GeoDesign Research on Land Use Changing Spatial - Temporal Database

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Key Words: Spatial - Temporal Database, GeoDesign, Geographic Information Science, Land Use

SUMMARY: The objective of this research is to build a land use changing spatial - temporal database within a specific research area and implement the GeoDesign concept, along with this database, to point out strategic decisions and planning policies of land use management for this area. First, this article discussed the development of geodatabase on different time and spatial dimensions and gave a solution on how to add the time scale into a common land use changing spatial database. Taking Liangjiang industrial zone as the research area, we designed and built the Liangjiang industrial zone land use changing spatial - temporal database for further use. Then, this article introduced a new concept "GeoDesign" and researched on how to apply this new idea into land use management work. At last, based on the land use policy of China and the Liangjiang industrial zone land use changing spatial - temporal database we built, we "geodesigned" the land use changing procedure for Liangjiang industrial zone and answered the following questions: (1).How to use the land use changing spatial - temporal database to describe the land use status within Liangjiang Industrial zone. (2).How the land use management works within Liangjiang industrial zone. (3).Whether the land use management works properly or not. (4).Based on the land use changing spatial - temporal database, under the help of geodesign, how to plan the future land use within Liangjiang industrial zone. (5).What impacts would be made to Liangjiang industrial zone if the land use is changed as we designed. (6).How to make best land use management decisions and plans for Liangjiang industrial zone.

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1. INTRODUCTION

Geodesign is a decision-making methodology by integrated designing and planning activities into real time geographical phenomenon models based on geographical information system, it is also an interdisciplinary and comprehensive approach to solving social problems and optimize locations, orientations, and features both in regional areas and worldwide [Flaxman 2010, Ma 2013]. Geodesign brings the geospatial analysis into the design process and make the beginning draft available for reviewing. This kind of reviewing is based on the space and time scales of the project, and refers to various natural and social factors data layers. During the design process, spatial - temporal data information and GIS would let the design match the characteristics and functions of the nature perfectly and by understanding them, informed design decisions and plans could be formulated and this is "design the future" [Dongermond 2010].

Supported by the distributed geospatial - temporal database and precise analysis and management tools, Geodesign now is started to penetrate into land use planning and manage activities. In China, because of the unprecedented speed of the urban exploration, land use changes very fast. With regular geographical information system and technology, space data is well provided for land use management but very hard to evaluate the past and estimate the future, which seems to be very important for the land use planning activities day to day. This gives the opportunity for the adoption and implementation of the geodesign. The problem is that there is very few time series data or historic data to simulate the land use changing process, and with only space data, geodesigners could not have any meaningful feedbacks from GIS. In this paper, a spatial - temporal database was built for geodesign usage, different time scales were added into a land resource database to create the land use changing spatial - temporal database and by applying it, a sample study explained how the land use manage and planning work could be geodesigned.

2. LAND USE CHANGING SPATIAL - TEMPORAL DATABASE

In this section, the land use changing spatial - temporal database and data structures, which are used to support geodesign, are explained

2.1 Regular geospatial land use data

For the daily work with land management and land use planning, only geospatial data format is considered. Regular geospatial land use database is usually composed by three types of datasets. One of them is the basic land information dataset such as boundaries, rounds, natural (rivers, mountains, environment, minerals, and est.) and social (infrastructures such as schools, hospitals, markets, and est.) factors, and remote sensing images, this dataset is often used as underlying data for land use map products. Second is the professional land use dataset which contains current land use data, land use overall planning data, land use classification data, and urban planning data. This dataset is considered as rules and references while managing and planning the specific land use activities. The last one is land use management dataset. Within this dataset, we can store the land acquisition, land supply, and land reservation data which are created by the daily land use management work. Table (1) shows the data contexts for regular geospatial land use database.

