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Eco-environmental information system of Tianjin City — Design, implementation and applications

Hu Xiaolin, Yang Bangjie, Zong Yaoguang, Lu Li

Research Center for Eco-Environmental Sciences,
Chinese Academy of Sciences, Beijing 100085, China

Abstract — This paper describes the design, implementation and applications of the eco-environmental information system in Tianjin City, which is the kernel of the decision support system for urban eco-environmental regulation (DSSUER). The design of this information system is based on the analysis of the requirements of users. The system features that it has expendability, maintainability and universality, makes data be shared between different components of DSSUER and provides help facilities and protection. The system is built by using database and graphic base technologies. It consists of the main control module, data-management module and data-processing module. The applications of this system is demonstrated by an example which is the case of suitability analysis of land use for residential areas in Tianjin.
Keywords: eco-environmental information system; land use; database and graphic base technologies.

1 Introduction

With the development of science and technology, information has become an important resource of the society. All activities of decision and management are supported by information. The complete systems of information management built with computers are the basis for modern scientific management and decision-making.

The system of integrated database, graphic base and data processing models is a new technique for information management. The database enables us to deal quickly and efficiently with large quantities and varieties of data. It is not only the computer extension of human memory but it also forms the basis of decision-making. With the developmnet of information systems many elements of work, from ordinary business processing, to decision-making, and prediction-making, have been influenced and improved. Graphs can express the characterization and changing process of things with the advantage of clarity, intuition and vividness. There is a saying: "a picture is worth a thousand words". The information system used for eco-environmental research in Tianjin is a software system based on the theories of urban ecology and computer science, built by using database and computer graphic technology, supporting the decision support system for urban ecology regulation (DSSUER) in Tianjin (Yang, 1989).

2 The analysis and design of the system

2.1 Requirements and data analysis

The analysis of the requirements of users is the basis of the design of an information system. This stage can greatly effect other stages in the design process and the use of the system. By consulting with officials, researchers and specialists in urban management departments, economics, city planning, education and environment protection, we analyzed the requirements for information and processing needs. The users will be municipal leaders and management officials. They hope that this system can be used for planning, decision-making and prediction. The main area of concern will be macro-urban information, such as the quantity, quality and distribution of population and the urban areas, the scale and distribution of basic facilities, the state of resources, and pollution and other environmental conditions. The users need to know not only the current state but also the history and developing trends. In addition, they need also to know not only the overall situation but also the conditions in individual districts or counties. Finally it will be useful for these decision-makers to think about not only an independent Tianjin but the relationship between Tianjin and other cities. Therefore, this information system must contain the quantitative and graphical information from different times and different places. Since 1949, a large quantity of data on the population, economic state, resources and environment have been accumulated in Tianjin. During the Sixth and Seventh Five-Year plans, research of many diverse subjects was done. During this period much comprehensive data pertaining to the urban ecological situation and the city's environment were obtained. In recent years environmental maps have been established by photogrammetry and remote sensing. We collected, analyzed, processed and sorted this data to lay a basis for the development of our system.

2.2 The design of the system

The principles of the system design are as follows: (1) The system is oriented to users and its operations are simple and convenient for users; (2) It has the expendability, maintainability and universality; (3) The organization makes it possible for data to be shared between different components while at the same time reducing redundancy in the database. Not only implementation of the exchange of data and graphic base information within this system but also interfaces between other systems are considered. So this may be a supporting system of DSSUER and as well as for other subsystems which should be able to access data directly; (4) Provide help facilities and protection within the system. When input errors occur the system is able to protect itself and help the user to input correct information. In the execution of commands the system provides the ability to interrupt and exit; (5) The system is

