The Synchronized Updating Technology Research of Spatio-temporal Supervision Data Model About Organizing of Construction Landuse Data in Distributed Environment

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Abstract： As China advances toward urbanization, the relation between supply and demand of land use is growing acutely. Effective supervision of various land use has become necessary to achieve reasonable and lawful use of land. The change of land use from farmland or unused land to construction land use in the process of urbanization usually undergoes the following stages: approval, expropriation, provision, application, and supplement. The change to construction land use similarly undergoes this process, and then the outcome before and after the change is compared to determine potential land use problems. The present process-oriented spatio-temporal data model for organization and supervision data management records the supervised spatio-temporal variation process and state by using new-added auxiliary tables. This model can efficiently organize and demonstrate multiple relationships among landuse stages and the evolution process in the life cycle of spatial entities. To achieve effective supervision from the upper to the lower in the three-level “province-city-county” distributed environment and to detect potential land use problems early, data from different places are collected and synthesized for analysis. To ensure that the database is up-to-date, real-time synchronization of spatio-temporal supervision data should be studied and the integrity of the spatio-temporal data model should be maintained. Therefore, this study introduces an updating mechanism based on the trigger technology for data synchronization.When importing basic data from distributed databases into the supervision database, simultaneous updating in related auxiliary tables is performed along with changes in the basic tables. That is, records are added automatically into auxiliary tables that reflect the spatio-temporal change of the process and state when basic data are imported. This method not only achieves and maintains consistency in the database, but also ensures integrity and currency in the auxiliary tables. Change information can be expressed duly in all supervision stages ,and highly efficient supervision of construction landuse is guaranteed.

Keywords: distributed, spatio-temporal supervision data model, synchronized update, consistency, integrity

1.Introduction

In the urbanization process of China, the relation between land supply and demand is increasingly becoming distinct. With the aims of controlling construction land use growth rate, strengthening regulation to achieve economical and intensive land use, and preventing unreasonable or unlawful use of land use, the process of approval, supplement,application, expropriation, and investigation of construction land use must be supervised [1].In the supervision data of construction land use in the urbanization process, a certain flow and life cycle are demonstrated in approval, expropriation, provision, application, supplement, and investigation these stages. Hence, vertical supervision, aside from horizontal analysis at these stages is necessary[2].In the current supervision systems, land use data of related stages are scattered in thematic databases, and only the land use data of the current stage are supervised. Supervision data in different databases lack a dynamic connection, thereby resulting in difficulty to achieve full supervision of urbanization land use from the perspective of horizontal correlation[3,4].

With this demand, Gao Bingbo et al proposed a process-oriented spatio-temporal supervision data model for construction land use [5].On one hand, this model introduces an improvement to the database structure to suit existing supervision data and constructs the incidence relationship among approval, supplement, application, expropriation, and investigation land use stages. On the other hand, auxiliary tables are employed to record the evolution process of related land use entities and determine multiple relationships among land use stages. This model realizes the supervision of urbanization development, including the recording of change processes to allow review of land use entities and reconstruction of land use projects, and improves the efficiency of supervision of construction land use.

In the process-oriented spatio-temporal supervision data model for construction land use, supervision data on land use are analyzed. Basic geographic data and thematic data are collected from different places to achieve efficient supervision of construction land use. In China, land use management databases and other related business systems are distributed vertically at three levels: “province-city-county”[6]. Data are obtained from different systems that are distributed in different network nodes. In the importation and updating of related supervision data in the “province-city-county” distributed environment, related change information should be reflected in the supervision database system duly. That is, when data in basic tables from the corresponding levels change, the auxiliary table should reflect such change to ensure consistent and up-to-date information in the supervision database. The problem of synchronized updating of the entire supervision database will be discussed in the succeeding section.

This study introduces a synchronized updating technology for the spatio-temporal supervision data organization model for construction land use in a distributed environment. The role of this technology in maintaining the consistency of database is analyzed.

2.Organization of supervision data in the spatio-temporal database

Supervision of construction land use refers to both vertical and horizontal supervision of the approval, supplement, application, expropriation, and investigation stages of the entire land use process. Land use starts from the application for approval of new construction land projects and ends with the completion of the construction project. To determine the construction land project and the land use entities involved at a certain time, the state of land use should be reconstructed at a specific moment. Gao Bingbo proposed a process-oriented spatio-temporal data organization and management model in construction land use supervision based on the requirement mentioned previously.

