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Exploiting WebGis technology to build an environmental database to support the environmental management of Ho Chi Minh city

Phu Cuong Tran*, Thi Van Tran

University of Technology, Vietnam National University, Ho Chi Minh city

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Abstract:

Recently, climate change and its effects have been significantly influenced by human life. Human activities, mostly from urbanization, are the main contributors to the pollution of soil, water, and air, which has been proven by several observations and studies. However, it is necessary to raise awareness, by including support from society as a whole, in order to maximize the efficiency of environmental campaigns. In this work, the geodatabase model of geographic information system (GIS) combined with the WebGIS system based on ArcGIS server technology was employed to build environmental database for Ho Chi Minh city, which will be used by the HCM-SSED system (Ho Chi Minh city - system for sharing environmental database). This system supports the environmental administration with the management, updating, and sharing of environmental databases, as well as providing environmental information to the community quickly and efficiently.

Keywords: **environment database, GIS, sharing environmental databases, WebGIS.**

Classification number: **5.1**

Introduction

It is obvious that pollution is a controversial issue that has attracted tremendous interest of many countries and communities around the world. Pollution and climate change negatively affect our ecosystem and living conditions, through the air we breathe, the water we drink, and the soil we cultivate our crops to eat.

With its intuitive capabilities and object positioning characteristics, GIS is one of the best tools in terms of environment management. GIS can pinpoint the location of emission sources and project its spreading potential. Many developed countries around the world have applied GIS to effectively manage their environment. The main advantage of GIS is that users can search and extract information from the database quickly and easily, so that management can make practical and accurate decisions. In addition, we live in the era of technology and sharing information using the sharing function of this tool will greatly support management's efforts to catch up with this new trend. Therefore, the combination of the internet and GIS system will bring great efficiency to the management and distribution of environmental data to citizens.

Ho Chi Minh city is the largest city in Vietnam in terms of population size, economic development, level of urbanization, and is an important cultural and educational hub of the country. Together with its great socio-economic achievements, Ho Chi Minh city is also facing certain challenges in urban management. For example, a dramatic increase in urban population, lack of infrastructure, proper planning, and management systems. As the living conditions increase gradually, people are more considerate of their quality of life and the effects of pollution on their soil, water, and air. However, the current system cannot offer an efficient method to provide accurate information

*Corresponding author: Email: 1670387@hcmut.edu.vn

to the community, and this has led to little improvement of the people's awareness to support local administrators with solving environment issues. In order to build green and smart cities as the provisioned by the government, Ho Chi Minh city has a short period of time to employ an innovative solution to manage and educate its citizens by providing suitable information.

Based on those necessities, this paper presents the construction of the HCM-SSED system based on a WebGIS environmental database in order to support the city with their efforts to update, manage, and share environmental data and information to the community quickly and effectively.

Database and system structure

Building database

Data collection: data is provided by the Ho Chi Minh city Department of Natural Resources and Environment and is divided into two groups as follows:

- The administrative data of Ho Chi Minh city, such as maps of the land use status in 2005 in scales of 1/500 and 1/1000 in .dgn format, the terrain background in scales of 1/2000 and 1/5000, also in .dgn format, basic geographical information of the 24 districts at district level and 322 areas at ward/commune level in .mdb (geodatabase) format, a cadastral map with land boundaries and addresses in 2005 in scales of 1/500 and 1/1000 in .mdb format (geodatabase), and a topographical map in scales of 1/2000 and 1/5000 in .mdb format [1].

- Thermatic data on the water and air environment extracted from the data synthesis process of the Centre for Resources and Environment Monitoring. Then spatial and attribute data are merged and stored in the same database to allow for fast and accurate updates, searches, statistics, and data extraction tasks.

Standardized data: the surveyed and collected map data sources include many different formats such as data from paper maps and digital data (MicroStation, MapInfo, and AutoCAD). Then, each type of data is converted and edited accordingly. For the data extracted from paper maps, it is scanned and digitized into AutoCAD format, the coordinates are adjusted and checked for geometric errors. Similarly, for digital data, its coordinates will be adjusted and checked for geometric errors, and then updated with attribute information. All these steps are completed through the use of ArcGIS, which also was used to build standardized background data layers and thematic data according to the Geodatabase model.

Geodatabase is a spatial data model provided by the company Esri that is used for storing, accessing, and processing GIS data, and it is controlled by database management systems such as SQL servers. Geodatabase is an ideal storage model for geographic features due to its outstanding data structure that allows extensive data to be saved in the form of a data table. There are two geodatabase models: geodatabase one user (personal geodatabase) and geodatabase multiple users (enterprise geodatabase). It stores the structure and collection of objects, attributes, relationships between attributes, and relationships between objects in the form of specific spatial and attribute data. The geodatabase model has the nature of an object-oriented data model. This model and data structure provide high data integrity and efficiency [2].