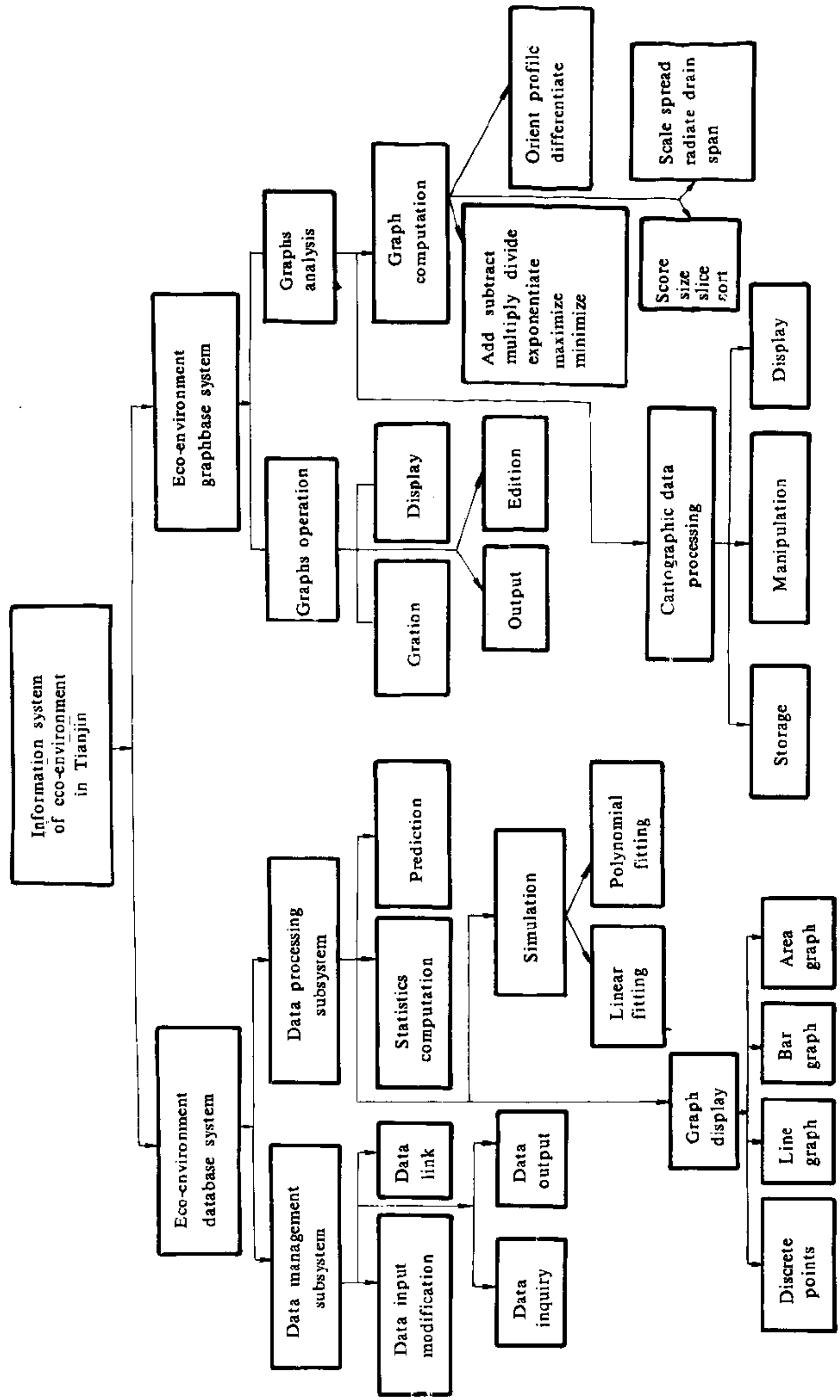

Fig.1 The structure and functions of the eco-environment information system in Tianjin