In the model, the basic data of each link are connected with each other in a certain manner. The evolution of land use entities in the approval, supplement, application, expropriation, and investigation stages is the foundation to construct the correlation among these stages. The storage structure of basic supervision data is shown in Figure1. In every two links, “consolidation, reclamation, and development” land use projects and supplementary cultivated land projects are connected by supplementary cultivated land use entities. Meanwhile, supplementary cultivated projects and approval projects are connected by the approval project serial number. The relationship between the approval project and expropriation project is established by expropriated land entities. The relationship between supplement and expropriation projects, which is much more complex, is established through the relationship between related supplement project and approval project and that between related approval project and expropriation project. The application project and supplement project are connected by related application land use entities. The vertical correlation between two links is established in the same manner, thereby allowing vertical supervision in the system by vertical association.

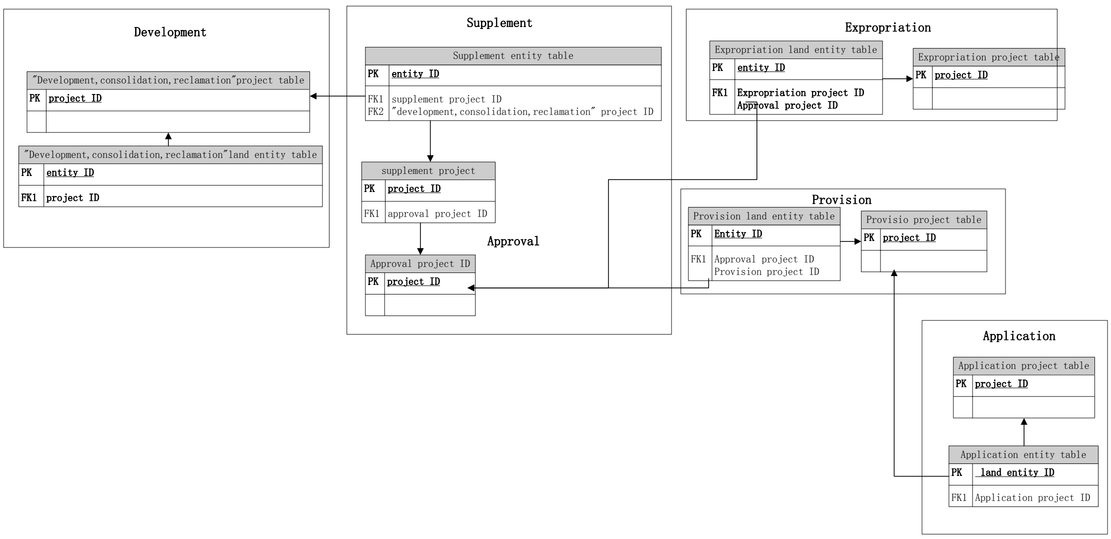

Figure 1 storage structure of the basic table data in supervision database

With regard to the basic data storage structure, four auxiliary tables, namely process, sequence, state, and evolution tables, are newly added in the supervision data organization model. The process table presents a list of different land use projects in the supervision database.The sequence table displays the relationship among land use projects. The state table contains information related to land use entities.Lastly, the evolution table exhibits the relationship among entities, such as cutting, merging, copying, and complementary. The organization of these tables and the storage structure are shown in Figure 2.The four tables indicate the correlation of land use processes and the evolution information of land use entities in construction land supervision. In the basis of these auxiliary tables, we can immediately reconstruct the relationship among land use projects and recall land use entities. As a result, the historical state of construction land entities at a particular instance in a time series will be easy to extrapolate.

Process Table

Process ID	Process type	Begin time	End time
F12	development, consolidation ,reclamation(0)	2009.8.5	2010.6.12
B123	supplement(1)	2011.8.12	2011.9.12
P235	approval(2)	2011.9.12	2011.10.12
Z231	expropriation(3)	2012.5.6	2012.8.6
G215	provision(4)	2012.9.8	2012.10.8
Y123	application(5)	2012.11.6	2013.3.5
C123	investigation(6)	2011.10.12	2013.3.5

