Development priority zoning in China and its impact on urban growth management strategy

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Abstract

Urban growth management is a popular topic for study area all over the world. Despite the increasingly rich literature, however, little has been considered of the complex relationship between the various urban development factors and their feedback structure. This paper contributes in understanding the mechanism of, and establishing a link between, urban growth management oriented by zoning in China (namely development priority zoning or DPZ). A system dynamics urban growth model is presented that is integrated with China's socio-economic development situation. With Yiwu city and Qingtian County as case studies, the model is applied in simulating urban growth under different driving modes. The results indicate that the DPZ in these two areas has an influence on urban growth management strategy, with the driving mode of urban growth affecting economic development levels, migration and types of land conversion. It is concluded that different driving modes are needed for different types of regions according to the functional positioning of their DPZ and that the model contributes to their identification.

Keywords

Urban growth, development priority zoning, modelling, system dynamics, China

Introduction

Managing urban growth is an important contemporary topic worldwide. Due to rapid economic growth and urbanization, there has been widespread urban sprawl in western cities since World War II (Sheridan, 2007), causing many problems, such as deterioration of the environment and the inefficient land use (Freeman, 2001; McCann & Ewing, 2003; Carruthers & Ulfarsson, 2003; Kahn, 2000; Zeng et al., 2014; Elbeih et al., 2013; Ewing et al., 2010; Lata et al., 2001). These have presented a great threat to urban sustainability, leading to many new urbanism theories and practical methods (Smith, 2002; Filion & McSpurren, 2007), with growth management becoming widely used by western nations. In North America, Europe and Japan, urban growth management provides an important means of controlling urban sprawl and encouraging intensive development (Pendall et al., 2002; Munton, 1983; Sorensen, 2003). The effect of acceleration of economic development and globalization on urban sprawl has not only troubled North America, Western Europe and other developed countries, but also many developing countries too (Sun, 2011), which have even more pressure in managing urban growth (Wu et al., 2009).

China has been experiencing a period of rapid urbanization, with its urban population reaching more than 50% of the total population in 2011 according to National Bureau of Statistics data - entering the upper half of the "S-shaped urbanization curve" (King and Golledge, 1978). By 2014, it had increased to 54.77% from the original 17.92% in 1978, with an annual average growth of 1% (National Bureau of Statistics, 2015). It is predicted that China will have an additional 310 million urban residents by 2030 (UN, 2013). However, the population and industrial distribution deviation index shows that there is a huge mismatch between the spatial distribution of the population and economy activities in China (Xiao and Shen, 2012). Moreover, urban-rural construction involves a

dual inefficient expansion phenomenon. It is inefficient in that urban land in cities is mainly expanding outwards, while the farming population in rural areas continues to reduce because of migration, increasing the amount of rural residential land. How to guide migrant movement, so that the population and economy agglomeration are matched, therefore, is a question of considerable importance in China.

In order to solve these problems, the Chinese government has implemented a strategy of development priority zoning (DPZ) since 2011, with the target of regulating the order of space development and forming a rational structure. There is no doubt that, as a spatial planning strategy (Fan, 2009), DPZ can it be carried out well only when it focuses on land (Wu et al, 2012). Cities are the main driving force for regional development, however, and, as Ding (2005) points out, China's urban land use has excessive expansion and extensive growth spatial development characteristics. This kind of urban sprawl leads to the decreased efficiency of urban land and a waste of land resources, as well as environmental degradation and the reduction of cultivated land. In other words, against the current background of rapid urbanization, the utilization of urban land not only determines the efficiency of land use, but also maintains the ecological function of the land. Rational urban growth is therefore the key to the rational use of regional land, and is one of the preconditions for fulfilling the DPZ strategy.

This paper contributes to understanding the mechanism of, and establishing a link between, urban growth management in China oriented by DPZ. Starting from urban growth strategy, we investigate the adaptation of DPZ and the driving mode of urban growth. In terms of the research approach, there is a lack of studies in both developed and developing countries of the complex and changing relationships between various urban development factors and their feedback structure. The dynamics and feedback characteristics of the system dynamics model can be used to explain the change of urban growth in a more comprehensive way. Therefore, the system dynamics approach provides a suitable means for carrying out the urban growth boundary (UGB) in the complex system associated with DPZ and urban growth management in China today. In this paper, a system dynamics model is used to describe and design the feedback relationships between the population, economy, land and DPZ strategy.

