A Web-Based GIS-T Data Warehouse System for Value-Added Applications

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***Abstract*—This paper firstly describes key issues of developing a web-based GIS-T data warehouse system to lay a solid foundation for value-added applications. An integrated concept is then presented to ensure previous data warehouse system can be transformed into a web-based one. The system architecture of the proposed data warehouse system is designed for user interface end, system end, data end and web service end. To demonstrate system performance, metadata search function is taken as an example. Finally, a framework of the integrated tourism information system is proposed as a value-added application.**

***Index Terms*—Data warehouse, GIS-T, metadata, web GIS.**

I. Introduction

In recent years, many research studies and development projects have started using geographic information systems (GIS) and geographically-referenced data. GIS can leverage geo-location feature differences through spatial analysis which plays an important role in a decision support system (DSS) [1], [2]. To serve as the central repository and single - access, data- sharing point for free GIS or geospatial data that focus on sustainable development and good governance of Taiwan, a national GIS promotion committee was founded in 1990 to bring GIS in to national infrastructure plans which divide NGIS's database into 9 groups including topographic database, public pipelines database, land use planning database, land information database, transportation network database, social economic database, environment quality database, natural resources and ecological database and natural environment database (shown in Fig. 1). The next stage to achieve NGIS's goals from 2008 to 2015 will cost 6.25 billons USD.

It is difficult for end-users to acquire complete and real-time spatial data from various data collection agencies due to the lack of an integrated NGIS data warehouse and clearinghouse system. In 2003, the Information Center of Ministry of the Interior constructed the NGIS data warehouse and clearinghouse which was named as Taiwan Geospatial One-Stop Portal (TGOS) for providing the e-commerce service of processing data supply services. TGOS provides 3-tier architecture, supporting the web map service (WMS) of the XML framework, and conducting demo verification on the web feature service (WFS). At present, TGOS has collected spatial data from 6 governmental organizations and 52 map data which are appropriate for storage. There are 12 agencies participating in the alliance and offering online purchase and payment, map data supply, and other services. The amount of metadata has accumulated to 817 records.

Fig. 1. Framework of Taiwan's national graphical information system.

From perspectives of the transportation network database group, a virtual GIS for transportation (GIS-T) data warehouse system accessed by current agencies of Ministry of Transportation and Communications (MOTC) is necessary to be transformed into an integrated GIS-T data warehouse system to cope with government reorganized policy by the end of 2011[3], [4]. The information management center of new MOTC will be responsible for speeding up the promotion of TGOS alliance nodes, and addressing issues of sustainable operations, reinforcing the value added applications of geo-spatial mapping, and improving the data and process services of a Service-Oriented Architecture (see Fig. 2).

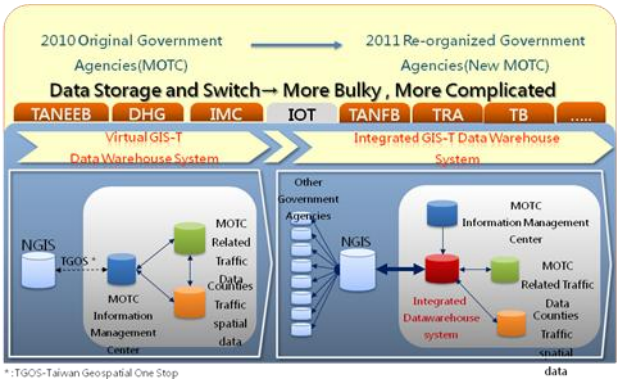

Fig. 2. Evolution of the Data Warehouse System of Taiwan's MOTC.

This paper firstly describes key issues of developing web-based GIS-T data warehouse system to lay a solid foundation for value-added applications. An integrated

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concept is then presented to ensure previous data warehouse system can be transformed into a web-based one. The system architecture of the proposed data warehouse system is designed for user interface end, system end, data end and web service end. To demonstrate system performance, metadata search function is taken as an example. Finally, conclusions are drawn and future work will be suggested.