Evolution table

ID	Type	Sequence ID	Begin time	End time	Pre-process ID	Input status	Output status
1	merging(1)	B123-1	2011.8.12	2011.9.12	F11	200	324
2	merging(1)	B123-2	2011.8.12	2011.9.12	F12	201	325
3	cutting(2)	P235-1	2011.9.12	2011.10.12			425
4	cutting(2)	P235-2	2011.9.12	2011.10.12	B123	324	426
5	cutting(2)	Z231-1	2012.5.6	2012.8.;6	P235	425	725
6	copying(3)	Z231-2	2012.5.6	2012.8.6	P235	426	725

Sequence Table

Sequence ID	Process ID belonged	Begin time	End time	Pre-process ID	Properties
B123-1	B123	2011.8.12	2011.9.12	F11	
B123-2	B123	2011.8.12	2011..9.12	F12	
P235-1	P235	2011.9.12	2011.10.12		
P235-2	P235	2011.9.12	2011.10.12	B123	
Z231-1	Z231	2012.5.6	2012.8.6	P235	
Z231-2	Z231	2012.5.6	2012.8.6	P235	

Status Table

Status ID	Begin time	End time	Spatial Properties	Temporal Properties
200	2011.6.12	2011.8.12		
201	2011.6.12	2011.8.12		
324	2010.9.12	2011.9.12		
425		2011.10.12		
426	2011.10.12	2012.5.6		
725	2012.8.6	2013.2.6		

Figure 2 The storage structure of auxiliary table data in supervision database.

The traceback of supervision data mainly includes the spatial form or property of land use entities and the spatio-temporal process of approval, expropriation, provision, application, supplement, and investigation in land use two parts. The traceback of the evolution of land use entities can be achieved by examining the state and evolution tables. The traceback of the spatio-temporal process requires a step-by-step analysis of the evolution, sequence, and process tables to obtain land use project information at a certain time. In reconstructing the historical state of land use entities, the existence of land use projects and entities can be analyzed using the process and state tables, while the information of reconstructed land use projects and entities can be obtained using the sequence and evolution tables. Storing evolution information of spatio-temporal processes and entities by using auxiliary tables is more intuitive because these tables increase the operational and practical review and reconstruction work of supervision data and reduce the complexity of supervision operation that requires different supervision data at multiple time periods. Consequently, the efficiency of construction land supervision is improved.

3.Construction land use supervision database in a distributed environment

3.1Supervision data flow in the “province-city-county” network

Supervision data mainly comprise basic geographic data, land use data at approval, expropriation, provision, application, supplement, and investigation stages, and thematic data. In the “province - city - county” network environment, three types of data are distributed in different network nodes and business systems. These data are extracted from other related databases or systems between two levels. The flow of supervision data in the distributed environment is shown in Figure3.

In general, land use data at approval, expropriation, provision, application, supplement, and investigation stages in the “province-city-county” environment are complex. Databases at the top, bottom, or same levels must be accessed to extract related data at each corresponding stage. The supplement data in the supervision database at the county level contain consolidation, reclamation, and development data that are then imported into the supplement database at the city level. The supplement data of different cities are subsequently imported into the supplement database at the province level. The approval data are obtained from the electronic government affairs systems at the county level. City-level approval data can be extracted from the data at the county-level or from the electronic government affairs systems at the same city level. Province-level approval data are from the land resource remote reporting system or the provincial e-government affair system that gathered data from the subordinate level. The county-level expropriation data are extracted from the land reserve database, while the expropriation data at the city level is gathered from the related county data, and the provincial expropriation data is formed from city nodes with the same way. The provision data in county nodes are encoded manually, while the city- and province-level expropriation data are gathered from lower-level nodes. The application data at county level are obtained from the law enforcement and inspection processes. The city-level application data are extracted from subordinated county nodes,and the provincial application data are gathered from the same but lower county nodes.

The supervision database uses a series of indicators. Basic geographic data and thematic data are required as reference data, and land use data at approval, expropriation, provision, application, supplement, and investigation stages are checked if reasonable and legal to identify potential problems. The basic geographic data are propagated by the Ministry of Land and Resources to provinces, cities, and then to counties, forming the three-level, “province-city-county” basic geographic database. The thematic data in the supervision database are extracted from the province-level, city-level, and county-level a-map databases in the distributed environment.

