

A GIS-Based Computer Supported Collaborative Work (CSCW) System for Urban Planning and Land Management

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Abstract

There are three requirements for improving the efficiency of a collaborative decision-making process. They are (1) an agile communication and interactive methods, (2) reliable information, and (3) effective processing and visualizing tools. The GIS-based Computer Supported Collaborative Work (CSCW) system is a powerful assistant for achieving these requirements. It has been successfully applied to the Urban Planning and Land Administration Bureau of Changzhou Municipality in Jiangsu Province. This paper presents the method used in developing the CSCW system, which has been in operational use since 1997. With the assistance of the system, the efficiency of collaborative decision making has been significantly improved by reducing duplication of effort, minimizing redundant data collection and analysis, and maximizing information sharing. More reasonable decisions have been made based on the integrated information from the federated database and various analysis tools. The Bureau has become more "just and open," as the public admits. Some suggestions for further work are discussed.

Introduction

In Changzhou Municipality (Jiangsu Province), the tasks of urban development control are undertaken by the Urban Planning and Land Administration Bureau. It is a collaborative decision-making process, where a group of urban planners and land management staff, located in different geographic divisions within the Bureau, review or process the building/land-use application(s) submitted by public agencies or private citizens according to the pre-defined regulations and workflow. Since the 1980s, urbanization has occurred at a rapid pace in China (Chen, 1999), as well as in Changzhou, as a result of rapid economic development. Large volumes of information about land administration and building construction are pouring into the Bureau. Rational urban planning and land management are crucial to government officials and planners (Yeh and Li, 2001). But traditional (manual) means for development control are no longer applicable for three reasons:

- Many documents and maps are created and referenced during the process of urban development. With manual operations these documents and maps are housed in different departments of the Bureau, and it is difficult for staff to retrieve the ones that are needed rapidly. Even more difficult is the ability to integrate and analyze them.
- There are many steps required to process each application case. In each step the results (maps and documents) created by previous steps are used as the basis for decisions in the current step; and the results of the current step will, in turn, be referenced

by subsequent steps. Transferring such information in traditional ways is usually not timely enough and might cause problems in information consistency if there are data updates along the way.

- As a local government office, the Bureau must be open and impartial to applicants. Supervisors need to know and control the review process dynamically. Because it might take several weeks to finish a case and usually more than four departments will be involved, it is very difficult for supervisors to know how a case is progressing or if there are any irregularities.

There are three requirements for improving the efficiency of this collaborative decision-making process. They are agile communication and interactive mechanisms (Golay and Nyerges, 1995; Churcher and Churcher, 1996; Churcher and Churcher, 1999), reliable information (Obermeyer and Pinto, 1994; Spencer, 1997), and effective processing and visualizing tools (Chen *et al.*, 1998a). Improved communication and interactive mechanisms are important because staff members need to share information about applications, to co-produce maps of land lots, to supervise the review process, and to solve conflicts and negotiate settlements (Wu, 1997). Reliable information is very essential when verifying whether the submitted applications fit with the urban planning laws and regulations. Specific tools are needed for delineating land lots or building layouts on large-scale maps and for filing forms to state the opinions assessing the applications. Tools for qualitative and quantitative analyses (such as site location and environmental impacts) are also necessary.

In the past 15 years, more and more local authorities have been active in developing urban GISs in China. Their main purpose is to improve the efficiency of urban management and development control. Three main phases can be identified for the development of these applications:

- In the mid 1980s, GIS technology was used to assist cartography and spatial analysis in specific projects such as land suitability evaluation, environmental quality assessment, and urban traffic simulation (Yeh, 1985; Chen *et al.*, 1989).
- In late of 1980s, some departments in urban planning and administration organizations (such as cadastre departments) began to digitize spatial data and create GIS databases that focused on integrated management of spatial and attribute data (Yeh, 1990; Lee, 1990). It was shown that it is not easy for one department to access the databases developed by other departments in the same organization.