II. Development of Web-Based Data Warehouse System

A. User Requirements

The proposed web-based GIS-T Data warehouse system is designed as an overall system of inter-relationships among the data warehouse components to meet following user requirements [5]-[8]:

1) System manager: The status of all graphic layers in the data warehouse system can be monitored and analyzed by a powerful analysis module with authorized user's account number and password.
2) Data maintainer: Tasks of data collection and maintenance are well performed by updating and adding database to ensure the latest status of the data warehouse system.
3) General user: User needs for data query and service of the web-based GIS-T data ware house system can be satisfied with web browsers by up- and downloading traffic related data and metadata.

B. System Architecture

The system architecture of the proposed web-based GIS-T data warehouse system is shown in Fig. 3. The operation process is demonstrated as follows:

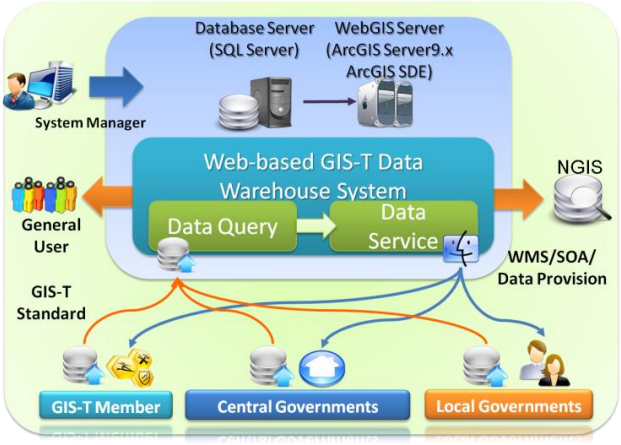

Fig. 3. System architecture of the proposed web-based GIS-T data warehouse system.

1) To make the transportation network database of NGIS serve as the one-stop portal of GIS-T, all possible data produced by GIS-T members, central governments and local governments are firstly collected, stored and then generated to be metadata through ESRI ArcSDE according to Taiwan Spatial Metadata Profile (TWSMP). The metadata are finally stored and updated into TGOS database as well by using Web Accessible Folder (WAF).
2) The core of WebGIS Server of the proposed data warehouse system is ArcGIS which can provide functions of data query, data service, web map service (WMS) and hyperlink with other agencies for general users.
3) General users can easily access the web-based GIS-T data warehouse system through current web browsers to search and inquire related traffic data and web maps with keywords and map toolboxes. The inquired data in terms of metadata and graphical information are downloadable if the user has been permitted by the system manager with authorized account number and password.
4) System manager can monitor current status of each graphic layer with a specific analysis module in addition to user auditing and managing tasks. The analysis reports are regarded as system diagnostic results which will be helpful to improve system functions.

C. System Development

Technologies of system development are used for user interface end, system end, data end and web service end which can be shown in Fig. 4.

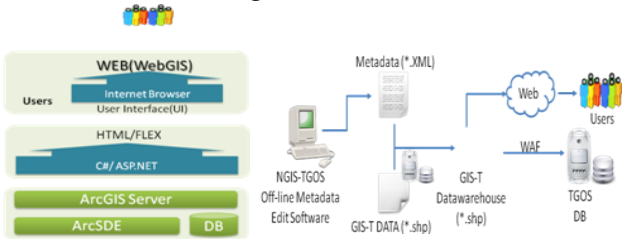

Fig. 4. Technologies of the proposed web-based GIS-T data warehouse system.

