

The Unit Growth Countermeasures of TOD Mode Based on the Concept of Smart Growth—Beijing’s Development Countermeasures of Mega-City Decentralization as an Example

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Abstract—Choosing the smart growth model requires a good time to intervene at a certain stage of urban development. As a premium mode for urban growth, unit growth can make a city much more convenient, significantly improve its using quality, reduce the demand for urban transportation, and alleviate urban traffic problems. The TOD mode is the basic mode of land use for “Beijing-Tianjin-Hebei on the track”, so it is important to promote unitary TOD within city clusters and develop unitary TOD within cities. It is a smart decision on urban development to combine the concept of smart growth and unit growth in TOD development.

Index Terms—smart growth, unit growth, TOD mode, Beijing-Tianjin-Hebei on the track, Beijing decentralisation

I. INTRODUCTION

Northern China relies on the capital to gather a strong development momentum, which is the inevitable choice for northern China based on geographical factors. Beijing also has had a strong development momentum by virtue of the capital effect, which is strong and sustainable. Beijing’s population stood at nearly 22 million in 2020 [1], reaching a historical peak. The ratio of its population to the national population has increased from 1.46% to 1.55%, though it is only 1/500th of the size of the country. It is clear that the ratio is too high, and depopulating the city has been on the agenda for several years. As a result, however, after declining for several years between 2017

and 2019, Beijing’s population rebounded in 2020, rising to nearly 22 million. The city is still expanding, and this momentum will continue for several more years. In view of the problems of mega-cities such as Tokyo, Seoul, and Mexico City, especially the consequent problems about the environment, traffic congestion, ecology, and internal depletion, the Beijing government has changed its policy on further developing the city into a mega-city or super-city and on the metropolitan area development. The government has adopted the idea of city cluster development, building the mode of Beijing-Tianjin-Hebei on the track. [2] The mode of mega-city and the monocentric metropolitan areas will be replaced by that of Beijing-Tianjin-Hebei on the track. In addition to the core area, the rest of the region, which is moderate in scale, will be scattered geographically, while people will be concentrated mainly in each region. It is undoubtedly a wise decision for Beijing to abandon the mode of blindly expanding along the periphery, to define the urban development boundary, to adopt the smart growth mode internally, and to adopt the mode of “Beijing-Tianjin-Hebei on the track” city clusters externally.

Smart growth, an urban planning strategy, was put forth by the United States in the 1990s. [3] The questions in China then were, what reflects smartness in Chinese cities and what decisions constitute correct ones to solve urban problems, especially congestion, internal friction, and optimisation of the urban structure. Transit-Oriented

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Development (TOD) and unit city are growth modes to improve the structures of cities. These are not simply ways to construct cities using all available single space or renovating old spaces, but these are ways to utilise existing urban resources, guide urban demand, achieve structural optimisation within cities, and build better human settlements.

Smart growth and TOD can bring vitality to Beijing, forming a benign city with TOD at its core, improving the ecological environment and creating a benign inner-circulation consumption environment. These are essential for reshaping the industrial development of cities and will form new dynamic energy for industries, especially the service industry, in future, for optimising industries and integrating regional industry development.

II. SMART GROWTH REPRESENTS A SHIFT IN URBAN PLANNING FROM HIGH GROWTH TO HIGH-QUALITY DEVELOPMENT

'Smart Growth America', an organisation established in 2000 [4], advocates that: urban spaces should not be expanded, growth within cities should be achieved, and urban stock spaces should be created; [5] existing communities should be reconstructed, transformed, and improved, and industrial land that has lost its vitality should be redeveloped; urban spaces should be concentrated and compact, and the idea of broadacre cities should be abandoned; mixed land functions should be encouraged and clear zoning should be opposed; the development of public transportation and slow transportation should be encouraged; public open spaces should be protected to ensure public facilities have a comfortable environment and sharing can be realised at multiple levels.