Table (1): Regular Geospatial Land Use Database Information

Dataset	Data Layer	Data Format	Geometry
Basic Land Information	Boundaries	Vector	Polyline
	Districts	Vector	Polygon
	Rounds	Vector	Polyline
	Natural Factor	Vector	Point, Polyline, Polygon
	Social Factor	Vector	Point, Polyline, Polygon
	DEM	Raster	Cell
	Iamge	Raster	Cell
Professional Land USe	Current Land Use	Vector	Point, Polyline, Polygon
	Land Use Overall Plan	Vector	Point, Polyline, Polygon
	Land Use Classification	Vector	Point, Polyline, Polygon
	Urban Planning	Vector	Parcel (Polygon)
Land Use Management	Land Acquisition	Vector	Parcel (Polygon)
	Land Supply	Vector	Parcel (Polygon)
	Land Reservation	Vector	Parcel (Polygon)

2.2 Time Scale for geospatial data

Spatial data with [X, Y] coordinates can represent static land use status very well. However, unlike some developed countries where the land use status might keep stable for quite a long time, the land use activities in China are very changeable due to the high speed of urban exploration. To better stimulate the dynamic land use activities and reflect the real time land use changing status, time scale must be integrate into geospatial data. The time scale is defined as three types, time point, time line, and time zone. Time point set up the start time and end time for every land use activity, and it is similar to the spatial point data which describes the information at a single point. The end time point could be a new start time point. Time line is consisted by several time points and reflects the linear continuing status. Time zone is made up of different time lines vertically and horizontally. Like polygons for spatial data, time zone also defines a region of time. It has time boundaries and give information of time attributes inside the region. Figure (1) shows the structure of the time scale. By adding the time scale into spatial data, land use changing activities could be better stimulated and analyzed, land use management would be better understood, the future land using will be better "designed".

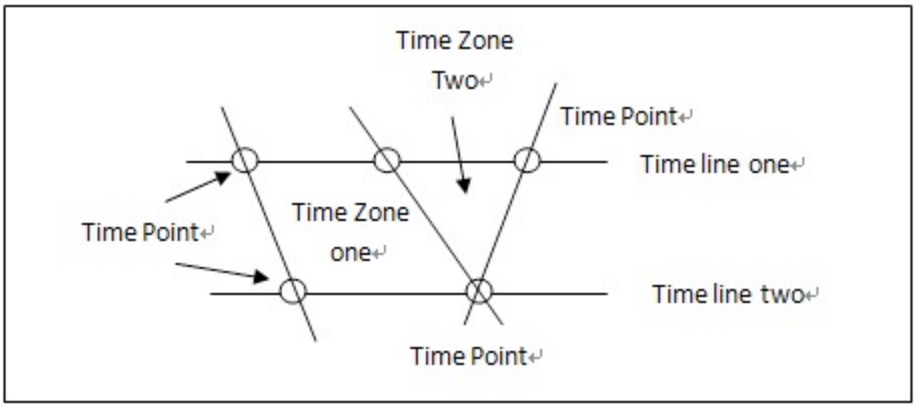


Figure (1) Structure of time scales

2.3 Spatial - Temporal Data Integration

By integrating time dimension into 2D geospatial land use database, the 3D spatial - temporal land use changing database is built for further use. The structures of 3D spatial - temporal data are designed for flexibility and extendibility. Higher dimensional data are extended from 2D spatial data structures.

$$\sum_{ord}(X, Y) \text{ …… (1) [Iwamura 2011]}$$

Here, $\sum_{ord}$ means an ordered [X, Y] coordinates sequence and (1) gives the description for the spatial only coordinates in 2D sequence.

Time scales can integrate into this 2D coordinated sequence, and the structures for time scales are:

$$\sum_{ord}(X, Y, T) \ldots\ldots (2)$$

Here, T represents the time coordinate and it might be time point, time line, or time zone. Some scholars defined the T in (2) as $|T|$ because they only related the time coordinates with changed spatial coordinates [Iwamura 2011]. But due to the complexity land use changing situations in recent years in China, the land use status vary could only in space, vary only in time, or vary both in space and time so that for the land use changing spatial - temporal database we built, almost every spatial coordinates are paired with a time coordinates. Table (2) shows the data contexts for the land use changing spatial - temporal database.