1) User interface end: Web browsers serve as display interfaces and the ArcGIS server acts as a map service platform.
2) System end:
   - Web-based services: C#/ ASP.NET/ Flex programming.
   - Web server: Microsoft IIS7.0.
   - Operating system: Microsoft Windows 2003 Server.
   - GIS web server software: ESRI ArcGIS Server 9.x.
   - Spatial database search engine: ESRI ArcSDE 9.
   - Data base management system: Microsoft SQL Server.
3) Data end:
   - Metadata production: According to Taiwan Spatial Metadata Profile (TWSMP) standard.
   - Metadata editing: Using TGOS editing functions to export files in XML format.
   - GIS-T data uploading: In *.shp format.
   - Web map platform: Using the digital network map produced by Institute of Transportation (IOT) and Formosa satellite photos sent by National Taiwan University as the basic map which will be overlaid by different map layers from various GIS-T members.
4) Web service end:
   - Web Map Service (WMS) and Web Feature Service (WFS) are used to follow Open GIS Consortium (OGC) standards.

D. System Functions

The functions of web-based GIS-T data warehouse system

are designed to meet requirements of each end mentioned above. For example, the functions of search by subject or time, metadata display, maps download and files export are essential when users need to inquiry metadata. Fig. 5 shows the functions of the proposed data ware house system.

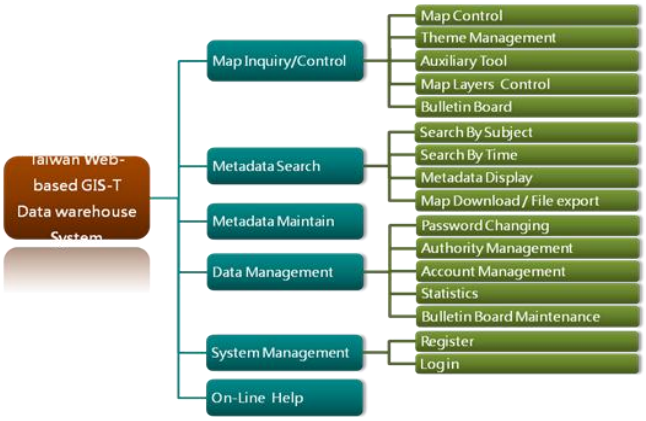

Fig. 5. Function design of the proposed web-based GIS-T data warehouse system.

III. Implementation of Web-Based GIS-T Data Warehouse System

A. Data Collection

The proposed web-based GIS-T Data warehouse system is designed as an overall system of inter-relationships among the data warehouse components to meet following user requirements:

To implement the proposed data warehouse system effectively, a comprehensive project of data collection among GIS-T members and related agencies are conducted in three phases (see Fig. 6):

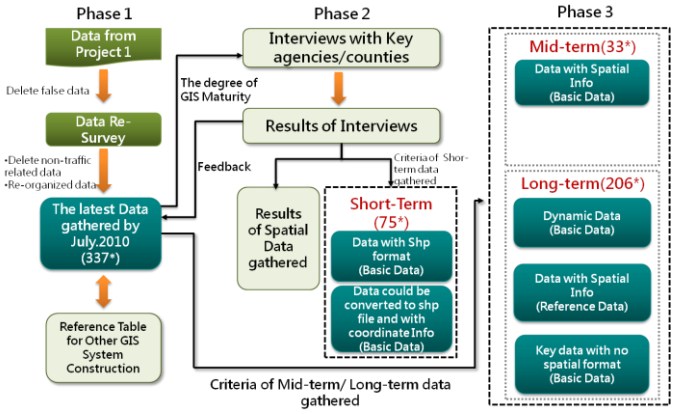

Fig. 6. Three Phases of data collection for the proposed web-based GIS-T data warehouse system.

1) Phase 1: In addition to previous traffic database, tourism and disaster prevention related data are added and non traffic data are deleted as well. At present, there are 337 sets of GIS-T related data from MOTC and local governments are gathered and stored in the proposed data warehouse system.
2) Phase 2: Related agencies whose GIS needs are highly recognized were interviewed with Delphi method to verify collected data items in Phase 1 with the help of their professional judgments. There are 75 sets of additional data are collected.
3) Phase 3: Insufficient data items after comparing those in phase 1 and 2 are listed in summary to be a future work for the mid- or long term development plan.