Development priority zoning (DPZ) and the urban growth boundary (UGB)

Development priority zoning (DPZ)

DPZ is the guideline for optimizing the spatial pattern of regional development in China, which entails both theoretical and methodological innovation in the academic field of economic geography (Fan & Li, 2009). As a Chinese innovation, DPZ was gradually formed based on summarizing the practical experience gained from the country’s regional development strategy and learning from developed countries about the relative conceptions of national spatial development. Although Western countries do not use the DPZ concept, the origin of its ideology can be traced back to the Western concept of *zoning* (Peng, 2009). Zoning is one of the main tools used by urban planners to control urban development, including the types of land use, open space and construction density (Wilson et al., 2003). Internationally, using zoning to promote the reasonable development, or protection, of resources is also the concern of academe. Conway and Lathrop (2005) use a simple spatially explicit model to explore potential build-out conditions under different sets of regulations,

and assert that it is a way to examine the impact of future urbanization and alternative land use regulations on the environment before irreversible changes are made. Deboudt et al. (2008) note that the institutional framework for coastal zone management in France has often foundered due to difficulties related to natural heritage reservation and land use planning designed to control urban expansion in coastal areas, arguing that the coordination of management and protection activities can considerably improve the situation. Moreover, studies such as the economic analysis of zoning (Crecine, 1967) and methods for ensuring fairness between different zones (Gary, 1981) have a particular significance for China for improving the policies of DPZ.

Based on the theoretical foundation of developed countries, China's strategy of DPZ covers a series of concepts, including spatial equilibrium, development according to resource capacity, providing ecological products, adjusting spatial structure and controlling development intensity (Yang et al., 2012). However, DPZ planning was initiated very recently and therefore academic research has mainly concentrated on theoretical principles (Li & Mi, 2008; Zhu, 2007; Fan, 2009), partitioning approaches (Zhang, 2007; Ding et al., 2010) and supporting policies (Zhang et al., 2010). While the literature indicates that DPZ has become the most important policy influencing China's urban growth, there is nevertheless a lack of studies into the complex and changing relationships between DPZ strategy and urban growth management. With its further implementation, the effects of development factors such as land expansion, economic promotion and population growth are expected to be the subject of new studies.

Urban growth boundary (UGB)

The UGB is one of the most widely used planning tools in growth management to control urban sprawl, curb speculative behaviour, improve the efficiency of city services and conserve the areas outside boundaries (Jun, 2004; Tayyebi et al., 2011; GreenbeltAlliance, 2012). The American Planning Association suggests that UGB be established “to promote compact and contiguous development patterns that can be efficiently served by public services and to preserve or protect open space, agricultural land and environmentally sensitive areas” (Meck, 2002). As a proactive growth management tool, the UGB limits urban development to within a reasonable and fixed area (Calthorpe and Fulton, 2001; Anderson, 1999) to promote compact and continuous urban development, and avoid low-density and dispersed development (SmartGrowthBC, 2014). On the other hand, some argue that UGB can yield undesirably draconian outcomes (Brueckner, 2000). It is important to understand that, rather than limit and conflict, the purpose of urban growth management is to provide a balance. As Chinitz (1990) notes, growth management is aimed at maintaining the equilibrium between development and protection, form of development and infrastructure supply, public service demand and financial capacity, as well as progress and equity. It is a dynamic process in which governments balance local and regional interests, as well as conflicts over land use objectives, to adapt to community development (Chapin, 1997). This is reflected in Lv and Xu’s (2010) research, which argues that, although it presents a boundary between construction and non-construction areas, UGB is essentially the balance of growth and restriction, demand and supply, and power and resistance.

With the rapid development of urbanization in China, studies of UGB in urban growth management have gone further. In its early stages, many researchers (e.g. Lv & Zhang, 2005; Feng