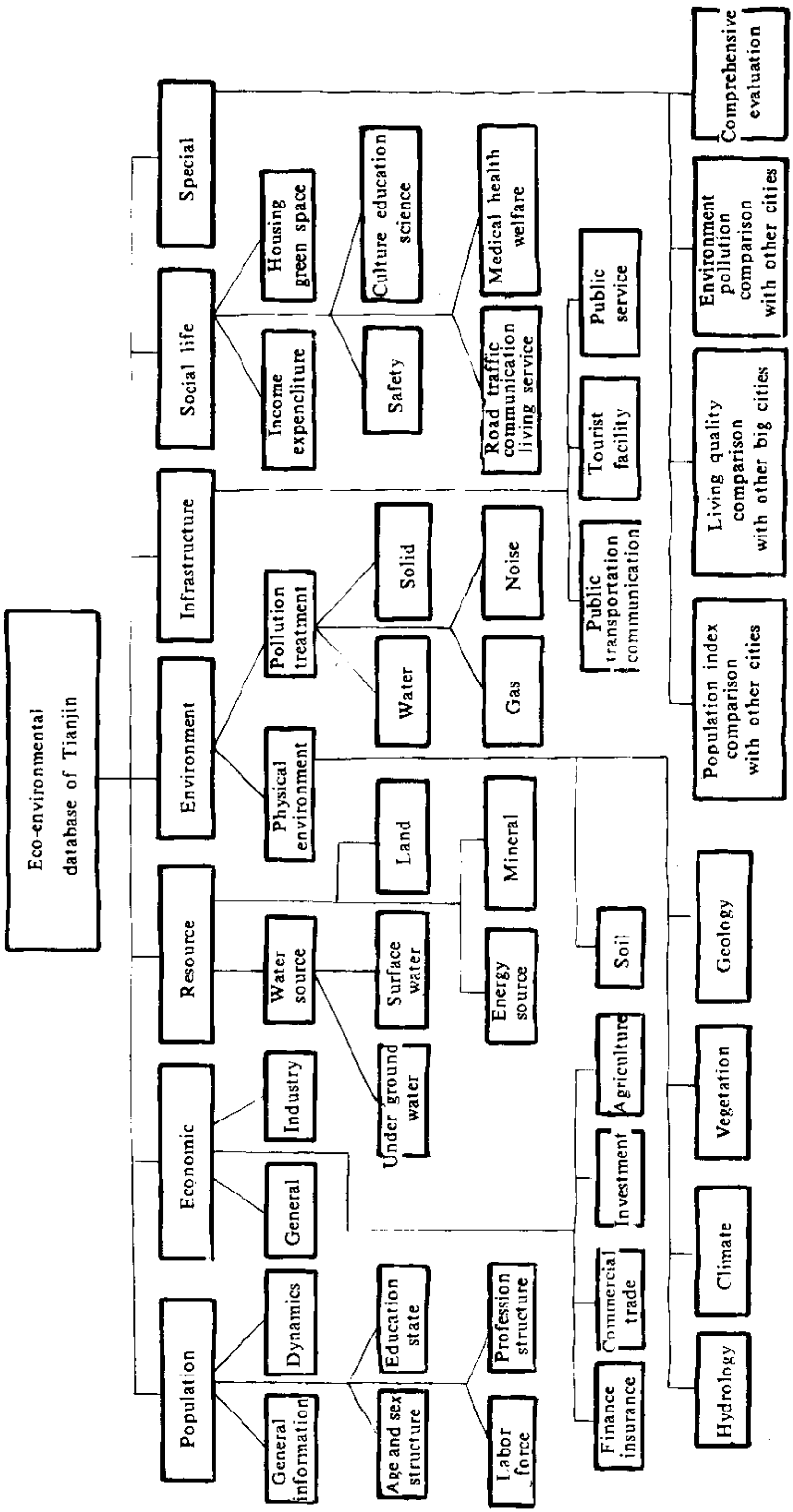

Fig. 2 The structure of data

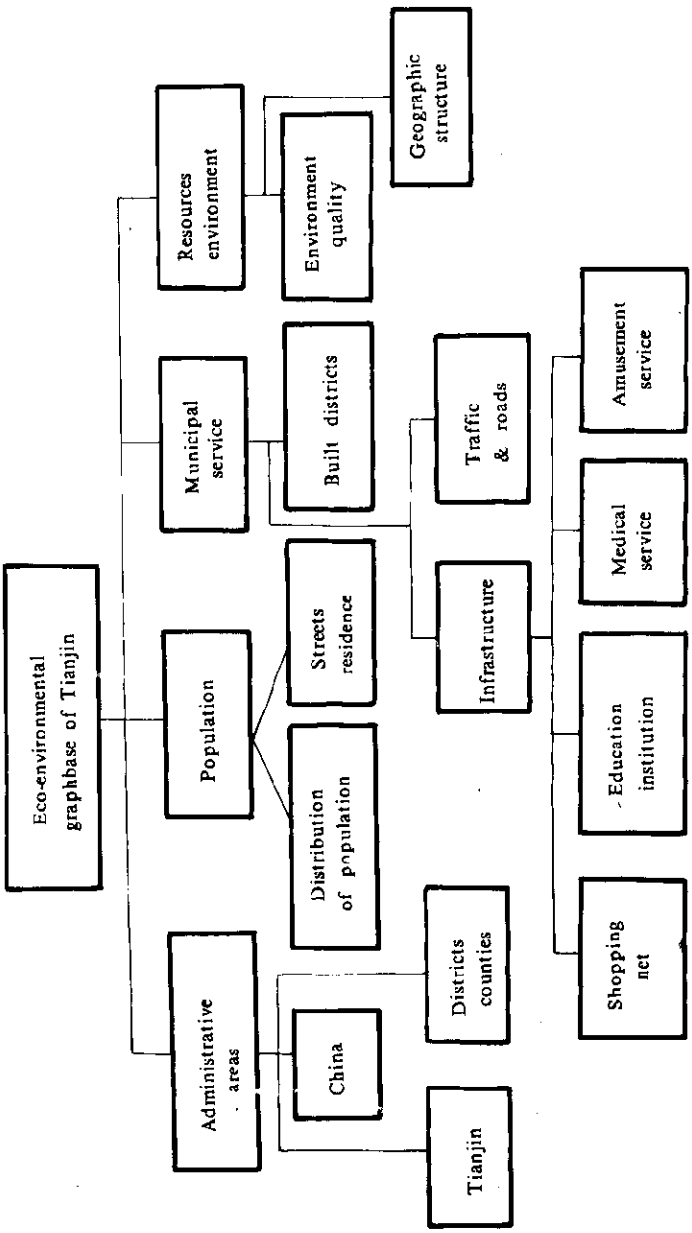

Fig. 3 The structure of graphs

structured. The top-down and stepwise-refinement design methodology is adopted.

The function and structure of the system and the data structure as well as the graphic structure are shown in Fig.1, Fig.2 and Fig.3, respectively.

3 The implementation of the system

The database system, a subsystem of the top-level system, is mixture of DBASEIII Plus, C and GWBASIC programs. It is implemented by the main control module, data-management module and data processing module. The functions of the main control module are to manage the initialization of the system states, and to display the banner of the system. The main menu of the subsystem plays a role as a dialogue interface between the user and the function modules. The users, without the need of special knowledge, can accomplish their desired task using the main menu. That is, they can issue commands to the system and the system is directed by the function operations of the main control module to carry out the desired service. Before entering the user's required utility a database menu is called in which the objects of specific operations are chosen by the user. These selections are used as parameters in the main control module which are transferred to the submodules to be executed. The data-management module implements the main functions of the database system as well as serving as a link to the databases. These functions include addition, modification, inquiry, deletion, output of data. By using addition, modification and deletion modules the system expands and maintains itself. For the convenience of the user, the inquiry module contains two submodules. One of which is used for unconditional inquiry, and the other for conditional inquiry. In the unconditional inquiry module there is no need for users to input any conditions. The system displays every record of the indicated files one by one. In the conditional inquiry module, the user may input inquiry conditions, selecting interested records and fields. Inquiry conditions include both logical and numerical formulas. The output module is a more powerful submodule of the data-management module. It contains three submodules, printer output, screen