Table (2): Land Use Changing Spatial - temporal Database Information

Dataset	Data Layer	Time Scale	Geometry
Basic Land Information	Boundaries	None	Polyline
	Districts	None	Polygon
	Rounds	Time Point	Polyline
	Natural Factor	Time Point	Point, Polyline, Polygon
	Social Factor	Time Point	Point, Polyline, Polygon
	DEM	None	Cell
	Iamge	Time Line	Cell
Professional Land USe	Current Land Use	Time Line	Point, Polyline, Polygon
	Land Use Overall Plan	Time Line	Point, Polyline, Polygon
	Land Use Classification	Time Line	Point, Polyline, Polygon
	Urban Planning	Time Point Time Line	Parcel (Polygon)
Land Use Management	Land Acquisition	Time Point Time Line Time Zone	Parcel (Polygon)
	Land Supply	Time Point Time Line Time Zone	Parcel (Polygon)
	Land Reservation	Time Point Time Line Time Zone	Parcel (Polygon)

For basic land information data, such as stable boundaries and district areas, there is no time coordinate added. For rounds, natural and social factors, any start and end time point coordinates is needed because they affect the land use process in a large scale and it is good enough to apply the geodesign with time point. For remote sensing images and data in professional land use dataset, time line is applied. These time series data need to be identified and play a critical role of land use management and planning activities. For data in land use management dataset, all the three types of time scale are integrated because these data record and reflect the real time land use changing. We need to know the start and end time for every land manage and use activities, calculate and analyze the data changing based on time series, and finally we can plan and design the land use for the specific spatial and temporal zone.

3. GEODESIGN with LAND USE CHANGING SPATIAL - TEMPORAL DATABASE

This section discussed how the geodesign can be fulfilled with land use changing spatial - temporal database and a sample study is given out to demonstrate the suitability between geodesign and spatial - temporal database.

3.1 Concept

As the CEO of Environmental Systems Research Institute, Inc. (ESRI) Jack Dongermond has said [Dongermond 2010], "Geodesign borrows concepts from landscape architecture, environmental studies, geography, planning, regenerative studies, and integrative studies. Much like GIS and environmental planning before it, Geodesign takes an interdisciplinary, synergistic approach to solving critical problems and optimizing location, orientation, and features of projects both local and global in scale." In general speaking, geodesign can be identified as a decision-making methodology through any geo-related planning activities and dynamic or we could say spatial - temporal phenomenon models. It is both old and new because it is established on an innovative geo-view, integrated merits of different traditional disciplines, and provided solutions and plans for issues between human being and nature [Dongermond 2010]. The appearance of geodesign is not an accident at all. On the contrary, it is the result of the evolution of GIS and related geographical practices. Also geodesign represent the progress of science and technology and raises to satisfied the demands of society and nature. Thus, geodesign is a methodology, the ultimate gold of it is to assist, not to rule or coach [Ma 2013].

3.2 Framework and Model

The most detailed description about geodesign framework is described by Prof. Carl Steinitz, within his book 《A Framework of Geodesign》. As he mentioned in that book, "Geodesign is changing the geography intentionally [Steinitz 2012]". And the Steinitz Model of Landscape Change (figure 2) is widely used as the stander model for landscape geodesign. But in our research, the database used for geodesign is not only contains land use spatial data but also temporal data. In order to better meet the local geodesign work with the land use changing spatial - temporal database, we modified the Steinitz Model of Landscape Change into a new model and named it as "The Geodesign Model of Land Use Change (figure 3)."