et al., 2008) discussed the use of UGB in western countries and its potential for China. Later, major studies turned to the adaptability of UGB in China (Wu & Zhong, 2011; Han, 2014). Because of the similarity between the delineation and control methods, in the broad sense, Wu et al. (2009) argue that the combination of China's current forbidden zones, limited construction areas and the urban construction land boundary is effectively China's UGB. Recent studies are mainly concerned with modelling and performance evaluation. Fu et al. (2016) use the BP artificial neural network method combined with GIS and RS technology to establish a UGB prediction model, while Long et al. (2015) propose an analytical framework for the evaluation of the adoption of UGBs in China. A key aspect is in deciding on how much urban land is to be included inside the boundaries and when it should be extended. To support such decisions, Knaap and Hopkins (2001) propose a land inventory model based on the concept of inventory management, with time- and event-driven modes to control the UGB. Han and Kung (2011) suggest that event-driven mode costs are lower than those for the time-driven mode, while Wei K (2013) finds that if the holding cost of land is low, the event-driven mode can become an ideal way of controlling UGB. In contrast, if the holding cost is very high and the land management system is inadequate, governments are more likely to choose the time-driven mode. When demand is uncertain, the event-driven system is more effective, partly because it does not need to expand the initial reserve to prevent a shortage in land supply (Intriligatou & Sheshinski, 1986). In terms of research approach, there is a lack of studies in both developed and developing countries of the complex and changing relationships between various urban development factors and their feedback structure.

In summary, urban growth management is an important aspect of urban development that aims to maintain a balance between development and protection. Different cities have a different foundation and potential and, to achieve smart growth, it is necessary to establish scientific urban development goals guided by DPZ. UGB offers a potential means of helping to bring this about. In this paper, therefore, we examine the integration of the driving modes of the UGB with DPZ to ascertain their impact on China’s land use, population and economic development.

Methods and data collection

System dynamics is a type of simulation method, established in the 1950s. It is based on systems theory, drawing on the essence of control theory and information theory, using computer simulation technology as the main means of operation, and involving structure-function analysis to study and solve complex dynamic feedback system problems (Cai, 2008). System dynamics is known as the strategy and decision-making laboratory, which is used to solve problems associated with social, economic, ecological and other nonlinear complex systems (Xie, 2010). According to the mutual effects between urban growth management and DPZ, the system dynamics approach is used to understand the mechanism of urban growth management oriented by DPZ. *Vensim* is one of most popular simulation software tools in system dynamics research and its rich set of features emphasizes model quality. In this paper, we build an urban growth system with the help of the *Vensim* software. We then examine the system for consistency, sensitivity and subsystem rationality to show that the model is reliable. The land use situation is next simulated under two different driving modes of urban growth strategy. One is the *time-driven mode*. In this mode, UGB is adjusted according to a time interval and the rest of the land supply is predictable. The other is the *event-driven mode*, where land can be provided as long as there is a demand, which means there is no restriction on overall quantity. Neither mode is best for all situations and each’s application

depends on its adaptation to different regions. Therefore, we then analyse the adaptation of the modes in DPZ based on the simulation of urban growth scenarios.

The paper compares the cases of Yiwu and Qingtian, both of which are located in China's Zhejiang province. Data relating to Yiwu and Qingtian were collected for the 2005-2012 period from the Statistical Yearbooks of Yiwu, Qingtian, Zhejiang province and China City, the official websites of the Yiwu and Qingtian governments and other published literature. The results of two research studies linked with the Central Government of Yiwu and Qingtian ensure the quality of data available for analysis.

System dynamics model for urban growth oriented by DPZ

This section presents an urban growth system that aims to (1) use system flow diagrams to depict the process of urban growth; (2) explore the mechanisms of different urban growth driving modes with the influence of DPZ strategy, and (3) observes the responses of the population, economy, land use and other indicators.

As discussed earlier, this paper focuses on urban land expansion guided by the DPZ strategy, and therefore the major components of the system are the DPZ subsystem and land subsystem. The population subsystem and economic subsystem are also included, as they are major driving forces of urban growth and closely related to the implementation of the DPZ strategy.

Conceptual model

The paper studies the influence of urban growth management strategies oriented by DPZ. As the literature review indicates, urban growth is comprehensively driven by natural, economic, social, policy, sci-tech factors, etc., with the most fundamental factors being economic and social. Figure 1 illustrates our urban growth system conceptual model combining these driving modes and DPZ. To simplify the model, only economic and social factors are used at this stage. This conceptual model provides the theoretical support for the establishment of the system dynamics model.

