DECIPHERING CHINA'S URBANIZATION: AN APPROACH TO RESOLVING URBAN ISSUES OF CITY SIZE AND LAND-USE PATTERN

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Deciphering China's Urbanization: An Approach to Resolving Urban Issues of City Size and Land-use Pattern

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CERTIFICATE OF ORIGINALITY

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Abstract

China has urbanized at the rate of 55% in 2015 from 20% in 1978, which was the year that marked the start of national economic reform. This substantial change in population and landscape are accompanied by the undesirable consequences of urbanization, thereby necessitating the analysis of the underlying rationales. China's central government presented city development guidelines in the Central Urban Work Conference in December 2015. In the conference, transforming existing urbanization patterns were set as one of China's core development goals. This dissertation aims to apply a quantitative method to decipher China's urbanization issues and develop a policy approach to new urbanization via city size and urban land-use patterns. The objectives of this study are 1) to identify the crucial issues of urbanization in China in terms of urban land-use pattern and city size; 2) to analyze the dynamics of urbanization in China via the lens of city size in quantitative analyses; 3) to understand Chinese urban systems via urban land-use patterns; and 4) to develop a policy approach of planning for Chinese cities to resolve the crucial urbanization issues in the new-type urbanization period.

This study applied the power law of scaling to investigate how urban factors are scaling with one another and the type of scaling relation in Chinese cities, as well as to propose a planning policy for the optimal scale of Chinese urban systems. Scaling theory was used as basis to analyze the allometric scaling relation of Chinese cities in linear log–log regression in MATLAB and integrate such analysis with quantile regression (quartile) in R with emphasis on the scaling factor (exponent). This study used population, urban area, transportation network (roads) area, and gross domestic product (GDP) to compare the latitudinal and longitudinal studies. The latitudinal study compared results generated from the National Population Census of China (Census), *China Urban Construction Statistical Yearbook* (UCSY), and *Urban Statistical Yearbook of China* (USY) with theoretically predicted values. The longitudinal study compared results generated during the periods 1990–2014 and 2000–2012.

To evaluate urban land-use patterns, this study applied entropy to investigate the degree of urban (sprawl) expansion and mixed land-use among 61 major Chinese

cities in 2011. The spatial metric established indicators per item of entropy, including spatial entropy (SE) and dissimilarity index (DI) for different building types ($SE_{Residential}$, $SE_{Commercial}$, SE_{Public}, SE_{Mean}, $DI_{Residential|Commercial}$, $DI_{Commercial|Public}$, $DI_{Residential|Public}$, and DI_{Mean}). The indicators were used to compare the structural and functional differences via land-use pattern, quantify the spatial characteristics of urbanization, and analyze the effects of urbanization on land use and urban space. Urban land-use maps were constructed and classified in ArcGIS based on a road network survey in 2011 and points of interest data. Residential, commercial, public, undeveloped land use, and other sectors were used to analyze urban land-use patterns in China. Thereafter, the land-use map of each city was converted into images and calculated in a cellular automata (CA) model in Python.

The key findings are that Chinese cities follow the universal law of allometric scaling and will constantly evolve toward the theoretical status by self-adjustment. However, the scaling relations are often affected by external forces, such as government intervention. The scaling indicators (exponents) are changing in rhythm with different urbanization stages, whereas Chinese urban systems are at an early stage of this evolution process. Furthermore, the driving force of urbanization is shifting among different tiers of cities based on urbanization stages because strong state-led development policies are adjusted over time. Cities are categorized into three tiers based on administrative hierarchies. In land use pattern analysis, each tier is determined to have different land-use sectors as their primary economic driving force during urbanization. In general, large cities have good mixed land use, whereas small cities have a low degree of expansion. Large cities have developed substantial areas of commercial land, whereas small cities have developed considerable public land because of state-led investments to stimulate the local economy. In addition, the evidence on urban growth patterns reveals that cities are not in the direction of smart growth. “Chinese Zoning,” which comprises *Regulatory Detailed Planning* and *Master Planning*, has rigorously segregated urban district functions by land-use pattern. By contrast, the existing planning standard systems for indexing urban development and finance system for urban revenues lead to urban expansion that is opposed to intensive development.

This study pioneers the quantitative deciphering of Chinese cities with respect to city size and land-use pattern using fine-scaled data and intrinsically structural

assessment; such a process is different from urban performance evaluation on policy implementation. To date, mixed land-use and infill development within reasonable city scale are validated through semi-structured interview among the professional and academic spheres, as well as policy makers. These schemes are the most fundamental and direct strategies to facilitate China's rapid urbanization toward sustainable and robust development. Given the focus of developing "inventory planning" (*Cun Liang Gui Hua*) for the Chinese *New-type Urbanization*, this policy adapts the principles of smart growth, thereby redirecting urban growth to be substantially optimized and efficient. These goals can be attained by (1) optimizing city scale that is determined by population, urban areas, transportation networks, and GDP via planning control; (2) reducing the expansion of critical land-use sectors via planning codes; and (3) increasing the mixture of critical land-use sectors via planning adjustment. The findings of this study would provide implications for China's future urban planning and development toward the long-term *New-type Urbanization* because of the country's transformation from increment planning to inventory planning.

Publication arising from the thesis

[1] **Wei Lang**, Xun Li, Edwin H.W. Chan, Tingting Chen, Zehui Yong, Ying Long. (2016). Allometric Scaling of Cities: One of China's Urbanization Mysteries. *PLOS ONE*, (revision under review).

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[3] **Wei Lang**, Hao Lang, Tingting Chen, Nordli Atle, Marianne Jahre, Hung Pham Van, Achim Czerny, Edwin H. W. Chan. (2016). A comprehensive evaluation framework on urban vibrancy: identifying the spatial distributions of functional areas in Oslo, Norway. *European Urban and Regional Studies*, (under review).

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Table of Contents

List of Figures

Lists of Table

CHAPTER 1 INTRODUCTION

1.1 Introduction

China has urbanized at the rate of 55% in 2015 from 20% in 1978, which was the year that the national economic reform began. This significant change in population and landscape are accompanied by the undesirable consequences of urbanization, thereby necessitating the analysis of the underlying rationales. The complexity of urban landscapes is considerably related with urbanization policies. The following questions related to urbanization must be asked: (1) What are the emerging spatial characters of city development that have substantially affected urbanization trajectories? (2) What are the impact factors behind the emerging inefficient urbanization performance? Furthermore, China and its cities are facing a serious problem with the increasing urbanization issues in terms of urban land-use pattern and city size. Thus, research on urbanization and land use development should be revealed in the agenda of distinctive stakeholders, including government officials, policy makers, and planners; and the academic community, which is attempting to facilitate China's rapid urbanization toward sustainable and healthy development.

1.2 Problem Statement

1.2.1 Urbanization

In most countries, urbanization is characterized by people moving from rural to urban areas; this movement is normally accompanied by a large expansion of urban areas. In 2008, the global urban population reached over 50% for the first time; this figure will have increased to 70% by 2050 (UN-Habitat, 2009). These development patterns are of significant global concern because over 90% of the additional urbanized population will occur in the cities of developing countries in the coming few decades (Knaap and Zhao, 2009).

For example, in the U.S., urbanization fostered urban sprawl and recession of urban central areas. Urbanization was also a drastic event in the U.S., with the urban population increasing from 65.9% in the 1960s to nearly 80% in the 1990s. However, this imbalanced growth was characterized by only 15.2% growth in central cities but 71.1% in the suburbs (Platt, 1996). Thus, extensive development in suburban areas has occupied vast areas of land. People in newly developed urban areas emit more carbon dioxide per person than people in existing urban areas (Man, 2013). As regards quality of life, the Americans have recognized that land stewardship, that is, promoting the efficient use of the land and rational decision-making about its use, is central to realize their desires for a strong economy, healthy environment, and livable communities (Diamond and Noonan, 1996). The built environment from this urbanization process is conceived as a result of industrialization that reflects different modes of the city's spatial arrangement (Gu et al., 2015).

Industrialization-driven economies have led Chinese cities to urbanization at remarkable rates. Rapid urbanization in China advances the growth of the urban population and economic development, as well as increases the demand for urban settlements. Population growth has resulted in a demand for housing, whereas economic growth has resulted in a variety of economic activities and services that require developing additional space (e.g., industrial, commercial, public, and green space requirements). Urban expansion has a strong association with economic growth (Seto and Kaufman, 2003; Ho and Lin, 2004; Deng et al., 2008). These aspects increase the demand for urban land use. However, China's urbanization can only be comprehended via an understanding of the specific configuration over time.

1.2.2 Evolutionary China's urbanization at different stages

1.2.2.1 First stage (1949–1966)

1949–1957: Restoration and industrialization infancy

When the People's Republic of China was founded in 1949, only 86 cities were established; the urbanization rate was approximately 10.6% (Yeh et al., 2011), which was substantially lower than the world average. Between 1949 and 1957, the government placed considerable emphasis upon economic development (Yeh et al., 2011). The government favored of industrializing cities into manufacturing bases across the country. Industrialization requires employing many people from the agriculture labor force (Gong et al., 2012). To provide sufficient labor for industrialization, migration from rural to urban areas was encouraged. Thus, the urbanization rate increased rapidly in this period, with an annual average urbanization growth rate of 0.46% and an annual urban population growth of 4.55 million (National Bureau of Statistics of China (NBSC), 2010). The number of statutory cities increased from 120 in 1949 to 176 by the end of 1957; the urban population increased from 10.1% of the national population in 1949 to 15.4% in 1957 (Li and Yu, 2008).

1958–1963: Industrialization campaign and urban–rural regulations

The "Great Leap Forward" campaign (1958–1960) resulted in massive state investments in industrial production, which was considered technically and economically unrealistic for China. This campaign promoted industrialization that was concentrated in cities and towns, thereby accelerating urbanization. In 1960, the urban population of Chinese Cities increased by 4%, which was equivalent to the increase of past eight years (NBSC, 2010).

A critical policy measure was introduced to control the substantial increase in urban population because of rural labor force pouring into the cities. In 1958, regulations to stringently limit rural-to-urban migration were promulgated. These regulation policies know as *hukou system* stated that all Chinese were permanently assigned with an agricultural or non-agricultural *hukou* residency at birth. Only non-agricultural *hukou* residents were entitled to employment in cities. Agricultural-registered residents were designated to be agricultural laborers for their livelihoods. Since 1962, Chinese government has begun to intentionally reverse cities back to counties, and to convert non-agricultural *hukou* residents to agricultural *hukou*. Over 20 million of urban population was changed back to agricultural *hukou*, which accounted for 17.8% of total Chinese urban population in 1962 (NBSC, 2010).

However, the increasing pace of urbanization was slowed down by the economic downturn that resulted from improper industrialization campaigns and inevitable natural disasters (Ren et al., 2003). Natural disasters and political factors resulted in a decline in urban population by 14.27 million from 1959 to 1963, and the urbanization rate declined by 1.6%. Chinese statutory cities declined from 208 cities in 1960 to 168 cities in 1965.

1.2.2.2 Second stage (1966–1978)

During the *Cold War,* the Chinese central government launched a “third line” (*sanxian*) program in 1964; this program relocated industries from eastern and big cities to the western regions. Moreover, this program instructed most capital investment and industrial development in China for over 10 years until late 1970s. Many factories were closed in the late 1980s. In the period of *Cultural Revolution* from 1966 to 1978, economic development was replaced with political movements, thereby resulting in economic crisis and stagnation of urbanization. Chinese government commenced a national wide program that relocated 14 to 18 million urban youth to rural areas. China’s urbanization level was substantially reduced from 20.7% in 1960 to 15%–16% in the late 1960s.

1.2.2.3 Third stage (1978–1995)

Since late 1978, China has started economic reform and open-door policy. During the early period of reform, the government endeavored to promote economic development and urbanization by implementing a series of reform initiatives; thus, urbanization progressed smoothly. The urban youth in the rural areas were allowed to return to cities. China’s national urbanization policy evolved to emphasize controlling big cities development, moderating medium-sized cities development, and encouraging small cities development (Lin, 2007).

The central government recognized that local governments needed resources to upgrade severely under-invested urban infrastructure. In 1988, these local governments introduced land use rights leasing system for enabling municipalities’ revenues over state-owned land (Lin, 2007). Eventually, this principal source of off-budget revenue of for municipal governments led to massive development in the outer urban and suburban areas.

The establishment of “special economic zones” in 1980s led to the rapid development that triggered a first wave of urbanization with long-standing public policy. The influx of foreign investments and the real estate boom in the 1990s have substantially driven China’s economic growth for the past 15 years. During this period, the urbanization rate increased by 10.6%, with an annual growth rate of 0.62%

and annual average increase of the urban population by 10.55 million.

1.2.2.4 Fourth stage (1995–2010)

In 1994, China’s fiscal reforms decentralized the country’s fiscal system. In this period, China completely established a market economy and achieved rapid economic growth. Industrialization has rapidly driven urbanization, thereby resulting in the rapid increase of the urban population. Thereafter, rapidly expanding scale of rural-to-city migration (wave of rural migrant workers) became a major concern for the central government (Lang et al., 2016).

In the late 1990s, in order to ease the challenge of widening regional and rural-urban disparities, China’s national urbanization policy for 1996–2000 emphasized to strictly control the growth of big cities, reasonably develop medium-sized cities and small cities. Three key policy aspects to advocate towns-based urbanization include: 1) allowing *hukou* conversion from agricultural to non-agricultural, 2) allowing farm land rights trade to encourage production economies, and 3) promoting industrialization and allowing the conversion of agricultural land to construction land.

In the late 2000s, the government recognized that large cities could significantly contribute to the country’s economic development and to sustaining China’s long-term growth. Thus, the government has substantially emphasized on the introduction of measures to substantially integrate metropolitan economies and to promote urbanization regardless of town size. The government strengthened suburban towns in metropolitan regions to foster the growth of “strategic” towns into satellite cities with strong connections to their respective metropolitan centers.

1.2.3 China’s current state-of-the-art of urbanization

In 2014, China’s 655 metropolitan centers contained nearly 55% of the 1.4 billion national population, compared with 18% urbanization level in 1978. Most cities have been experiencing strong population and area growth (National Bureau of Statistics of China, 2015). With the foundation of New China (People’s Republic of China) in 1949, the focus of city development in the country was to construct manufacturing cities, to emphasize industry and prioritize production instead of dwelling. In the

1960s, China continued to restrict city development, particularly that of big cities, to ensure that the disparity between the urban and rural areas would be reduced. In 1989, the first planning law promulgated in China, namely, the National Urban Planning Law, systematically regulates city development and planning, strictly restricts the scale of large cities, and has reasonable provisions for the development of medium and small cities (Shao and Shi, 2012).

The "extensive development" has resulted in over 36,680 km^2 of natural land (non-urban land) conversion from 1980 to 2015 (UCSY, NBSC, various years). Most developed countries are approximately 76% urbanized. Based on the evidence from international cities, China's urbanization will expedite in the years to come. Thus, 65% of the Chinese population are expected to be living in urban areas by 2050 (Song and Ding, 2009), with at least 200 million rural dwellers joining the urban population (Yusuf and Saich, 2008). The annual growth rate of urbanized areas has nearly tripled in two decades (CSY, 2014).

The China Academy of Social Science (2012) estimated that China's urban population will increase by at least 50% in 2025. China has the world's largest urban population, which is approximately 480 million (Pannell, 2002). From the present until 2025, over 400 million people will be urbanized moving from rural to urban areas. China is estimated to add approximately the population of New York City to its urban population in every year (Oster, 2006).

The increasing urbanization that is expected in the coming years requires continued large-scale construction, thereby threatening to increase urban sprawl (Song and Ding, 2009). The number of cities, sizes, and built-up areas has increased remarkably. Remarkable urban spatial expansion is both a cause and effect of rapid economic growth, particularly true for big cities (Ding, 2009). Extensive spatial development patterns have become one of the leading concerns in China's urbanization issue. If China follows the U.S. development pattern, then the disruption on land use and environmental may imply enormously.

1.2.4 Identification of critical issues of the spatial characteristics of Chinese cities

The urban form and spatial structure that are associated with land allocations and utilizations are of interest to designers, planners, geographers, and decision-makers.

Urban spatial structure is a physical outcome of regulation, planning, and land markets upon the terrain constraints and topography of a city, which is complex, path-dependent, and slow to change (Ding, 2009). Identifying the existing urban development characteristics is important to inform planners, the government, and the public. In the U.S., local governments rely heavily upon local property taxes, thereby inducing substantial development to expand the tax base (Daniels, 2001). Similarly, municipal governments in China rely heavily upon land release for their revenue because of the separate fiscal system of tax distribution between central and local authorities. However, certain features and situations differ from those of their Western counterparts. Many Chinese cities share the same key characteristics and face common urban development challenges, thereby affecting the possibilities and appropriate strategies for moving toward considerable sustainable patterns of urbanization. Related challenges have been identified by the government as follows: “The first is about achieving sustainable economic and social renewal in declining areas to reclaim land, restore economic activity and improve services. The second is about planning for sustainable economic growth in areas which are expanding but which may have problems such as land shortages” (DETR, 2000, p. 65). Pressures are placed upon the land in the expanding and declining areas.

1.2.4.1 China’s urban expansion

Urban sprawl (urban expansion) has developed into the expanded focus on urban planning and studies to explain urbanization issues. Different from the American suburban lifestyle, which attracted many families and caused urban sprawl, the original Chinese urban expansion was the result of of government-led urbanization, which began after the 1978 reform. Concerns about the new urban development mode are rising in China because rapid urbanization has led to massive urban expansion. The unprecedented explosive growth has manifested in the Chinese hinterlands in parks, forests, and mountain ranges, and in the agricultural and rural sectors. Pressures on land development in urban fringes are intense, thereby resulting in urban expansion outside the existing metropolitan areas. Land in China is rapidly being converted from rural to urban uses as the country modernizes and urbanizes. Converting land to urban uses is a typical concomitant of economic growth, thereby resulting in urban spatial expansion (Lichtenberg and Ding, 2009). The negative aspects of extensive sprawl development include environmental harm and excessive infrastructure, traffic congestion, and inefficient economy (Beatley and Manning, 1997). This pattern of development is economically, environmentally, and socially undesirable (Ewing, 1997). Related developments include (1) urban areas expanding outward into rural areas, (2) sprawl along major arterial roads from city centers, and (3) scattered residential development in new districts (Daniels and Bowers, 1997; Daniels, 1999). Similar to urban sprawl in the U.S., extensive growth in China has become a major public policy issue. The pressure on land development in urban fringe and exurban areas is intense, thereby resulting in urban sprawl outside the former metropolitan planning districts.

The urban development mode of spreading out is not environment-friendly because high energy is consumed to serve the dispersed urban population. Low-density expansion is equal to the American sprawl, that is, people consume more land than they need, city size expands beyond a rational scale, and land use per capita is more than the datum line of urban planning standards. Chinese cities have higher population densities than cities in North America or Europe; however, the former is less motorized and suburbanized. Kenworthy and Hu (2000) explained that by any international standards, Chinese cities are similar to their other Asian neighbors, in which the former has high urban densities and characterized by intensively mixed land uses in their built-up areas. However, the evidence suggests otherwise (Knaap and Zhao, 2009). Aggregate density is not the entire story. Density in Chinese cities is failing and urbanization has been consuming large areas of natural land and open spaces (Knaap and Zhao, 2009). In the urbanization process of low-density spreading development, the urban form in Chinese cities should be shaped by a series of policies in the long term (Ding et al., 2005). Studies from the previous decades show that low density development will generate substantial costs in public expenditure and private investment (Muro and Puentes, 2004; Campoli and Maclean, 2007). This type of urban development approach requires a significant quantity of energy, natural resources, land-use resources, and fiscal expenditures.

1.2.4.2 Irrational structure of land use pattern

In urban development, sufficient fragmentation accelerates the spread of land use; a large percentage of industrial land corresponds to a low percentage of housing, transportation, environment and afforestation, and tertiary industry land. The *Code For Classification Of Urban Land Use And Planning Standards Of Development*

Land (GB 50137-2011) generally states that in urban land use structure, residential land accounted for 20%–32%; industrial land, 15%–25%; roads and squares, 8%–15%; and green space, 8%–15%. A survey on 55 Chinese cities indicates that the percentage of industrial land is 10% over the aforementioned criteria, whereas the percentage of residential, commercial, and service land is 3%–10% below the aforementioned criteria. The percentage of urban industrial land in the total urban construction land in Chinese cities is larger than the percentage in those in developed countries under the same urbanization level.

The rapid increase in city volume leads to a disrupted urban internal structure, which should have been in a considerably effective pattern. Chinese cities have large parcels and spatial separations of land uses, such as dense and large residential districts with few commercial or non-residential uses mixed in, specialized areas (e.g., university towns, development zones), and extensive provisions of infrastructure for automobiles; these areas are seen in developed countries (Ingram et al., 2009). The cities are locked into the increasing costs of extending public facilities or of providing disaster relief because of inefficient land-use patterns.