output, and files output. The files output module sends specific data to an output text file. This is a bridge connecting the database with graph-base and the information system with other systems in DSSUER. This allows programs outside the database system to call data in the database directly. Similar to the inquiry module, the data output module can output complete records and database files. Users can also choose desired fields and records. In addition, it is possible that the data output module can do statistic computation of fields and generate a two-dimension output graph. The data-management module also contains a connection module user for connecting any two database files. If the user wishes to deal with data in more than two database files (i.e., more than two relational forms) he can call this module. the connection module can generate a new database file by choosing fields and records from two database files. For example the average economic output level may be found by choosing the field of total population from the basic population information file in the population sub-database and connecting this with the GNP database file in the economy sub-database. Connecting the pollution discharge file in the environment sub-database with the above data, the discharge amount per unit output value can be calculated. In general the user has the ability to combine data in the database to analyze and process information smoothly and effectively.

The data-processing submodule contains three submodules, figure display, statistical computation, and simulation forecasting. In the data-management module, data is displayed in text and charts. In the figure, display submodule, the data are displayed in figures. This submodule displays data in text files generated by the output module, using histograms, discrete points, area graphs and bar graphs. Both single data and comparative data can be handled. The graph display is more intuitive than a number display. This form of output is more acceptable to managers and decision-makers. The statistical module contains general statistics programs for processing data. In the simulation prediction module there are a number of prediction modules, 10 linear fitting equations, and 8 polynomial fitting equations for users to predict the future from past and present data.