Building the database: the process of building a database for HCM-SSED is shown in Fig. 1. After data collection, based on the objectives of the research, a review of the current status of data is conducted and the role of the data for a particular topic is analysed, thereby establishing a criteria framework for each data. Then, the data is standardized for the processes of converting and linking spatial and attribute data. Finally, the object-oriented database is designed with 3 levels (concepts, logic, and physics) to construct the data structure, define topology, declare the coordinate system, define relationships, and apply data rules to the geodatabase.

- Conceptual database design: the properties of objects and the relationships between them are identified and defined based on the professional procedures for the management and distribution of the environmental database given by the Centre for Environmental and Resources Monitoring, thereby building a conceptual model using the entity link model.

- Logical database design: the primary key, foreign key of each object, and domain for the attributes are identified. In the logical model, the data is specified in the form of tables, frames, and steps on the WebGIS system. From there, a logical model is built through the use of relational data models.

- Design of physical database: the description of a physical model is directly related to the selection of technical solutions and compatibility with software such as storage structure, technical facilities to ensure the operation of the system through a defined geometry, properties for each data, and the defined relationship between data layers corresponding to geodatabase components.

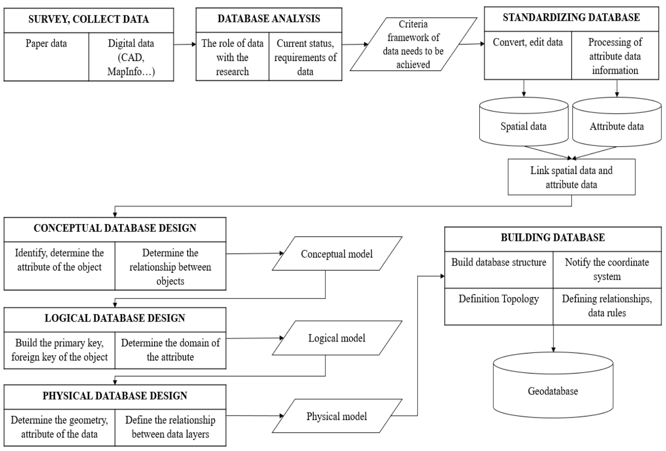

Fig. 1. Procedure of building HCM-SSED's database.

System structure

HCM-SSED (Fig. 2) is built through the combination of ArcGIS server technology and SQL server database management system [3] and is designed to store spatial objects along with attribute information of object layers and associated data sources monitored by time. Spatial and non-spatial data are stored and managed uniformly in the same database so users can update, search, count, and extract data in a convenient and easy way. Environmental databases are designed to serve multiple users and allows multiple user access at the same time.

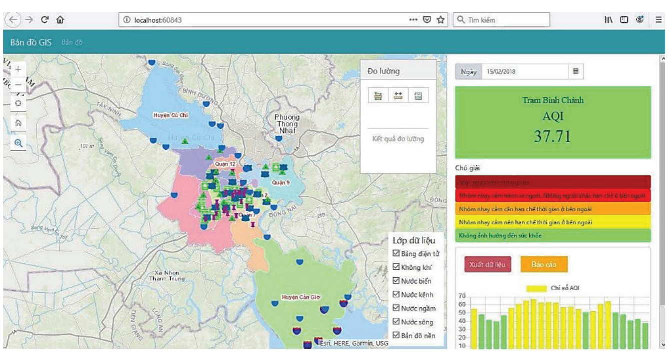

Fig. 2. Interface of HCM-SSED system.

The overall structure of the HCM-SSED system (Fig. 3) is based on three main layers including the web layer, application layer, and database layer. System users will communicate via the web interface to send their desired requests to the server via the Internet. After receiving the request from the user, the server will access the database to retrieve the desired data and then return it to the user [4]. Geographic data includes both spatial and non-spatial data and managed by SQL. The spatial database is used to manage and retrieve spatial data that is placed on the data server. Based on data management components, server applications and server models calculate spatial information through specific functions. The information processing procedure used to extract the maps is based on the IIS platform, ArcGIS service, and ArcGIS server. Meanwhile, the procedure used to access the attribute information on the web is coded in .NET language [5].