The growth of urban land use size and spatial structure is also changing rapidly because of rapid urbanization. Urbanization is more dependent on the growth quantity than the development quality. Cities face a huge demand for land use; therefore, a reasonable urban growth strategy is of particular importance to reflect the direction of China’s urbanization. The existing urban development is low-performance and lacks the effective principles of urban planning policies that are able to address rapid urbanization. Redefining planning and development policy facilitate smart growth principles such that planning statutory and design standards are adjusted. For example, a conventional planning system and a majority of the people do not account for mixed land-uses in which residential, commercial, and administrative buildings are compatible in one proximate area. Therefore, to promote positive planning policies, we must enlighten planning professionals, inform decision makers, and educate the public.

1.2.4.3 Contradiction in land use

GDP growth-oriented urban expansion is one of the fundamental reasons for the current excessively rapid growth rate of China’s urban construction. First, many new residential developments on large lots have expanded from the city core to the outskirts. Furthermore, excessive infrastructure in terms of sewer and water facilities, schools, and transportation facilities has been built to fulfill service demand in the new development communities. Other drawbacks include the separation of people’s residences and places of work, which is a condition that is reinforced by China’s zoning regulations; and the evident segmentation among the different shops, offices, commercial districts, and residential neighborhoods, among others.

Epitaxial expansion-oriented urban spatial growth often bears extensive and epitaxial land use patterns that show a main rapid transition “from non-urban construction land to urban construction land” in various types of suburban “development zones.” Since 1999, a promotional wave of “development zone,” “university town,” “new town,” and “high-tech development Zone” has been observed in most Chinese cities. These single land growth modes in cities result in the current extent of land occupation that appears to be in an out-of-control trend. Spatial separation between the city core area and development zones is a result of low-efficient land-use resources.

Since 2005, the rapid construction of transportation facilities has resulted in the main expansion of the city development scale. Urban spatial expansion in Chinese cities, such as Beijing, Shanghai, Guangzhou, and Shenzhen, mainly relies on the principle of transit-oriented development and strong road infrastructure construction. The increase in road infrastructure supply remains the most preferred strategy for urban spatial expansion for two reasons: major demand pressures from the rapid development of the automobile industry and a lack of clear and effective planning intervention. Many cities in China have exerted considerable effort to develop new subway systems to offer unparalleled services to supplement bus systems. By the end of 2015, the China subway system has reached 3375.9 kilometers in 27 cities; in 2020, these figures are expected to increase to 7000 kilometers and 40 cities (Urban Mass Transit, 2016). However, over expansion with road transport infrastructure investments result in severe financial stress and social problems at the local government level.

The preceding lessons and issues should encourage Chinese city planners to adopt available overseas policy tools. Doing so will promote feasible urban development and sustainable use of land resources, as well as avoid repeating the mistakes of the U.S. urban sprawl.

1.3 Emergent Transformation for New Urbanization

1.3.1 New-type urbanization

China’s urbanization will continue but how and where the new growth occurs will substantially determine the costs and efficiency of infrastructure, open space and environment, and quality of life. In March 2014, the State council released the *National New-type Urbanization Plan*, which is a new state policy and guideline for urbanization. The implementation of this plan reveals a new development vision of urbanization in China, represents a new stage in the development of cities and towns in China, and demands new requirements in urban–rural development and planning. The landscape of China’s urbanization has changed from rapid, investment-fueled growth to a considerably sustainable and highly efficient model in response to the new-type urbanization. Thus, new-type urbanization, as a national urban development strategy, has become a significant concern of the central government and has been comprehensively promoted by local governments.

This change indicates that China’s urbanization has evolved from “exogenous development” to “endogenous development,” has gradually shifted from large-scale macro-narrative urban development to micro-scale spatial adjustment, and has transformed from incremental planning to inventory planning and people-oriented new-type urbanization. The following questions are inevitably raised because China’s cities have started to enter a new period of growth: How will China’s cities be shaped and developed over the next 10 years? How well can the country absorb its new residents given that China’s urban population is projected to increase by over 460 million up to 1.2 billion residents by 2050 (UN, 2014)? How could the government regulate urban growth in the local Chinese context? New-type urbanization and sustainable urbanism have posed challenging questions and issues that should be investigated.

The pace of urbanization in China continues to be impressive by international standards; however, this new development is notably different from the investment-fueled growth of the previous years. For accommodating a large population and new development, new urbanization is achieved by placing new growth in a proper place within the existing urban areas by influencing the sequence and pattern of land development, as well as the placement of infrastructure (Downs 2005; Yin and Sun, 2007). Finding additional space for newly urbanized people will be one of China's significant missions in the coming years. Thus, government, professionals and the public must understand how cities should be planned and developed as a response to new urbanization against urban sprawl and urban fragmentation. Moreover, we must consider policy approaches to the problem of unsustainable growth.

1.3.2 Urban policies and approaches

The enormous challenges mentioned in the preceding section suggest that an appropriate approach to promote proper urban development is likely to be a theoretical planning policy. Capabilities to manage urban change and structures of urban governance are substantially weak in China. Inefficient urbanization in the past is often attributed to misguided regulations, incentives, and disincentives. The government must introduce a new system for nationwide unitary land use control, as well as develop a policy approach at the local and regional levels with the combination of planning practice and planning theory. The principles of smart growth include the three interrelated issues of "spatial separation of land-use," "land expansion," and "city size." The most significant goals are detailed as follows:

- To regulate the city size and manage the total amount of urban land use, as well as coordinate the needs of population growth – Control of total urban land use does not necessarily mean to regulate the absolute growth of urban land use. However, measuring the population's land carrying capacity ratio is necessary.
- To improve land use intensity and efficiency to suppress urban expansion – This objective can be realized by reasonably and substantially increasing the multi functions of per unit land use; mixed land-uses can also reduce the number of vehicle trips (Song, 2005).
- To strengthen urban the infill development and inventory planning of land re-use – Brownfield redevelopment and transformation of villages or

shantytowns with low-income residents and migrant workers can improve urban economic vitality, improve utilization efficiency of the stock land, and reduce new land consumption.

The evolution of urbanization requires considerable time, as do efforts for smart growth. The central and local governments have reviewed local planning systems rather than mandating funds as an incentive to advance a new policy approach in the beginning of the next stage of new-type urbanization reform. State and local efforts to regulate growth "smartly" shape development patterns in desired means (Gale, 1992; Howell-Moroney, 2007). The existing spatial pattern of urbanization in China increases the necessity for smart growth. Smart growth was presented by President Xi in the "Central Urban Work Conference for city development guidelines" in December 2015 as a primary goal for Chinese city development in the imminent years.

To resolve the critical issues of urbanization, Chinese policy makers and scholars considered the "American" approach to manage urban growth (Qiang and Xu, 2004). The components of desirable planning, which are often labeled as "smart growth" in the U.S., reflect long-lasting experiences and practices in many developed countries. Increasing evidences found in the U.S. indicates that smart growth can mitigate the adverse environmental effects of urbanization (Knaap and Zhao, 2009). Knaap and Zhao (2009) argued that China's adoption of smart growth policies is likely to mitigate or reverse a few adverse consequences. By adopting the American smart growth policy for land use, urban development, and planning practice, Chinese planning professionals and researchers have been attempting to adopt smart growth to resolve the emergent challenges of China's rapid urbanization. Although smart growth is a multi-faceted approach that includes many aspects of policy concern, adopting the target principles on the identified critical issues is necessary for sustainable new-type urbanization. However, change at the local level must occur so that new planning policies can be adopted for smart growth.

Although the significant impacts of land use have been recognized in the recent literatures, such as about Chinese new urban economies, the influence of urbanization imposes a compelling need for the formation of cutting-edge policy approaches and to coordinate land use and support smart growth in a fast industrializing, urbanizing, and globalizing urban and regional growth in economy (Lin, 2007). How can we use this new reform movement for smart growth to reverse the existing developed urban space?

In China, the government has played a critical role in city development by enacting various plans. Government incentives and regulation have the most effective and direct influences on urban spatial development.

Current local zoning ordinances are restrictive regulatory code. Regarding changes in land-use permit to encourage desired development scenarios, government should provide a framework that is necessary for mixed and flexible decision alternatives, that is, reducing environmental liability to encourage development in urban areas and allow high density to preserve green space elsewhere. The task ahead is to adjust land-use regulatory and planning systems that may be considerably effective and rapid to reach smart growth policies. These tentative systems are similar to American zoning ordinances. *Master Plan* and *Regulatory Detailed Planning* have been deep-rooted in China to control residential density, building height, and mixed development of land use function; these practices have resulted in counterproductive decisions. For many decades, urban land-use has been nearly segregated by zoning. However, zoning should not rigidly separate land use but allow for a mix of multiple function development that is essential to promote new urbanization for urban livability. By contrast, “increment planning” (“Zeng Liang Gui Hua”) is conventional planning for new urban space expansion and economic development that is completely discouraged, controlled, and prohibited across China.

Smart growth policies may encourage particular types of spatial development in certain locations (e.g., creating infill development), which may be designated as “infill zones,” or establishing “mixed-use zones” to encourage balanced development and the achievement of sound land-use patterns using investment incentives (e.g., density bonuses). The need to borrow smart growth policy continues to emerge in China. The public must understand the adverse effects of urban expansion and the benefits of smart growth, which must be addressed by planning efforts as the first step. To inform planners and the government in recognizing the effectiveness of smart growth on urban development patterns, a comparative study is necessary to identify differences in urban development patterns. Recognizing the necessity of smart growth for the Chinese urban system and decipher urbanization is an initial step along the smart growth policy roadmap.

1.3.3 Quantitative analysis of the urban system

Interest in applying quantitative methods in urban environments has recently increased because of their use in bringing out the spatial component in urban structure and in the dynamics of land use change and urban growth process (Zhou, 2000; Sui and Zeng, 2001; Luck and Wu, 2002; Weber and Puissant, 2003; Li and Yeh, 2004; Dietzel et al., 2005; Deng et al., 2009; Long and Zhang, 2015). To quantify urban spatial characteristics, involve the three dimensions of goals in response to these characteristics, and provide insight assessment of China’s urbanization over time, this study attempts to develop three sets of indicators that are related to city size, land-use mixture degree, and urban expansion degree. Furthermore, quantitative methods have the potential for detailed and in-depth analyses of urbanization process that are indirectly observable. To simplify the analysis, this study focuses on two aspects of urban spatial structures: land use pattern and city size. Although the former can be interpreted as measures of existing conditions, the latter represents measures of the urbanization process.

A comparative analysis was performed to analyze whether these cities have common land-use patterns (Song, 2005), such as assessing the actual value of mixture in urban land-use. The analysis is built on a careful review of what measures can explicitly interpret and what data are available. Thus, to evaluate the performance of urban spatial structures, we must use certain indicators to measure a few of the most important spatial characteristics. Although interrelated, the three sets of measures provide unique information on urban spatial characteristics and trends of the studied cities. To ensure a comparable time series, the formats of data are collected and adjusted consistently across all cities.

1.4 Research Aim and Objectives

1.4.1 Research questions addressed in this study

The twin issues of land use pattern and city size for sustainable development are deemed to be crucial to the interaction of geographical and sectoral clusters. Previous studies focus on the measurement of performance of urbanization across China in time series. However, practically no prior empirical research has asked whether the spatial pattern of urbanization has shaped the desired characteristics. The relationship between urbanization and diverse spatial characters in various spatial and geographical backgrounds remain less understood.

Since the 1980s, diverse efforts have been placed on policies that re-shape the urban spatial patterns and mitigate the effects of low-density urbanization. The current planning system regulates the development of urban areas and use of land-use resources for public interest. These phenomena have attracted international and domestic researchers to conduct relevant studies, such as efficient urbanization (Cervero, 2001), reproducing spaces of urbanization (Lin, 2007), and urban dynamics and evolution of land use change (Deng et al., 2009; Lopez et al., 2001). Research on the interaction between spatial structure, land use pattern, and city size has a long tradition. However, urbanization in China is at a historically unprecedented rate, which has left limited time to develop such institutions as municipal government, urban infrastructure, educational establishments, and civil society organizations; these institutions develop gradually in response to urban problems (Lang et al., 2016). Policy intervention should be relatively strong and theoretically sound, as well as affect the land use planning in observable, quantifiable means. Traditional research methods on urban spatial studies have mainly relied on qualitative methods, site observation and interviews. Thus, we endeavor to answer the following questions: **What are the crucial issues of China' urbanization with respect to urban spatial characteristics? What are the features of city scale (size) and land-use pattern of Chinese cities via an advanced measurable interpretation?**

Defining and addressing these urban problems remain difficult and undetermined (Ewing, 1997; Gordon and Richardson, 1997). A good plan must guide the timing, location, and intensity of urban development, as well as consider a variety of regulative tools and incentives to guide urban development patterns (Song and Ding, 2009). Furthermore, the effects of specific smart growth policies has a key role to play in contributing to the government's strategy for sustainable urbanization by helping to provide for necessary land allocations. Furthermore, the key to a new policy is to convince the public that living on limited land can be livable and reasonable (Horton, 1999). The current study will answer the following questions: **Can mixed land-use and infill development approaches address the identified urbanization issues for Chinese cities? How can a new policy approach achieve**

mixed land-use and infill development in the long-term under new-type urbanization?

1.4.2 Research aim and research objectives

This study aims to apply a quantitative method to decipher China’s urbanization issues and develop a policy approach to new urbanization via city size and urban land use pattern. In particular, the research objectives are as follows:

- To identify the crucial issues of urbanization in China in terms of urban land-use pattern and city size;
- To analyze the dynamics of urbanization in China via the lens of city size in quantitative analyses;
- To understand Chinese urban systems via urban land-use patterns; and
- To develop a policy approach of planning for Chinese cities to resolve the crucial urbanization issues in the new-type urbanization period.

1.5 Significance of This Research

This study develops a novel method of quantitative analysis to address the critical emerging issues of China’s urbanization via the lens of land use and city size. Existing urban development needs quantitative assessment to propose any new approach. Although consensus has been reached by researchers and decision makers on the disadvantage of low-density urban expansion, the profile and state of this development have limited exposure. Many arguments have emerged for smart growth and the elimination of the negative aspects of urbanization, including controlling outward expansion of new development, promoting mixed land-use, and regulating cities to appropriate and reasonable sizes. However, these statements are generally qualitative discussions rather than a metric to evaluate and explain cities in a quantitative manner. By contrast, smart growth has been theoretically discussed and its principles enacted, implementation obstacles overcome, policy legitimized, and smart performance evaluated in the U.S.; these processes are ongoing in China. Thus, the findings support decision-making on planning and policy for future development in China. This study supplements smart growth theory and practice by combining international experiences with local context.

This study also contributes to the knowledge of Chinese planning and governance under the background of China's *New-type Urbanization*. This contribution is a critical step to ensure that planning theories and policies are proposed in practice. The proposed policy approach facilitates to shape the form of the urban built environment or reshape the new urban development pattern in China. The public would be sufficiently persuaded to agree to a specific policy approach based on the aforementioned quantitative analysis.

For Chinese cities at this stage, overcoming the traditional attitude toward urban development and recognizing the need for a new policy approach to grow smart is a fundamental undertaking. The existing literature has not elaborated on how the complexity of land-use can be measured with explicit and quantifiable descriptions for the decision-making process. Furthermore, only a few studies have focused on the use of this policy tool of choice for various approaches, such as adding numerous people to existing populations, encouraging mixed land-use, or addressing new development density. Thus, recognizing the policy and urban context that involves detailed analysis of the objectives, principles, and symptoms identification may eventually shape real and meaningful policy approaches in the future.

1.6 Dissertation Structure

This study was conducted in three main stages (Figure 1.1): critical literature review of China's urbanization, quantitative analysis of city size and land use patterns, and provision of a policy approach with planning strategies. The corresponding methodology used by this research will be presented in Chapter 4 (i.e. analytical framework). The application of these methods will be elaborated in Chapter 4, Section 4.3 ("Research methods").

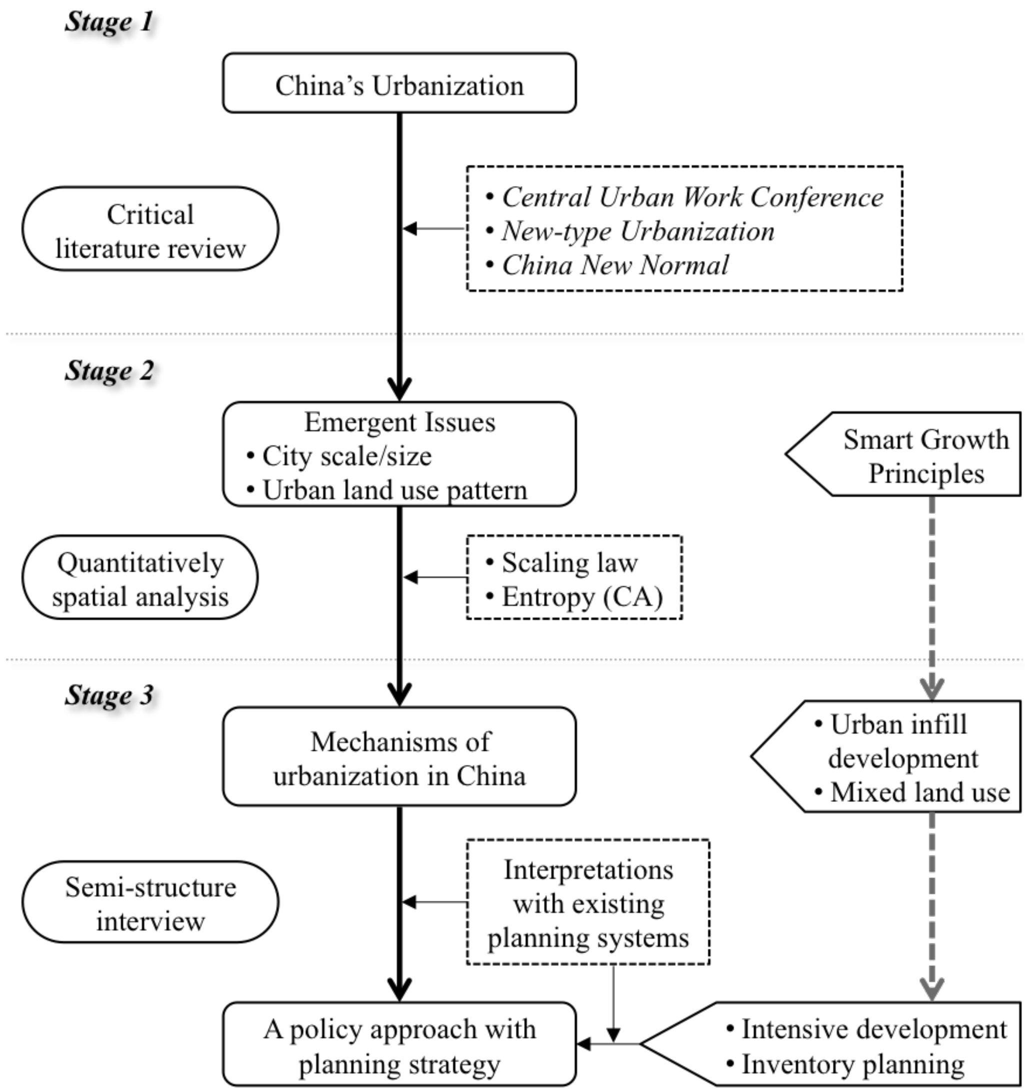


Figure 1.1 Study framework of this dissertation.

This thesis comprises seven chapters. The current chapter emphasizes issues that are related to urbanization in urban systems in the context of global discourse and local land use policy. The research aim and objectives were formulated based on these issues. Chapter 2 reviews the literature and the claims of proponents to characterize the nature of smart growth approaches in relation to sustainable development. Chapter 3 introduces the analytical framework, research methods, data resources, and data processing.

To refer to the research objectives in Section 1.3.3, Chapter 4 explores the allometric scaling of city size in China. Chapter 5 deliberates the characteristics of urban land use patterns in China. Chapter 6 proposes mixed land-use and infill development for smart growth. Finally, this study concludes by placing smart growth in the context of urban planning systems. Chapter 7 summarizes the major findings, contributions to knowledge, limitations of the study, and determines the future research directions.

1.7 Summary

Chinese cities have witnessed substantial spatial expansion and fundamental landscape reshaping. The reshaping of urban spatial structure is manifested mainly in changes in land-use patterns and increases in city size. Currently, Chinese cities are facing the dual pressures of rapid urbanization and scarcity of land resources. Therefore, research on city size and land use pattern has important practical significance to strengthen urban growth management, improve urban land use efficiency, and advance planning policy in China. This study is specifically concerned with the land-use characteristics of urbanization because these traits are perceived by planners to be the most critical issues in urbanization. This thesis is an effort to dissect a range of approaches and public policies that adopt specific principles from smart growth to solve the critical issues of China’s urbanization, given a selection of review on websites of advocates, planning files, publications, legislations, and government programs. A quantitative analysis of the positive and negative effects of each situation will facilitate to relive the uncertainty of urban development.