B. Metadata of the Proposed Data Warehouse System

As mentioned in previous section, it is not easy to manage and apply metadata when they are transformed into digital data. However, there is a tight relationship between metadata and data content to be described by metadata. The contents of metadata are always different for each database.

Geographic metadata means descriptive information of spatial data set, and is spatial/attributive/temporal exterior mode, interior mode and detailed description to obtain, process, apply data set. It can provide information of spatial data sets for the generalization and abstraction of spatial data characteristics. User can determine the name, source, structure, scope of data sets by the information. The difference between geographic metadata and metadata is that there is a lot of information with spatial location in geographic metadata.

The content of metadata in the proposed data warehouse system includes metadata and geographic metadata which can be shown in Fig. 7.

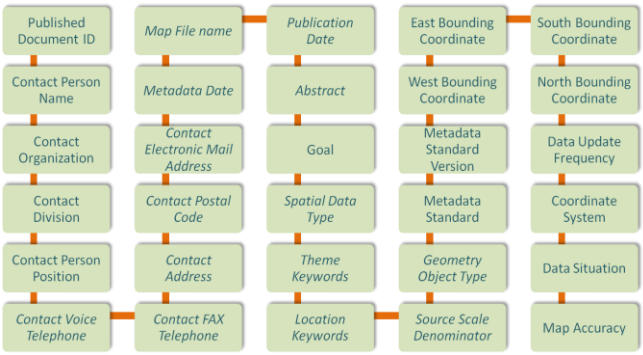

Fig. 7. The Content of metadata of the Proposed web-based GIS-T data warehouse system.

C. Value-added Applications

From technological perspectives, basic layers of web-based GIS-T data warehouse system are currently established. More valuable layers consisting of multi-dimensional spatial data are then shared among stakeholders by using improved the proposed data warehouse system that address data management, integration, and access issues by creating a repository of quality data that can be manipulated to meet changing business needs. This repository allows enterprises to collect, organize, interpret and leverage the information they have for decision support. It provides the foundation for effective business intelligence solutions for companies seeking competitive advantage [9], [10].

For example, based on the proposed web-based GIS-T data warehouse system many innovative business models are proposed for value-added applications such as Intelligent Transportation Systems (ITS), logistics, tourism, etc. An integrated tourism information system based on the proposed data warehouse system shown in Fig. 9 is under development and will be soon implemented in the famous Sun Moon Lake National Scenic Area of Taiwan.

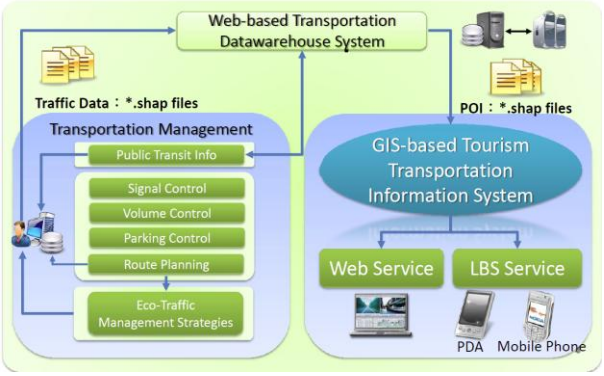

Fig. 9. Framework of an integrated tourism information system.

IV. Conclusion and Future Work

This paper presented an integrated design for web-based GIS-T data warehouse that can be expanded by different types of transportation applications. The purpose is to ensure a solid traffic related data acquisition from various agencies through the proposed data warehouse system. The paper shows that system functions can be integrated in a web-based way to satisfy user requests. This deployed system may be useful to other geographic data organizations that must assimilate data in many ways to satisfy user requests. The proposed data warehouse system is though a sort of prototype, the choice of implementation with WebGIS is regarded as a positive decision by related authorities. How to include more value-added applications in the proposed data warehouse system will be one of the "must" works in the future. It will be explored and introduced in a forthcoming paper.

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