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- At the beginning of 1990s, as more and more urban planners and land management staff became proficient in the use of GIS tools, people began to integrate GIS with office automation (OA) functions for day-to-day routine tasks. Many systems have been developed since then. Some of them are OA-based, in which office automation is the primary function and GIS is used for archiving the results of office automation. Others are GIS-based, where the contents of OA are treated as the attributes of spatial objects. But neither of these fully meet the three requirements we mentioned above (Jiang *et al.*, 2000a).

Among many cities in China that are involved in GIS applications for urban planning and land management, Changzhou municipality is a pioneer. It began its GIS development in 1987 initiated by a World Bank loan. By 1996, a digital city database at 1:500 and 1:1000 scale had been created using Arc/Info 7.0, and most urban planning projects were executed with the aid of GISs for spatial retrieval, spatial statistics, spatial analysis, and mapping. To meet the requirements for handling day-to-day routing work, a network-based GIS was developed in 1997. It has operated incessantly since then. In this system, heterogeneous and disparate sources of spatial and attribute data in the organization are assembled into an integrated GIS database. Computer network-based spatial data handling and office automation functions were developed and provided to staff for their daily use. Actually, this system is a prototype for the GIS-based computer supported collaborative work system (CSCW) described here (Jiang *et al.*, 2000). It was recognized that such prototypical CSCW systems have particular characteristics and that additional methods should be introduced to enhance their design and development (Chen and Jiang, 2000).

Development and application of Changzhou's CSCW system is based on the three requirements mentioned above. Actually an architecture was established (Figure 1) to achieve the goals, where a reasonable and flexible workflow was re-engineered within the organization to accommodate the new technology. A federated database was established to integrate spatial and attribute information used and created during the management process. An agile mechanism was set up for communication and interaction between staff that might be located in different offices during their collaborative work. Effective tools were provided to staff for handling their routine workflow in the environment of the CSCW system.

This paper presents the method for achieve the three requirements. Workflow re-engineering is discussed in the next section. The third section explains how to provide good information. The agile communication and interactive mechanisms are then described, followed by a discussion of effective processing and visualizing tools.

Re-Engineering the Workflow of the Organization

By the nature of collaborative work, the staff work within a network, where decisions made by one trigger consequent decisions by others before the case is handed to someone else. The resultant chain of such actions is referred to as workflow (Wu,

1997). Reasonable and flexible workflows improve the efficiency of any organization. Traditional organizational structures are often cumbersome in responding to the needs of computerized and networked environments. It is becoming clear that application of new technology, in the absence of organizational restructuring or "re-engineering," may not deliver the expected benefits (Newton *et al.*, 1995; Chen *et al.*, 1998b). To build an operational CSCW system that ensures that staff conduct their day-to-day activities efficiently, the Changzhou Urban Planning and Land Administration Bureau was restructured to standardize and simplify the workflow. Functional offices were reorganized and the responsibilities among offices were made more explicit. Figure 2 shows an example. Workflow before the restructuring is shown in Figure 2a. It indicates that, when an application was submitted to the Bureau, the director previewed the case before passing it to the Vice-director. The Vice-director then passed the case to the appropriate department(s) having responsibility for the content of this application. When the department received the application, the director of the department previewed it before passing it to one of the clerks. Obviously, before actions by a clerk began there were too many intervening steps and too much time lost. After the restructuring, most of these unnecessary processes were eliminated (Figure 2b). The applications now go directly to a clerk. The department director reviews the decisions made by the clerk, and the director of the Bureau examines the results from the departments. The number of transaction forms between offices has thus been reduced from 67 to 16.

A visualizing notation protocol was designed to describe software behavior based on the methods proposed by Bennett

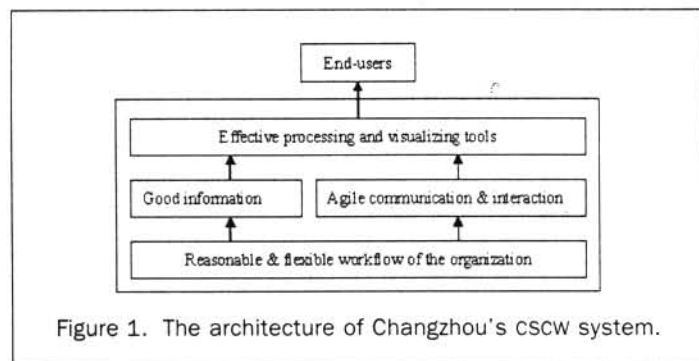


Figure 1. The architecture of Changzhou's CSCW system.