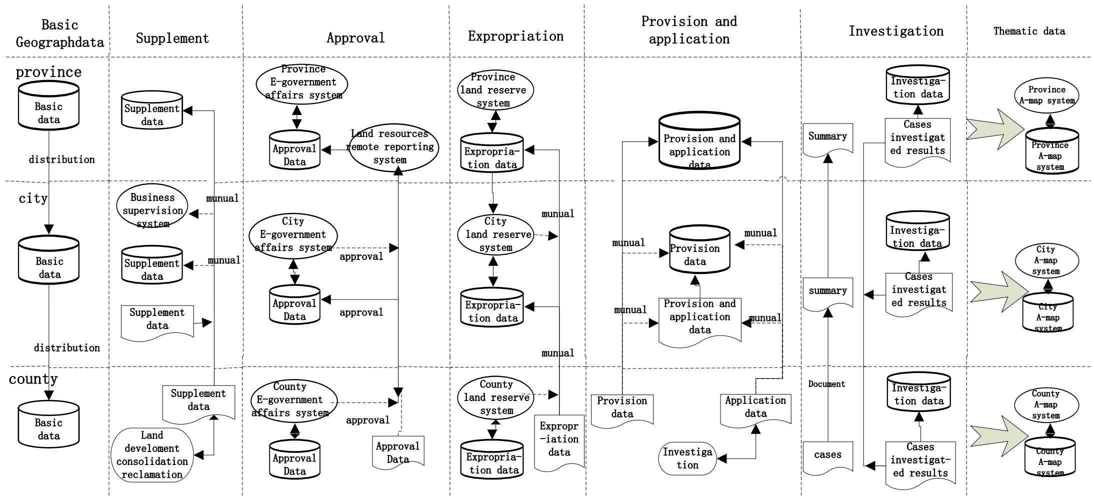

Figure 3. The supervision data flow status in “province-city-county” distributed environment

In the upper analysis, related land use systems distributing scattered and system structures are found to vary in the“ province -city-county ”distributed environment. The data at different levels and in different business systems are obtained manually. Thus, the collection of full supervision data and supervision efficiency are affected. A high degree of automation of the data flow would clearly increase the satisfaction level of supervision business needs. Therefore, the current supervision data flow should be changed to a new and more adaptive data flow in such distributed environment.

3.2 Synchronization of construction land supervision data in a distributed environment

In the construction land supervision database, we use the model proposed by Gao Bingbo in storing supervision data. The supervision database is deployed in the distributed environment characterized by a three-level, “province-city-county” vertical management mode. We set provincial, city, and county supervision nodes, and the county and city nodes interact and share data with each other, as well as the city and provincial nodes, thereby achieving a top-to-bottom control and effective management. The interaction among nodes is shown in Figure4.

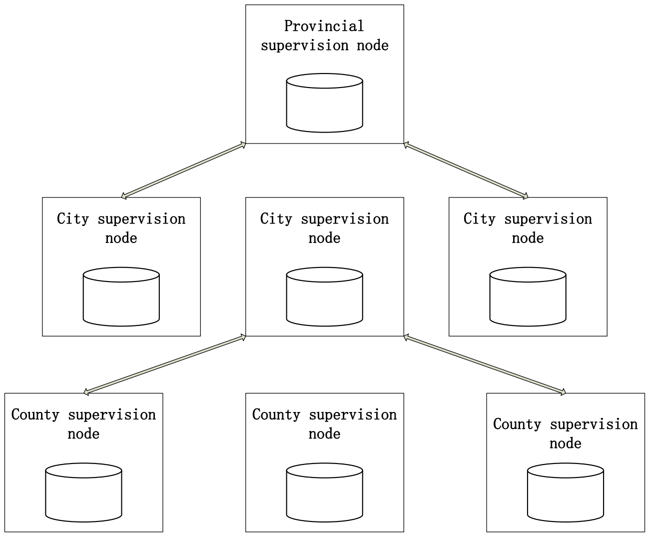

Figure 4.**Construction land use supervision database management system in “province-city-county” three-level network environment**

In the“ province-city-county ”network environment, we need to consider the content of two aspects in constructing the supervision database. One aspect is the corresponding relationship among different business data, such as basic geographic data and land use data, and the other aspect is the corresponding relationship between province and city nodes or between city and county nodes. The basic tables in the supervision database contain three types of data: geographic data, land use data, and thematic data. Geographic data could be obtained from superior level nodes of “province-city-county” network. Thematic data could be extracted from the a-map system at the same level. Land use data could be collected from subordinate level nodes by subscription and use of distribution technology on a certain interface. Lastly, data in auxiliary tables could be obtained from basic tables. When the data in basic tables are updated, related records in auxiliary tables are also updated. Figure 5 shows the new data flow of the construction land supervision database system in the distributed environment.