The graphic base of the system is implemented by a combination of software from two systems, Auto-CAD, and map analysis package (MAP). The creation, editing functions (including deletion restoration, removal, duplication, orientation, extension, etc.), display, and output are implemented by Auto-CAD. Inquiry and execution commands, automation, and computation within maps are implemented by Auto-Lisp. The functions of storage, display and manipulation of cartographic data, superposition, connection, computation (including addition, subtraction, multiplication, cross products, differentiation, orientation, radiate, cover, scaling and copying), as well as spread conversion of graphs are implemented through the MAP software. With these powerful functions for graphic analysis we can process cartographic information efficiently. We can input graphic data using the keyboard, digitizing tablet, and through text files. It is also possible to transfer to the MAP system cartographic data created by other GIS software. The output modes include the screen, printer, and plotter.

The two subsystems of the information system— graphbase and database are connected by using text files. The database files are converted to text through the database management module. These text files are read by Auto-Lisp to produce input to the Auto-Cad system. Alternatively the text files may be converted to input files, the graphic data format required by MAP software. Similarly, the quantified graphic information can be converted into text files for entrance to the database subsystem.

In the development of the system we emphasized the readability of the programs, considering the generality and ease in debugging the programs. In the early 1970s when the concept of "style" of programming was refined, several key points facilitating good style in programming were emphasized. In order to obtain good style, the following techniques were adopted: (1) to standardize the naming of variables, procedures and files of in system; (2) to have an indentational form promoting readability and organization; (3) to use comments in programs for debugging and comments on displayed information for users.

4 Examples

The case of suitability analysis of land use for residential areas in Tianjin City. The analysis steps are as follows:

4.1 Choosing evaluation indices

We choose the level of traffic convenience, social service facilities, environmental quality, the state of the land in the area, and the current state of urbanization as evaluation indices.

4.2 Structural analysis

The land use suitability analysis for residential areas is based on consideration of both development potential and development constraints. The analysis of development potential is based on consideration of development opportunity of natural potential as well as development opportunity of the current suitability. For natural potential capability we consider two factors, environmental quality and the physical geography conditions. The current suitability includes social service facilities and the level of traffic convenience. The development constraints encompass the current state of developed districts and the trees and foliage in the areas. The structure is shown in Fig.4.

4.3 The method of analysis

We use a method of combining hierarchical rules to evaluate the land use suitability. The principles of evaluation are set first, then suitability overlays proceed according to these principles. The suitability is determined through the analysis of the combination of development opportunity and development constraints of land use for residential areas. The four indices of social services are first classified into two or three ranks or classes. These four classification graphs are then superimposed one by one to form the main classification graphs for social services. This has a total of four separate levels. In terms of other development opportunities, the rules within each