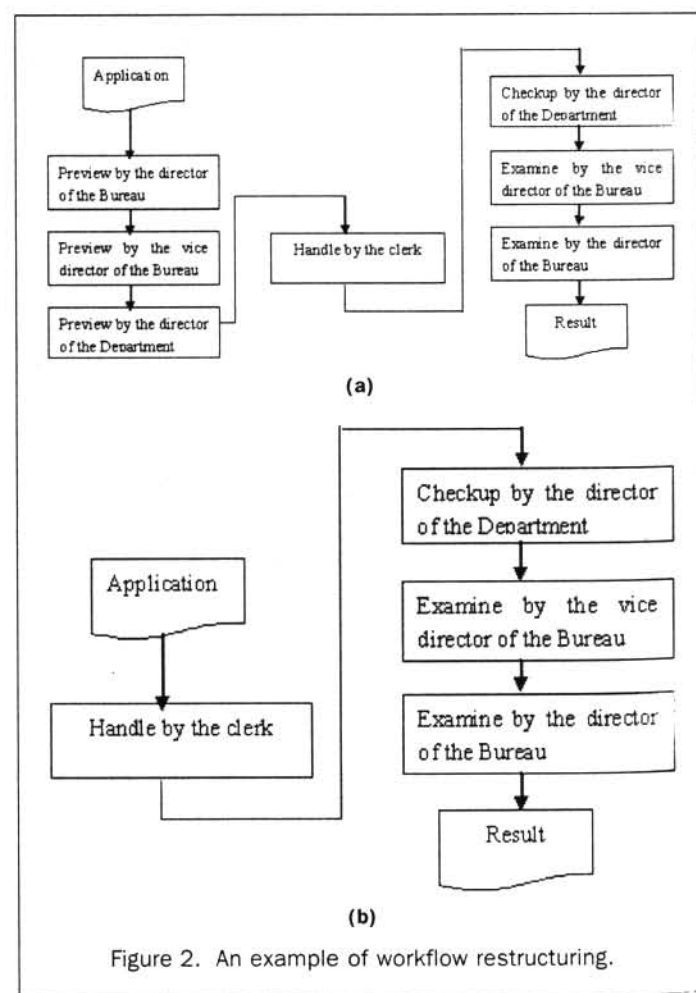
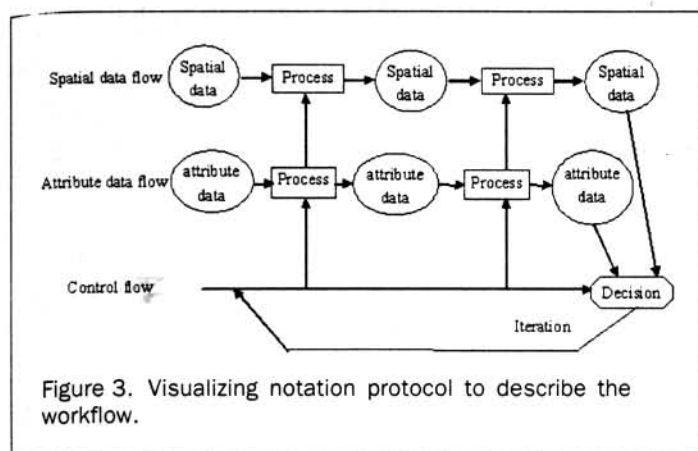