This study focuses on the investigation, assessment, and evaluation of the emerging urban spatial development patterns in light of smart growth theory across Chinese cities. The most egregious drivers of inefficient spatial expansion under the aegis of smart growth will also be investigated for China because of the unprecedented scale and scope of spatial expansion. This study focuses on determining a multitude of urbanization measures, a few of which are composite indices (e.g., land use mix and sprawl) and others that are direct measures of the urban built environment scale. For example, we consider the degree of mixing of different land uses and the actual types of land use involved in the mixing. In addition, we analyze the influence of the urban built environment scale while controlling for the effects of demographics and other variables within cities. This study illustrates that government-driven development forces have played an important role in shaping and reshaping urban landscape during China’s period of reform.

The next chapter, which is a literature review, will interpret and demonstrate the relationship among urbanization, land use, and city size within the contextual changes of urban space.

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL CONTEXT

2.1 Introduction

The concept of urbanization has been extensively explored and discussed by academics, practitioners, and policymakers for the last three decades to enhance sustainable urbanism. However, few studies have explored existing knowledge for improved management of city size and the inside development pattern of land use based on a comprehensively quantitative interpretation by explicitly recognizing the link between the form/shape optimization of a city and the allocation of land uses. Urbanization is a global issue, and its achievement hinges on the local context. Sprawling land use has a parallel change in urban population. Moreover, planning strategies in the context of China lack an effective policy approach.

This chapter provides an extensive and in-depth review on the impact of urbanization and urban policies on spatial characteristics to establish a critical theoretical foundation regarding the relationship among urbanization, city size, and land use pattern to help develop the analytical framework for this study. This chapter consists of six sections. Following the introduction, the second section presents the overview of the key concepts of urban spatial characters for urbanization. The third section discusses fractal theories, allometry growth, and their relationship with urban systems. The fourth section presents urban spatial modeling and the measurements of urban sprawl. The fifth section reviews the concept of smart growth to identify the key principles with application in China. The last section provides the summary for this chapter.

2.2 Expected Urban Spatial Characters for Continuous Urbanization

2.2.1 Urban sprawl

Urban sprawl is a pattern of development associated with outward expansion, low density housing and commercial development, the fragmentation of planning among multiple municipalities with large fiscal disparities among them, autodependent transport, and segregated land use patterns (Squires and Kubrin, 2009). The urban development mode of spreading out will not be environmentally friendly because high energy is consumed to serve the dispersed urban lives. The increasing popularity of automobile use is the driving force of American urban sprawl; walking or biking for physical exercise is discouraged, but instead Americans drive to every destination of their daily life. Urban developments far from urban centers require mass infrastructure construction and exhaust more land, resources, and energy. Research on urban sprawl has proven that the linkage between urban form and urban economic growth is positive given the increasing size and concentration (Ding and Zhao, 2011; Muro and Puentes, 2004; Campoli and Maclean, 2007).

The impact of the sprawl phenomena has been well documented (Table 2.1). The low-density patterns of development rely on an auto-reliant transportation system but increase congestion and air pollution (Deal and Schunk, 2004). As urban densities decrease, per capita gasoline consumption increases, nationally and internationally (Newman and Kenworthy, 1989). Most communities in Europe and the U.S. have attempted to increase urban densities to make optimum use of infrastructure (Calgary, 1995b; HRM, 1997; Lewinberg, 1993). Thus, urban sprawl is closely linked with exceptional economic prosperity, size, population, and density.

Table 2.1 Negative Impacts of Urban Sprawl

Substantive Concerns	**Negative Impacts**
Public-Private Capital and Operating Costs	1. Higher infrastructure costs 2. Higher public operating costs 3. More expensive private residential and non-residential development costs 4. More adverse public fiscal impacts 5. Higher aggregate land costs
Transportation and Travel Costs	1.More vehicle miles travelled (VMT) 2. Longer travel times

	3. More automobile trips 4. Higher household transportation spending 5. Less cost-efficient and effective transit 6. Higher social costs of travel
Land/Natural Habitat Preservation	1. Loss of agricultural land 2. Reduced farmland productivity 3. Reduced farmland viability (water constraints) 4. Loss of fragile environmental lands 5. Reduced regional open space
Quality of Life	1. Aesthetically displeasing 2. Weakened sense of community 3. Greater stress 4. Higher energy consumption 5. More air pollution 6. Lessened historic preservation
Social Issues	1. Fosters suburban exclusion 2. Fosters spatial mismatch 3. Fosters residential segregation 4. Worsens city fiscal stress 5. Worsens inner-city deterioration

Source: Kay, 1998; U.S. Department of Transportation, 1998; U.S. Geological Survey, 2000.

2.2.2 Landscape change in urbanizing China

Urbanization has been a prominent phenomenon in China's economic development since the country adopted the "reform and openness" policy in 1978.

The landscape and economic development have changed significantly (Liu et al., 2003); a large amount of rural land has changed into a built-up urban area, which consequently lacks appropriate infrastructure and basic amenities. Large cities, such as Beijing, Shanghai, and Guangzhou, have been changing from the concentric zone cities to the decentralized multi-nuclei cities (Yu and Ng, 2007). This transition of Chinese cities to more post-industrial forms is similar to those seen in the U.S., Canada, Australia, and Europe (Schneider et al., 2005). Rapid urbanization, especially in China, will continue to be one of the crucial factors that must be considered in the 21st century (Sui and Zeng, 2001). However, the lack of basic knowledge of the urbanization process results in the inevitable ignorance of the nature of the urban systems (Sui and Zeng, 2001).

Urbanization processes are complex and varied (Antrop, 2000). The changing processes in urban places of different sizes range from large metropolises, cities, and small towns. The increasing population and urbanization result in the most complex process of land use changes from a local to national scale. This growth has been led by two primary determinants: increased standard of daily living and upgraded demand in urbanization processing. This process has profoundly disrupted the structure and function of urban systems. Thus, the relationships between urbanization and land use pattern have been gained increasing attention in recent studies. Unfolding complex urbanization make shows that the quantitative understanding of organization of cities is a major issue for sustainability (Parris and Kates, 2003; Kates and Parris, 2003). However, less attention has been paid to the land use pattern in China; the pattern correctly depicts the general situation of urbanization and consequential landscape change.

2.2.3 Dense urban form

A more livable environment should be guaranteed in the dense neighborhood, thereby preserving open space for leisure. Open space (Campoli and Maclean, 2007) should be "extensive, varied, interconnected, and accessible to all neighborhoods." Concentrated growth would have many positive economic implications that are linked to higher productivity and efficiency. Concentration is more reasonable when it occurs in developed areas where public transit and pedestrian access are available to those working and living within a certain distance (Neuman, 2005). Concentration is allocated within the built area with existing infrastructure, services, and/or the deprived area accessible to public goods (Hartig, 2008, Dempsey et al., 2012). A certain number of people hold the view that dense urban development is a threat to cities, which leads to the declining values of property, increasing crime, and emerging congestion (Crookston et al., 1996). Concentration without services or amenities and with less green space, limited parking lots, noisy and less private spaces is regarded as negative compact development given uncomfortable crowding (Lindsay et al., 2010). Thus, the positive compact mode facilitates a balanced population use per square meter with the impression of livability.

The government imposes restrictions on urban developments for concentration development. Those developments far from urban center will require mass infrastructure construction and facility building, which exhaust more land, resources, and energy (Oppenheimer, 2006; Campoli and Maclean, 2007). In the dense area and delicate urban planning and urban design, determining specific approaches to different areas, which may vary the results, is associated with the enhancement of living quality (Table 2.2). The ideas of urban infill compact development from the city center to the suburb increase the density of places and activities. The regulation on underutilized urban land plays a critical role on the compact urbanization for sustainable urbanism, particularly at the neighborhood level (Huang, 2007).

Table 2.2 Development for Dense Urban Environment

Intensification of built form	▪ Development of previously undeveloped urban land; ▪ Redevelopment of existing buildings or previously developed sites (increase in floor space results); ▪ Subdivisions and conversions (increase in the use of buildings results); ▪ Additions and extension (increase in the built densities or an intensification of the use results).
Intensification of activity	▪ Increase use of existing buildings or sites; ▪ Change of use (increase in use results); ▪ An increase in number of people living in, working on, or travelling through an area.

Source: Deng et al., 2008.

Scattered and sprawl development occurred across the entire suburban area of Chinese cities have been raised the awareness. A large volume of literature focuses on the impacts of governmental regulations on land use and urban development (Shen, et al., 2007). Shen (1996) examined the cumulative spatial impact of locally enacted growth regulations in the case of the San Francisco Bay Area. Pendall (1999) investigated the relationship between land use regulations and low-density urbanization and found that old land use regulations mandate low density and increased sprawl. Although growth management influences population density, farmland preservation, transportation accessibility, energy conservation, and tax burden (Nelson, 1999), political fragmentation leads to low densities (Carruthers and Ulfarsson, 2002). However, the existing knowledge of the relationship between state growth management efforts and urban sprawl has major gaps (Anthony, 2004); states with growth management experienced less population density decrease than states without growth management. However, state growth management did not have a statistically significant effect on curtailing sprawl. Howland and Sohn (2004) offered important insights about the impact of smart growth programs by examining the effect of Maryland's "Smart Growth Area Act" on the spatial distribution of water and sewer investments and suggested that a high population growth rate and a strong local tax base increase the likelihood for infrastructure investments to take place in the outskirts. However, previous studies on urban form in terms of compact city and governmental regulations on land use and urban development are fragmented (Chan and Lee, 2008; Gehl, 1987; Neuman, 2005). Few studies quantitatively analyze the impact of planning policy and system on urban land use pattern.

2.2.4 Urban density

Density, city size, and urban physical environment are closely linked. The adapted density of the spatial structure is inseparable with density in environmental, economic, and social aspects of urban development. Urbanization in concentrated growth patterns appears to have the most positive implications for Chinese cities; these include attracting talent, investment, network effects, and the increase of density in terms of population and activity (McKinsey, 2012).

The concentrated development would limit the sprawl of urban centers, reduce traffic, improve accessibility, and improve the quality of urban life. High-density development does not halt the loss of arable land or diminish environmental impacts. It can intensify local environmental impact to land, air, and water. The dense pattern of a city benefits the environment and community via the concentration of houses, work, education, and entertainment in a small geographical area. Dense urban mode performs optimistically on pollutants per capita than low-density neighborhoods although the total amount of concentration of pollutants is high in dense urban areas. The significant ecological effect of land conservation presents advantages in dense urban area by increasing density while regulating growth. Urban dwellers consume less energy and produce less waste pollution compared with that of suburban and rural neighborhoods (Campoli and Maclean, 2007). Moreover, urban economy and fiscal outcomes are benefited by building a highly dense form to boom a scale economy. For example, the employment density is increasing with average labor productivity of a city, and population density has a significantly positive relationship with innovation (Ciccone and Hall, 1996; Sedgley and Elmslie, 2004).

Based on social theory, the researchers have examined the influence of population density on social attitudes and behaviors. Simmel (1950) and Wirth (1938) suggested that high density causes emotional stress and other negative psychological conditions. Handy et al. (2002) opened a new line of research into the effects of the built environment on physical activity. The compact form and mixed uses enable people to walk, bike, and be fit. Researchers, planners, and designers have begun to rigorously define the compact city apart from population density, which used to be the only factor (Galster et al., 2001; Song and Knaap, 2004; Lee, 2016).

Density has been long-term study content in areas such as urban planning, human geography, spatial economics, and epidemiological aspects (Neuman, 2005, Sedgley and Elmslie, 2004). Quantitative evaluation on urban density includes traditional and static building density, population density, economic density, and ecological density and comprises the dynamic density of people’s activity in the urban space. The measurement of changes in urban density is an important means to study the spatial order of compact urban form (Neuman, 2005; Lee, 2016; Jin, 2016) and a core issue to the current study of the compact city.

2.2.5 Mixed-use

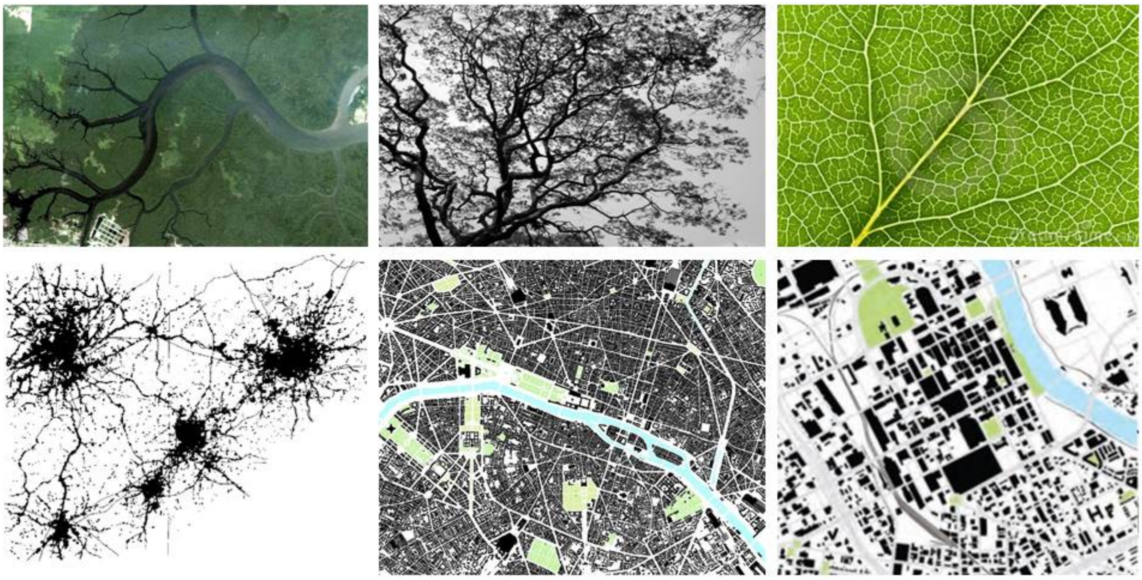
A typical large city is a circular city with a mixed-use core surrounded by a suburban belt. Most jobs and a significant share of residents are located in the core. The surrounding suburban belt consists of residential areas developed along radial corridors (Man, 2013). People demand less travel in an area of dense, interconnected communities and mixed jobs with housing will occur. Concentration without services or amenities and with less green space, limited parking lots, noisy and less private spaces are regarded as a negative compact development with uncomfortable crowding. Corresponding to the negative compact development, the positive compact mode is productive when design and planning are delivered and well maintained for the built environment. Living neighborhood is beneficial via the urbanization process without the harmful impact from overcrowding and monotony (Campoli and Maclean, 2007). The uncomfortable effect of concentration in compact urban development is mitigated by public spaces when people are connected to nature. People stay close to the living environment and easily interact with each other within the dense districts. Traffic demand is reduced dramatically, and people relations are brought close within walking distance owing to the concentration of living and activities; the concentration is considered one of the distinct benefits of compact urban development. Streets that are pedestrian friendly and naturally connected with open spaces via green infrastructure enable citizens to easily reach nature with more activity and urban life. Those conveniences of high accessibility expressed a preference to services within walking distance (Campoli and Maclean, 2007), which require residents to maintain local business equally. Concentrated urban life provides high proximity to living and working with diversified services, which cannot be sustained in a low-density neighborhood of less population. The strategy of improving variety should be kept in place.

2.3 Fractal Theories, Allometry Growth, And Scaling Relation

2.3.1 Fractal cities

Cities reflect economic, social, and environmental processes in their change; thus, all are thoroughly driven by the ‘evolving urban spatial structure itself’ (Herold et al., 2003). The numerous systems of environment resources, economic activity, and social interactions make cities intrinsically complicated to understand. Moreover, the characteristics of urban expansion have been neglected (Batty, 2002). The spatial patterns of cities are fractal in a self-similar organizing complex system (Batty et al., 2008; Batty, 1991; Batty and Longley, 1987). Mandelbrot first introduced the concept of self-similarity and fractals in science (Mandelbrot, 1967), and fractal theory has been applied to examine urban morphology (Batty and Longley, 1994) (Figure 3).

Urban form can be treated as a fractal body (Thomas et al., 2008). The land-use pattern, urban form, and spatial structure of cities can be understood in modeling and simulation from the perspective of fractal geometry (Thomas et al., 2008). In such a new stage of scientific research on cities (Batty, 1992), fractal theory can analyze the spatial structures of urban systems (Chen and Zhou, 2001) that link with urban growth and urban form. The application of fractal theory to urban studies addressed urban form and structure but less about urban systems and hierarchies, which improve existing knowledge of how efficient cities are in terms of physical geometry (Batty, et al., 2007). Fractal geometry theories must also be linked to measures, such as streets



and socio-economic volumes (Kuhnert et al., 2006; Bettencourt et al., 2007).

Figure 2.1 Fractal cities, trees, and leafs. North Carolina Cities of Winston Salem, Greensboro, High Point (lower row).

Source: Thomasville and Lexington, (1958); Batty and Longley, (1994).

Cities should be regarded primarily as dynamical social networks that are constantly changing in terms of their composition and interactions (Gomez-Lievano et al., 2012). Different cities have their own development mode of fractals. This fractal dimension changes over time. Benguigui et al. (2000) suggested that a city is fractal only at certain early stages of its urbanizing process. Urban evolution largely involves the scaling power law in the physical processes, consistent with the fractal geometry concept (Batty et al., 1989). The assumption of power law implies scaling relationships of city size in fractal geometry (Batty and Longley, 1994; Batty, 2005). Such scaling relationships among urban structures are statistically fractal (for example, Figure 2.4), particularly in urban systems, the properties of which are far from equilibrium state (Batty et al., 1989). The urban population in the real world is unstable (Batty et al., 1989). However, evidence shows that urban systems evolve toward self-similar patterns by means of self-organizing process, and the urban systems try to reconstruct the broken symmetry of nature (Chen and Zhou, 2003). Thus, cities are emerging in universally connected fractal clusters following the scaling law.

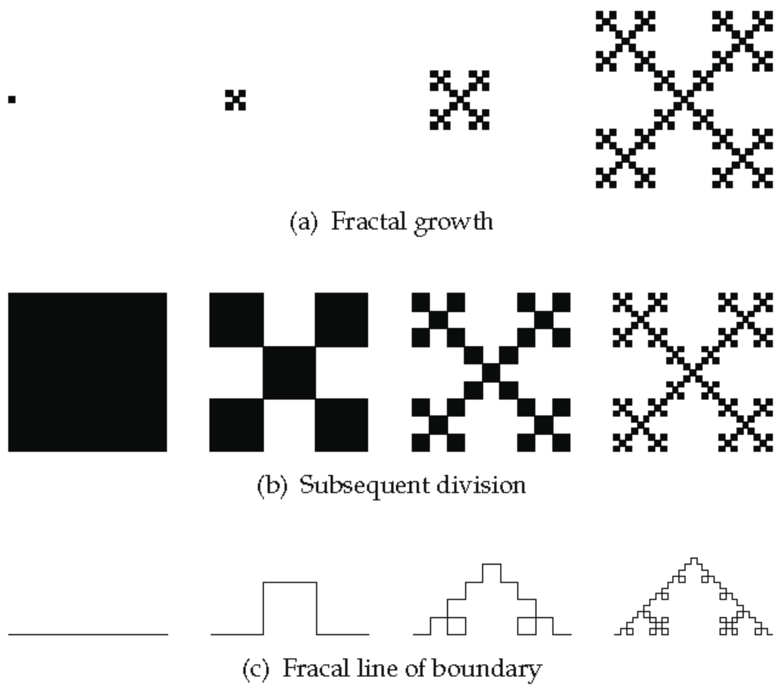


Figure 2.2 A growing fractal and its self-similar pattern.

Source: Longley et al. 1991; Frankhauser, 1998.

2.3.2 Cities as complex systems

Cities are complex systems (Bettencourt and West, 2010), and the existing understanding of them remains inadequate (Batty, 2008). Complex systems evolve because of highly interacting units driven by a simple mechanism (Batty, 2014). The new developments of complexity sciences are based on systems, such as cities, that are no longer considered to be equilibrium structures; city systems are likely to be in disequilibrium or even classed as far-from-equilibrium (Batty, 2009). The key ideas defined cities as sets of elements or components tied together through sets of interactions (Batty, 2009). Developments in several disciplines supported these early developments. The applications of physical analogies to social and city systems have been explored since the mid-19th century under the banner of “social physics” (Batty, 2009). Bertalanffy (1969) in biology and Weiner (1948) in engineering provided a significant impetus to this emerging interdisciplinary field of urban systems. The movement began in biology in the 1920s, which gradually eclipses parts of engineering in the 1950s and spreads to the management and social sciences, particularly sociology and political science in the 1960s. The movement was part of a wave of change in the social sciences, which have appeared successfully in building applicable and robust theory (Batty, 2009).

2.3.3 Allometry in biology and ecology

The search for a general multidisciplinary science of cities is a fundamental scientific problem that would have important consequences for the fundamental understanding of human societies and for urban planning and policy (Bettencourt and West, 2010). An allometric scaling theory in biology and ecology was first developed in the relationship between the brain size and body size of mammals (Schmidt-Nielsen, 1984). Allometry refers to the size differences in proportion of one component of a system to changes in a second component of the system (Coffey, 1979); modern literature in biology explained that organic systems grow to change proportionally (Ranko, 1972). The allometry in biology formally refers to the rate of relative growth of an organ and is a constant fraction of the rate of relative growth of the total organism (West et al., 1997). Allometry is interpreted as the ratio of relative growth of a unit of a complex system and is a constant portion of the rate of relative growth of the whole or another unit of this complex system (Figure 2.3). The complete theory of allometry of size is found in biological systems (Bonner, 2006) although the new application of these theories is in the making (West et al., 1997). The allometric growth law initially describes size differences in the proportion of the total organism in biology (Gould, 1966); that is, the increase in size of one component or organ is relative to the increase in size of another component or organism as a whole (Lee, 1989).