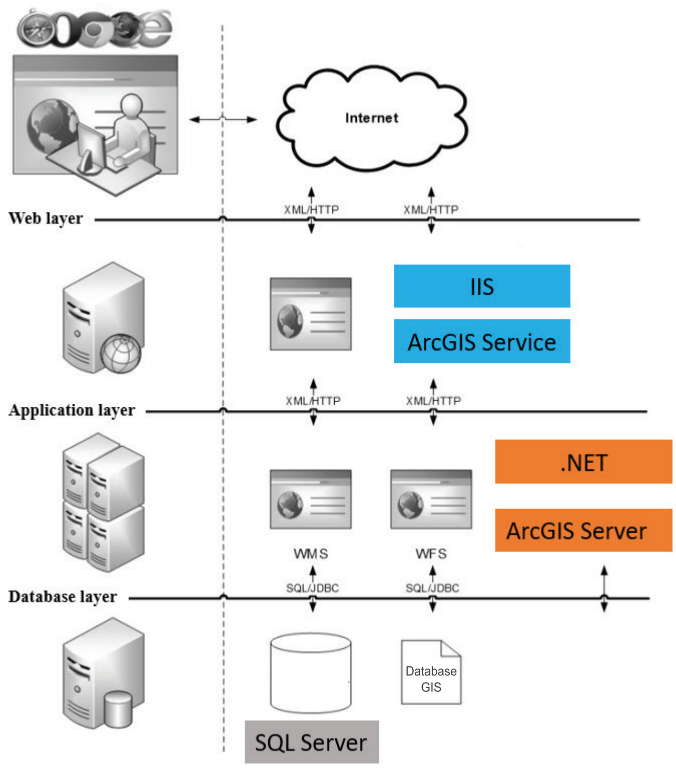

Fig. 3. Overall structure of HCM-SSED.

System operation

Functions of HCM-SSED

HCM-SSED is constructed as an information system for air and water environmental monitoring and uses ArcGIS Server technology with the following information groups (Fig. 4):

- Air: this group contains information related to air monitoring stations such as their name, station code, coordinates, address, and detailed monitoring indicators such as SO_2, CO, NO_2, O_3, TSP, PM_{10}, $PM_{2.5}$, and Pb.

- River water: this group contains information related to river water monitoring stations such as name, station code, coordinates, address, and detailed monitoring indicators such as BOD_5, COD, DO, Coliform, turbidity, salinity, E. coli, NH_4, temperature, PO_4, TSS, Cd, Cu, Fe, Mn, Pb, and Cr^{6+}.

- Canal water: this group contains information related to river water monitoring stations such as name, station code, coordinates, address, and detailed monitoring indicators such as BOD_5, COD, DO, Coliform, turbidity, salinity, E. coli, NH_4, temperature, PO_4, TSS, Cd, Cu, Fe, Mn, Pb, and Cr^{6+}.

- Groundwater: this group contains information related to groundwater monitoring stations such as name, station code, coordinates, address, and detailed monitoring indicators such as As, Cd, CN, Coliform, Cr^{6+}, Cu, hardness, E. coli, Fe, Mn, NO_3, NH_4, Pb, pH, SO_4, TDS, Zn in the Pleistocene, the upper Pliocene, and the lower Pliocene layers.

- Seawater: this group contains information related to sea monitoring stations such as name, station code, coordinates, address, and detailed monitoring indicators such as As, Cd, Coliform, Cu, Hg, NH_4, Pb, pH, oil in seawater, and bottom mud.

- Electronic board: this group contains the information related to the electronic board placed on main routes in Ho Chi Minh city such as name, table code, coordinates, address, and information about environmental quality from the air and water monitoring stations near the monitoring areas.

- Information: this group gathers data and information on monitoring indicators from air and water monitoring stations as a basis for calculation of the AQI (air quality index) and WQI (water quality index) environmental quality indicators.

- Model: includes two models for calculating the AQI and WQI.

- Report: this group will gather information about AQI and WQI calculation results by station and time. All the statistical data shown in charts and reports will be given in the report format of the Centre for Monitoring Environmental and Resources.

- Permission: this group will gather functions for HCM-SSED such as configuration of user permissions according to specific permission lists.

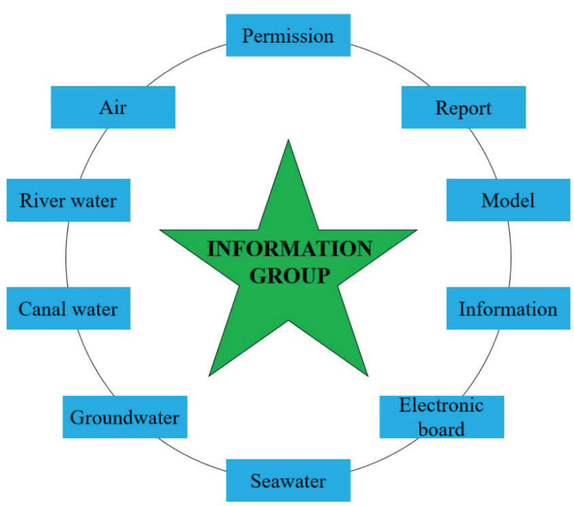

Fig. 4. Information grouping in HCM-SSED.