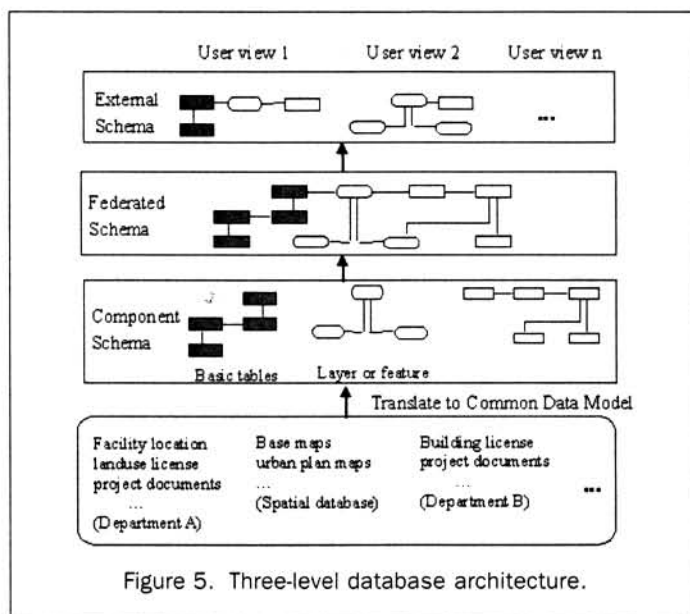
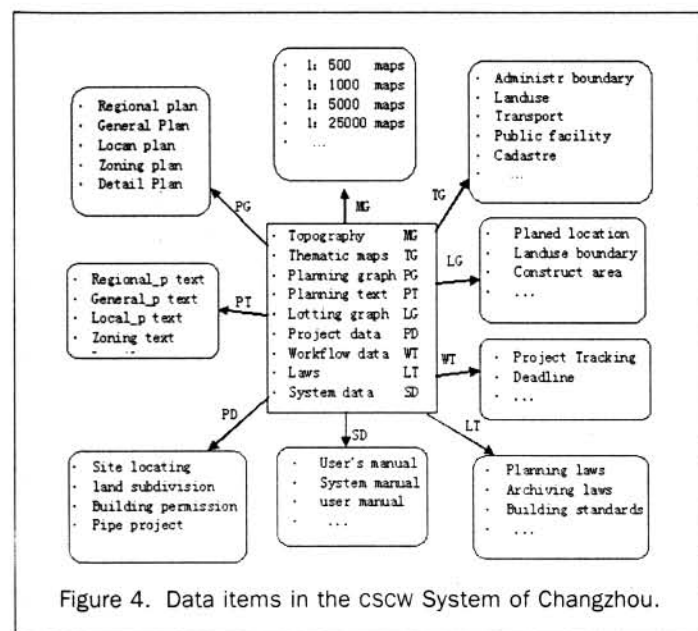
Figure 2. An example of workflow restructuring.



(1992). With this approach it is easier and more explicit for system designers to represent the workflow, dataflow, and control messages that trigger functions in collaborative actions. Figure 3 shows how the attribute data flow, spatial data flow, and control flow are integrated and represented visually in this protocol.

Reliable Information

No reasonable decision can be made without reliable, full-scale, and up-to-date information. In urban planning and land administration, many kinds of data are referenced, created, and handled by the staff (among them plans, topographic maps, facility maps, administrative boundaries, cadastral maps, decision related documents, permits, and laws and regulations), as well as information about how cases are progressing. Consequently, it is essential to build an integrated database to manage these various data types, and to find a suitable mechanism for updating data created during the process. Figure 4 illustrates the heterogeneous and disparate sources of data needed to be assembled into an integrated database within the urban planning and land management bureau of Changzhou. A three-level database architecture was proposed (Figure 5) on the basis of federated database studies (Sheth, 1990; Goodman,



1994). The original spatial and non-spatial data were translated into component schemas after attribute conflicts, structure conflicts, and name conflicts were resolved. They are represented as basic tables in the relational database management system (RDBMS) and spatial layers or features in GISs. These component schemas were later integrated into a federated scheme. Data redundancy was eliminated and logical relationships were defined in this stage. Finally, different external schemas were created on the basis of the federated database scheme according to different end users' requirements. Oracle and MapInfo Spatialware were used for managing the non-spatial and spatial data, respectively, and open database connectivity (ODBC) was used as a common interface for linking these two heterogeneous database systems. The interface enables users to access these two different databases from the client side.

One of the characteristics of a CSCW system is that the database is driven by the workflow; that is, when an action within the workflow is executed, an I/O of the database might be triggered (Chen and Jiang, 2000). Thus, the update of the federated database is fulfilled synchronously with the execution of workflow.