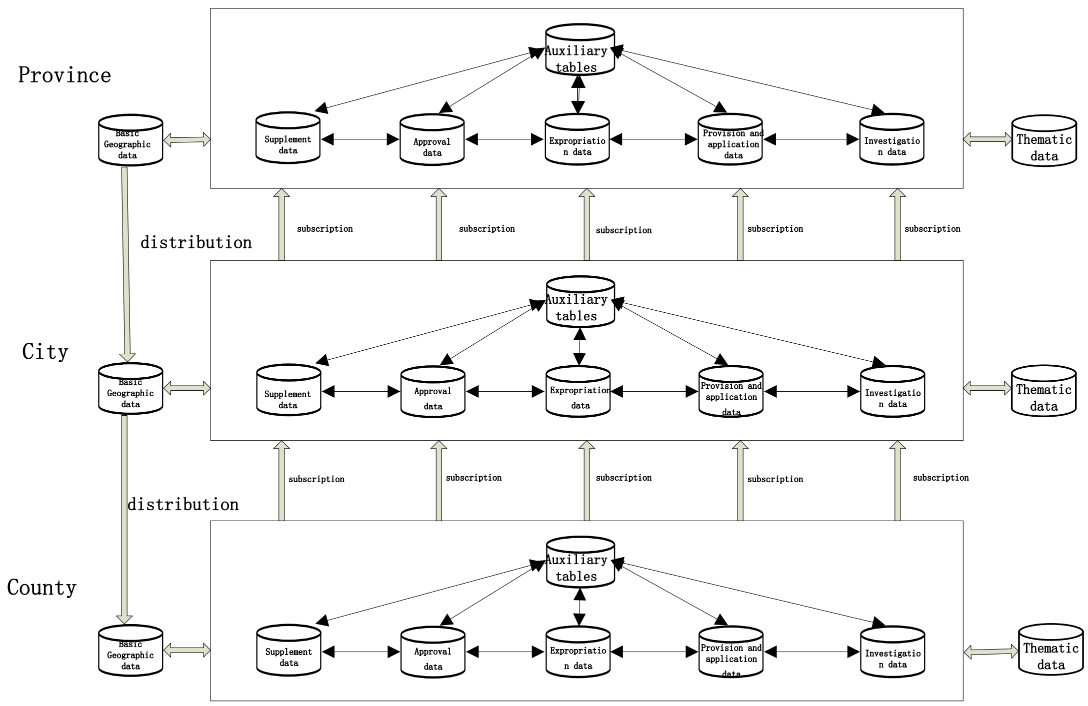

Figure 5 New data flow of construction land supervision database system in distributed environment

In the new data flow, the superior database could gain data from subordinate databases by subscription and use of distribution technology based on the data service. Data service is used to package the data in each level and to provide access by deploying a responsive distribution service, registration service, and subscription service at a superior platform. Data service is equipped with the functions of service registration and real-time data push. Service information is registered to the registration service, and then the changed data is pushed to subscribers in real time. Subscription service uses the information registered by the data service. The subscription mission is registered in the registration service, and related data are relayed to the receiving interface. Distribution service receives the pushed data, charges the execution of subscribed data, and pushes changed data to the interface of the subscription service. Registration service maintains the registered information of the data service and the subscription mission and activates the subscription service to execute data push as the subscription mission. The concrete process of data acquisition is as follows: First, data are distributed by publishing the data as data service in a subordinate database server that requires superior synchronized updating. These data are then registered in the registration service. Second is the subscription of data. The subscription service at a superior-level platform creates subscription mission and registers on a registration server according to the current distributed land use data service. When data are changed, the data service will push changed data to the subscription service. The registration service will simultaneously activate the data distribution service according to subscription mission and send the changed data to the subscription service.

The previously described process can ensure the automatic updating of the database at the superior level as the data of the basic tables change at the subordinate level. Consistency is consequently guaranteed. However, the supervision database management system not only includes the basic tables, but also the auxiliary tables that contain data from the basic tables. As mentioned earlier, when the data of the basic tables are updated, the auxiliary tables must have a certain mechanism to create related records based on the basic supervision data and then form the topological relationship information of the spatio-temporal process. In this new data flow design, the integrity and up-to-date quality of the entire supervision database system are maintained, subsequently ensuring the accuracy and efficiency of supervision work.