Based on the information groups, the organizational model of HCM-SSED is systematically designed with main functions such as the introduction of the HCM-SSED homepage interface, user permission interface, WQI and AQI calculation models, monitoring stations information, monitoring indicators index, reports, and maps. The main contents of the functions are shown in Fig. 5.

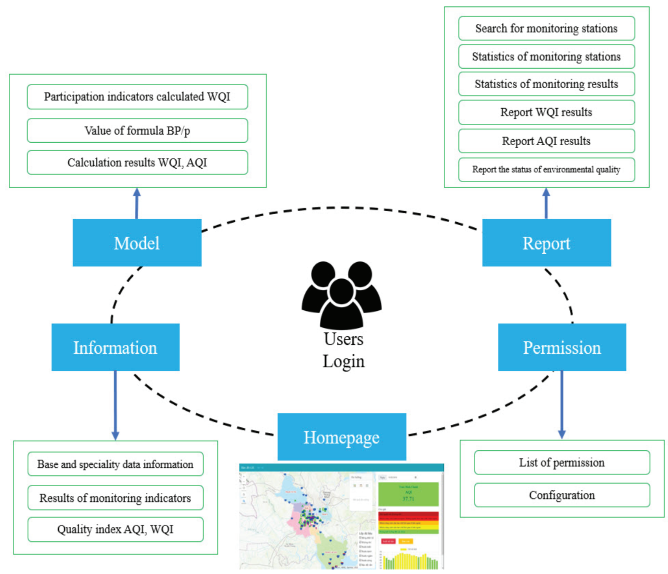

Fig. 5. Functions in HCM-SSED.

The information function includes the display of thematic maps and base maps (Fig. 6), zoom in/out functionality, map movement, and an on/off toggle for the display of data layers. In addition, users can view the results of monitoring indicators, such as the water and air quality indexes of each monitoring station.

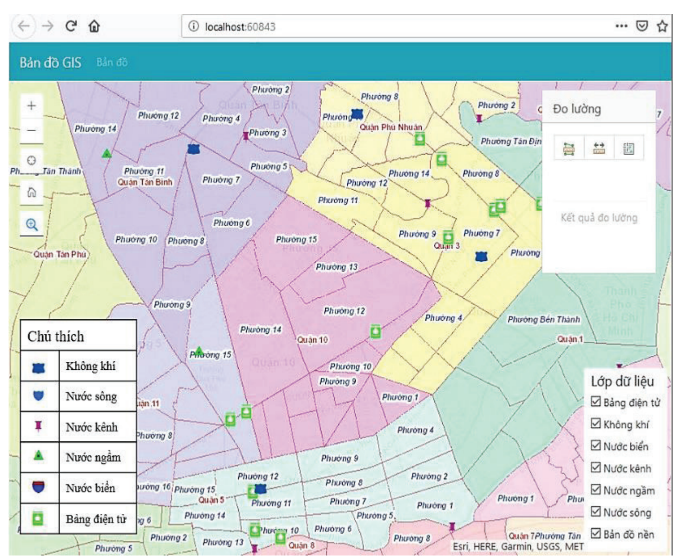

Fig. 6. Interface of the map display function.

The report function includes information searching (Fig. 7) where the HCM-SSED system allows its users to find the location of monitoring stations by administrative boundaries to assist with the handling of information and decision making.

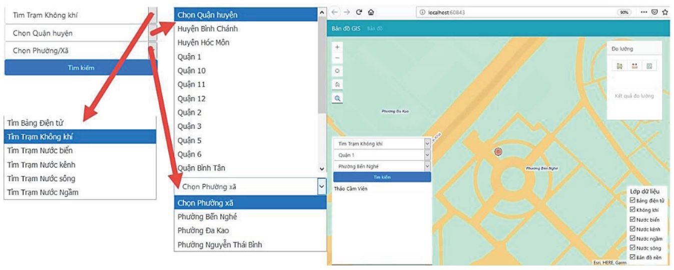

Fig. 7. Interface of information searching function.