In addition, the staff members need to access the information easily while handling their routine work (Obermeyer and Pinto, 1994). Thus, data in the integrated databases are classified by their nature and application, and four kinds of queries are developed, including process query (Figure 6a), facts-query (Figure 6b), spatial query (Figure 6c), and laws query. These queries are all represented with the formulae "Select * From (View1), ..., (Viewn) Where (conditions) Reformat (formats)." A node-link structure was also used for the associative linking of multi-media information. In addition aerial images, ground photos, 3D landscapes, narrative descriptions, digital video, and sound can be encapsulated by nodes and associated with spatial object(s) on digital maps. The maps are used as spatial references attached by other document nodes. Staff can navigate in or through geographic space to retrieve multi-media information about the past and existing conditions of a particular location (Figure 7).

Agile Communication and Interactive Mechanisms

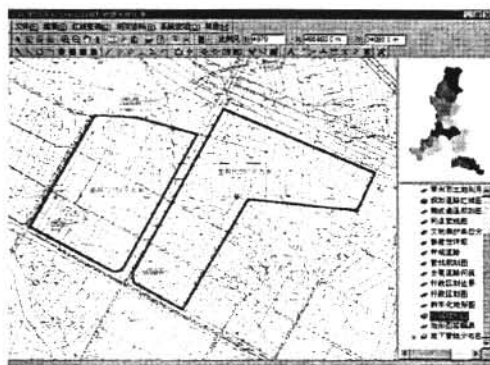
Most GISs support multi-user facilities only to the extent that many people can access the same data simultaneously. General CSCWs provide some generic functions such as whiteboards and



(a)



(b)



(c)

Figure 6. Easy access to the database. (a) Process query. (b) Facts query. (c) Spatial query.

text editors for message transfer. However, urban development control is a multi-disciplinary activity, and reviewing a case might involve staff from several offices and with different backgrounds. In reviewing case applications, both spatial and attribute information about each case should be transferred, and procedures for handling cases disputed between different staff need to be established. Thus, the requirements for com-

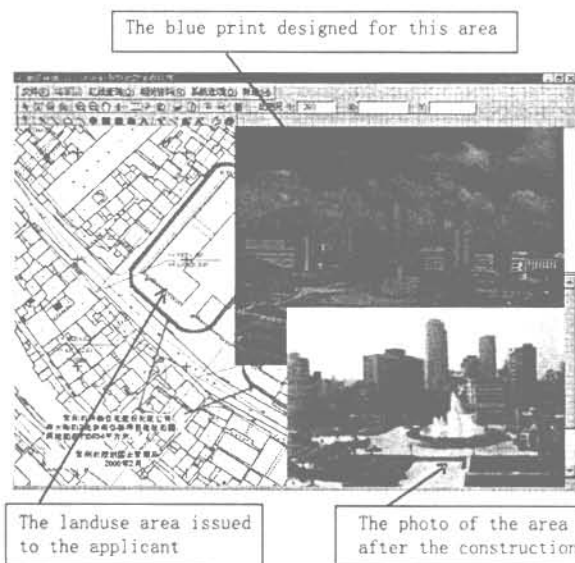


Figure 7. Link to multi-media information.

munication and interactive methods of such GIS-based CSCWs are much more specific than those used by traditional GISs. First, spatial features, together with their attributes and other related documents created or modified by one staff, should be transferred to subsequent staff in the workflow for further handling. Two methods were used to accomplish this:

- One snapshot of the spatial object after the first reviewing action is defined as one "state" and is recorded in the spatial database, including the shape, location, and attribute of the object decided by this action. The next staff member in the workflow accesses this state and, in turn, a new "state" is created based on the previous state and is recorded in the spatial database again. This procedure is shown in Figure 8, where S_n represents different states of one spatial object under review and A_n represents different actions taken by staff.
- Documents carrying various decision-making messages created by staff in different actions are transferred in the form of "table." Each item in the table corresponds to one staff member's decision and is read-only to other staff. Figure 9 is an example of such a "table." Other functions are also developed in Changzhou's system to facilitate communication and interaction between the staff. Among these are (1) a supervising function for the principal staff to inspect and control the schedule of a case, (2) a whiteboard for message broadcasting, and (3) a multi-media touch-monitor for public querying and group discussion.