In the United States, the most serious problem brought by the idea of broadacre cities is urban sprawl. [6] The primary goal of smart growth is to control urban sprawling and bring prosperity by innovating spaces in productive cities. Thus, smart growth is a revision of the idea of the broadacre cities, and it provides new development opportunities. [7]

The TOD mode was also proposed to deal with urban sprawl. It differs from smart growth in the United States. The smart growth mode includes the development of old towns, while the TOD mode includes construction of new high-density mixed-use urban growth poles at train and subway stations. [8]

In the early stages of urbanisation, cities would choose the smart growth mode to save costs, relying on resources in old towns to develop new functional areas. Beijing adopted this mode between 1949 and 1980. In the medium term, urbanisation has developed rapidly, and cities have expanded considerably; they require large amounts of urban construction land. In such cases, the amounts of construction land were often more than ten times as much as those in the old towns. It is not possible to use the smart growth mode in old towns to meet the demand of growth, so governments actively planned to build new urban spaces. In the late stage of urbanisation, the scale of cities has expanded, occupying a lot of arable land. The problem

of extensive development within cities has become apparent and serious, and the main contradiction of urban development is not expansion, but internal deepening, optimisation, and internal restructuring. Delineating urban development boundaries, using internal urban resources, and dependence on the developed stock of land resources are optimal development countermeasures, and these constitute smart growth. [9]

The main countermeasures for smart growth are.

- (1) Using the stock of land resources.
- (2) Regenerating urban areas that have lost their vitality. For example, deserted industrial areas and failed economic and technological development zones.
- (3) Transforming old cities and upgrading cities.
- (4) Improving the internal structures of cities. The idea of unit city and TOD urban development is the smart growth mode with internal structure optimisation.
- (5) Organic growth. Urban infrastructures are properly optimised and increased to properly increase urban space.

Smart growth can prevent cities from becoming larger and rejuvenate the ageing centres of cities. Most importantly, adopting the smart growth mode is inexpensive and quite feasible.

III. UNIT GROWTH FUNDAMENTALLY RESHAPES URBAN SPACE AND RAISES THE LIMITS OF CITIES

A. The Concept of Unit City

1) *Large cities form a huge transportation network due to various different transportation needs.* The larger the city, the clearer the zoning. The more diverse and dispersed the starting points and destinations, the more complex the transportation networks. As a result, people end up wasting increasing amounts of time on transportation, and trip efficiency is greatly reduced. Thus, the overall efficiency of cities is reduced. We can conclude that the scale and complexity of a city are negatively correlated with its efficiency. If functions are arranged properly, each unit in a certain area will be a complete and appropriately sized urban functional complex, and most of the residents will live, work, and enjoy pastimes in this area. This area can be called a city unit, and a city composed of several urban units is a unit city.

2) *Job-housing balance is the most important feature of a unit city, and it can be achieved under three situations.* First, residents have lived in old residential buildings and compounds located in the central area of a city for a long time. Before housing reforms, their companies and factories provided them housing to facilitate their commute to work, and so, their houses were not too far away from their workplaces, forming a point-point job-housing balance. With the development of cities and the country, these people gradually retired. Furthermore, the quality and development intensity of these residences lag behind the average level of cities, and so, housing prices in these residences also lag behind, and the values of their houses are not at par with that of the value of the land. Second, new residents of a city, such as young people

attracted by well-paid jobs, are willing to rent cheaper housing near their companies along subway lines, forming a point–line job–housing balance. The proportion of this type of people is positively correlated with the employment opportunities provided by the city. For example, Shenzhen, as a young city, has the shortest commute time and better job–housing balance. The third type of job–housing balance is usually in the employment growth pole of some multi-core cities, and the growth pole should be located at the edge of a city, forming a point–point job–housing balance. However, it is challenging to meet such conditions. If the growth pole is not sufficiently strong, the city will not be able to attract enough residents to work for forming the job–housing balance, and if it is too strong, it will increase the price of surrounding land, and so, people who work here would not be able to afford housing; as a result, people from farther away will move to these areas to work and affect the job–housing balance. [5]

3) *The daily operation of a city can be measured in terms of speed as well as efficiency.* A unit city can effectively improve the operational efficiency of cities and allow citizens to have plenty of time to enjoy pastimes or exercise. In contrast, an inefficient city is congested, peoples' extra input no longer yields more output in industrial and commercial industries, and young people living in remote and crowded rooms do not have the desire to expand their families, suffering from an urban disease together with their city.