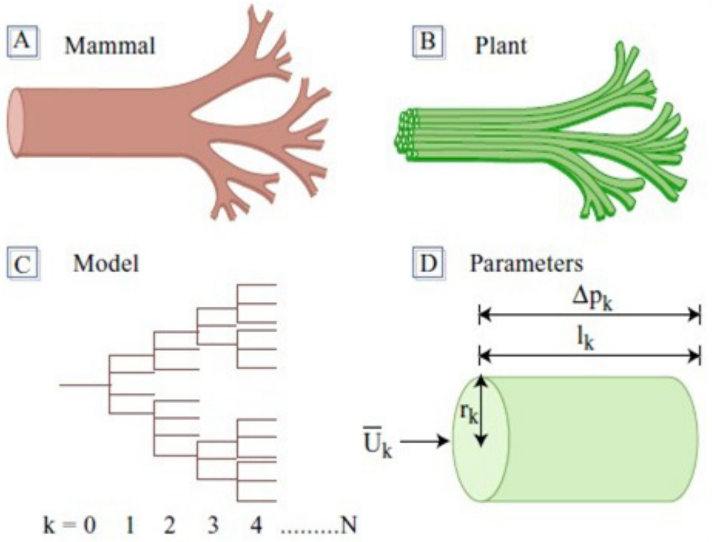


Figure 2.3 Diagrammatic examples of segments of biological distribution networks.

Source: West et al., 1997; also see Alexander, 1965, 2002.

Similar to organisms and ecosystems, urban systems could be analyzed by the same method (Odum, 1971, 1973). In biology, systems are known to scale with the size of organism (Peters, 1983). Biological interaction among the internal components of an organism and among the components of an ecological system may be applied to a wide range of urban and regional systems. This approach relevant to tools from biology is in the academic discovering the metabolism of cities (Decker et al. 2000, 2007), the ecological footprints of cities and regions (Luck et al. 2001), and the ecological impacts of human societies (Bettencourt et al. 2007; Vitousek et al. 1986, 1997; Wackernagel et al. 2002). Thus, the metabolism of a city explains a number of long-standing observations in biology as results from scaling (Samaniego and Moses, 2008), such as the metabolic scaling theory (Brown et al. 2004), the metabolic rate growth (Moses et al. 2008; West et al. 2001), and the reproductive rate and lifespan

(West and Brown 2005). The power law of allometric growth is significant for us to reflect a type of relations in various systems.

2.3.4 Allometric scaling of urban growth

The allometric growth law describes the relative growth phenomenon (Naroll and Bertalanffy, 1956). If urban areas are portrayed as the bodies of animals, then the corresponding elements of cities can be depicted as the animals’ organs, and the urban population can be illustrated as the animals’ body weights. This allometric relationship can be explained as a growth partition coefficient in the completion of a system, of which each component shares the available resources of the total system based on its capacity (Julian, 1972). This different growth ratio is a consequence of competition among internal components in a system for the resources available to the system from the surrounding environment (Coffey, 1979). Urban systems, such as organisms, are usually not isometric (Calder, 1984). The law describes the relationship between urban population and any its corresponding elements for all cities. Many other pairs of elements of a city also have such kind of scaling relations. Urban systems have shown that the relationship between any two elements in a given urban system follows the law of allometric growth. Individual needs are the natural flow of people that is similar across cities of different sizes (Bettencourt et al., 2007).

2.3.5 Allometry study of China urbanization

Primary urbanization began in the reform and open-door policy in 1978. Urbanization in China accelerated in 1992 when Deng Xiaoping visited Southern China and promoted special economic zones in Shenzhen and Shanghai. Therefore, anchoring the urbanization periods of China into four sections, the 1980s, 1990s, 2000s, and 2010s, is necessary. People who live in urban areas grew from 19.7% in 1978 to 49.7% in 2010 (NBS, 2014). The expansion of cities is accelerated given the large, increasing, and fast moving population from rural to cities. Allometry in urbanization has been recognized, such as land use proportions that change with the size of cities. Some classic studies on allometric scaling have been found, including work on city size and number of manufacturing establishments (Zipf, 1949); residential areas, urban facilities, and land uses (Woldenberg, 1973); urban population density (Newling, 1973); urban structure and population size (Veregin and Toble, 1986); dynamics of temporal urban-rural relationships between area and population distribution (Naroll and Bertalanffy, 1956); and relationships between urban area and their population (Boyce, 1963; Dutton, 1973; Lee, 1972; Maher and Bourne, 1969; Nordbeck, 1965; 1971; Stewart and Warntz, 1958; Tobler, 1969a; 1969b).

Cities reflect economic, environmental, and social processes (Herold et al., 2003) and evolve like complex systems driven by a simple mechanism (Batty, 1998), the characteristics of which have long been neglected (Batty, 2002). Urbanization processes are complex and varied (Long et al., 2012); they range from large metropolises, cities, and small towns. Together with economic development, the landscape has changed significantly, where a large amount of rural land has changed into a built-up urban area, which consequently lacks appropriate infrastructure and basic amenities. This process has profoundly disrupted the structure and function of urban systems. Thus, the relationship between urbanization and urban system has gained increasing attention in recent studies. In addition to the complexity of urban morphology and the diversity of driving forces for urbanization, more comparative studies are needed to formulate the dynamic urban expansion (Yu and Ng, 2007). However, the conventional measurements cannot fully describe the increasing population and urbanization process from a local to national scale. Given the long research tradition in the fields of urban modeling (Batty, 1989; Knox, 1994), the combination of new data sources and method, such as commuter technology and the proliferation of urban metrics (Herold et al., 2005), can support well informed decision-making for urban planners and local authorities.

2.4 Urban Spatial Modeling And Measures Of Urban Development Patterns

The combination of new data and method is beneficial to support well-informed decision-making for urban planners and local authorities given the long research tradition in the fields of urban modeling (Batty, 1989; Knox, 1994). Extensive literature on urban modeling related to planning policy and regional development has been found. Given the development of computer science in the 1950s, urban simulations emerged in transportation studies (Klosterman, 1994), to which models for locating residential and retail development were added in the 1960s. Urban dynamics introduced a temporal approach into previously static computer-based simulation tools to describe the dynamic changing urban environment (Forrester, 1970). Large-scale urban modeling was applied for the metropolis studies in 1973 (Lee, 1973). The dynamic spatial modeling was later developed to environmental and ecological systems (Westervelt and Hannon, 1995; Hannon and Ruth, 1997; Costanza and Ruth, 1998; Dendrinos, 1992; Deal, 2001). The mathematical models allow for the adoption of a nonlinear approach to be constructed into dynamic geographic processes (Allen and Deneubourg, 1978; Sonis, 1983).

Earlier urban studies have used various kinds of urban spatial measures to capture the effect of urbanization. However, most studies have only considered a single measure, urban density (Bhat and Singh, 2000; Spillar and Rutherford, 1990; Dunphy and Fisher, 1996). A handful of studies have considered multiple measures, such as density and mixed land use (Frank and Pivo, 1994); density and accessibility measure (Holtzclaw, 1994; Kitamura et al., 2001); accessibility, mixed land use, and land use balance (Kockelman, 1996); pedestrian environment factor, population, and retail densities; and the proportion of gridiron streets (Greenwald and Boarnet, 2001). However, most of the current studies of urban modeling on the list are concentrated in developed countries, and few focus on developing countries, such as China.

2.4.1 Measuring urban growth

Fractal theory is an effective spatial measurement for urban form and growth and has provided powerful tools for research on the spatial organization of urban patterns (Batty and Longley, 1994; Frankhauser, 1994) and a new way of looking at cities (Batty, 1995). Research in the modeling, representation, and understanding of the complex urban system has a long process within urban planning domain (Alberti and Waddell, 2000; Batty, 1989, 1994). Nonetheless, urban growth and land use change continue to presents major challenges. Urban modeling also continues to suffer from less comprehensive knowledge and poor understanding of the driving forces of physical and socioeconomic development; this deficiency contributes the dynamics of urban areas (Banister et al., 1997; Batty and Howes, 2001; Longley and Mesev, 2000). Changes in land use involve both human and natural systems, and detailed land use and land cover are fairly complex (Clarke et al., 2002; Herold et al., 2001). Therefore, the conventional measurements cannot fully describe the urban form. The rapid development of commuter technology, together with the proliferation of urban metrics, also provides detailed information for the understanding of how urban patterns evolve and change over time (Herold et al., 2005).

The nature and pattern of land use subsequently requires the emergence of perceptive landscape metrics to describe such relationships (Geoghegan et al., 1997). Barnsley and Barr (1997) probed a chart theory that maps and represents urban land use patterns through spatial primitives, such as locations, areas, and topologically spatial-temporal relationships, because they describes the spatial heterogeneity of landscapes. Adopting from landscape ecology, where spatial metrics are termed as "landscape metrics" (Gustafson, 1998; O'Neill et al., 1988), recent studies have employed this method in the analyses of urban growth. Moreover, a large number of studies have affirmed the application of spatial metrics in urban simulation and quantitative modeling (Alberti and Waddell, 2000; Herold et al., 2001; Parker et al., 2001). Spatial metrics are used to quantify the spatial properties of individual patches. The spatial metrics can be computed as patch-based indices or as pixel-based indices (Gustafson, 1998). Spatial metrics are delineated as derivational quantitative and accumulated measures that show spatial heterogeneity. Recent efforts have underlined the application of spatial metrics to chronicle the structures and patterns of the urban system and built environment as an advanced image of spatial characters and interpretation for planning policy. Therefore, this research employs spatial metrics to illustrate the allometric scaling relation of China's city size between population and land use.

Spatial metrics have been already generally applied to quantify the cities' shapes and patterns (Gustafson, 1998; Hargis et al., 1998; McGarigal et al., 2002; O'Neill et al., 1988). These numerical measurements that characterize urban form and urban sprawl are generally referred to as spatial metrics, which have been applied to many studies on urban areas (Herold et al., 2005; Herold et al., 2003). Seto and Fragkias (2005) conducted a comparative analysis of four rapidly developing cities in China using metrics. Tsai (2005) classified the metrics that describe the urban form into three categories: density, diversity, and the spatial-structure pattern. Schneider and Woodcock (2008) examined the characteristics of the urban form and growth of 25 mid-sized cities across the world using spatial metrics and statistics. Taubenböck et al. (2009) analyzed the spatiotemporal urban types in India by a combination of statistics and landscape metrics. The five attributes of urban spatial structure describe urban sprawl (Angel et al., 2007). The researchers employed spatial metrics to characterize urban form and used the variation of the metrics to evaluate the degree of urban sprawl (Li et al., 2013; Xu and Min, 2013). Alberti and Waddell (2000) recommended peculiar spatial metrics for assessing urban land use patterns and land covers, which have improved the manifestation of the urban heterogeneous characters (Alberti and Waddell, 2000; Goldstein et al., 2003; Herold et al., 2002). Land use analysis is important for urbanization studies from the studies mentioned above. Spatial metrics are utilized to quantitatively analyze the characteristics of land use pattern and project an accurate profile of the land use area in Chinese cities.

2.4.2 Measuring urban sprawl and expansion

Urban sprawl is labeled as a problem for inefficient land use and fragmented land conversion from non-urban to urban. Urban sprawl is the new development scattered on vacant land, which also often referred to leapfrog development (Gordon and Richardson, 1997). Many studies are found on definition and confinement of urban sprawl (Ewing, 1997; Daniels, 1997). The urban morphology formed by urban sprawl have been hot topics in geography and other disciplines, and several classic theories have been developed, such as the Concentric Zone Theory, the Sector Theory, and the Multiple Nuclei Theory (Luck and Wu, 2002; Zhang et al., 2004). These theories focus on economic and social issues and the urban hierarchy that cannot fully address physical parameters.

Galster et al. (2001) developed a conceptual definition of sprawl based on eight distinct dimensions of land use patterns: density, continuity, concentration, compactness, centrality, nuclearity, diversity, and proximity. These eight dimensions of land use pattern were elaborated as follows: 1) Density: average number of residential units per square mile of developable land in an urbanized area; 2) Continuity: the degree to which developable land has been developed at urban densities in an unbroken fashion; 3) Concentration: the degree to which development is located in a few square miles of the total urbanized area; 4) Compactness: the degree to which development has been clustered to minimize the amount of land in each square mile of developable land occupied by residential or nonresidential uses; 5) Centrality: the degree to which residential and/or nonresidential development is located close to the central business district of an urbanized area; 6) Nuclearity: the extent to which an urbanized area is characterized by a mononuclear pattern of development; 7) Diversity: the degree to which two different land uses exist within the same micro-area, and the extent to which this pattern is typical of the entire urbanized area; 8) Proximity: the degree to which different land uses are close to each other across an urbanized area.

Two general categories are grouped to measure urban development patterns (Landis, 2001). The first category, land conversion and density trends, includes the amount of land urbanized, net urban density, marginal density, and a sprawl index. The second category, urban form in terms of compactness, fragmentation, and continuity, further describes the following measures: 1) amount of increase in urbanized area during a period; 2) the net urban density of population to urban land area; 3) the marginal density of a new urban development (change in population divided by the change in urban land area); 4) sprawl index, which is the relative pace of urban land conversion in comparison with population growth (rate of growth in urbanized land divided by the rate of population growth); 5) compactness, which is the degree to which development is clustered or dispersed around one or more centers; 6) fragmentation, which is the degree to which urban development is organized into a single contiguous area rather than multiple, disconnected fragments; and 7) continuity, which is the degree to which other urban sites surround urban sites.

Some researchers have identified measurable characteristics of sprawl; others have proposed specific indicators of sprawl to characterize patterns of land use; still others have used measures of sprawl to perform empirical analyses. Downs (1999) derived ten traits of urban sprawl: (1) unlimited outward extension of development, (2) low-density residential and commercial settlements, (3) leapfrog development, (4) power fragmentation over land use among many small localities, (5) the dominance of transportation by private automotive vehicles, (6) the lack of centralized planning or control of land uses, (7) the widespread strip commercial development, (8) great fiscal disparities among localities, (9) the segregation of types of land use in different zones, and (10) reliance on the trickle-down or filtering process to provide housing to low-income households. Some can be easily quantified and describe land use patterns, and the others are causal factors and consequences of urban sprawl.

Sprawl has increased over the past decade in most metropolitan areas, which are of important geographic variations (Fulton et al, 2001; Lopez and Hynes, 2003;

Landis); for example, the sprawl debate in the 1990s (Lopez and Hynes, 2003), explain zoning in relation to urban sprawl (Staley, 2001). Fulton et al. (2001) found that metropolitan areas in the U.S. add urbanized land at a much faster rate than they are adding population. Ewing, Pendall, and Chen (2002) developed quantifiable indicators of sprawl index based on four factors and applied these measures to 83 metropolitan areas in the U.S.: (1) residential density, (2) the neighborhood mix of homes, jobs, and services, (3) the strength of activity centers and downtowns, and (4) the accessibility of the street network. Hasse and Lathrop (2003) examined sprawl impacts on land resource through five indicators: (1) the density of new urbanization, (2) the loss of prime farmland, (3) the loss of natural wetlands, (4) the loss of core forest habitat, and (5) the increase of impervious surface.

A rapid increase in the amount of literature on the measurement of urban development patterns has been observed. Many scholars have studied urban sprawl and contributed to the current debate over its causes, consequences, and policy implications (Brueckner, 2000; Carruthers and Ulfarsson, 2002; Downs, 1999; Ewing, 1997; Galster et al, 2001; Gordon and Richardson, 1997; Landis, 2001; Peiser, 2001; Pendall, 1999). However, few studies focus on the quantitative characterization of urban expansion and its dynamic growth, which is a fundamental activity of urban expansion research (Jiao, 2015).

2.4.3 Measuring land use pattern and urban form

Land use patterns appear as a natural result of citizens and planners' interaction with urban space. From an urban planning perspective, the land use pattern represents the structural and functional differences of transitional cities in the complexity of urban dynamics. Land use change is a dynamic process, and the direction and magnitude of fast growing cities could be different (Li and Yeh, 2004). Driving factors that influence the magnitude and extent of land use change are often related to the function of local and national policy and demographic conditions (Verburg et al., 2004). A link between land use pattern and the urbanization process presents a clear understanding of driving mechanisms and explicit knowledge. Researchers have recently addressed issues to better understand the causes and consequences of land use change and explore the extent and location of future land use changes. Given that spatial metrics can describe the land use pattern changes, they provide a method for measuring urbanization. However, these studies have not addressed the spatial characteristics of the inner city. Owing to the complexity of urban morphology and the diversity of driving forces during urbanization, more comparative studies of the characteristics of urban form are needed to formulate a more general theoretical framework of dynamic urban expansion (Yu and Ng, 2007). Especially in the context of urban growth, local decision-making processes produce macroscopic urban form (Verburg et al., 2004).

The analysis of urbanization caused expansion facilitates that help planners and decision makers understand the process and features of urbanization that have valuable implications for urban planning and policy. However, spatial measurement on urban sprawl and its emerging reasons is limited. Quantitatively characterizing and evaluating urban expansion are urgent and important to support urban growth related decision making, especially for the areas that are expected to experience rapid urbanization. In the background of fast urbanizing cities, new urban growth should be planned and properly monitored to maintain internal equilibrium through the sustainable management of natural resources (Ramachandra et al., 2012). Thus, new approaches to the urban planning must be identified to improve existing knowledge of the motivation, foundation, and impact of the procedure of urbanization and its leading determinants (Klostermann, 1999; Longley and Mesev, 2000).

2.5 Smart Growth

2.5.1 What is smart growth?

Smart growth was developed in the U.S. and designated primarily to solve American urban sprawl issues (Knaap and Zhao, 2009). The target of smart growth is sprawl, low-density residential and commercial development that extends from urban areas to rural areas. Much debate on smart growth has been addressed in the U.S. since the official and popular use of this term in the mid of 1990s. Smart growth was originally appreciated as a solution to American suburban sprawl and has been presented by the American Planning Association (2002) as a way to meet the challenges of sustainability. The Environmental Protection Agency defined smart growth as an alternative term that is far from the conventional planning debate (Smart

Growth Network, 2015). Current information on smart growth relates to a strategy that calls for a more intelligent way to manage resources and change the development patterns in emerging urban areas (Szold and Carbonell, 2002).

Smart growth embraces characters of urban space that creates high density mixed-use and pedestrian oriented development; promotes the proximity to work, open spaces, other environmental amenities, and efficient land use; increases transit ridership; and involves a high degree of public participation for all citizens in the process of decision-making (Knaap and Zhao, 2009). Smart growth implies desirable future development patterns (Staley, 2001) to make cities more compact, restrain automobile use, promote transit travel modes, and encourage citizen participation (Holcombe and Staley, 2001; Cox and Utt, 2001; Shaw and Utt, 2000; and Burchell et al., 2000).