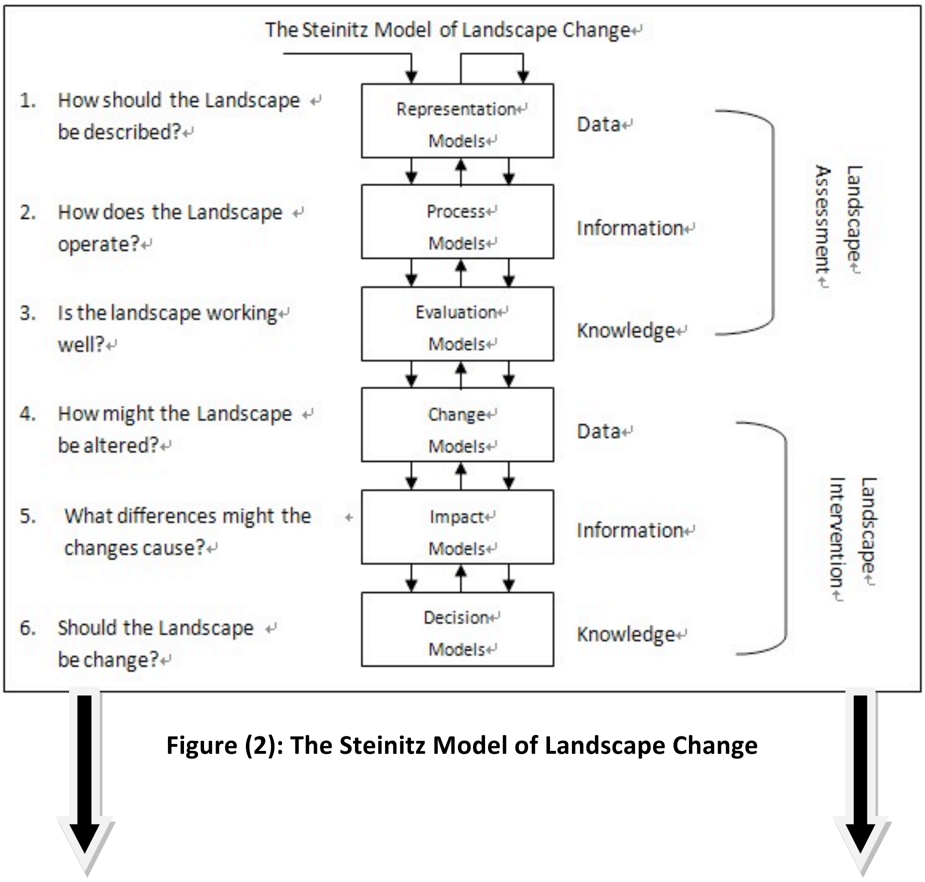


Figure (2): The Steinitz Model of Landscape Change

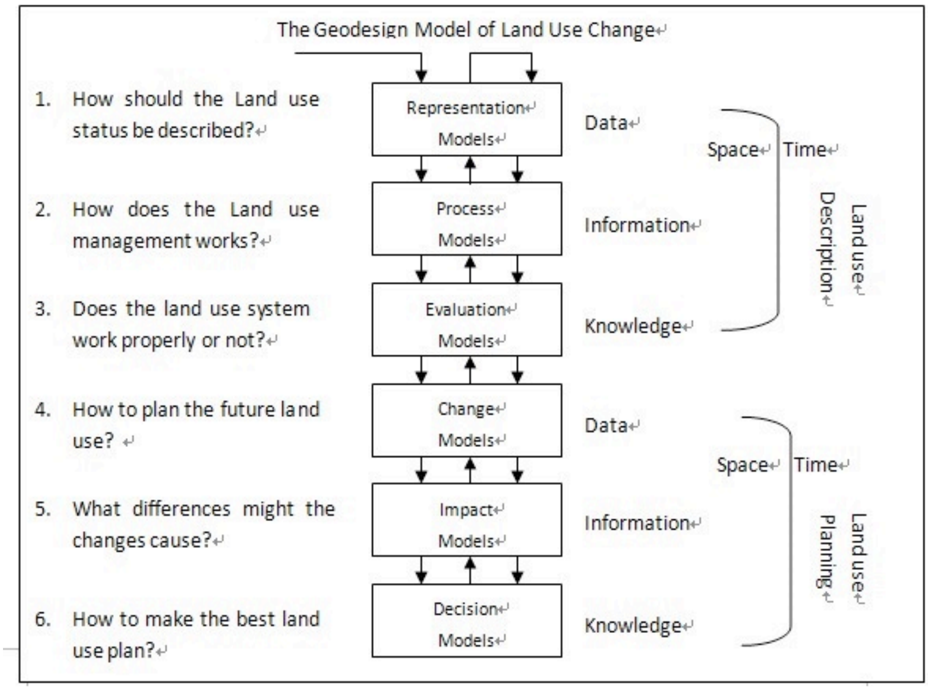


Figure (3): The Geodesign Model of Land Use Change

This model is the core part of the geodesgin framework. Based on the geodesign model of land use change, there are six questions need to be answered three times during the geodesign process. For the first round, from question one to six, we need to understand why this project is worth to be researched. For the second round, on the reverse, we look at questions from six to one to found out how to get this research done. And at the last round, once again from question one to six, we go back to these questions to answer what, where, when, and how. All the processes use the spatial - temporal land use changing database as the input for data, information, and knowledge.

3.3 Case Study with Lijiang Industrial Zone

During these years, many sample studies of geodesign have been done and well recorded. In this paper, a recent study about the geodesign for the land use change of Lijiang industrial zone is given out. Due to the lack of paper space, only general ideas is described and interested people can go to 《Report of the Land Use Status of the LiangJiang Industrial Zone》 and 《The 2013 – 2015 Plan for Land Use of Liangjiang Industrial Zone》 for more details.

Liangjiang Industrial Zone, which is located in the district city - Chongqing, is identified as the first national inland development zone in China. It is the bridgehead and open door for the Mideast of China and plays a very critical role for the regional economy and urbanization development. Land use is the most significant factor to affect the development of Lijiang industrial zone so that how to monitor the land use change and make the future land use plan are very important. In order to better manage the land resource and planning the land use, the Bureau of Land Resource at Liangjiang Industrial Zone was established at 2012 to perform the duty of land use management. The primary work they had been done is to set up a project which implemented the overall geodesign and planning for the land use within this area. Following the land use policy of China, the ultimate goal of this project is to provide the best land use plans and decisions.

This project has applied the GIS technology, spatial - temporal database, and the framework and models of geodesign during the implementation process. By the guidance of the "the Geodesign Model of Land Use" we discussed in section 3.2, the project had tried to integrate the geospatial data with time scale to stimulate and evaluate the land use and planning the land use in a best way.

As we mention above, the goal of the project and the research process is clearly defined. Thus, the six questions within "the Geodesign Model of Land Use" needed to be answered. A time series pie charts (figure 4 to Figure 6), which are created based on the basic land information dataset and professional land use dataset for the spatial – temporal database, were used to describe the land use status and to evaluate the previous land use plans. Each pie chart illustrates the land use status and land use plans for a specific year. And by comparing them together, the annually land use and planning table (Table 3) can also be generated to describe the time linear land use changing.