B. *Concept of Flat Management for Unit Cities*

For small systems, management is direct and efficient, but as the size of cities and the number of management levels increases, efficiency gradually decreases, and a large number of people are in management positions rather than in production. Rather than copying the same city model several times, unit cities have to change from urban planning and urban management to flat and unitary management, forming a management mode similar to that of community autonomy units, reducing unnecessary procedures and management positions and facilitating the formation of public participation.

C. *Apical Dominance as the Main Reason for Unit Cities to Become Gigantic*

The development of cities has apical dominance. Cities that want to achieve a competitive advantage in a certain area need to focus on developing a certain industry. By doing so, an internal aggregation effect can be brought about and a representative pillar industry can be eventually developed by selecting superior industries and eliminating the inferior ones. However, for cities that already have apical dominance, such as Beijing and Shenzhen, overpowering growth poles inhibit the development of other areas in the cities. For example, Zhongguancun and the China World Trade Center have gathered too many jobs and talents. Thus, many communities within the Third Ring Road have high costs of land but no vitality. Therefore, it is important to transform single-centre giant cities into unit cities for lightening the traffic burden on downtown areas and reducing unnecessary traffic

demands in cities. [2]

1) *Unitisation*

- (1) Unitisation of urban functions. Controlling the scale of growth poles within a reasonable range is the core of urban unitisation. At the same time, the production parts in cities should be less motley, for example, enterprises in the same office building should be of the same type or can complement each other instead of being a motley collection of companies. In the case of limited scale, we should ensure the benefits of the aggregation effect as much as possible to ensure the grade of industries.
- (2) The unitisation of urban spaces does not mean forming monotonous and homogeneous urban units but means forming distinctive units according to functions. The urban appearance of units and traffic patterns should maintain uniqueness and avoid expansion and integration between units.
- (3) Different units should have certain boundaries. A strong tendency of integration between different units will form a complex and ambiguous urban space again, which will reduce the unitary nature of cities and increase the cost of housing and employment, and this is not conducive to urban renewal.

2) *Transportation inside and outside units*

- (1) Circulation inside units ensures travel efficiency. Long commuting distances lead to low traffic efficiency. A large number of people spending large amounts of time on the road due to long-distance trips is the main reason for serious traffic congestion. Therefore, circulation traffic inside units such as shared traffic and public transportation can meet peoples' most frequent daily travel needs, providing a larger supply capacity, reducing the total traffic turnover, and making traffic a guarantee of high efficiency within units rather than a guarantee of high demand in giant cities.
- (2) Slow travel inside units ensures travel quality. Since the average travel time in unit cities is greatly reduced, people have more leisure. Furthermore, slow travel has greater benefits for physical and mental health as well as low carbon emissions, ensuring environmental protection. Small neighbourhoods comprising slow travel systems can also create a congenial atmosphere for streets, maximising the liveability of people.
- (3) Rail transit is the main way to connect units as well as the main way to form a point–line job–housing balance. It can make up for the inability to form a job–housing balance within units, making a complex traffic OD network unnecessary. If traffic demand among units is low, the intervals of stations and the speed of rail operation can be significantly improved, thus making urban rail transportation faster. The fact that a rail ride consumes approximately 1.7 times more time than a motor vehicle ride will change.