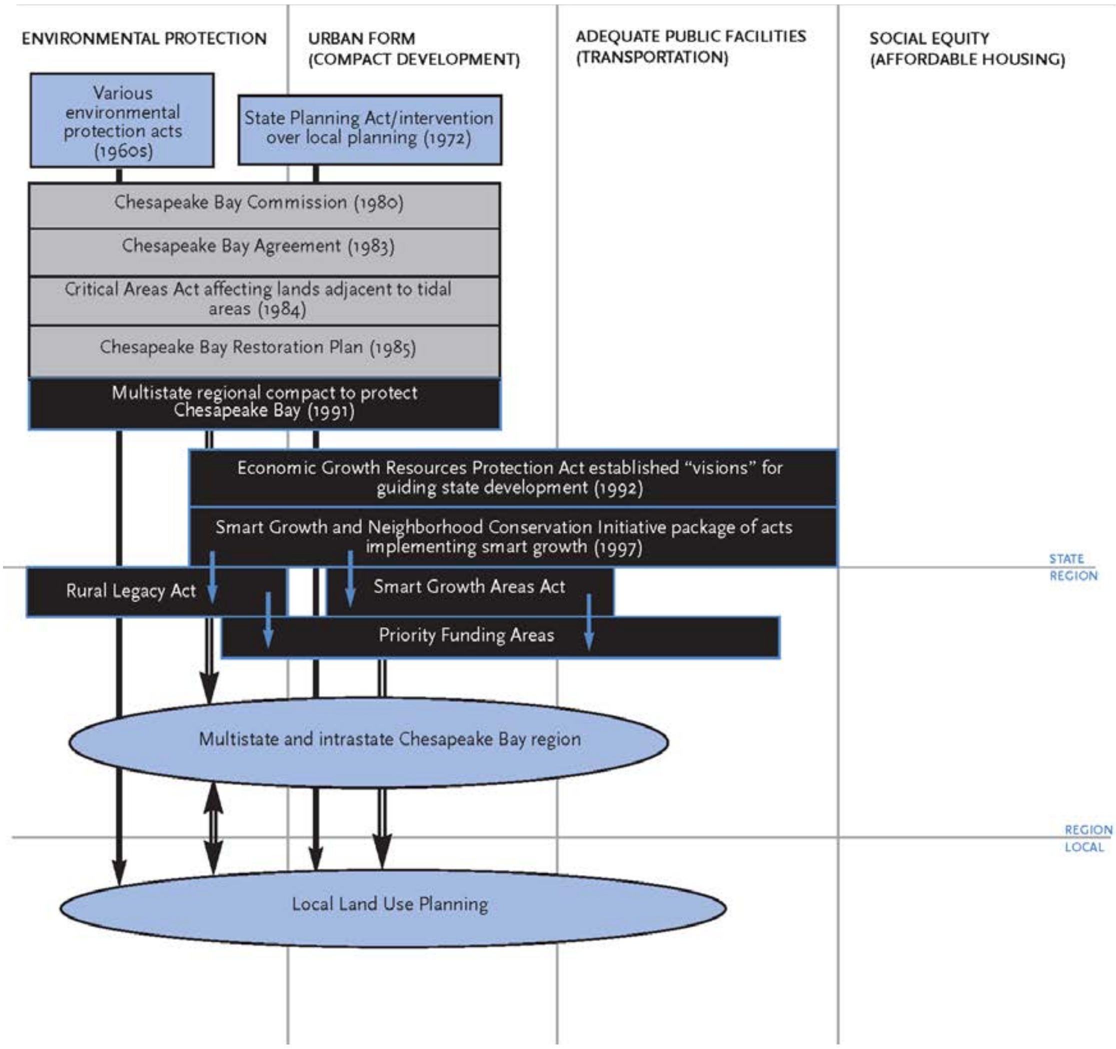
Smart growth offers a real opportunity to reshape development patterns over the next decades (Szold and Carbonell, 2002), which prevent the sprawling and strengthening of the city core with infill development (Sorensen et al., 2004). Smart growth means planning for growth and not slowing growth or no growth. Smart growth addresses not a better way to expand, but rather a better way to contract that concentrates on infrastructure and services (Speck and Lydon, 2010). Smart growth concepts prefer building where infrastructure and development already exist, as opposed to building on green fields, especially where infrastructure does not exist (Szold and Carbonell, 2002). Unlike growth management, which aimed merely to minimize negative interactions and sought improved process management, smart growth focuses on the location of the development and attempts to maximize proposed locations.

2.5.2 Smart growth development in the U.S.

The green belt policy dates back to the 1950s, and was a specific response to the long-standing land use problem of urban sprawl. Green belts are designations of the central policy guidance; the fundamental aim of the green belt policy is to prevent urban sprawl, and to move towards more sustainable patterns of urban development (Elson et al., 1996). The growth controls started in the 1960s. The growth management revolution has been around since the early 1970s, when initial efforts were made to provide growth management techniques designed to control the rate, amount, type, location, and quality of growth. The Chicago Exposition's "City

Beautiful" (Scott, 1969) promised clean cities with wide boulevards, gardens, and economic prosperity set amid an attractive environmental backdrop. After the second wave of planning reform, 'growth control' gave way to "growth management." This second wave of growth management expanded beyond environmental concerns to issues of infrastructure cost management and quality of life. The shifting away from direct interventionist policies has led to a search for market-based solutions. The initial enactment of urban growth management was to protect the environment in the U.S. (DeGrove, 1984). Growth management refers to the following (Nelson and Duncan, 1995; Ervin et al., 1977): appealing for the preservation of public goods; infill development; preventing sprawl; and a comprehensive framework to control development within the urban boundary. Then, between the 1980s and 1990s, urban planning was aimed at economic growth, infrastructure deployment, and protecting resources (DeGrove, 1992). The Ebenezer Howard's Garden City (Fishman, 1989) was a new satellite town surrounded by green belts. In the 1990s, American approaches to resolving the challenges of sustainability increasingly revolved around the concept of smart growth and sustainable development (Jenks, Burton, and Williams, 1996; Szold and Carbonell, 2002). Smart growth is used as a market based approach, or a 'third wave' approach, to achieve the sustainable local and regional planning and development. The popular use of the term smart growth emerged in the mid-1990s, as it was involved in the evolution of land use regulations, urban design, and development practice (Szold and Carbonell, 2002). After the mid-1990s, positive incentives were set to influence growth; the incentives included urban revitalization, zoning reform, and national growth policies; also, several additional states come into smart growth regime (DeGrove, 2005).

Specific smart growth legislation began with the Maryland legislation in 1997 (Szold and Carbonell, 2002). As Maryland has enacted the *Smart Growth Initiative* in 1997 (Figure 2.1), a number of states and municipalities have experimented with the legislation on over planning, land-use, and growth management in response to the urban-suburban-rural interface development issues (Gale, 1992; Haeuber, 1999). In the mid-1990s, smart growth programs range from the Sierra Club to the National Association for Growing Smart, for example, the American Planning Association produced *Growing Smart Legislative Guidebook: Model Statutes for Planning and the Management of Change*; the Natural Resources Defense Council and the Surface



Transportation Policy Project published *The Tool Kit for Smart Growth*; the State of Maryland passed the *Smart Growth and Neighborhood Conservation Act*. American smart growth programs are innovative and enlightening in several ways (Ingram, 2009):

- Favored incentives over regulations;
- Preserved local autonomy;
- Could be rapidly implemented;
- Would not create a new bureaucracy; and
- Had modest budgetary effects.

Figure 2.4 Major growth regulations and initiatives in Maryland to the present.

Source: Ingram et al, 2009.

Smart growth policy does not guarantee legal protection through the urban planning system or the government in terms of law or legitimacy. These regulatory policies or codes are the most vulnerable to any legal effect. However, in most places, people do not have a choice, because it is actually illegal to build in a traditional neighborhood pattern. *Smart Code* was then created to deal with this problem to create a decisive effect in the intersection of law and design. *Smart Code* is a form-based code that incorporates smart growth and new urbanism principles. The *Smart Code* manual illustrates commentaries, checklists, and supplementary modules step by step. Until early 2009, over 100 American municipalities and counties have adopted Smart Code (Duany et al., 2007). *Smart Code* is different from other conventional codes, as it is a unified development ordinance, which addresses the development of all scales of design, from regional planning down to the building signage, based on the rural-to-urban transect rather than the separated-use zoning (Figure 2.5a). *Smart Code* is also a model ordinance, as it is neither persuasive nor instructive like a guideline, and is it intentionally general like a vision statement, but it is meant to be law, which is precise and technical, administered by municipal planning departments and interpreted by the local government (Figure 2.5b).

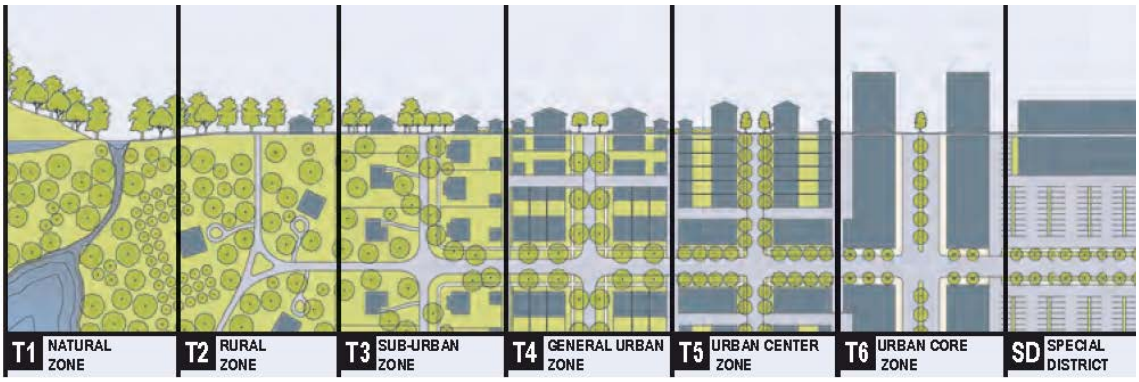


Figure 2.5a. A typical rural-urban transect with transect zones. Define natural and infrastructure elements, and community types of various intensities in specific sectors.

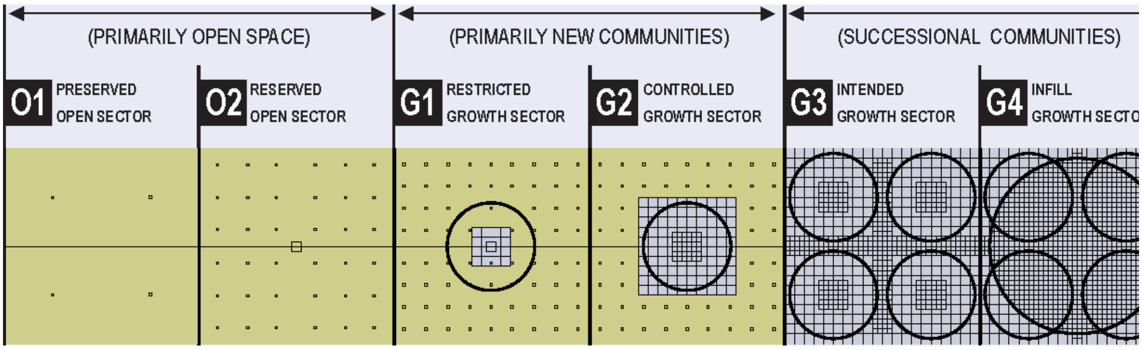


Figure 2.5b. Sector/Community Allocation. Determine areas suitable for development and allocates the proportions of transect zones within each community type.

Figure 2.5 A part of *Smart Code* for municipalities in the U.S.

Source: www.smartcodecentral.org and www.transect.org.

2.5.3 Smart growth goals, objectives, and principles

By looking at the various definitions of diverse scholars, many goals of smart growth are often similar (Table 2.3). These goals include having a more coordinated planning with the inclusion of public input, providing multiple modes of transportation and housing choices, providing green space to make communities attractive, using mixed-use development, and utilizing infill development within the urban core of cities and the inner suburbs. In most smart growth policies, the objectives in principle are population and space distribution by using four measures to assess urban spatial changes and patterns; these measures consist of land use, compactness, urbanization, and centralization (Ingram et al., 2009).

Table 2.3 Smart growth studies in international studies

Smart Growth Goals and Objectives	
Szold and Carbonell (2002)	1. Preserve public goods; 2. Minimize negative land use impacts, and maximize positive land use impacts; 3. Minimize public fiscal costs to provide public facilities and services; 4. Maximize social equity, maximize jobs/housing balances;

	provide equal accessibility to work, shopping, services and leisure; ensure life-cycle housing opportunities within neighborhoods; and offer socioeconomic balance within neighborhoods.
Duany et al. (2010)	1. Neighborhood liveability; 2. Better access, less traffic, mixing land uses, clustering development, and providing multiple transportation choices helps us manage congestion, pollute less, land save energy; 3. Puts the needs of existing communities first by guiding development to already built-up areas, investments in transportation, schools, libraries, and other public services can go to the communities where people live today, especially important for neighborhoods with inadequate public services and low levels of private investment; 4. Shared Benefits, enables all residents to be beneficiaries of prosperity; 5. Low costs, lower taxes; 6. Keeping open space open, and preserves natural reassures.
Smart Growth Principles	
Szold and Carbonell (2002)	1. Prevent further expansion of the urban fringe 2. Use a ecosystems approach to environmental planning 3. Preserve contiguous areas of high-quality habitat if it is at or outside the urban fringe 4. Design to conserve energy 5. Prevent negative externalities of land uses. 6. Separate auto-related land uses from pedestrian-orientated uses. 7. Achieve jobs/housing balance within three to five miles of development. 8. Design the street network with multiple connections and relatively direct routes. 9. Provide networks for pedestrians and bicyclists as good as

	the network for motorists. 10. Incorporate transit-oriented design features. 11. Channel development into areas that are already disturbed. 12. Provide for affordable single-family and multifamily homes for low- and moderate-income households.
Duany et al. (2010)	1. Mixed Land Uses. 2. Take Advantage of Existing Community Assets. 3. Create a Range of Housing Opportunities and Choices. 4. Foster “Walkable,” Close-Knit Neighborhoods. These places offer not just the opportunity to walk-sidewalks are a necessity- but something to walk to. 5. Promote Distinctive, Attractive Communities with a Strong Sense of Place, Including the Rehabilitation and Use of Historic Buildings. 6. Preserve Open Space, Farmland, Natural Beauty, and Critical Environmental Areas. 7. Strengthen and Encourage Growth in Existing Communities. 8. Provide a Variety of Transportation Choices. 9. Make Development Decisions Predictable, Fair, and Cost-Effective. 10. Encourage Citizens and Stakeholder Participation in Development Decisions.
Knaap and Zhao (2009)	1. Mixed land uses. 2. Take advantage of compact building design. 3. Create a range of housing opportunities and choices. 4. Create walkable neighborhoods. 5. Foster distinctive, attractive communities with a strong sense of place. 6. Preserve open space, farmland, natural beauty, and critical environmental areas. 7. Strengthen and direct development toward existing

	communities. 8. Provide a variety of transportation choices. 9. Make development decisions predictable, fair, and cost effective. 10. Encourage community and stakeholder collaboration in development decisions
Smart growth principles for Minnesota (2000)	1. Make efficient and effective use of land resources and existing infrastructure by encouraging development in areas with existing infrastructure or capacity to avoid costly duplication of services and costly use of the land. 2. Provide a mix of land use to create a mix of housing choices and opportunities. 3. Make development decisions predictable, fair, and cost-effective. 4. Provide a variety of transportation choices, including pedestrian-friendly neighborhoods. 5. Maintain a unique sense of place by respecting local cultural and natural environmental features. 6. Conserve open space and farmland, and preserve critical environmental areas. 7. Encourage stakeholder participation rather than conflict. 8. Provide staged and managed growth in urban transition areas with compact development patterns. 9. Enhance access to equitable public and private resources for everyone. 10. Promote the safety, liveability, and revitalization of existing urban and rural community centers.

2.5.4 Smart growth studies in China

The questions on how and where to grow are rooted in urban planning. Smart growth focuses on the formulation and implementation of planning regulations and development policies in the process of urbanization, through administrative intervention on urban land use and spatial layout. To control urban sprawl and to improve the efficiency of land use, the government implements a series of specific policies on land development and utilization. Overall, these studies are the only reference of smart growth theory for Chinese cities, although it puts forward the corresponding countermeasures and suggestions. The current stage of the integration between smart growth and land use planning remains to be a guiding ideology. At present, China has not yet established a complete smart growth tool or policy. However, the U.S. smart growth provides references of index system and policy tools that help China to implement specific measures toward sustainable development. China’s smart growth is still in the theory and trial stage, without specific tools and policies. Smart growth is a new theoretical tool to coordinate urban development.

Zhang (2001) introduced the smart growth concept by summarizing the main content and basic practical framework of smart growth in the U.S., and emphasized its compact, concentrated, and efficient development model. The core of smart growth is science and fairness, and the extension-oriented urban spatial expansion trend should evolve towards a direction of optimized connotation development (Ma and Xu, 2004). Smart growth may provide new perspectives and ideas for a new method of land use planning revision work: planning evaluation, planning guidance, public transportation systems development, public participation, establishment of urban growth boundary, the establishment of land monitoring system, and the land development right (Li, et al., 2005). Wang (2001) believed that smart growth is a significant reference for urban planning with China's socialist market economy, especially its ideas on mixed land use, compact development, public transport, and halting the spread to the suburbs, most of which are actively promoted in Chinese cities’ development principles.

With smart growth as the guiding principle, Liu and Gan (2006) explored the rational and efficient use of underground space through the urban planning process in Chongqing. Zhang and Li (2006) analyzed the specific circumstances of China’s urban spatial expansion, and combined it with the use of smart growth for developing urban development strategies and technical approaches. Liu, Li, and Gong (2006) emphasized that China's urban spatial expansion must be combined with its own urban development characteristics; they referred to the targeted principles of smart growth; there principles include to strengthen intensive urban development and excavate land use potentials by distinguishing the dynamic drivers between urban sprawl in the United States and urban spatial expansion in China. Zhu and Liu (2006) established smart growth indicators from the low land consumption perspective, including the total amount of urban growth, urban growth intensity, urban growth cycle, and urban growth benefits. Via scenario analysis, they predicted the future growth trend of Shanghai, and proposed strategies and recommendations on government policies, market discipline policies, and public participation policies. Sun Limei (2006) discussed how to build a mechanism of smart growth for urban land use in Xiamen. With the introduction of smart growth to land use planning, Tan (2006) analyzed the relationships among smart growth, land structural change, intensive land use, land market, and regulation, and proposed a mode to achieve smart growth through urban land use planning in Xuzhou by considering structural optimization, intensive land use, market surveillance, and effective control.

Based on the smart growth theory in the U.S., Yang and Huang (2007) proposed ideas and countermeasures of urban land use regulation for smart growth in Guangxi, and provided several suggestions for coastal cities in Guangxi on overall planning, scientific layout, and coordinated development. Founded on the study of smart growth strategies and successful case in the United States, Huang (2007) discussed the issues of spreading Chinese cities, urban border management, compact development mode, land use mix patterns, and multiple transportation; he also said that China's unique urbanization should be considered in the application of smart growth to China. A smart mode of urban space must maximize the use of urban resources, minimize urban transaction costs, maximize the combination effect, and balance the economic, environmental, social, and other aspects of development (Ding and Meng, 2007). Based on urban smart growth considering balanced development and protect relationships, Fu, et al. (2007) built an urban development preference model and farmland loss model to analyze the urban development patterns in different directions, and explore the planning methods for balancing urban development and farmland protection. Wang and Wang (2007) summarized the main issues of smart growth encountered in practice, including conflicts with existing laws and policies, residents' distrust and opposition, and delayed policy reform. Drawing from the smart growth theory and on the analysis of the main problems in urban land use utilization in Wuhan, Li (2007) emphasized the delimitation of urban growth boundaries to strengthen land stock for the redevelopment of old urban areas; he also highlighted the construction of compact cities to protect open space and to improve the level of intensive urban land use.

Before transplanting the idea of smart growth to China, we should objectively determine the status quo of urban development, and the clear difference in the growing background in Western cities; the differences among the spread power of the American cities and the urban spatial expansion power in Chinese cities should also be distinguished (Tang, 2010). Ma (2010) introduced an index system integrating the smart growth theory with the evaluation of intensive land in the “Economic and Technological Development Zone” in Shaanxi, evaluated the intensive land use level in “Development Zones,” and put forward countermeasures and suggestions to promote intensive land use. In the analysis of smart growth for optimal allocation of land use structure, Wang, Yang, Wang, Zhang, Liu, and Yang (2014) studied the regional land use structure optimization configuration in Yixing, Jiangsu Province, and Jining, Shandong Province respectively, by using a gray, multi-objective dynamic programming model with land use and socioeconomic data; this ultimately determined the land use structure optimization scheme, and proposed measures to realize smart growth, including optimizing land use structure, strengthening land management, and increasing land reclamation.

2.6 Summary

Urbanization is a process of the demographic growth of cities following the law of allometric growth in a broad sense. Previous research have discussed that the relationships among urban factors (for example, population, land use, GDP, and road area) conforms to the law of allometric growth. Allometric growth is a self-organizing transition from a rural to an urban settlement system. Cities that fit this general systems concept need to be understood via a new approach, and this required subtle interventions in the name of the policy approach of planning. Cities need to increase the use efficient use of built-up areas that will be an important issue of future urban planning. Previous studies show that low density and sprawl development will generate more costs on public expenditure and private investment and the built environment will have to bear the burden. In this situation, cities will benefit from a new policy mode through the new-type of urbanization process without the harmful effects resulting from previous extensive urbanizing campaign. Smart growth, from the experiences of the Americans with their desirable urbanization spatial results, gives us the best references for such a new policy approach development, which constitutes a range of land use policies and includes a set of disciplines for an effective decision-making process and good governance. In China, where the pace of urbanization is increasing, the understanding of the evolution of cities and characterization of urban land use pattern still leaves a complex gap.

This chapter constructs a theoretical context of this thesis based on an international background and China's local situation, and recognizes the challenges of urbanization and the desirable spatial development form for mixed land use and infill development. Then, with a comprehensive introduction of smart growth policy, the theory and practice in the U.S. is compared with the smart growth adoption and development in China. To provide a more advanced understanding of China's urbanization in spatial characters; that is, the city size and land use pattern, the theoretical presentation of the background method of spatial analysis, from urban analysis model to fractal cities. Hereafter, for cities which are complex systems, spatial entropy, and allometric scaling growth is formed as the methodology for this thesis to investigate Chinese cities, which will be more systematically elaborated in Chapter 3. This discussion is followed by the description of statistical data that has been affected and changed by the delineation of China's administrative adjustment, so that readers can be more aware of data issues including census, statistical yearbook, urban boundaries, and definitions of cities, administrative levels, and size appointment. Changing the statistics traditions and administrative designations of urban and rural boundaries over the about 40 years has induced the accurate definition of cities and urbanization trends in China more difficult. Thus, the comparable observations of Chinese cities with international cases should be viewed with caution, which is discussed in the following chapters.