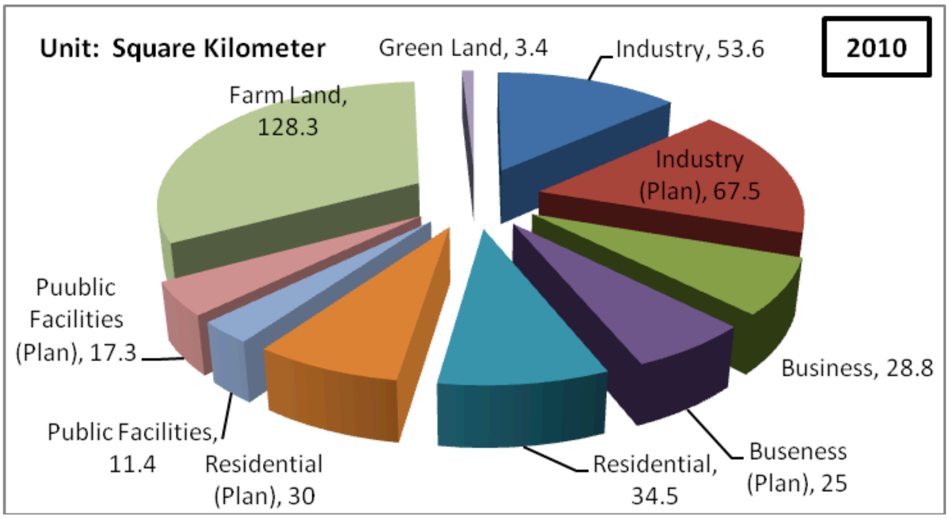
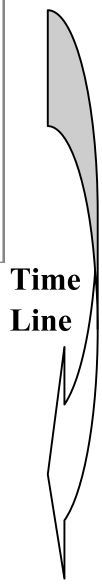


