architecture, basic service can be found via catalogue services and reused for complex functionality. It will benefit for improving the sustainability of GI services.

The system quality characteristics are discussed, and analyzed with the transportation information service scenario. How to find the parameters to calculate the value of the quality characters are also identified. But because these parameters need to be obtained in service implementation, the data is just assumed.
6. Conclusions and Recommendations

This chapter presents conclusions and recommendations of the research. Section 6.1 lists the conclusions generated from the previous content of research; Section 6.2 enumerates some general recommendations for further research.

6.1. Conclusions

The purpose of this research is to explore the way to develop sustainable GI-service in general. To achieve this purpose, in this research, we use GI service at SBSM as a specific example. The work of research can be divided into three phases:

- First phase: define sustainable GI-service, and form the criteria for sustainability evaluation.
- Second phase: find the customers’ requirements and capability to develop GI-service at SBSM.
- Third phase: develop service system for customers’ requirements at SBSM, and evaluate sustainability of the service. In this phase, components and architecture of the system have been defined.

Base on the method to develop sustainable GI-service for SBSM, we can summarize the way for general sustainable GI-service development. According to the research objectives and questions, the following conclusions are extracted from the whole study:

- Geo-information service means to provide data and data processing via standard interfaces to fulfill customers’ requirements.
- The increasing requirements for GI-service cause the needs of GI-service system with flexible architecture, which aims to supply the required functionality by services interaction.
- Sustainability means the ability to meet needs not only currently but in a following specific period. Sustainable GI-service is defined basing on the concept of QoS. It means GI-service with a desirable level of QoS in the development lifecycle of the service provider enterprise. The desirable level will be fixed according the customers’ quality requirements to GI-service, and the states of GI-service development.
- The sustainability of GI-service depends on the quality of basic service and quality of the GI-service system where the basic services interact for complex service requirement. The quality of basic service will be affected by quality of data and operations using in the basic services; and quality of service system is affected by both functionality and non-functionality characters. So the criteria to evaluate sustainability of GI-service are defined to evaluate these quality characters of service, and then to assess the sustainability of the service by comparing the value of characters with the desired level of quality of sustainable GI-service.
- By review the state of the art at the SBSM, we can find that currently SBSM don’t have such GI-service, but they have raw data which provide the base for service development. And by analyzing customers’ requirements, the SBSM are confirmed to develop a service system with
basic services, such as data service, location service, routing service, integration service, visualization service, and catalogue service. To make GI-service to be sustainable components and architecture of the system are defined in chapter 5. The architecture is explained from different aspects, such as use case, interactions between use case and actors, and components interactions.

- The requirements for the SBSM to develop sustainable can be enumerated as:
  1. to develop required core services which are well specified and can interact with each other
  2. to establish a flexible service oriented architecture (SOA), which provide required functionality to customers
  3. to organize the service system with the consideration of indicators of sustainability, including data quality, operation quality, functionality, performance, availability, usability, interoperability, testability, modifiability, and security

6.2. Recommendations

The sustainability evaluation of GI service hasn’t been done in this research, because these services have not been implemented at SBSM, there is no data for indicators which can only be obtained from service application. We just give the framework of sustainability estimation without evaluation. The framework can be used for further research of GI-service sustainability evaluation. Based on the case of transportation information service at SBSM, recommendations related to developing sustainable GI service at SBSM can be summarized as:

- Collect data and encoding data in GML format which facilitates the internet data exchange and be used for web GI-service broadly.
- Develop core service according OGC service specifications which are used as a standard of GI-service. Define and specify service interface in standard way to support service interaction well.
- Advertise these services in GI-service infrastructure as service resource for further using.
- Define the sequence of service chains, which will affect time, and accuracy of service interaction.
- After implementation of GI-service, value of sustainability characters can be obtained, and the desired level of QoS can be decided according customers’ quality requirements and expert advises. Then sustainability of the service can be evaluated.
- According to the result of evaluation, the service can be improved respectively to advance the level of QoS, which means to improve the sustainability of GI-service. It can be considered as process to develop sustainable GI-service.

Based on the case of developing sustainable GI-service at SBSM, recommendations related to developing sustainable GI service in general can be concluded as:

- Find the potential customers’ requirements as many as possible, and apply analysis to get the core service requirements for the service system development
- Following the way to develop sustainable GI-service at SBSM, sustainable GI-service of an enterprise can be developed. It could be done by further work that find out the specific elements
affecting sustainability of GI-service, and then decide sustainability of GI-service previously when constructing service component and architecture.

- Sustainability of GI service can be used as one item of service metadata, which will be provided to the users for service selection.
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Appendix

Record 1 of Interviews

<table>
<thead>
<tr>
<th>Person</th>
<th>Li Pengde</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td>Deputy director general</td>
</tr>
<tr>
<td>Responsible</td>
<td>Contact with other departments and customers, management of technology, production, and human resource in the whole Bureau</td>
</tr>
</tbody>
</table>

Question 1: What are the situations in the bureau?

Answer:
- Provide geo-data to customers, include government, special organizations, and public
- Develop geo-information systems for different use according customers’ requirements from different specialization.

Question 2: What’s the ability of technology, economic, and policy in providing GI services in the Bureau?

Answer:
- We have high technology to do surveying and data processing, but we still have many problems to provide GI services:
  - It’s difficult to communicate with customers from different special fields
  - Because there are many differences on areas, such as ability of data collecting, the frequencies of data updating are different
  - Because different area use different data model, it’s difficult to manage geo-data
  - Because of their own benefits of each department, sometimes they don’t want to share data
  - Because of secrecy policies, not every one can get data
  - There is no unified standard to provide GI services in China

Question 3: How do you understand sustainable GI services?