CHAPTER 3 MIXED LAND-USE AND INFILL DEVELOPMENT ISSUES IN URBANIZING CHINA

3.1 Introduction

Identifying the characteristics and issues of urbanization and land use in urban China is vital. The current chapter discusses China's general urbanization issues by applying the conceptual framework developed through the literature review in Chapter 2 to determine the key scope for further analysis in this study. Following the introduction, section two provides an analytical description of urbanization in urban China. Section three examines the general characteristics and development of land-use pattern in Guangzhou. Section four elaborates the current urban planning system in China and the current urbanization issues under the planning context. Section five discusses regulatory systems for mixed land-use and infill development. Section six concludes this chapter.

3.2 Urbanization Issues Of Onward Expanding Chinese Cities

The rapid urbanization in the latter half of the 1950s peaked at 20% in 1960, and then dropped to 15%−16% during the National Social Re-engineering campaigns in the early 1960s and throughout the Cultural Revolution period. The major event was China's economic reforms embarking on the ‘‘Open Door’’ policy in 1978. This reform gradually rebounded the urbanization level to 20% (the level in 1960) in 1985. Land tenure and lease evolved for 30 years leading to the dynamics of urban development of Chinese cities (Chang, 1981; Kirkby, 1985; Lo, 1987; Cannon, 1990; Chan, 1992; Pannell, 1990; Lin, 1998; Ma, 2002). Urbanization rate reached 26% in 1990, and increased firmly to 30% in 1996. Over a period of 34 years, from 1949 to 1983, China’s urbanization level increased from a mere 11% to 22%. However, in the 17 years after that, urbanization reached 36% in 2000 (National Bureau of Statistic, 2001). According to the National Bureau of Statistics of China (NBSC), China’s urbanization is continuing with current 55% of total population living in urban areas, which will reach to 70% by 2025, with an additional 170 million people. The historical development features of cities in developed countries indicate that an urbanization rate of 40%~50% may result in faster urban development that slows down when cities urbanized at 70% or more (World Bank, 2000). The primary driving factor of urbanization is long standing rural population influx into cities.

China's urbanization pace may well accelerate during the next 10 years. According to the data from NBSC, China's urban population nearly amounts to 800 million, which is greater than the entire urban population of the United States. The average urban built-up area in China increased from 6720 sq km in 1982 to 49,900 sq km in 2015, and urban area changed from 1,868,981 sq km in 1982 to 4,779,788 sq km in 2015. During the same period, between 1980s and 2010s, China's urban population increased by 265.8% from 210,820,000 (20.91%) to 771,160,000 (56.1%) and its personal income increased by 9,108% from 836 RMB in 1982 to 76,978 RMB in 2015; furthermore, the urban built-up area increased by 644%, and the urban area increased by 155.7%. The density of total urban area changed from 266 people per sq km in 1982 to 267.4 people per sq km in 2015, whereas the density of urban built-up area varied from 263 people per sq km in 1982 to 615.4 people per sq km in 2015.

Urban expansion has the most notable impacts of urbanization on land use, which largely occurs at the expense of valuable farmland around the cities (Lin and Ho, 2003). Urban expansion is associated with large-scale investments in spatial development (Seto and Kaufmann, 2003), which plays a major role in massive infrastructure extension. Urban built-up land area per capita (the inverse of population density) rose fairly consistently across all cities between 1982 and 2015. Urbanized land per capita was lowest in the small cities, and highest in the large cities. The change in population relative to the change in developed land provides a measure of marginal land consumption. Marginal land consumption in incremental land consumption (new urbanized land per additional urbanized person) averaged about 193.55 sq m (urban built-up area−urban population rose from 191,150,000 in 1982 to 414,250,000 in 2015) and 5,200 sq m (total urban area), which is nearly twice the average land consumption. China's urban construction area is 129.57 sq m per capita in 2015, greatly exceeded the national standard of 85.1 to 105.0 sq m per capita, and it is also higher than its corresponding levels in other developed at 84.4 or developing countries at 83.3 sq meters per capita, respectively. Thus, the spatial size of its cities may have to continue to expand. If cities are expanding beyond the carrying capacity of their environments, the urban systems will crash. This scenario raises the following questions: What has been the extent of urban expansion of China? What are the main determinants?

3.3 Urbanization Issues Of Emerging Urban Land-Use Patterns In Chinese Cities

Land use is critical to the long-term urbanization of China. The association between the wide range social and environmental challenges in Chinese cities and the dispersed development has been raised (Satterthwaite, 1999). Excessive urban expansion does not transpire without tremendously potential expenses to archive optimum forms and shapes of cities (Ding, 2009). These changes, in turn, drive the spatial separation of land use (Ding, 2004). For example, office and commercial development have an economic advantage in locations close to the city center, whereas industrial development is pushed farther away toward the suburbs. Residential development is most likely to occur in between. The appearances of urban fabric may vary remarkably among the urban districts; some of which can be restricted areas or preserved to natural and open space; however, some districts can be developed by densely incorporating housing, working, and recreating. The urban context is gradually shaped because of either the natural city growth or the various urban planning approaches. The latter has greater impact in allocating development across the whole city or region and enhancing urban center while restraining suburban expansion.

Land-use pattern can be characterized by type and composition. Different land use patterns underlie a series of physical form and spatial arrangement that are self-organized by an internal logic and are the cause and effect of the multiple functions of the built environment (Deng et al., 2008). The typical urban spatial patterns can be recognized through qualitative assessment, which can provide planners with the tools for policy formation. Understanding the performance of cities in land use is essential to decision-making. Such knowledge would provide a sound base for the development of urban policies and regulations throughout the country. Thus, it is important to investigate the urban land-use patterns of Chinese cities and their implications in response to the recognition of the environmental problems in urban sprawl and the spatial segregation of land-use functions.

Research on measuring and quantifying urban land-use patterns is greatly necessary, even though assessing the impacts of urban land-use transformation have become complex and acrimonious. Continuing work is therefore necessary to refine urban land-use development patterns. To model urban development pattern at the parcel level, this study divided cities into various number of cells based on road networks. The model was built upon entropy theory, which measures diversity or variation and dispersion. Note that the link between urban spatial characters and urbanization can be measured through land-use shares in each category. The use of the classification with five land-use categories made it possible to make reliable cross-city comparisons at multiple points in time.

3.4 Spatial Development And Urbanization Reform in China

Except for the major driving force in China's urbanization, the continuous and rapid inflation of urban population and economic activity, the exploitation of new urban land by the local government for higher GDP (e.g., continuous new district development with exhaustive urban expansion) is a more significant power. The Chinese government undertook major fiscal and tax reform in 1994 with the aim of modernizing the public finance system and increasing the ratio of tax revenues by the central government over total tax revenue (Ding, 2009), which prompted local authorities to rely on land lease revenues and spend a major part of this revenue on upgrading transportation, expanding urban road networks, building more public squares, and improving open spaces. Land revenues in several Chinese cities are used to finance infrastructure leading to more urban spatial expansion. Unless there are substantial planning and administration reforms to govern and influence urbanization, these patterns are inevitable.

The spatial distribution of urbanization is highly uneven. Cities are developing and urbanizing rapidly in large cities. The widespread attitude for every city is to develop as large as possible for the booming economy, the hierarchical administration, and the urban landscape. Urban expansion varies across all Chinese cities, and is generally high in large cities and low in small cities. For rapid urbanization, the government and decision-makers need to pay close attention on small cities and medium-sized cities. Efficiency gains would be substantial if the principles of urban agglomeration, economic scale, mobility, and externality are considered. However, from an efficiency point of view, China's large cities should be allowed to continue growing, because China's small cities require huge investments for infrastructure, housing, and unities, as they have less population demand than supply.

Shifts in urbanization would include the following spatial features of infill development and mixed uses to prevent sprawl. Various urban areas can be constructed through a set of strategies of mixed land-use, multi-functional building, and varied compactness. Alternatives provide a more diversified urban context through the mix uses of commercial, residential, industrial, infrastructure, and open spaces. It is far easier to achieve by bringing about compliance with these ideas. A policy context cannot ignore the urbanization reality. Therefore, Chinese decision-makers need knowledge on how to achieve intensive development rebalancing away from investment-led growth toward mixing development and land utilization based on economic interests in order to solve the land-use issue.

The 13th Five-Year Plan released in March 2016 indicated China's priorities with an understanding of what the future holds for urbanization. The *New-type Urbanization* labeled for "scientific and rational urban development" focuses on an intensive model of mixed land-use and dense infill development, which pioneers China's official planning policy, although this kind of principles are similar to that smart growth that is now standard in the U.S. Favourable planning practices are often labelled "smart growth" in the U.S. Ingram et al. (2009) described the evolution of smart growth from anti-growth policies to growth-accommodating approaches. Smart growth policy can help form the cities, characterized by less spatial expansion and mixed land-use in the proper size. This can reduce travel demand, preserve more green space and farmland, and eventually archive sustainable urbanization. We can be confident that planning and regulation are playing a significant and enabling role in improving the livability of China's urbanization.

To prevail in a new urbanization, Chinese cities have to think about the unique applicable advantages of an alternative planning with a new policy approach. The success in this vision of China's future is less dependent on the conventional planning layout. The transition is already well underway, and the new urbanization model with a policy approach embedded in planning should boost the development in China's cities. The approach to a malleable administrative procedure needs to: 1) control urban expansion and improve land-use efficiency to gradually strengthen mixed features of construction land and to control suitable city size; 2) identify suitable development areas and restrict those development areas that require new infrastructure or located in environmentally sensitive areas; 3) use government incentives and coordinate policies to prioritize urban infill development and mixed land use with a special planning enforcements and codes.

3.5 Regulatory Systems For Mixed Land-Use And Infill Development

3.5.1 Mixed land-use

Mixed land-use, one of the most important planning strategies to promote efficient urban spatial forms, is widely proposed as an important policy to counteract urban sprawl in the U.S. (Ding and Zhao, 2011). The anticipated benefits from mixed land-use include reduced automobile dependency and travel demand and public spaces and pedestrian-oriented retail development, as well as denser and more compact development (Victoria Transport Policy Institute, 2008). Mixed-use districts provide housing and retail options that offer opportunities to meet some of their daily needs by walking or bicycling. In general, mixed use districts and live/work buildings are characterized by multi-storey construction that uses the ground floor for retail, service or office space, whereas upper floors are usually residential. The compound function of land use in the blocks would provide the most reasonable value benefiting the central urban area. Small block division is a dense network of spur track in the urban center that strengthens development and avoids waste generated by road over built. The plot with compound land-use functions also frequently coincides with intensive land-use policy. To produce the best possible benefit of land and realize the most utilitarianism, a new policy approach should focus on the mixed function of assigning commercial services and public functions for each land parcel.

Mixed land-use, which attempts to intensify and diversify land uses in an already urbanized area, generally is enhanced by new planning codes. The principle is to build a compound function of land use, which frequently coincides with intensive land use policy. This policy utilizes the vertical mixed function to assign commercial services and public function close to ground level and to arrange offices, hotels, and apartments upward vertically to obtain the best possible benefit and utility of available land. That mixed land-use may seem to be an economically sound and socially justifiable smart-growth strategy in the United States does not mean, however, that it can work well in other countries, particularly in China. Caution must be used in promoting mixed land-use development in Chinese cities. Notwithstanding, urban planners have progressively recognized the reality of planning practices and incorporated mixed land use principle into their plans. A shift from single-use projects to more mixed uses has occurred. In creating mixed neighborhoods, the virtuous side of China's policy priorities comprises the following (International City/County Management Association, 2003):

- Adopt comprehensive plans and sub-area plans that encourage a mix of land uses;
- Use enhanced zoning techniques to achieve a mix of land uses;
- Provide regional planning grants for projects that produce mixed land-use;
- Encourage the redevelopment of single uses into mixed-use developments;
- Accommodate the reuse of closed, decommissioned, or obsolete institutional uses;
- Provide incentives for ground-floor retail and upper-level residential uses in existing and future developments;
- Locate neighborhood stores in residential areas;
- Use floating zones to plan for certain types of undetermined uses;
- Organize a variety of land uses vertically and horizontally.

3.5.2 Infill development

Growing out of the existing boundary of towns since China's fast urbanization starting from the economic reform has dominated in China's cities, expanding on farmland, forests, and wetlands for urban development. Large amounts of natural land have been rapidly converted into urban land, leading to low density with lower rates of population growth. The necessary approach to reduce spreading is to grow vertically and infill development to achieve concentration. Cities will grow denser as population increases more quickly than land use in terms of shared square meters per capita. This scheme makes much more sense in Chinese cities, reusing land, controlling locations over new urban development, and building vertically with convenient access. Infill development in vacant land parcels, reconstructing existing structures, and improving urban capacity within a limited area that is fully accessible to public transport and pedestrians are the key to better urbanization. Broadly speaking, this principle can be understood as an attempt to restrain sprawl. This policy encourages more compact development, urban revitalization, transportation, and housing diversity.

China’s cities will need to utilize the space that has already been built. Land use planning efforts should enhance contiguous urban development at the existing urban area instead of using more land at the far fringe. Infill development is thus enacted as an effort to address the potential negative impacts of urban sprawl, such as the effects of the increased costs of infrastructure, transportation, urban environment decay, and so on. In order of general preference, infill development in existing urban areas is preferable to development in new urban areas or in rural areas. Consequently, it is a way to achieve higher density development in urban areas. Furthermore, funding infrastructure and related public service in existing urban areas involves essential regulatory efforts to achieve infill development. These regulatory efforts strengthen and direct the development toward existing communities through the following (International City/County Management Association, 2003):

- Encourage the creation of a business improvement district;
- Use priority-funding areas to direct development toward existing communities.
- Offer home equity assurance programs;
- Establish a land bank authority;
- Create a development finance insurance program;
- Develop asset-driven market analysis to encourage commercial and retail investment in underserved communities;
- Encourage infill by adopting innovative storm water regulations and practices;
- Increase transit-oriented development by adding infill stations on existing transit lines and retrofitting existing stations;
- Develop a revolving loan fund to support local independent businesses;
- Designate a vacant-properties coordinator to use code enforcement, provide incentives, and develop partnerships to minimize and abate vacant properties.

3.5.3 Revisiting urban planning systems and codes in China

Urbanization is a positive phenomenon for improving a better quality of life. Urban planning plays a crucial integrating role in robust urbanization. A true understanding of the existing planning system and law is recognized as the basis for solid action. The major challenges of rapid urbanization require government intervention to fundamentally change the nature of the development pathway for every city in China. The challenges should be addressed by fully recognizing the need for planning as an important tool in addressing urban spatial growth issues. Essential compositions of the urban planning system include physical layout, infrastructure development, land use allocation, site construction and formation, etc., which includes decision on urban land locations, and spatial/geographical distribution of economic activities. Thus, urban planning has a key role in the government's strategy for sustainable development by helping to provide for necessary development in locations. Urban planners can influence city shapes at their disposal to influence urban spatial structure through land use planning and regulatory action.

Urban planning systems

Land use usually administrated by planning departments is viewed as a tool to implement development policies or regulations. The conventional wisdom of planning, long adopted by most planners and government agencies, has advocated for the separation of urban and rural land-use systems and population registration systems (Li et al., 2010). Mandated by the 1998 Land Administration Law, all governments above the county level should develop a land plan ("land plan" is used in reference to China because the contents and meanings are different from land use plans in the U.S.) (Ding, 2009). The primary objectives of a land plan include the following: 1) to strictly protect basic farmland and control the amount of agricultural land for construction; 2) to improve land use efficiency; 3) to coordinate and balance land uses across regions; 4) to protect ecological and environmental systems and pursue the sustainable use of land; and 5) to maintain a balance of urban use and land reclamation.

Given the nature of impending urban inefficiencies and externalities, the planning tool has been less effective, and many parts of it will need revision. Figure 3.1 generally shows the structure of China's conventional urban planning system that is based on *China Urban and Rural Planning Acts 2008.* (see Table 3.1 for general explanations of major statutory plans). By imposing land use regulations, the planning system is criticized as partly responsible for fragmented land use patterns in China. There is a substantial need to improve the competence of planning approaches on top of only as physical layout and design exercises, or only as practices policy-making. They must broaden their approaches. If urban planning only takes advantage of technical and analytic facets, urban planning should receive expanded concern over the practical integration of adjustment processing. The restriction of land resources results in inflexible zoning and land supply. Conventional plans are based on single use zoning, whereas mixed uses are forbidden. The deficiencies of segregated land use in zoning have long been discussed, and more attention is currently imposed on mixture of different land uses in order to shape a desirable and comfortable urban environment.

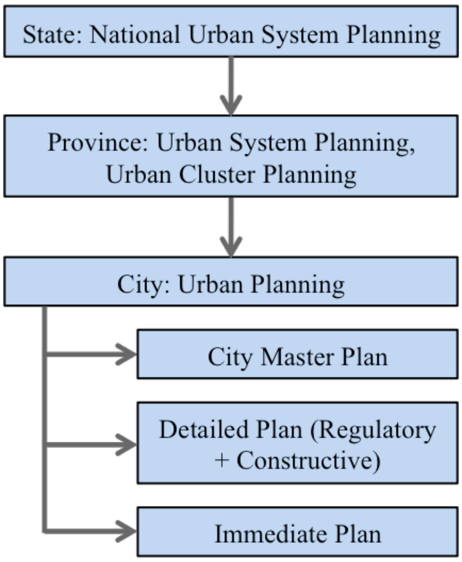


Figure 3.1 Urban and rural planning systems in China (statutory planning), (national urbanization, strategies, regional development plans, urban comprehensive plans, historic and cultural heritages, housing, transport, etc.).

Source: Based on Urban and Country Planning Act (2008).

Table 3.1 Selected major terms in use of China's planning system

Type of plan	Description
Master plan	*These are physical plans that depict on a map the state and form of an urban area at a future point in time when the plan is "realized." Master plans have also been called "end-state" plans and "blue-print" plans.*
Strategic spatial plan	*The terms "structure plans" and "strategic plans" are closely related, and the latter term is now more commonly used. A strategic plan is a broader-level, selective (or prioritizing) spatial plan, usually showing the desired future direction of urban development in a more conceptual way.*
Land-use zoning	*Detailed physical plans or maps show how individual land parcels are to be used and assigning to the landowner (which may also be the state) certain legal rights and conditions pertaining to the use and development of the land. Ideally, the zoning plan aligns with the master plan.*
Regulatory plan	*Refers to the rights and conditions set out in the zoning plan, along with legal requirements pertaining to the process of allocating or changing land-use rights, buildings, and space use.*

Note: Designated in Chinese planning law, *China Urban and Rural Planning Acts 2008.*

Urban planning usually fails to implement when planning policies or approaches were produced without obligation, statutory, and specific adjustment. Effective implementation mechanisms can help planning reshape the urban fabric and landscape into efficient forms during the process of rapid urbanization. Planning involves legal tools for implementation through land-use zoning, where the enforcement of planning legislation in land-use zoning is strong. Experience shows that changing the nature of directive plans is often not too difficult, but changing the regulatory system is much more difficult. Adjustment in land-use management is necessarily to allow greater mixed land-use and permit more adjustable land-use classifications and changes.

Urban planning codes

Traditional governmental statutory planning, which is the most influential and most frequent in contact with day-to-day life of urban development, has moved cities away from sustainable pathways such as master plan and detailed plan (regulatory and construction). The existing planning codes are challenges that national and local codes are a powerful tool for development control and are hard to change in Chinese urban systems. China’s planning system, in which legal control plans must be drawn up and stamped by a local design institute in accordance with national codes or legitimized guidelines, is a barrier to the new urbanization agenda. The set of plans fulfill their regulation requirements and specifications through auxiliary statutory quantized standards.

These standards comprise planning codes from Chinese planning systems’ *Code for Classification of Urban Land Use and Planning Standards of Development Land (GB 50137-2011)*, which, together with planning system itself, often involve segregated land use and extensive consumption of land use. For example, as parts of the standers, Table 3.2 explicitly enumerates the limit requirement on land use per capita for different category cities according to their population size and the geographical locations of the climate zone in China (see Figure 3.2). Table 3.3 provides a specific quantity range limit on residential land per capita for different climate zone cities. Table 3.4 clearly delineates the proportional structure among different land-use sectors of a city. All requirements and prescriptions in this planning code are legitimized as a statutory manual of planning in any single development project.