- (4) Driving vehicles is the main way people travel in the suburbs. Unlike the US, where people often commute from suburbs to cities, people often travel from cities to suburbs for recreation.
 - (5) External transportation in cities. Transfer between high-speed trains and subways should be seamless. The awkward situation that it takes half an hour to travel on high-speed rail and one and a half hour to board trains between city clusters should be changed.
- 3) *Size of units*
- (1) The size of units is determined by traffic. The travel distance of internal circulation is generally within 4 km. Therefore, the maximum size of an eco-city (ecological city) unit can be equal to a rectangle with one side 4 km long, a circle with a radius of 2 km, or an octagonal shape, which also corresponds to the area of the eco-city unit function configuration service area. If we plan according to area, the residential area will account for approximately 1/3 of the total area of the eco-city unit, i.e., approximately 5 km², and the population of each eco-city unit can be controlled within 100,000.
- 4) *Functions of units*
- (1) If each eco-city unit has a large number of functions similar to others, the traffic between units is greatly reduced. Due to the presence of work zones, urban eco-city units often have their own characteristics based on the idea of heterogeneous centres, and a certain amount of traffic is inevitably generated between units. Units should be arranged as close together as possible. Furthermore, streamline crossing should be avoided.
 - (2) Ecological urban units do not exclude partial polarisation. They take on the function of urban characteristics. The resulting problem of huge traffic volume can be solved by means of public transportation, especially rail transportation.
- 5) *Planning points*
- (1) Although a unit city is an urban model, as an idea of urban planning, it differs from single-core giant cities, that is, not building a new city from nothing; as a result, the number, size, and type of units are reasonably delineated according to the scale of the city.
 - (2) Most of the problems in modern cities are a result of cars. City planning prioritises vehicles, ignoring slow travel. Therefore, there are several short-distance trips in ecological units. Inner road design prioritises the needs of pedestrians and bikers, and motor vehicle lanes are not too wide.
 - (3) Balance of unit advantages. Equalising the allocation of resources among districts of a city is a challenging task. High-quality resources, such as key schools and medical institutions, tend to accrue in certain districts. These need to be allocated to each unit of an urban centres during urban unitisation. [10] The TOD mode narrows the gap between regions by extending advantageous

districts along bus routes, while the TOD mode arising from the planning practice of new urban districts in recent years has increased the advantages of new districts by transferring administrative and other service facilities to the districts. Both modes provide valuable insights. The allocation of commercial, educational, and medical resources in a chain mode is desirable.

- (4) Real estate management. Inflated charges for real estate transactions will cause long-term disparity between places of residence and work. Governments should take the responsibility of managing basic housing. The real estate development mode should be transformed and policy support should be increased to prevent inflated housing prices and rents and ensure an acceptable cost of living.
- (5) Employment mobility is high in giant cities, unlike in small- and medium-sized cities where occupation and residence are relatively stable. Flexible policies on renting and changing houses are needed to reduce the cost of moving houses, and thus, ensure advantages of unit cities.
- (6) Maintaining the agglomeration effect. To address the contradiction between unitary land use and the agglomeration effect, more detailed research is required on the spatial layout of urban industries; this will ensure that closely connected industries are spatially close to each other, public service facilities are shared, and fast and effective transportation is provided between units to reduce barriers to business communication. [11]
- (7) Internal deconstruction. Construction of unit cities can effectively address the traffic and environmental pressure as well as inefficiency resulting from giant cities; this is equivalent to deconstructing the original mega structures and returning cities to their optimal size, thus improving the quality of life of residents.

D. Implementing the Idea of the Unit city in Beijing

There are many important business districts and rail nodes in Beijing. The area of 2–4 km covered by each shopping area or important transportation node can be regarded as a unit city. In the process of urban renewal and future urban development, Beijing, guided by the idea of the unit city, can try to achieve intensive and efficient development of urban spaces and evacuate and distribute its urban population.