Figure (4): Land Use and Plan for 2010



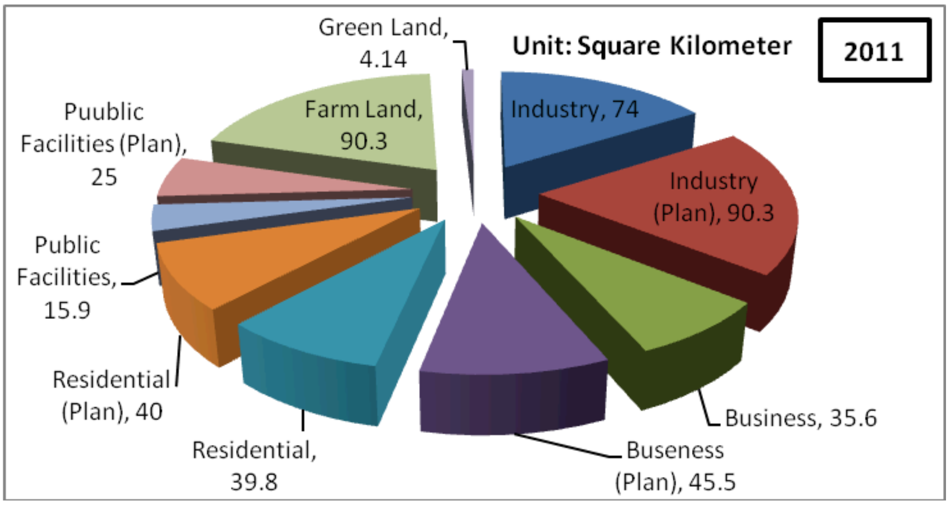


Figure (5): Land Use and Plan for 2011

Time Line

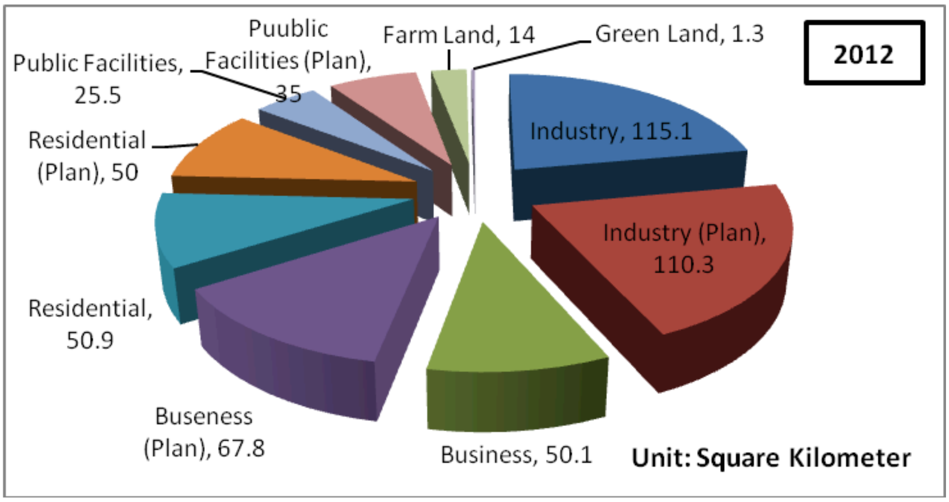


Figure (6): Land Use and Plan for 2012

Table (3): Land Use and Land Use Plan Annually Data

Unit: Square Kilometer

Land Use and Plan	Year		
	2010	2011	2012
Industry	53.6	74	115.1
Industry (Plan)	67.5	90.3	110.3
Business	28.8	35.6	50.1
Business (Plan)	25	45.5	67.8
Residential	34.5	39.8	50.9
Residential (Plan)	30	40	50
Public Facilities	11.4	15.9	25.5
Public Facilities (Plan)	17.3	25	35
Farmland	128.3	90.3	14

Greenbelt	3.4	4.14	1.3

As we can see from the figures and table, the industry, business, residential area and public facilities doubled their areas very year but the increase ration of the land use plan for these three types kept relatively still. Taking industry land use for example, it increased nearly 21 square kilometers from year 2011 to 2010 and doubled into 41.1 square kilometers in the year 2012. But the plan kept relatively unchanged, the annual increasement is around 20.0 square kilometer, same for the other types of land use plan. Another issue is that some of the land use plans does not cover the areas of real time land use, which means the plan that made before cannot catch up the speed of the development of this area. The plan for a certain type of land use might be taken by other types of land use. This mess between real time land use and land use plan might cause many problems such as inefficient land use, waste of land resources, and confusions for land manage activities. One more important thing needed to be pointed out is the decreasing of farmland and greenbelt. This issue is caused by the urbanization process. Before 2010, there are very few urban areas within Lijiang industry zone. In 2010, Lijiang industry zone was established to promote the regional development and due to the high speed of the development and urbanization, the farmland in this area decreased very fast. Considering what we have discussed above as well as the environment and cultivation protection, new land use planning must be carryout to take place of previous plan. From the spatial - temporal land use changing database, the land use status was well described and evaluated and to draw up a new land use plan, geodesign was implemented. Using the spatial - temporal land use changing databaseas as input resource, based on the land use policy in China and the “the Geodesign of Land Use Model”, a new Liangjiang industrial zone land use plan for year 2015 was designed (figure 7) and this geospatial related figure was generally projected into a manuscript (figure 8) which more matches for the “design” concept. On the manuscript, only important land use types were painted to give the general view of the geodesigned land use planning.