Table 3.2 Planning standards of urban development land use per capita (m^2/ person)

Climate Zone	Status quo urban land use per capita	Planning standards of urban land use per capita	Adjustment allowance		
			Population size ≤200, 000	Population size 201,000-500,000	Population size >500,000
I, II, VI, VII	≤65.0	65.0~85.0	>0.0	>0.0	>0.0
	65.1~75.0	65.0~95.0	+0.1~+20.0	+0.1~+20.0	+0.1~+20.0
	75.1~85.0	75.0~105.0	+0.1~+20.0	+0.1~+20.0	+0.1~+20.0
	85.1~95.0	80.0~110.0	+0.1~+20.0	-5.0~+20.0	-5.0~+15.0
	95.1~105.0	90.0~110.0	-5.0~+15.0	-10.0~+15.0	-10.0~+10.0
	105.1~115.0	95.0~115.0	-10.0~-0.1	-15.1~-0.1	-20.0~-0.1
	>115	≤115.0	<0.0	<0.0	<0.0
III, IV, V	≤65.0	65.0~85.0	>0.0	>0.0	>0.0
	65.1~75.0	65.0~95.0	+0.1~+20.0	+0.1~+20.0	+0.1~+20.0
	75.1~85.0	75.0~100.0	-5.0~+20.0	-5.0~+20.0	-5.0~+15.0
	85.1~95.0	80.0~105.0	-10.0~+15.0	-10.0~+15.0	-10.0~+10.0
	95.1~105.0	85.0~105.0	-15.0~+10.0	-15.0~+10.0	-15.0~+5.0
	105.1~115.0	90.0~110.0	-20.0~-0.1	-20.0~-0.1	-25.0~-5.0
	>115	≤100	<0.0	<0.0	<0.0

Note: The new town/city planning standard of urban land use per capita should be within 85.1 m^2/ person to 105.0 m^2/ person. China's capital land use per capita should be within 105.1 m^2/person to 115.0 m^2/person. Remote areas, ethnic minority areas, mountain cities, less populous mining and industrial cities, scenery, and other tourist cities should not exceed 150.0 m^2/ person.

Table 3.3 Standards of urban residential land per capita (m^2/ person)

Climate Zone	I, II, VI, VII	III, IV, V
Per capita residential area	28.0~38.0	23.0~36.0

Note: Administration and public service land per capita should not be less than 5.5 m^2/person. Road, street, and transportation land per capita should not be less than 12.0 m^2/person. Green space and square land per capita should not be less than 10.0 m^2/person, of which park land per capita should not be less than 8.0 m^2/person

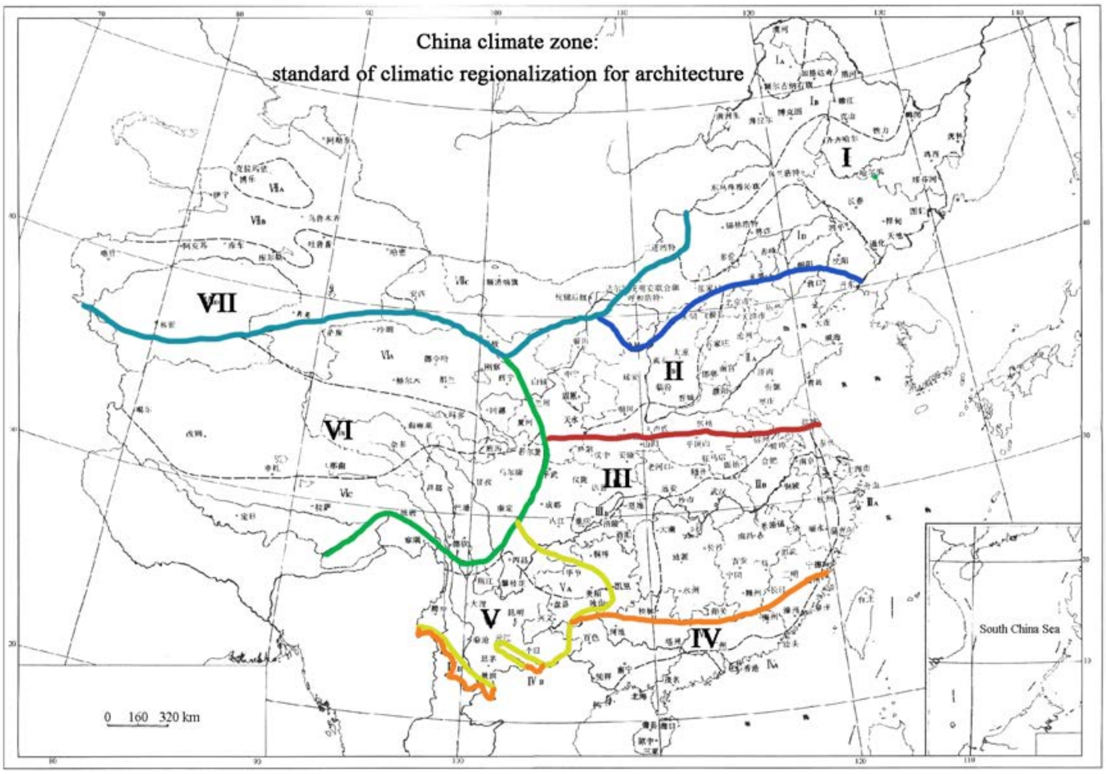


Figure 3.2 China climate zone: standard of climatic regionalization for architecture.

Source: Adaptation based on *Code for Classification of Urban Land Use and Planning Standards of Development Land, 2011.*

Table 3.4 Planning standards of urban development land-use structure

Codes	Urban development land use sectors	Proportion of urban development land
R	Residential	25.0% ~ 40.0%
A	Administration and public services	5.0% ~ 8.0%
M	Industrial, manufacturing	15.0% ~ 30.0%
S	Road, street and transportation	10.0% ~ 25.0%
G	Green space and square	10.0% ~ 15.0%

Zoning and codes adjustment for a new approach to in the U.S.

Many cities realize that the current zoning and subdivision ordinances did not produce desired urbanization vision. Zoning is proscriptive by nature, indicating what not to do at a specific location, but doesn’t specify what a city actually wants for that location (Dover 1996). Zoning encourages the monotony of land use by regulating the kind of use instead of the scale of use, no matter what size effect. The intent of separating land use is thus unnecessarily exacerbated (Jacobs, 1961). The contributions and the widespread adoption of zoning trends over time have resulted in not just the separation of land uses, but increasingly the separation of urban land uses into large, homogeneous districts (Song et al., 2013). However, the overly strict separation of land uses through zoning has the consequence that planners and local decision makers would like to change the zoning laws. The question is when and how to shift towards smarter urban land use.

Cities are consistently amending and revising static zoning or ordinance to meet the needs of evolving cities. Smart growth program was not integrated with existing planning and land use law into a coherent framework, e.g. mixed-use neighborhoods were seldom allowed. Municipalities were difficult to make project compliance with smart criteria and introduce standards that allow smart growth, or to modify a conventional zoning into an adjusted planning guideline, as the two models are incompatible. But it is typically neither necessary nor politically possible to completely replace existing regulations. A process for altering zoning and subdivision regulations requires public, planning commission, and city council approvals that is time consuming and costly in reality. Thus, a new policy approach of planning, like *Smart Code* aerated in the U.S., is conceived to be introduced in parallel as an incentivized alternative. In the U.S., *Smart Codes* legislation drafts model guidelines for infill development and mixed land-use. The purpose of a new so-called “smart code” is to hold proposed development and redevelopment projects to quality standards while encouraging flexibility.

For the American cities, a form-based code is a smart code or a code for smart growth that abandons the use-based orientation of a conventional zoning ordinance, and focuses instead on design characteristics, typically such as architectural style. Form-based codes are one of the most influential and popular approaches to urban smart growth for adjusting zoning and codes. They can also add new metrics that are more prescriptive than conventional standards, such as built-to lines or maximum front setbacks. Embracing form-based code is a way to implement smart growth principles under national wide concurrency planning system with policy guidelines and techniques to address potential negative impacts on future urbanization from the application of infill development and mixed land use with corresponding conventional codes elements.

3.5.4 Formulation of a policy approach of planning

Distinguishing contextual background of a policy approach

Numerous Chinese cities share similar characteristics, and they face common urbanization challenges which differ from those of their western counterparts. First, the levels of GDP per capita are much lower than those in western cites. Second, Chinese cities have more population than the cities of North America or Europe, although they are less motorized and suburbanized. Finally, the capacities to manage the urban change and urban governance structures are much weaker. Each of these factors affects the possibilities and appropriate strategies for moving toward more sustainable urbanization patterns. These enormous differences in the basic conditions suggest that appropriate measures to promote more sustainable urbanization are likely to be specific to China.

Smart growth typically occurs in the inner city and the older suburbs (rather than in greenfield spaces) and creates mixed-use spaces rather than separates housing, commercial, and retail zones. The goals of smart growth are not to stop or slow growth but to manage its pace and location. Smart growth is often implemented through planning efforts (Szold and Carbonell, 2002), and it remains necessary to arm planners with policy guidance. Now is the time for China’s government to do its regulatory and planning role and to enforce standards for urban development. The strategy of infill development and mixed land-use is expected to be realized unless a host of new planning approach will resolve weaknesses in planning control and land-use governance.

Only to distinguish characteristics between urban sprawl in the U.S. and urban expansion in China, can the targeted principles of smart growth be well introduced and adopted. First, the spread subjects are different from the current situation of China's urbanization. Residential urban sprawl in the U.S. plays the main role. The U.S. did not experience China’s special industrialization process. The most important outskirts growth in China is industrial land. In addition, the mass construction of urban fringes characterizes China’s urban sprawl. Second, development is spread in different means. The private car-based highway urban sprawl in the U.S. is different from China’s urban spatial expansion owing to transport development and GDP growth, among others. The main travel structure of the public transportation system supplemented by private car will decide China's long-term urban spatial growth. Finally, culture is different. Having a house in the suburbs and enjoying a good environment is part of the American dream, whereas, in China, people still tend to live in urban areas, symbolizing their residency in large cities.

Emergent need for a policy approach to the urbanization issues

The *Central Urban Work Conference*, which is the first such conference in 37 years and shows that the central government has begun to understand the need for proper management of urban development, laid out city development guidelines. China is almost reaching to a critical point for development reform. Urbanization is considered to be the most likely core breakthrough of the next reform stage of the nation. Promoting the new urbanization plan is a key to change from previous over-emphasis on pursuit of urban space expansion to intensive development, such as smart growth, stock land, rational layout of internal urban land use, and infill development.

Abiding by natural law, urban development is a process of rural–urban agglomeration with a corresponding size of agricultural land transformed into urban construction land. The dual interrelated relation of population and land is a fundamental basis for determining city size. At the current stage, China's population and land use shows a mismatch and an inconsistent state. Longitudinal comparison, the coordinating relation between population and land-use size, is associated with the economic and social development stage of a city. Horizontal comparison, the numeral relation between population and land-use size, is different among cities of different scale or different types. An emergent mission is to reasonably adjust urban population scale, improve small and medium-sized cities’ attractiveness to a population, emphasize balanced development between large cities and towns, and stringently manage the scale of large cities. In principle, the regulation of urban land-use size and population growth has arrived into a new historic period.

A new regulatory tool for the policy approach

Government intervention plays a key role in land resources usage. The current institutional shift from government to governance in urban planning is commonly regarded as a self-conscious collective effort of a city (Healey, 2004). The regulatory systems can profoundly shape development patterns, either to encourage or discourage development in particular policy areas for preserving open space, protecting environment, or providing infrastructure for transportation, water supply, waste management, and energy transmission. This new approach has a set of important principles, but it needs real implementation by significant supporting regulations. Policy-makers should therefore enforce through a variety of regulatory instruments, which will lead to more sustainable patterns of development. The most important concept is the goal of alternative planning approaches should be considered.

A new regulatory framework for planning has also perceived the obligation to reconstruct the relationship of planning system with fragmented and inefficient urban growth effects. Shifts in urban planning relate to both the planning process (procedural) and the content of plans (substantive) as well as to the fundamental objectives and values of planning. The emerging approach can adopt smart growth strategies that are categorized into two general types (Talen and Knaap, 2003): 1) proscriptive policies, similar to conventional zoning codes, place restrictions on development and specify minimum requirements on lot size, types of development allowed, parking lot requirements, density, and street design; 2) prescriptive policies, so-called smart codes opposed to simply restricting, encourage quality development, permit reductions in lot size, setback, block length, parking requirements and narrower street width, allow accessory buildings to be used as dwellings, allow for mixed housing, and emphasize street connectivity, e.g. bike lanes and sidewalks.

Questions addressed in a survey to experts on the policy approach and identified issues

The new planning approach aims to produce and shape desirable spatial characters as a response to challenges of urban expansion and land use segregation. This future negotiable and operational urban planning system is fundamentally policy-based and will allow more efficient land use in future developments. Therefore, based on literature review in Chapter 2, and identification of urbanization issues with revising planning systems of China in this chapter, a list of five key questions are established which will be discussed in the survey to be conducted with opinion leaders from both practical professionals and academic researchers. In order to achieve more validated and objective commendations and conclusions of this study, the experts constructively will be asked to give their suggestions and opinions basically on the following topics:

1. What are the challenges that Chinese cities faced during your involvement in the planning, regulation, policy, and development project in your organization?
2. How can an effective policy approach be addressed to achieve the goals of mixed land use and infill development by local government’s discretion on planning regulations, e.g. sanctions and incentives? 1 indicates “not effective” and 5 indicates “very effective” in a five-point scale.
3. How effective is this approach in coordinating the regulations across local jurisdictions that comprise the existing planning system and code? 1 indicates “not effective” and 5 indicates “very effective” in a five-point scale.
4. Will the review and approval process to complete regulatory compliance add significant costs to a new development (e.g. time delays to achieve project adjustment approval and excessive length of process related to public acceptance)?

5. What is the government’s role in leading the policy and planning regulations and on guiding the development of regulatory systems, such as control over land use decisions?

Besides the questions above, most experts also accept that a quantitative research can provide a more objective and precise method to measure relations among attributes in the urban systems. The theory, as well as the methods of a comprehensive spatial analysis can improve the understanding of entire urban systems and help provide the basis for more effective policy making in an increasingly urbanized world.

3.5.5 Research gap and research questions

Based on the investigation from Chapter 2 and Chapter 3, the twin issues of land use pattern and city size for sustainable development are deemed to be crucial to the interaction of geographical and sectoral clusters. Previous studies focus on the measurement of performance of urbanization across China in time series. However, practically no prior empirical research has asked whether the spatial pattern of urbanization has shaped the desired characteristics. The relationship between urbanization and varied spatial characters in diverse spatial contexts retain less investigated.

Policy intervention should be relatively strong and theoretically sound, as well as affect the land use planning in observable, quantifiable means. Research on the interaction between spatial structure, land use pattern, and city size has a long tradition. They focused more on the physical planning and construction, as the primary political agenda for government. Traditional research methods on urban spatial studies have mainly relied on qualitative methods, site observation and interviews. Thus, this study endeavors to answer the following questions: **What are the crucial issues of China’ urbanization with respect to urban spatial characteristics? What are the features of city scale (size) and land-use pattern of Chinese cities via an advanced measurable interpretation?**

A good plan must guide the timing, location, and intensity of urban development, as well as consider a variety of regulative tools and incentives to guide urban development patterns. Furthermore, the effects of specific smart growth policies has a key role to play in contributing to the government’s strategy for sustainable urbanization by helping to provide for necessary land allocations. The current study will answer the following questions: **Can mixed land-use and infill development effective approaches address the identified urbanization issues for Chinese cities? How can a new policy approach achieve mixed land-use and infill development in the long-term under new-type urbanization?**

3.6 Chapter summary

The purpose of this chapter is to provide a brief introduction of urbanization issues and urban planning from the period of traditional planning to new-type urbanization. A criterion switch in urban planning is needed to endow adaptability and particularity to approve land use and new developments through a special channel. This chapter first identified the main urban issues in various parts of China. The main identified principles of planning and strategies that support new approaches to planning were identified. More specifically, this chapter studied the evidence on the linkage between smart growth and China's planning system and code. Many aspects of plans and codes, however, remain incompatible and contentious. New urbanization polices must work with planning codes enforcers to find common ground and to permit unconventional projects to proceed.

The chapter discussed smart growth principles with the comprehensiveness and integrity of China's planning regulatory systems, including the effects of regulations implemented at the local level. The central argument in this chapter is that planning systems in many parts of the major urban challenges must be revisited. Revised planning systems must play a significant role in developing cities positively and creating benefits from exploring smart growth for local and regional development. The policy approach to urban planning provides a framework for making community development decisions. It focuses on specific policy aspects of regulation, administration, and a combination of sanctions and incentives. The success of mixed land-use and infill development depends on the specific magnitude of many planning policies. Overall, the implementation strategy mostly addresses legal and administrative means to propose a series of planning policies and measures from a legislative and regulatory point of view and applying the policies to development projects and the optimal allocation of land resources. The last part provided the validation questions of a survey to be conducted with opinion leaders. The framework developed in this study seeks to explain the complex system and provide an interdisciplinary understanding for urbanizing China. The next chapter introduces the main methods of the analyses in this research.

CHAPTER 4 RESEARCH METHODOLOGY

4.1 Introduction

This chapter shows the development of the research methodology used in the present study. First, city size measures are constructed by quantifying the allometric scaling relations of urbanized cities in a logarithmic model. The model includes multiple urban factors under power law growth, that is, population, land use, gross domestic product (GDP), and transportation network volume (road area). Second, urban form measures are developed by quantifying urban land use patterns in a spatial model to include more detailed information on land use dynamics, such as, dispersion/aggregation and segregation/mix. Finally, this chapter introduces the data collection methods and explains the quantitative analytical tools.

4.2 Analytical Framework

To answer the research questions and gain a better understanding of the dynamics of urbanization and its urban systems further, a complex multidisciplinary spatial analysis is developed. The framework of this study is illustrated in Figure 4.1, which shows the investigation of a city's development performance from the perspective of size and pattern analyses. Each step of the analysis is expounded further in the following subsections.

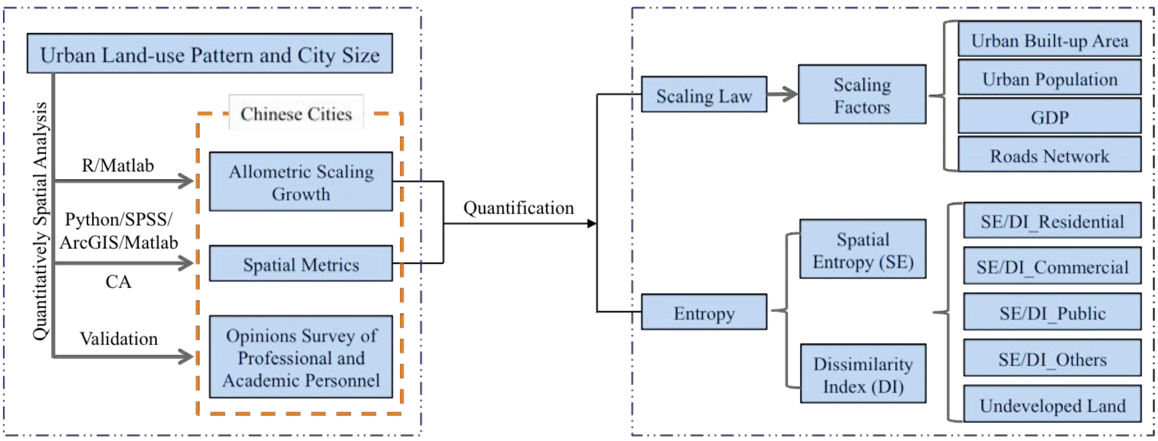


Figure 4.1 Analytical framework of research methodology.

Source: Compiled by the author

4.2.1 Identify the crucial issues of urbanization in China in terms of urban land-use pattern and city size (referring to objective 1)

This research investigates the structure and function of urban systems from the perspective of city size and land use pattern to understand the process of development in the cities of China. The essential issues of urbanization process and landscape changes in China are explored and depicted based on the quantitative understanding of the organization of cities.

4.2.2 Examine the dynamics of urbanization via the lens of city scale in quantitative analyses (referring to objective 2)

In investigating the level of urbanization and growth rate of different city categories, this study examines the nature of the city in terms of population, urban built-up area, GDP, and transportation network volume. Scaling factors, which are effective measurements of the performance of urbanization, are used. The quantitative analyses focus on the differences in urbanization peculiarities and the evolving processes among the different city categories.

4.2.3 Understand Chinese urban systems through urban land-use pattern (referring to objective 3)

The focus of this analysis is on land use pattern evaluation, its driving factors (i.e., urban population, urban land area, GPD, and paved road area), and its effect of urban development and urban policies. Spatial entropy is used to measure the concentration of land use within urban areas. Multi-measurements, namely, spatial entropy (SE) and dissimilarity index (DI), in combination with cellular automata (CA) modeling, planning maps, transportation survey maps, land parcels of points of interests (POIs), and statistical yearbook, are employed to model and compare the spatial dynamics of the urban form in China. Indicators (S_R, S_C, S_P, $D_{R|C}$, $D_{C|P}$, and $D_{R|P}$) are practical for characterizing urbanization and explicitly describing the basic properties of an urban form.

4.2.4 Develop a policy approach that adopts urban mixed land use and infill development strategies in planning for Chinese cities in the new-type urbanization time (referring to objective 4)

The planning and policy approaches to adopt a new urbanization will be developed by conducting a progressive analysis on the aforementioned three stages. The analysis is conducted to address the challenges of urban systems, to transform urbanization with the use of the spatial features of infill development, and to prevent the sprawling of Chinese cities in the future.