IV. TOD MODEL IS THE MAIN WAY TO ACHIEVE UNIT GROWTH IN CITIES

TOD is becoming a popular urban development mode in North America and around the world. [12] It was established in the 1990s in the United States to mainly overcome the drawbacks of suburbanisation after World War II. [13] It is an urban development concept and planning method aimed at making more efficient use of urban land and facilities, curbing urban sprawl and making urban development sustainable. [14] Although TOD was

established with focus on the US, the ideas are gaining favour among urban planners around the world. [15]

A. Significance of Developing the TOD Mode

1) *High capacity, fast and efficient, no congestion. It greatly boosts transportation efficiency.*

2) *High-density housing will make public facilities gain vitality and develop actively, and it will make peoples' lives more convenient and comfortable and save costs.*

3) *Urban environmental pollution will be greatly reduced.*

Developing cities along bus routes and constructing high-density business districts and residential areas around major bus stops can reduce people's use and dependence on private cars. The idea is consistent with that of unit cities.

The TOD development mode essentially uses traffic to create development momentum, which is a major contradiction in the transformation of giant cities into unit cities. Through the TOD mode, we can effectively solve the transportation problems of giant cities, concentrate important facilities around stations, and thus, centre the core areas of unit cities around them. By doing so, core areas can use huge human flow to serve the maximum number of people and constantly reconstruct and optimise the spatial structure and population distribution of the entire city. In contrast, Other areas away from stations weaken the resistance to urban renewal in unit cities because of the loss of traffic, enabling the transformation of giant cities into unit cities. Furthermore, they can act as a growth pole within unit cities, driving the development of unit cities and pushing a giant city towards becoming a unit city.

B. Implementation Space of the TOD Mode in Beijing

Beijing subway has opened 23 lines. According to the TOD mode, each metro station is 2–3 km apart. Each station can form a TOD unit city centred on the metro station or 2–3 rail stations can form a TOD cluster. [16]

In the process of urban renewal, we can renew the urban design around a metro station, forming a vital urban space in the TOD mode; in long-term metro station planning, the TOD mode is used as the guiding theory to step-by-step switch urban rail development into the TOD mode, centralise the use of urban land, and transfer its population. [17]

V. RECONSTRUCTION AND UPGRADING OF MEGA CITIES - BEIJING AS AN EXAMPLE

Areas inside the Fifth Ring Road of Beijing are overdeveloped; as a result, the population density in this area is too high, which causes ecological and efficiency problems. Beijing should adopt two approaches to transfer its population. First, population should be transferred from Beijing to nearby cities, which is called outward relief; second, relieve the overly polarised and congested areas within Beijing. Simply, if a car has a heavy head and a light back part, the former approach removes the excess weight from the head, while the latter transfers the excess weight from the head to the back part to ensure balance.

A. Beijing's Structural Relief Includes

1) *Centre change (multicentralisation, polycentralisation, decentralisation, unit, new cities).* In contrast to the central polarisation of single-centre cities, if the centre is on the decline, the main body of the core-edge structure will also be on the decline and the city will not prosper. Using this approach to relieve cities will lead to decline and collapse. If single centres polarise to a certain scale, the spatial density will be too high, leading to a spill-over effect, and other places will form centres, forming a multicentralised city. This is one way to manifest spatial structural relief.

The central spatial pattern will cause congestion in the centre of cities. When cities become gigantic, centralisation will greatly increase various costs. Decentralisation is a phenomenon occurring in giant cities because of which original urban centres degrade and cities become more homogeneous. In particular, the development of Internet has driven the decentralisation of cities.

Unitisation is a new type of structured urban space that can greatly increase urban capacity. It impacts the daily service function and work function of the original city centres.

2) *Transformation and upgrade of industrial structures and former industrial zones and decay of development zones.* Beijing has undergone a process of deindustrialisation for more than 30 years and has been upgraded to a tertiary industry city. The original industrial enterprises were transferred to the Hebei Province, and as a result, its county economy has developed considerably. It has developed into low-end township companies, causing extensive air pollution, which in turn has affected Beijing. The poor air quality has led to health problems for people in both places. Now, the Hebei Province is facing the problem of transferring industries.

3) *Conversion of spatial development mode.* The giant city mode is replaced by the city cluster mode, and giant cities get structural relief.