Effective Processing and Visualizing Tools

To make the system usable for the common staff that usually are not GIS experts, some specific tools must be provided for them to handle routine work. Generally, four kinds of such tools are

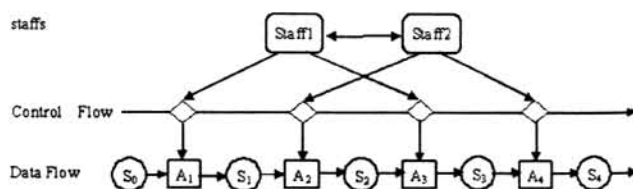


Figure 8. 'State' of the spatial object under review.

Figure 9. A form carrying the decision message made by different staff.

Figure 10. A form for the director of the Bureau to examine the application.

necessary, including information browse and query, documents processing, desktop spatial data handling and mapping, and analysis tools.

Information Browse and Query Tools

To ensure the justice and veracity of decisions, the staff have to reference various spatial and attribute information during the process of urban development control. As mentioned in the section on Reliable Information, four types of queries are developed based on the requirement. Thus, four kinds of query tools are developed accordingly. Each simulates the process that staff used in their traditional workflow. For example, while finding the spatial objects related to a certain case, the staff can query by the address, the title of the case, the date, or the name of the applicant. In addition, technical items used by the urban planners and land administrators, which are usually different from those used by computer technicians, are used in system interfaces. Some visual methods such as fancy icons and tip-wizard are also used to make the interface livelier.

Documents Processing Tools

The procedure of urban development control in Changzhou consists of three stages:

- Registering the application submitted by public agencies or private citizens for land use or building construction.
- Reviewing the applications to verify whether the submitted application fits with the urban plans and related laws or regulations, and
- Issuing the certificate or a letter indicating the non-compliance reasons.

It takes quite a long time from registering the submission to issuing the certificate, during which time much paper work is created, including application registering, forms filling, certificates or letters printing, and documents filing. In the system, each application is assigned a unique code as the identifier, and all related messages are stored in Oracle. Tools have been developed for handling these data and resulting paper work. Most of these tools are represented as forms in the desktop. Figure 10 shows a form designed for the director of the Bureau to examine the case before issuing a certificate.

Desktop Spatial Data Handling and Mapping Tools

Delineating and mapping land lots or building construction location on large-scale digital maps are key tasks of the discussed CSCW system. Specific desktop tools are developed with

MapX for the staff to handle spatial data, such as road arc generation, coordinates and area measurements, labeling and legend generation, and supervisory certifications.

Analysis Tools

Analysis tools are necessary as a means for assisting decision making. Some of the analysis tools developed for the CSCW system include statistics, 3D visualization, and facility service analysis. Figure 11a is a tool for providing statistics for the number of applications submitted to the Bureau during a certain time period. The height of each block indicates the number of the cases. Different colors are used to indicate the processing stages; for example, the red color means the case has been finished normally, the green color means the case is under processing, and the yellow color means the case is suspended for some reason. The numbers at the bottom of this figure indicate different content of the review. For instance, number 02 means site location reviewing and number 04 means land-use reviewing. Figure 11b shows the 3D model generated by the visualization tool. Figure 11c illustrates a tool for generating the profile of a road with underground facility networks.

Discussions

Changzhou municipality is a medium-sized city in Jiangsu Province having a population of about 0.6 million and an area of about 350 square kilometers. There are more than 800 sheets of 1:500-scale maps covering the downtown area and more than 3000 sheets of 1:1000-scale maps covering the entire city. The GIS-based CSCW system of the Urban Planning and Land Administration Bureau used Oracle and MapInfo Spatialware for non-spatial and spatial data management. The programs were developed with Borland Delphi 4.0. The size of the integrated database is more than two Gigabytes after several years' maintenance and expansion. The system was inaugurated in 1997 and has been operational since then. Some of the designers of the system were the professional staff of the Bureau who were familiar with the business of urban development control and also had experience in GIS applications. Other GIS experts came from the National Geomatics Center of China, which has the responsibility for providing consultant and project implementation services for various users. These GIS experts have connections with colleagues around the world and are cognizant of cutting-edge issues in GIS research and applications.