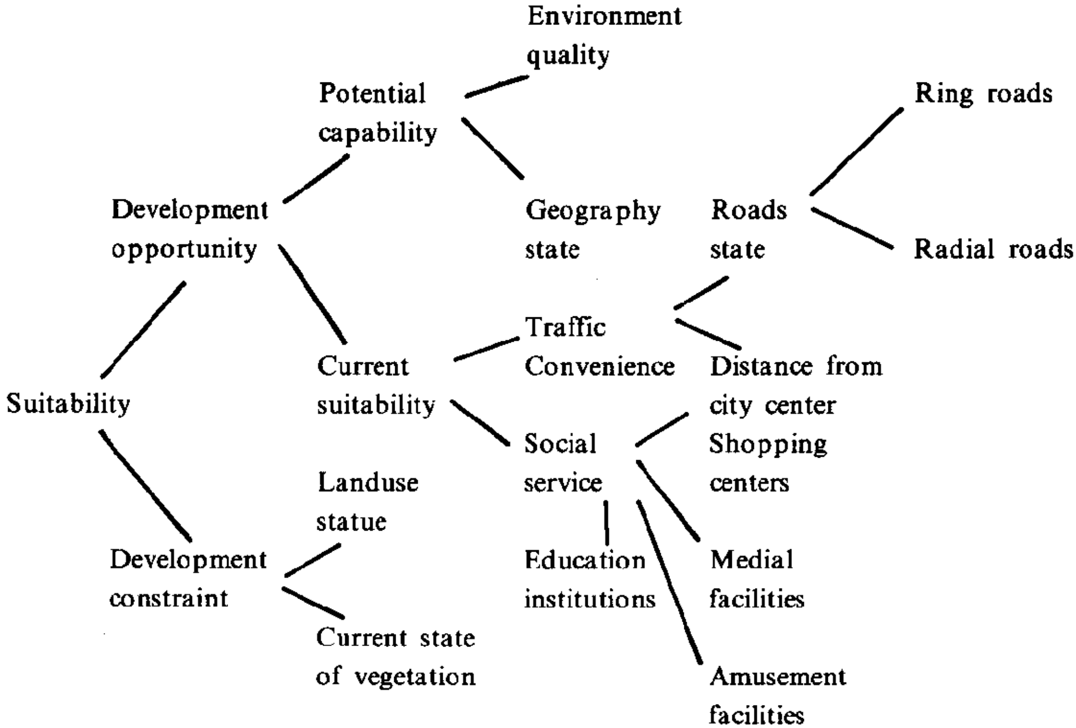

Fig. 4 The sketch of structural analysis

different level are ranked from Ist to 4th (the Ist level being the best and the 4th the worst). Development constraints are similarly broken down into four classes, where Ist class represents little constraint and 4th much constraint. The rules for analyzing suitability are ranked into six total classes, Ist the most suitable for development and 4th the least land use suitable for residences (Table 1).

4.4 Suitability overlays

According to the evaluation method and principles the MAP execution program is run. This is used to obtain the distribution map of development opportunity and constraints of land use for residences and land use suitability. The flowchart is shown below:

The roads map, the distribution map of social service, the environment quality map, geological state map and urbanized districts map are called from the graphic base.

The social service map is decomposed into commerce district distribution map, medical service areas distribution map, culture and education institution distribution map and amusement facility distribution map.

Spreading from each item, the service radius is computed, according to evaluation

Table 1 Suitability classing rules

Unit: meter

	Distance	Class		Distance	Class
Business	<600	I	Road 1	<130	I
center	<200	II	circle	<600	II
	Other	III		<1200	III
Medical	<750	I		Others	IV
center	<2300	II	Road 2	<130	I
	Others	III	rays	<500	II
Culture and	<1200	I		<800	III
education	<3000	II		Others	IV
center	Others	III	The distance	<2500	I
Amusement	<1500	I	from city	<5000	II
center	Others	II	center	<7500	III
				<10000	IV
				Others	V

I. developing area; II. improvement area; III. developed area; IV. unutilized area

rules the four classified maps are generated, then superposed one with one to generate social service classified maps.

The roads map is decomposed into ring and radial roads maps and they are spread and classified according to distance, then are overlayed to generate the roads state classification maps.

Spreading from the city center, the city area is classified as 5 classes by different distances, which are overlayed with roads classification maps to generate traffic convenient classification map.

The traffic convenience map is overlayed with the social service classification map to generate the current state suitability map.

The environment quality map is overlayed with the geography state map to generate the natural potential capability map.

The natural potential capability map is combined with the current state suitability to form the development opportunity map by rules.

The built districts map is converted into the development constraint map.

The development opportunity map is superposed with the development constraint map to generate the suitability map of the land use for residence.

Simulation result: suitability for residences is divided into 6 classes. The 1st class is most suitable for development and covers 10.6% of the city area. The 2nd class covers 19.2% of the city area. The 3rd class is considered a sub-suitable area and makes up 19.0% of the city area. The 4th (less suitable), 5th (unsuitable), and 6th (most unsuitable) classes make up 4.7%, 9.0%, and 37.7% of the city area respectively (The figure is omitted).

References

Dong H. 40 years in Tianjin. Beijing: China Statistics Press, 1989

Hu X. Annual report of the Department of Systems Ecology RCEES, Chinese Academy of Sciences. Beijing: China Science & Technology Press, 1991:110

Huang S. The study of application of ecological planning method in the land use planning. Technical report, Taiwan National Zhongxing Universtiy, Inst. of Urban Planning (NSC 76-301-H005-02), 1987

Huang S. Impact Assessment Bulletin, 8 (1 & 2):233

Kuang S, Li Y. The principle and applications of database. Guangzhou: The Southern China Technology University Press, 1988

Liu Z. The development methods and principles of information systems. Chongqing: Chongqing University Press, 1989

Tomlin CD. The IBM personal computer version of the MAP analysis package, Cambridge, MA (Laboratory for Computer Graphics and Spacial Analysis). USA: Harvard Graduate School of Design, 1986

Ullman JD. Principles of database systems. Potomac, MD, USA: Computer Science Press, 1980

Wu W. Computer Research and Development, 1987; 24(12):46

Xue H. Menagement information systems. Beijing: Tsinghua University Press, 1988

Yang B. Annal report of the Department of Systems Ecology RCEES, Chinese Academy of Sciences. Beijing: China Science & Technology Press, 1990:113

Zhao Z. Introduction to design of information system. Beijing: Golden Shield Press, 1985

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