4) *Institutional relief of urban management.* If the national ownership system is transformed into peoples' ownership system, and the public economy becomes a market economy, cities will become active, which is equivalent to relieving them. This institutional relief will trigger significant economic growth.

5) *Relief based on information technology.* Cities do not need large physical spaces due to the development of virtual cities. Commercial, office, and production spaces can be partially withdrawn from cities, which is the direction of urban relief that is based on technology and will not be shifted by human will. Cloud computing centres serve as information processing centres in cloud cities. Cloud networks are used to build the information society structure of the whole city so that any individual in the city can use the enormous processing capability of the cloud centres via their unique-identity documents. As the idea of cloud city concentrates a large number of shared public resources, unprecedented information, digital and intelligent cities will be realised, because of which, humans will no longer need to be dependent on the

physical spaces of their city. [18]

6) *Relief based on transportation development.* Rail transit and urban freeways can relieve the traffic pressure on cities and enable commutes to places that are farther away. The basis for the existence of low-density spreading areas in giant cities is urban freeways. Planned rail transit planning in cities can achieve the purpose of urban relief.

7) *Non-structural relief measures adopted by Beijing include government targeted removal and spatial control.* Specific means include demolishing shantytowns, restricting tenants, closing markets and factories, restricting industries and examination and approval, controlling traffic, relocating, restricting facilities, and so on.

Relying on the Beijing-Tianjin-Hebei region to relieve Beijing. Relying on rail transit stations to develop TOD and making TOD or TOD clusters urban units is an ideal way for the urban growth of Beijing.

VI. A TOD CLUSTER CONNECTS THE CITY'S INTERNAL AND EXTERNAL DOUBLE CIRCULATION, BUILDING A REAL SENSE OF URBAN CLUSTER

Many stations have been established when Beijing is developing rail transportation in recent years. As of July 2020, the operating mileage of the subway in Beijing stood at 699.3 km, with 23 lines in operation and 405 stations in total. Due to the limitations of existing urban development patterns, existing land-use policies, and spatial stickiness, the current large-scale emergence of rail transit stations has an insufficient impact on urban land use. [19]

Beijing is required to take the lead and play an exemplary role in promoting the synergistic development of Beijing, Tianjin, and Hebei. Therefore, it is necessary to consider Beijing's important background of serving the whole northern region and its leading position in Beijing-Tianjin-Hebei and to reallocate important resources and population to those most convenient "nodes" by combining the city's rail transit stations, railway stations, and high-speed railway stations. By doing so, Beijing can better carry out the above-mentioned function of the northern center, further promote the overall urban renewal and continuously reshape the existing mega-city pattern through consequent appreciation of the property.

TOD lines are equivalent to the pulse of Beijing's future urban renewal and high-quality development. TOD stations facilitate the renewal and development of unit cities. TOD clusters composed of similar TOD stations are the most dynamic and competitive growth poles of the whole city, while each unit city will be consisted of several TOD clusters.

According to the development concept, the structure of mega-cities will be reconstructed. According to the geographical factors, urban demand, and industrial characteristics, we should use rail transit networks as urban networks and TOD, TOD clusters, and TOD community as elements to construct cities. Different TOD clusters will be connected to different TOD clusters or small and medium cities. The mega-cities will become cities that closely integrate a networked, nodal and unitary rail transit with urban land use. For the central city, the

supply demand of the city and the external talent demand are ensured through the external circulation, and the development quality of the city and the happiness of the people are ensured through the continuous optimization of the internal circulation. For the city clusters on the track that replaces the mega-cities, the TOD cluster is the key hub, driving the development of the whole city.

AUTHORS' CONTRIBUTIONS

YZ conceived of the study. YZ developed the method. CY participated in data analysis and drafting of the manuscript. ZY helped to interpret the results and contributed to drafting the manuscript. All authors have read and approved the final manuscript and agreed to be accountable in all aspects for the submitted manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article.

DISCLOSURE STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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