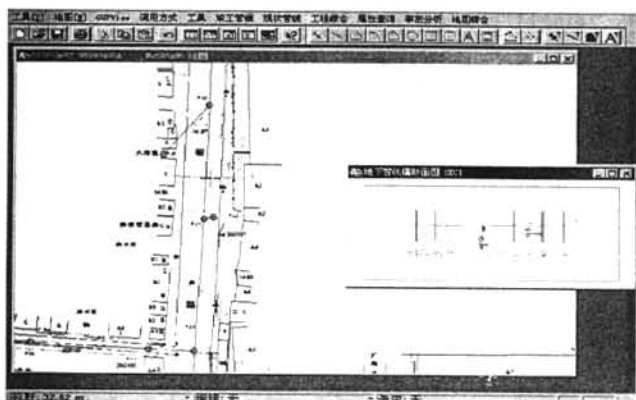
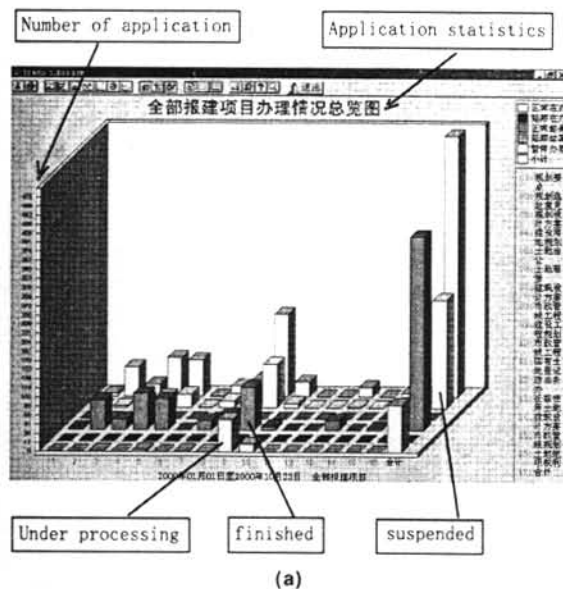


Figure 11. Example of analysis tools.

However, the structure and decision-making processes in China are very different from Western countries; these professionals found no direct experiences from the West that could be applied in Changzhou municipality. Nevertheless, some useful ideas and technology were obtained from the literature (as cited); for example, the federated database design developed for the Alberta Land Related Information System (Sheth, 1990; Goodman, 1994). The general idea and the architecture of this system is quite new in China, but has been a model for urban development control. More than 400 experts from more than 60 cities visited Changzhou to learn the technology. Two workshops have been conducted in Changzhou to introduce and transfer the technology. The system received a second-grade award from the State Bureau of Surveying and Mapping and a third-grade award from the Ministry of Construction in 2000.

The efficiency of collaborative decision making for urban development control in Changzhou has largely improved. The time required to process an application has been reduced by more than 40 percent, from 90 days to 56 days. The quality of service has also improved greatly by reducing duplication of effort, minimizing redundant data collection and analysis, and maximizing information sharing. More reasonable decisions have been made based on the integrated information from the federated database and various analysis tools. In addition, the Bureau has become more "just and open" because supervisors can control the handling procedures dynamically and can monitor and stop any illegal practices immediately. Applicants can now track the progress of the permit applications. The efficiency of the CSCW system has been noted in more than 20 letters of praise from the public in 1998, contrasting sharply from the complaints of earlier years.

Further research issues are under consideration by the CSCW system developers. These include

- understanding and modeling of the social cognitive and behavioral aspects of such GIS-based CSCW systems where human-human interactions and causal relations between human action and spatial object changes are involved;
- database revision and versioning, including back-end data revision, database integrity, and database anomalies; and
- adding more specialized functions such as knowledge-based decision making and intelligent spatial analysis.

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