4.Automatic maintenance of construction land use supervision data in distributed environment

The data in a distributed database are decentralized or stored in different physical location nodes. For the management system to be consistent, data in different nodes should remain consistent while mutual exchange or sharing between certain databases occurs. For these cases, the DBMS manufacturers have designed a mechanism, such as Oracle's advanced replication technology[7] and SQL Server's subscription replication technology[8],to achieve data synchronization and automatic maintenance. Some researchers have also studied synchronization and automatic maintenance from different perspectives and carried out many data synchronization technologies and methods[9],such as the Oracle technology [10], the multicast form in updating the database[11],the reduction method based on the SQL operation statement[12], and the data synchronization and updating technology for land use data [13][14].All these mechanisms can satisfy synchronization needs and automatic database maintenance. However, for the process-oriented, spatio-temporal supervision database management system, the relationship between basic and auxiliary tables is derived, and the traditional synchronization technology could not contain basic and auxiliary tables in the same database to allow synchronized updating and to maintain integrity. Therefore, further research on database synchronization technology is necessary.

In a distributed environment, the spatio-temporal supervision data model for construction lands includes not only the basic tables that contain land use information at each stage, but also the auxiliary tables that exhibit the association among land use projects and the evolution among land use entities. The model can reflect the evolution process of land use entities in their life cycle and backrtrace or reconstruct the land use stages at particular instances using this form. As shown in Figure 6,the auxiliary tables have a close derivation relationship with the basic tables. The process table corresponds to different land use projects, the sequence table records the association between two different land use projects, the status table records land use entities and their duration, and the evolution table expresses the evolution process between entities. A corresponding relationship is present among basic tables, as well as a derivation relationship between basic and auxiliary tables. When basic table data are imported, data in auxiliary tables must be updated to maintain the integrity of the entire database.

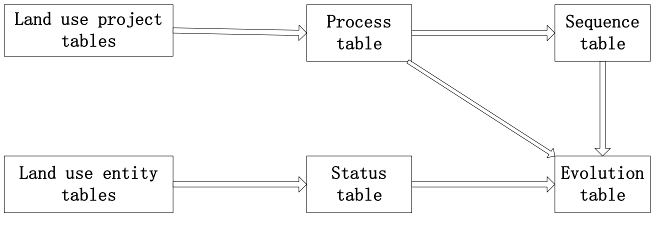

Figure 6.The relationship of basic tables and auxiliary tables

Considering the characteristics of data in the approval, expropriation, provision, application, supplement, and investigation stages and the four auxiliary tables comprehensively, a spatio-temporal data synchronization and updating mechanism is developed in this study based on the combination of the trigger and the traditional land use database synchronization and updating technology. Figure 7 illustrates this developed mechanism and the specific description.

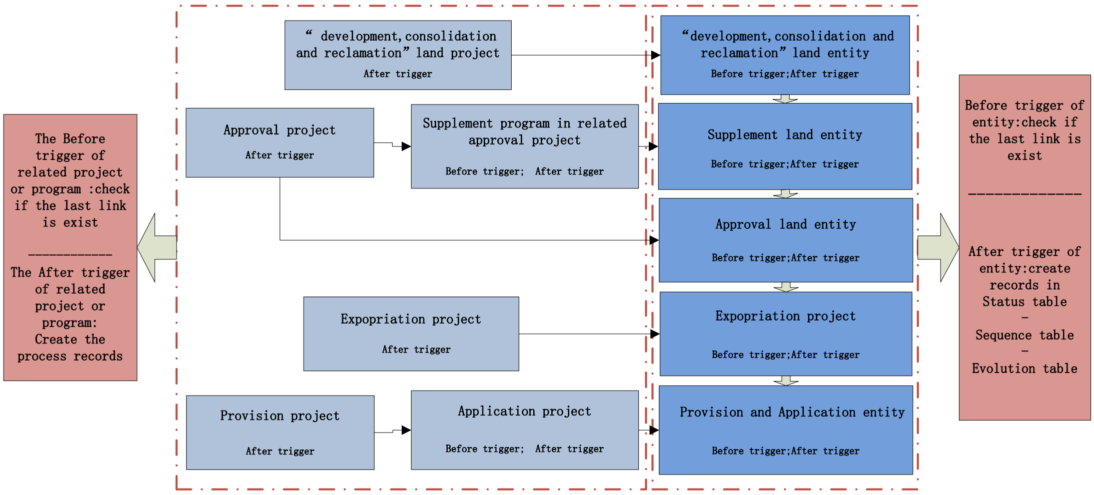

Figure 7.The synchronized updating mechanism of spatio-temporal data based on trigger

(a) In the importation of data on projects or programs and on the land use entities, related execution of maintenance operations is triggered.