Answer:
- It means: sustainable development of the organizations which provide GI services; And development of sustainable GI services.

Question 4: What is you suggestion about development of sustainable GI services?

Answer:
- Improve ability of technology to provide GI services to public, and develop value-added GI services

Question 5: Who I can contact in the Bureau?

- Wang Xiaoguo, Director of the Shaanxi Provincial Geomatics Center
- Liu Yunfeng, Chief of the section of foundational surveying and mapping

Others:
- There is a need of industrialization of geo-information

My observation
### Record 2 of Interviews

<table>
<thead>
<tr>
<th>Person</th>
<th>Wang Xiaoguo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td>Director of the Shaanxi Provincial Geomatics Center</td>
</tr>
<tr>
<td>Responsible</td>
<td>Management of technology, production, and human resource</td>
</tr>
</tbody>
</table>

#### Question 1
**What’s the function of the Shaanxi Provincial Geomatics Center?**

**Answer**
- Do process to data which are collected by the departments of the Bureau (because money are from the country, we do the process according the government requirements)
- Do process to data which are send by other government departments and organizations, such as forest, electric, environment, communication, mining, coal-mining, land resource, water conservancy, highway and railway

#### Question 2
**What are you doing now?**

**Answer**
- Data dissemination,
- Develop geo-information system to use for special use in different fields. For example, we have developed an geo-information system which based on the combination of foundational data and the thematic data from the Bureau of Highway, to provide information such as, route, mileage, traffic situation, and establishment on the highway, to the public. But most of the time the system is used to support government decision making and provide information for construction and maintenance of highway.

#### Question 3
**How is the database in the Geomatics Center?**

**Answer**
We use Geodatabase
The contents of database are DLG (Digital Line Graphic), DEM (Digital Elevation Model), DRG (Digital Raster Graphic), and DOM (Digital Orthophoto Map) in different scales, and some thematic data.

#### Question 4
**Whether you have address information in your database?**

**Answer**
Yes, in building cadastral map and land cadastral map, address is stored as attribute

#### Question 5
**Is there a Geomatics Center in every province?**

**Answer**
No

#### Question 6
**Do you have SDI?**

**Answer**
Yes

#### Question 7
**Which data model do you use to define data content? Can I copy it?**

**Answer**
NO

**Others**
- Normally the Bureau doesn’t provide foundational data to the public because of some secrecy policy.
- Some private companies can collect foundational data by themselves, or get foundational data from the Bureau, but they must promise that they will not provide the data to others without permission.

We have constructed some database, such as:
- Shaanxi foundational geo-database
- Thematic database of main road in China

We also have developed many GIS systems, such as:
- Zhujiangkou 3D maritime geo-information system
- Shaanxi highway information system
- Yinchuan information system for management of wireless
- Shanghai information system for management of building surveying
- And so on.
### Record 3 of Interviews

<table>
<thead>
<tr>
<th>Person</th>
<th>Liu Yunfeng</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td>Chief of the section of foundational surveying and mapping</td>
</tr>
<tr>
<td>Responsible</td>
<td>Management of technology of surveying, and human resource</td>
</tr>
<tr>
<td>Question 1</td>
<td>What’s your operation?</td>
</tr>
<tr>
<td><strong>Answer</strong></td>
<td>We do aerophotogrammetry, aerial remote sensing, topographic surveying, cadastral surveying, building cadastral surveying, city planning survey, topographic surveying, distorting of building monitoring and survey, engineering survey, digital photogrammetry</td>
</tr>
<tr>
<td>Question 2</td>
<td>Which fields are the customers from?</td>
</tr>
</tbody>
</table>
| **Answer** | Forest, electric, environment, communication, mining, coal-mining, land resource, water conservancy, highway, railway, and so on note:  
- Government — most of customers are from government and government departments  
- Organizations and private companies — there are some customers from these organizations and companies  
- Military — a little bit  
- The public — no |
| Question 3 | What’s the problem between you and customers? |
| **Answer** | The modes of products and services are rigescent and cannot fulfill customers’ requirements  
Others | There is a need of value-added geo-information |
| **My observation** | |

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Questionnaire for staff in the Bureau:

Question 1:
Please explain the concept of geo-information (GI) services in keywords

Question 2:
Do you think that your organization is providing GI services?

Question 3:
What is the current state of databases? Please give general explanation according the following list:
Format: …………..
Models: …………..
Content: …………..

Question 4:
What are products and the GI services provided by the Bureau?

Question 5:
Who can get these products and the GI services from the Bureau?

Question 6:
Who are the customers of these products and the GI services?

Question 7:
How is the sale of products and the GI services?

Question 8:
What’s the relationship between sale and invest of these products and GI services?

Question 9:
Which customers’ requirements do you think are not fulfilled?

Question 10:
Who are competing to provide GI services?

Question 11:
What’s the predominance of these competitors?

Question 12:
Which aspect do you think should be improved to provide sustainable GI services in the Bureau?

Question 13:
Can you name at least one organization/private company that is providing GI services?
Questions designed for interviews to customers of the Bureau:

**Question1:**
Please explain the concept of geo-information (GI) services in keywords

**Question 2:**
Do you know Web Feature Services (WFS) and Web Map Services (WMS)?

**Question 3:**
What are your requirements of GI services? Please give general explanation.

**Question 4:**
What kind of data you can provide to the Bureau?

**Question 5:**
Do you appreciate web, chained services?

**Question6:**
Are you ready to use GI services?

**Question7:**
What’s your understanding about sustainable?

**Question8:**
What kind of GI services can be thought as sustainable?

**Question9:**
How is your requirement fulfilled?

**Question 10:**
Which one you prefer when you need GI services, the Bureau or other organizations? Why?