<Insert Figure 1 here>

The urban growth system conceptual model (Figure 1) incorporates urban growth feedback loops. Economic development, population growth and major construction projects generate demand for land. However, not all needs can be satisfied due to the limited land resources available. Balance and restriction carry the most weight in the application of the urban growth-driving mode in China. In other words, urban growth requires scientific control to promote the rational use of urban land. The urban growth-driving mode is determined by DPZ policy and mode type. The most suitable urban growth-driving mode should not only conform to the DPZ functional positioning and meet the needs of economic development, but also take into account the land's resource capacity, intensive use and other restrictions. Therefore, the extent of satisfaction is determined by the urban growth-driving mode, while the intensity of the urban growth-driving mode is determined by efficiency restrictions, resource restrictions and economic promotion. The states of economic development, population growth and land use structure are fed back to the urban growth-driving mode through these restrictions and promotions. Depending on the choice of land demand or urban growth driving mode, the amount of new urban land supply can be ascertained and the land use

structure adjusted accordingly. This revised structure is fed back to the population and economic subsystem, prompting their further development and generation of demand for new land.

Variables

The variables in the urban growth system conceptual model are shown in Table 1.

<Insert Table 1 here>

Flow diagram

<Insert Figure 2 here>

The important feedback loops in the system are:

<Insert Figure 3 here>

There are seven major feedback loops. One is related to agricultural land. Changes in agricultural land are accompanied by changes in cultivated land, and changes in cultivated land affect the amount of land transfer via an urban growth driving mode multiplier; the affected amount of land transfer ultimately feeds back to the agricultural land; while two of the loops are related to urban land. On one hand, the urban land area determines land demand while, on the other hand, it also affects land use efficiency. These two variables affect the amount of land transfer by the urban growth driving mode multiplier and thus feedback to the urban land area; three of the loops are related to the GDP of the secondary and tertiary industries. The GDP of the secondary and tertiary industries in turn influences GDP per land and GDP per capita, both of which are major variables of the urban growth driving mode multiplier that have an effect on land transfer area, which then strengthens GDP growth. This last aspect is related to the permanent population. An increase or decrease in the population can cause changes in land demand, which affects land transfer area and GDP growth. GDP changes cause changes in GDP per capita, which in turn feedback to the temporary population. These feedback loops constitute the main structure of the model.

Scenario simulation

Case area

Zhejiang province started DPZ planning in 2013. Based on a comprehensive evaluation of land development, the planning divides the total area of the province into optimization development areas, important development areas, restricted development areas and forbidden development areas. These four types of areas are categorized here as *development-type areas* (optimization development areas and important development areas) and *protection-type areas* (restricted development areas and forbidden development areas), and typical cases of each type were selected.

Yiwu city and Qingtian County were chosen as a pair of study cases. Their location is shown in Figure 4.

<Insert Figure 4 here>

Yiwu, known as the largest commodity market worldwide, is located in the centre of Zhejiang province. With the rapid development of its exhibition, logistics, finance, tourism and other modern service industries, Yiwu's economic development has increased significantly in recent years, placing it at the forefront in Zhejiang Province. Qingtian County, located in the south of the province, has a long history. Its economic development level is relatively low, with a predominantly population outflow. However, the ecological environment in Qingtian is the best in Zhejiang province, so it has a strong ecological service value. The important indicators of Yiwu city and Qingtian County in 2010 are compared in Table 2.

<Insert Table 2 here>

Therefore, with its high level of economic development and population capacity, Yiwu city is chosen to represent the development-type area, while Qingtian County, with its small population outflow, low level of economic development and ecological services, is chosen to represent the protection-type area.

Simulation results

To proceed further, it is necessary to normalize the simulation results because they are measured on different scales. Taking the indicators in 2012 as the standard indicators to be indexed at 100, the relative values of other indicators of the calendar years (2013-2020) are transformed by dividing by the 2012 values to provide a comparison between the simulation results of actual values of Yiwu and Qingtian. The key indicators are illustrated in Figure 5.

<Insert Figure 5 here>

Figures 5(A) and (B) illustrate the simulation results in the *development-type area* (Yiwu) under the time-driven and event-driven modes respectively. In *time-driven mode* Figure 5(A), urban land grows slowly and agricultural land reduces at a relatively slow speed; economic growth is limited and the extent of GDP growth is small; the permanent population increases at a slow pace and GDP per capita grows slowly; due to the limited urban growth, land use efficiency within the boundary increases. This mode inhibits economic growth and population immigration, which is not suitable for a development-type zone. In *event-driven mode* Figure 5(B), urban land growth depends on demand, and the annual increase of land varies widely; urban growth is relatively quick, while agricultural land is rapidly reducing; even though the increase in permanent population is relatively large, GDP per capita growth is still faster than the time-driven mode; however, land within the boundary is of relatively low efficiency. This mode meets the functional orientation of the development-type zone.