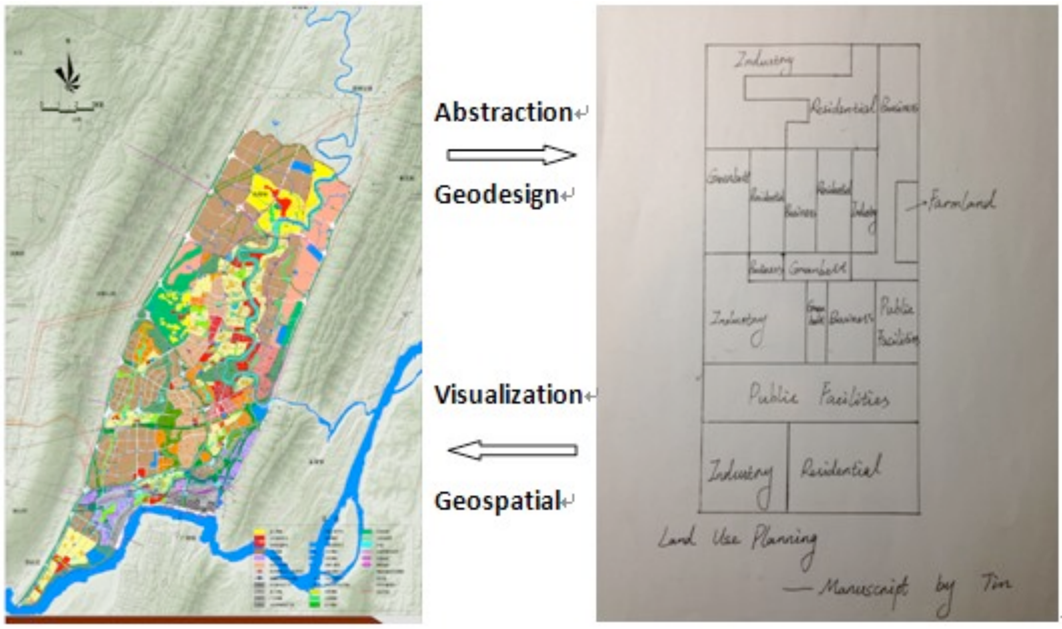


Figure (7): GeodesignedLiangjiangLand Use Planning **Figure (8): Geodesigned Manuscript**

4. CONCLUSIONS and FURTHER RESEARCH

4.1 Conclusion

Spatial - temporal database and geodesign are both new for today's geo-related researches. By integrating time scale into regular geospatial data, the spatial - temporal data can better simulate the dynamic land use process and better describe the land use changing status. And under the concept of geodesign, "the Geodesign Model of Land Use Change" was established and implement for a case study. As the results which we can see from the case study, spatial - temporal database can give more useful and meaningful land use information for users. And bring the geodesign into land use planning process, the geo-analysis was considered as one part of the designing work and this let the draft could also be evaluated and review at the first time, and better plan could be designed out.

4.2 Further Research

First, a spatial - temporal cube is being developed to display the land use changing and management process. All the spatial and temporal coordinates are projected into the cube. With this cube, features varying both in space and time can be well identified. It will be a powerful reference and tool that the geodesign could use to improve the designing work. Second, three years data (form 2010 to 2012) might not be enough for further research so that the data before 2010 will be considered and added into the spatial - temporal database to make the database more completed.

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Education Background

The University of Kansas, Lawrence, KS, USA
Master of Art in Geography (GIS), 08/2006 – 12/2009
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Working Experience

Chongqing Institute of Surveying and Planning for Land Resources and Housing, Chongqing, China
GIS Engineer *02/2012 - Present*

- Leaded the Chongqing Urban Land Classification System Program.
- Leaded the County Land Resource Data Integration Program.
- Supvised the information system implementation activities for Real Estate Price Monitoring and Management Process.
- Managed the Liajiang Land Use Planning Project.

Geographical Information Science Laboratory, University of Kansa, Lawrence, KS, USA
GIS Research Staff 10/2009 – 12/2011

- Maintained and managed all databases in the laboratory.
- Programmed GIS software for both scientific and engineering projects use.
- Analyzed spatial – temporal data, mainly for precipitation, hydrology, and land use project.

United States Geological Survey, Kansas Water Science Center, Lawrence, KS
GIS Specialist & *Computer Technician* 01/2008 - 12/ 2008

- Developed a GIS software package to store and display ground water data by using Matlab for the Kansas Water Center.
- Analyzed geo-spatial data to calculate land use properties of the entire Johnson County.
- Managed sub-watersheds delineation of Arkansas Red River Basin for geographical analysis.
- Maintained USGS and Kansas Water Science Center's publication website by using MySQL and managed publication web database on both Windows and Solaris platforms.

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