The reporting function demonstrates the role of database sharing (Fig. 8), where environmental information via reporting and statistical functions allow users to monitor environmental quality with the AQI and WQI by time, and also view statistical criteria and interactive maps, which can generate analytical and evaluation information. Users can download data and view environmental reports using data export and reports (Fig. 9). In parallel with the display of monitoring station data, data transmission and linkage to the digital board are also implemented to support database sharing within the community.

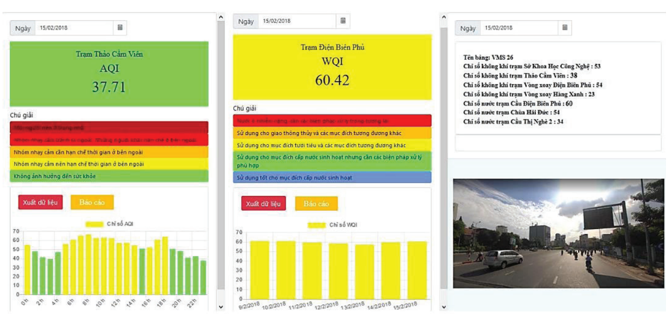

Fig. 8. Interface of report and statistical functions in the sharing environment database.

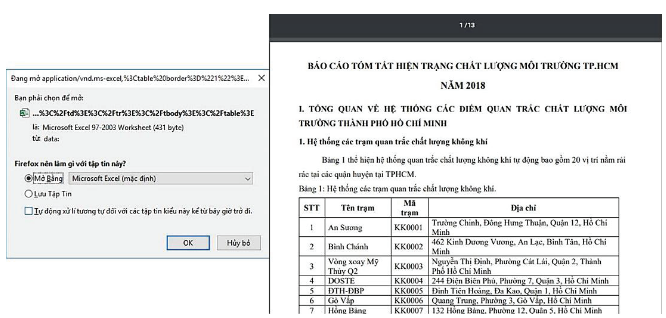

Fig. 9. Results of the data export and report functions.

Mechanism to allow permission and share databases

HCM-SSED is designed for many different users. Each user has a particular level of permissions set by the system administrator, such that each user may have different permissions to different functions (Fig. 10).

Fig. 10. Interface of permission setting function.

The system is divided into 2 types of users, management and normal. Details of the contents that these types of users can access are demonstrated in Table 1.

Table 1. Functional requirements of HCM-SSED by user type.

Function	Users	
	Management	***Common user***
Map interaction	Change map scale (zoom in, zoom out) Set map scale Move the map View full map Measure distance View object information	Change map scale (zoom in, zoom out) Set map scale Move the map View full map Measure distance View object information
Map display	Background map layers: ESRI maps, roads, parcel land, river, boundary administration by district or ward/commune Thematic map layers: air, river water, canal water, sea water, and groundwater monitoring data Turn on/off the data layer	Background map layers: ESRI maps, roads, parcel land, river, boundary administration by district or ward/commune Thematic map layers: air, river water, canal water, sea water, and groundwater monitoring data Turn on/off the data layer
Information access	Access to base data: roads, river, parcel land, according to boundary administration (district, ward/commune) Access thematic data: monitoring data of air, river water, canal water, sea water, groundwater according to boundary administration, by time Export data with Excel filetype by time	Access to speciality data: monitoring data about air, river water, canal water, sea water, groundwater according to boundary administration, by time Export data with Excel filetype by time
Statistic, report	Perform environmental statistics and reports for professional work in the department	Perform a simple environmental statistics and reports
User management	Search, view, edit, delete, create new account	

Conclusions

It is indisputable that environmental pollution is a problem that requires a sophisticated solution and an improved management system to evaluate and perform quick action under certain circumstances. Therefore, a WebGIS system with its many advantages plays a critical role to provide a solution for the local government to share and communicate environmental information to the community via HCM-SSED. The study has surveyed, collected, analysed, and built an environmental database specializing in the air and water monitoring of Ho Chi Minh City with 5 main data layers including air, river water, canal water, groundwater, and seawater monitoring stations. Building the GIS database as a centralized database also helps users to access and update data synchronously. If all departments and units at the Centre for Environmental and Resources Monitoring can update the data using a single database, the issues of fragmented, asynchronous data would be avoided. In addition, HCM-SSED is built with a user-friendly interface and functions that are very simple and easy to use. Building the system on in Web environment with a centralized database will also make the distribution and management of environmental data much simpler to control and upgrade. Furthermore, the web environment has the benefits of fast and convenient data extraction and distribution, which is beneficial to all citizens in the community.

The authors declare that there is no conflict of interest regarding the publication of this article.

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