Figures 5(C) and (D) illustrate the simulation results in the *protection-type area* (Qingtian). In *time-driven mode* Figure 5(C), urban land growth is relatively slow and agricultural land reduces slowly; economic growth is limited; the permanent population decreases and GDP per capita slowly increases; due to the limited urban land growth, land use efficiency within the boundary increases. This mode meets the functional orientation of the protection-type zone. In *event-driven mode* Figure 5(D), urban land growth depends on demand, and the annual increase in land varies widely; urban growth is relatively fast and agricultural land rapidly reduces; even though GDP per capita growth is relatively faster than the time-driven mode, the decrease in permanent population is small; while land within the boundary is of relatively low efficiency. This mode occupies a large amount of agricultural land and slows down population emigration, which is not suitable for a protection-type zone.

The scenario simulation results indicate that the urban growth strategy based on the event-driven model is more suited to Yiwu. In this way, although the city is relatively larger, a better economic development will be achieved, and with a higher GDP per capita than with the time-driven mode. The more advanced development of the upper level region matches its functional positioning of a new growth pole of economic development, to continually support the entire region and play the role of the engine of economic development. In addition, the temporary population in the event-driven model is greater than with the time-driven model, which meets Yiwu's function as a receiver of population transfer. More importantly, the construction of major projects is the foundation for social and economic development and the event-driven model fits the demand for land for such projects. The event-driven model is therefore better for promoting regional socio-economic development. Although the GDP per land is slightly lower in the event-driven mode, its land efficiency remains at a reasonable value because of the cultivated land constraint and land use efficiency feedback in the model. However, this is also a reminder that excessive focus on economic development and population inflow may lead to urban sprawl and consequent diminished land use efficiency. In conclusion, therefore, the UGB in Yiwu should be executed mainly under the event-driven model, since urban growth with no definite time limit is mainly determined by population inflow, economic development and the introduction of major projects.

Compared with Yiwu, the scenario simulation results indicate the time-driven mode to be more suitable for Qingtian County. Based on its overall function, Qingtian County should control development speed, encourage population outflow and focus on providing ecological and agricultural resources. With the time-driven mode, urban growth is relatively slow. Meanwhile, due to the limits on urban land, constraining industry development and major construction projects can slow the decline in agricultural land area. Furthermore, because of cultivated land protection and the internal restructuring of agricultural land, the amount of cultivated land in Qingtian could increase at a faster pace. In terms of population, the permanent population is relatively small under the time-driven mode, reducing the population burden of Qingtian County. Moreover, land use efficiency is relatively high with this mode, which is beneficial in reducing the occupation of agricultural and ecological land. Therefore, in terms of social and economic development, Qingtian County should choose the time-driven mode with cultivated land protection to determine its UGB.

Discussion

DPZ should play a positive role in aspects such as the rational exploitation and utilization of resources, ecological construction and environmental protection, amelioration of the production and

living environment, enhancement of regional capacity for sustainable development and competitiveness (Fan, 2009), as well as the ability of UGB to affect the pattern of spatial development and social economic development by controlling the density and location of open spaces (Meck, 2002). In order to integrate urban growth management closely with DPZ planning, both should ensure planning consistency and avoid unnecessary conflicts leading to the decentralization of regional strength. In scenario simulation with the system dynamics urban growth model oriented by DPZ, the variables involved in promoting planning consistency include *threshold value, urban land per capita, proportion of cultivated land, driven multiplier* and *policy coefficient*. In urban growth management, governments (especially in *development-type* areas) should make timely adjustments to the *threshold value* in accordance with the urban land use efficient. Once the extent of urban land intensive use becomes low and sprawl appears, it is necessary for the government to decrease the frequency of the UGB adjustment and reduce the scale of UGB expansion, to uncover the internal potential of the existing urban land and to promote population and industrial agglomeration. *Urban land per capita* is a key indicator of the extent of land intensive use and both *protection-type area* and *development-type area* should gradually reduce this indicator within reasonable limits to improve population carrying capacity. For a specific implementation, the government should develop an appropriate standard for urban land per capita based on the orientation of functional area and the characteristics of industrial structure. The *proportion of cultivated land* is more important for the *protection-type area*. The main agricultural producing areas should actively adjust the internal structure of agricultural land and increase the proportion of cultivated land in order to increase agricultural output. However, the ecological function areas should take measures, such as returning farmland to forests, to improve ecological services. *Driven multiplier* and *policy coefficient* are UGB and DPZ respectively embodied in the system, the settings of which should give a closely integrated regional function and development. These factors need to be the focus in the real urban growth system.