(b) When data are imported into the basic tables that contain data of the projects or programs at the approval, expropriation, provision, application, and supplement stages, two triggers, namely, before and after triggers, will be generated. In the supervision database, “supplement” corresponds to the supplement program in the approval project, and the application project has the same series number as the provision project; this series number is a unique key in the database. After the activation of the after trigger as data are imported into current land use basic tables, the process table creates related records. The before trigger is activated to check if the last stage of the project or program exists. The current stage data could be imported successfully based only on the existence of the data of the last stage. In the database, the importing operation of the provision program must be performed after the importing operation of its related approval project. For the application project, the provision project should be imported first and then the related land monitor information is obtained. The entire spatio-temporal supervision data of projects or programs should be imported into corresponding project or program tables in the following order:(1) consolidation, reclamation, and development project, (2) approval project, (3) supplement program in approval project, (4) expropriation project, (5) provision project, and (6) application project.

(c) When data are imported into the basic tables that record information on land use entities at the approval, expropriation, provision, application, and supplement land use stages, two triggers, namely, before and after triggers, are generated. The application land use entities are provision land use entities. The after trigger is used to add records into the status, sequence, and evolution tables, while the before trigger is used to check if the land use project, which is related to the current land use entity, exists. The importing operation of land use entity data should be followed by the importing operation of related land use project or program data. The entire spatio-temporal supervision data about land use entities should be imported into corresponding basic tables in the following order:(1) consolidation, reclamation, and development entities, (2) supplement entities, (3) approval project, (4) expropriation entities, and (5) provision entities.

In the distributed environment, to maintain the consistency and integrity of the database system, we can use the previously described synchronization and updating technology to import data using the principle “first land use projects, then land use entities.”Based on the trigger technology, when land use project data are imported, the mechanism will synchronize and update the process table. When land use entity data are imported, the mechanism will synchronize and update the status, sequence, and evolution tables. Updates in basic table contents should also correspond to updates in auxiliary table records to maintain consistency and integrity of the construction land spatio-temporal supervision database and to ensure that all data are up to date. The entire process of tracing is performed quickly ,thereby considerably enhancing vertical supervision efficiency.

The synchronization and updating technology ensures that the auxiliary tables are updated when the data are imported in the basic tables. This updating technology, which is based on the trigger mechanism of the database, is much more efficient than the synchronization and updating system proposed by Fu Zhongliang et al., which uses specific algorithms [15].As the basic technology of the database, trigger is more effective than the extended program module in immediately responding to changes and in constructing the spatio-temporal topological relationship. Compared with the method that uses spatial data to check and record changes in the spatial database, which was carried out by Zhangjian[16],the technology reported in this paper does not require spatial operation and the use of log records. The auxiliary can reflect the spatial data change information indirectly, rendering the complex spatial operation unnecessary, and the trigger works on the auxiliary tables directly, thereby simplifying the updating process. Efficient supervision of spatio-temporal data of construction land use is also ensured.

5.Conclusions

In the current “province-city-county” distributed environment, the construction land use spatio – temporal supervision data model is used to execute vertical and horizontal supervision or to comprehend historical land use situation at a certain time by traceback and reconstruction. The supervision data are extracted from different places. Supervision databases should remain consistent for efficient construction of the construction land. Therefore, this study proposes a synchronization and updating technology based on the database trigger mechanism. The technology maintains land use project data and land use entity data that are imported into related tables at a certain order. The trigger mechanism will be activated as related records are added into auxiliary tables. When data from different nodes or levels are imported into the supervision database, the data are kept up to date and consistent in basic tables and auxiliary tables. Information on land use process evolution based on the land use entity life cycle is immediately generated in the database. While the synchronization and updating technology is based on the specific spatio-temporal supervision data organization model, suitable technologies for different and common situations may need further study.

Acknowledgment

Funds for this research was provided by the National Science and Technology Plan Projects (2013BAJ05B01).

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