Rapid urbanization and inefficient land use is undoubtedly a major challenge for China's urban growth management. As one of the most popular urban growth management tools, UGB not only possesses a flexible management function but also can provide rigid-control. Thus, UGB offers a potential means of establishing scientific urban growth management goals guided by DPZ. China is currently exploring the use of UGB as a control tool, such as for the urban development boundary, the basic farmland protection red line and ecological protection red line. However, UGB was born in the United States and is mature in more developed countries with a background and ideas far different to China, so it is necessary to research, compare and integrate continually in practice (Feng, 2008). According to China’s national situation, Han (2014) believes that the time-driven mode is more suitable for planning practice in the short term, while the event-driven mode is more suitable in the long term as it takes into account multiple expansion decisions, with a lower cost and a relatively mature technology for monitoring and adjusting the boundaries. On the other hand, DPZ planning in China is very new, so there is a lack of practical experience to date in its application. Internationally, many countries use some form of zoning for urban or regional development and, although the practices involved vary, the purpose is the same, which is to implement different policies for different classes of regions to ensure that their development matches their characteristics (Edward, 2005; Shi, 2003; Surhone et al., 2010). The successful experiences of these countries and regions in the process of implementation have significant implications for China in improving its DPZ policies.

The simulation results show that, although involving two modes in different areas, the system behaves the same, but with a different meaning for the two different types of DPZ. However, DPZ has an important influence on urban growth, placing a greater emphasis on regional function. Accordingly, the development of a functional area and the changes to its environment and ecosystem will affect other regions (Ding, 2009). If there are no good measures to internalize the externalities, the discrepancy between the DPZs will increase. Therefore, the implementation of DPZ planning should be based on the ideal functional transmission. In line with the rational utilization of land, it is proposed that the DPZ strategy should be integrated with regional land use policy (Wu et al., 2012). In China, although the development of land resources has effectively supported the rapid development of the national economy and social progress (China's State Council, 2011), it has caused many problems. Currently, General Land Use Planning provides an important means of direct government intervention in land use, which uses indicator distribution means to control and guide land use, but in the context of rapid urbanization, planning targets have been repeatedly exceeded and frequently modified. Moreover, since General Land Use Planning is decomposed from top to bottom, the process of indicator distribution is fraught with subjectivity and arbitrariness. In order to solve these problems, it is necessary to explore the transfer of development rights (Ding, 2008) to promote urban growth, while still meeting the needs of the functional positioning of DPZ and the distribution indicators of General Land Use Planning, (Levinson, 1997).

Conclusion

Urban growth management strategies are needed to control urban sprawl, and areas with different functions (and hence with different spatial land patterns) affect their choice. The use of DPZ to guide the development of urban space was discussed and the adoption of urban growth driving modes to meet DPZ. A DPZ-based urban growth system was presented based on system dynamics to model the various feedbacks involved. This involved the concept of UGB which, as a principal approach for urban growth management strategy, provides a dividing line between urban areas and surrounding non-urban areas by controlling borders and a reasonable proportion of urban land and non-urban land. The system is demonstrated with a scenario simulation of Zhejiang province's Yiwu (a development-type area) and Qingtian (a protection-type area) to identify the appropriate strategies to use.

DPZ provides a macro perspective of regional planning and therefore potentially involves a very large number of variables involved in the urban growth system. Due to data and time constraints, these have been limited to (the pivotal) economic and social factors in this paper, leaving room for improvement in future work. The paper is also limited to the study of "quantity", namely urban growth scale, with no analysis of space. Taken together, DPZ as a regional planning concept and the UGB as a space-controlling tool should be closely combined with space analysis. In future studies, the result of this paper can be applied to space research to reflect the UGB on the map. Further research is also needed to investigate the effectiveness of the system by examining more cases to compare different DPZ practices and urban growth driving mode choices for improving urban growth management.

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