4.3 City Size And Urban Scaling

4.3.1 Origins of fractal and scaling cities

Scaling analysis actually originated from the field of physics, and was established by Newton. The original research on allometric growth started from biological sciences (Figure 4.2), and was later proposed to social science by Naroll et al. (1956, 1973). Scaling relationships have also been used throughout the development of social physics (Batty et al., 1989). Stewart (1947) conducted the first known estimate of the allometric parameter in his science article, which introduced social physics. Nowadays, allometric scaling relation analysis has reached the theoretical geometrical relation. The importance of this analysis is that it explains scaling in terms of the fractal and Euclidean geometries of the city. These geometries capture the primary effect of urban planning. The progress of allometric growth consistently involves a large amount of fractal growth relations that can be related to the fractal geometry of cities, with respect to city size (Batty and Longley, 1994). The scale of the city determines its benefits and the costs associated with the scale of cities (Bettencourt et al., 2007). Bettencourt et al. (2007) provides us with a theory that details how cities change as they scale rapidly until they become entirely urbanized. Bettencourt develops a theory for efficient infrastructure provision, which considers lesser space per capita for utilities, transport routes, residential living such as income, production of patents, services, and crime, which all scale superlinearly with respect to population.

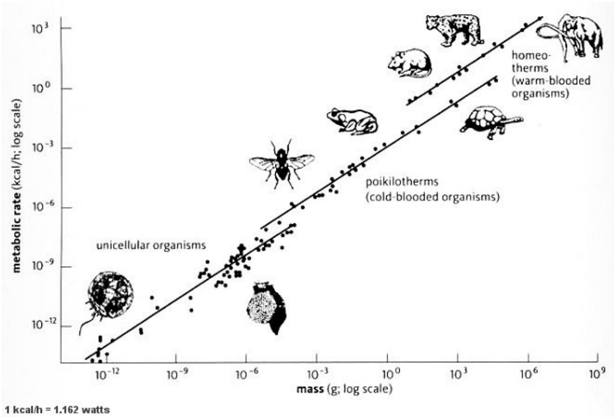


Figure 4.2a. Metabolic rate ~ animal body mass.

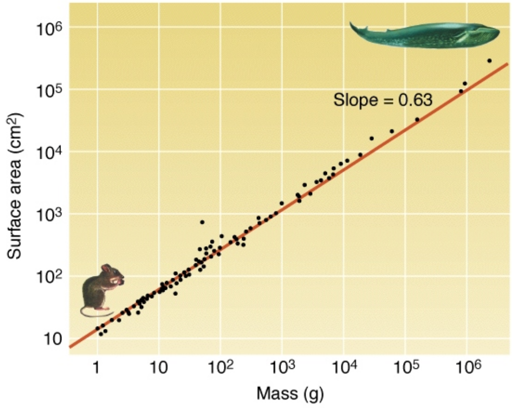


Figure 4.2b. Body surface area ~ animal body mass.

Figure 4.2Allometric relationships between adults of different species.

Figure 4.2a. The relationship between mass-specific metabolic rate and animal body mass for a range of mammals.

Figure 4.2b. The relationship between body surface area and animal body mass. Measurements on actual animals show organisms seem to follow a rule, known as Kleiber's law, that the value of scaling exponent is very close to 0.75

Source: Herbert, 2012

4.3.2 Urban growth and scaling factor

The values of allometric scaling factors can address the structure of cities. Studies of allometry on the characteristics of spatial and social relationships focused on the constant ration of growth exponent (Steward and Warntz, 1958). This allometric scaling is usually the equation form of the power law that estimates the log-log plot of two elements. Much attention has been focused on the exponent because it is an intangible index used to interpret the relationship of the urban area and population in the urbanization process. Considerable arguments have been raised concerning the universality of the scaling exponent (Meakin, 1986c). The allometric coefficient is also known as the allometric scaling exponent (Chen, 2010). The mathematical description of the allometric growth is dependent on various fractal allometric scaling exponents, and stresses on an evolutionary process or a spatial relation. The value of the exponent is a consequence of the system, rather than of any noise in the data (Curry, 1972). The researchers presented a constant exponent of the power function between the spatial area and the population size of urban systems. The allometric growth law in biology, which scales the body size, is shown as the function:

$$Y = aX^{b} \tag{1}$$

$$b = \frac{dy}{y} \Big/ \frac{dx}{x} \tag{2}$$

This expression states that the relative growth rate of an object *Y* is proportional to the relative growth rate of another object *X*, with *b* being the proportionality factor. The allometric exponent *b*, which is a scaling factor in biology, describes how *Y* is scaled to body size. When $b>1$, positive allometry results, implying that *Y* increases at a faster rate than *X*. When $b<1$, negative allometry results, implying that *Y* increases at a slower rate. When $b=0$ then X has no effect on *Y*. Finally, when $b=1$, isometry occurs, implying that the two variables increase in linear proportion with each other (Figure. 4.3). The proportionality coefficient *a*, is a supplement for comparison when scaling factor *b* is equal to or similar in a different case. For example, the coefficient can be regarded as a ratio between land area and population size in a city. In accordance with the principle in mathematics, one variable x is in ratio to another variable y only when the two variables, x and y, are in the equivalent dimensional measure. Otherwise, the two measures should be transformed to be in the same dimension. The basic geometric relations denote the linear unit as L, area A as L^2, and volume V as L^3. Therefore, V = AL. The standard allometric relations first proposed by Huxley (1932, 1993) imply that changes in the volume, area, or length relative to each other are as follows: $A = V^{2/3}$, $L = A^{1/2}$, and $L = V^{1/3}$. These functions imply that as the volume grows, the area grows at a rate 2/3 of volume growth. This measure can easily be observed in the relative growth ratio of A to V where the scaling parameter is the relative growth rate of y to x, which is defined in Equation (2). The relationships of the surface area (S) and volumes (V) in a geometric linear model are as follows:

$$S \propto V^{\frac{2}{3}} \tag{3}$$

Population is regarded as a volume having the dimension of 3, and area has the dimensions of 3, then the isometry is indicated by an exponent of 2/3=0.66 (Nordbeck, 1971; Ranko, 1972; Coffey, 1979). This correlation can be applied to any relationship scaling with respect to the different sizes of relative growth (Batty, et al., 2008).

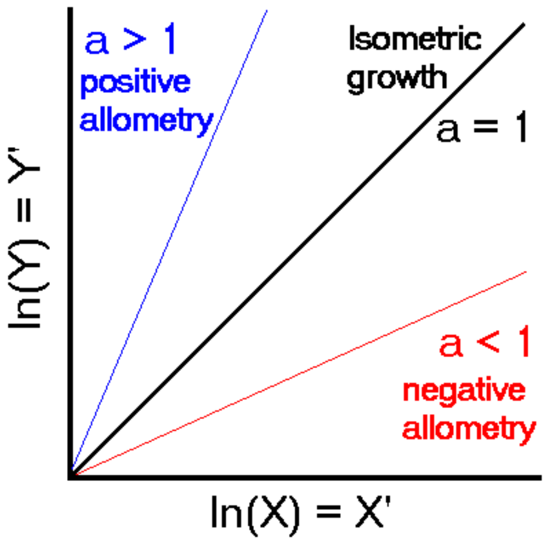
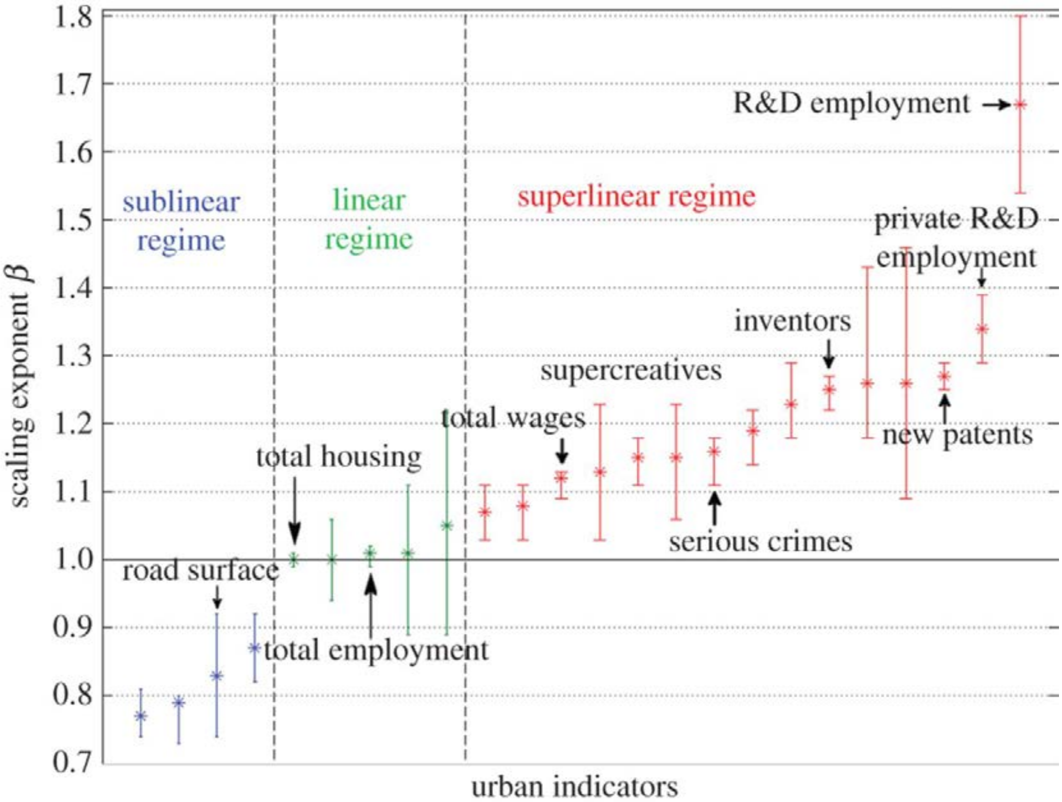


Figure 4.3 Proportional growth in log scale relation.

Substantial evidence support the scaling relationships in the United States, where cities are widely spaced and do not generally merge into one another. Stewart (1940) stated that the allometric parameter for all U.S. cities with a population of more than 2,500 was 0.75, which demonstrated positive allometry until the 1980s. Urban areas increase with stronger positive allometry. However, recent studies conducted in the U.S. and U.K. indicate a strong negative allometry and falling allometric parameter from the 1990s to 2010s (Batty and Ferguson, 2011). The allometric scaling (1960s–1980s) describes a situation where the more populated urbanized areas have proportionately larger land area than the areas with lower population size, and where b is almost always greater than 0.67 (Lee, 1989). The allometric coefficient and urban-population-density increase proportionally together with urban land expansion (Dutton, 1973b). When $2/3<b<1$, land area grows at a faster rate than population. Therefore, as the population density in the city center increases over time, the gradient of the population decreases. When b=1, the population density in the city center remains constant over time, and the gradient of the population decreases. A more drastic rate is found when b>1. However, in many U.S. cities, urban living is primarily a two-dimensional phenomenon, and the accommodation of additional population is horizontal and not vertical. The allometric coefficients for the U.S. urban system fit the dynamic similarity with 0.70 < b < 1.0 (Lee, 1989). In the U.K., the scaling relation against population for all 283 towns and cities with populations over 10,000 in England and Wales generated a superliner scaling for the urban system (Batty, 2013).

4.3.3 Allometric scaling analysis

The change in urban population may destroy the best-fit relationships in the area, economic output, and transportation network volume. Certain critical ratios among geometric attributes need to be adjusted accordingly if one element changes in size, for the element to still function (Batty et al., 2008). A different perspective could be adopted in measuring the performance of a city through scaling laws. Therefore, a



theory of cities needs to reproduce the relevant behaviors encoded in the diversity and heterogeneities of cities (Arcaute et al., 2015). Observations in the U.S., Germany, and China appear to provide empirical evidence of the exponent values (Figure 4.4).

Figure 4.4 Exponents with 95% confidence interval (CI) for different urban indicators found for the U.S., Germany, and China.

Source: Arcaute et al., 2015; Bettencourt et al., 2007

In this study, the allometric scaling law for the relationships among the population size, transport network capacity, transport network length, GDP, and urban land areas are used as variables. The four basic measures can be stated in the following equations:

$$A = aN^{\alpha} \tag{4}$$

where N is the population quantity, a is the proportionality coefficient, and $\boldsymbol{\alpha}$ is the scaling factor. A generalized relationship between population and city area is seen in the exponent $\boldsymbol{\alpha} = \mathrm{D}/(\mathrm{D}+\mathrm{H}) \simeq 2/3$, where D=2 and H=1. In the scaling relation, a larger $\boldsymbol{\alpha}$ will lead to a less dense city, which is consistent with the observed cities over time (Bettencourt, 2013). Exponent $\boldsymbol{\alpha}$ = 2/3 was derived from observed Swedish cities (Nordbeck, 1971), wherein it was noted that when urban population should scale into a 3D spatial volume, then $N \sim A^{3/2}$ or $A \sim N^{2/3}$. It is impossible for a city to cover the entire land area, especially for large cities. Many early studies characterizing the scaling relation used urban administrative areas, which led to several disparities. Nordbeck (1971) established the first theoretical view on $\boldsymbol{\alpha} \simeq 2/3$ using 1960s urban data in Sweden. Bettencourt (2010) also claims that the nature of cities has great variation in scaling. For example, the characteristics of small towns can lead to deviations. However, for general allometry growth, the researchers believe that heterogeneous urban space must have a natural dimension of a physical volume where the urban population scales have a larger dimension than that of city area. A number of studies since World War II discussed the value of $\boldsymbol{\alpha}$, where the variability in measuring $\boldsymbol{\alpha}$ is anchored at 2/3~1 because of the adoption of inconsistent definitions of city size (Batty and Ferguson, 2011). The range given (see Table 4.1) is a synthesis of these results. Future research should develop a more consistent city definition to measure this scaling relation.

With scaling parameters as input variables, exponents are only dependent on dimensionless parameters H and D, and are independent of network parameters or individual behavior. In this sense, exponents may be largely invariant in time, population size, or levels of socioeconomic development. Nevertheless, H is a means of measuring how connected (inclusive) a city is and how it may change slowly over time. The scaling relations depend on remaining input parameters that change over time, reflecting the socioeconomic development, changes in the properties of infrastructure, and individual behavior.

$$A_n = A_0 N^{\nu} \tag{5}$$

Networks of infrastructure fill the area of the city to connect each inhabitant by means of roads. The paved infrastructure, namely roads, provides a measure of the scaling relationship between the transportation network volume and the corresponding population size. Bettencourt (2013) synthesizes a value of scaling exponent with υ~5/6 that can be used worldwide as well as in China (Angel et al., 2011; Chen, 2010). Input variables are network volume (area) and population size.

$$L_n = L_0 N^{\lambda} \tag{6}$$

Network length

$$Y = Y_0 N^{\beta} \tag{7}$$

Social interactions and socioeconomic rates

Assumption H<1, H>1, and H=1,

in $\alpha = \frac{D}{D+H}$ (D=2, theoretically expected model when H is 1, $\alpha=\frac{2}{3}$),

in ν=1-δ (theoretically expected model when H is 1, $\nu=\frac{5}{6}$)

in $\lambda = \alpha$ (theoretically expected model when H is 1, $\lambda = \frac{2}{3}$)

in $\beta = 1 + \delta$ (theoretically expected model when H is 1, $\beta = \frac{7}{6}$)

a. Urban Area ~ urban population
b. Urban GDP ~ urban population
c. Urban Transportation Volume ~ urban population

We plot the scaling of the four attributes in logarithmic form. The log x is defined as $\log_{10}$ x in this study. When a logarithm is written without a base, it is a common logarithm. $\log_a x = N$ means that $a^N = x$. Power: $\log_a (x^p) = p \log_a x$. For this study, assume that x, y, a, and b are all positive. Assume that $a \neq 1$, $b \neq 1$. Given a monomial equation $y = ax^b$ and taking the logarithm of the equation (with any base) yields $\log y = k \log x + \log a$. The equation for a line on a log–log scale would be where b is the slope and a is the intercept point on the log plot. Log–log regression can also be used to estimate the fractal dimension of a naturally occurring fractal. While simple log–log plots may be instructive in detecting possible power laws, these graphs are also useful when data are gathered by varying the control variable along an exponential function. In that case, the control variable x is more naturally represented on a log scale, and the data points are evenly spaced, rather than compressed at the low end. The output variable y can be represented linearly.

The relationships among scaling law, allometry, and urban form are discussed in regard of hierarchical cities (Batty and Kim, 1992). Meanwhile, the progress of urban evaluation over different years presents us a longitudinal allometry that may be classified in different types in line with scaling exponent value. The classification of allometric scaling relations can help describe allometric growth and fractal growth of cities.

4.4 Research Methods

4.4.1 Data collection

The wide range of statistics data analyzed and employed in this research for 282 cities at prefecture levels across China were obtained from the National Bureau of Statistics of China (NBSC) and the "Ministry of Housing and Urban-Rural Development of China" (MOHURD) from the years 1985 to 2014. Relevant economic and urban statistics data were also collected from the China Urban Statistical Yearbook, China Urban Construction Statistical Yearbook, and the China Population Statistical Yearbook. Data for road surface volume of the selected cities in China were collected from the Urban Statistical Yearbook of China. This study processes the analysis by using socioeconomic data and dual log-log models. The evaluation focuses on urban performance indicators dependent on data from the National Census Bureau and other national databases. These data will help decision makers to perceive the policy approach and smart growth principles for mixed land use and infill development.

The secondary data (interacting parameters) acquired through computer research are listed as follows:

- Urban Area (built-up area when government agency used the term)
- Urban Population (urban registered population or urban permanent resident of population when government agency used the term)
- Urban GDP
- Transportation Network Volume (road area)
- Population Census Data: 1982, 1990, 2000, 2010.

4.4.2 Study area and data processing

This study examined a total of 61 samples of Chinese cities (Figure 4.5), ranging across three levels, namely megacities (first-tier cities, 6), provincial capital cities (second-tier cities, 21), and prefecture-level cities (third-tier cities, 33). This analytical scope utilizes urban land use data based on AICP, with Ordinance Survey Map of road networks and Points of Interest (POIs) built through the method developed in a previous study for Chinese cities defining land parcels (Liu and Long, 2016). The AICP method provides us with vector GIS data for all studied cities to extract urban land use patterns. The analytical scope is narrowed to a legally defined urban land, and use POI data and ordinance survey data of road networks for China (ORDNANCE, 2011) in land parcel identification. POIs are synthesized from an online business catalogue (2013) and aggregated into eight general categories. Each land parcel is generated as a cell in a vector-based constrained cellular automata (CA) model (Zhang and Long 2013), which simulates the total urban area (Long and Liu, 2014). The maps were then placed into the GIS software for classification and color correction pixel by pixel, and then converted into color-coded raster images as base maps. Land-use status quo maps (Urban Master Planning 2010) obtained for data validation are gathered from local planning authorities. Even though each classified image might have some potential errors in accuracy, road networks in the ordinance survey and land-use zoning maps are verified to ensure overall data quality and applicability. Moreover, the objective of this study was to characterize the overall dynamics of the land use pattern. Thus, the base map can reflect the observed land use configuration. In this study, three main types of land use as parameters are utilized to reconstruct urban land use classification, $T_{Residential}$ (residence communities), $T_{Commercial}$ (business, retails, and firms), T_{Public} (government and education), while T_{others} (manufacture, utility, infrastructure, and warehouse), and undevelopable land (water, reserved lands, and forests) are colored in yellow and not calculated. A cell of land uses type $T_{[R, C, P]}$ (where R=residential, C=commercial, P=Public) then calculated on the two-dimensional base map. All land used cells that correspond to the total number extracted from the base map (see detail example in Figure 4.5). Urban area and urban population data are obtained from *China City Statistical Yearbook* (National Bureau of Statistics of China, 2014).

Figure 4.5 Locations of study cities.

4.4.3 Spatial analysis methods

Spatial Entropy

Few studies have employed urban form measures at a high level of spatial resolution and conducted an analysis at the city level. In this study, we use a CA-based method to develop urban form measures at the street level of each city. The entropy method can handle the scaling problem well, where relative entropy and differences in entropy will not change regardless of city size (Yeh and Li, 2001). The relative differences in entropy among the towns will not change if the same frame size is used to calculate the entropy for different cities. The CA model is applied where the cell, which is a land plot unit, is in a pixel of 64 m^2 of a given land use sector in each city map. In the study by Decraene et al. (2013a), a series of experiments were conducted to evaluate and identify sufficient and suitable spatial resolution to measure spatial entropy to land. The experiments use plots at a satisfactory spatial resolution, where a suitable length frame to compute entropy is l_S=8 meters, whereas 64m^2 per pixel is used to compute each cell of the two CA models.

The spatial entropy S_T *(M)* given in Eq. (8) provides the degree of spatial concentration or dispersion of different land types among *N* cells across urban areas. City maps are divided into k frames as a regular grid, in which of each frame constitutes of $N_k = l \times l$ land plots (pixels). City maps are color-coded according to land use types, where a cell of land is categorized by its color value. Spatial entropy is utilized to evaluate the degree of spread for each land use type T in a city and is defined as

$$S_T(M) = -\sum_k [p_k \ln(p_k) + (1 - p_k)\ln(1 - p_k)\ ] \tag{8}$$

$$p_k = t/N_k \tag{9}$$

where P_k is the intensity of pixels of a land use type *T* (Eq.(9)), and t is the number of pixels of type *T* found in the i^{th} frame. SE varies between 0 and 1. When $S_T(M)$=1, *T* are dispersed throughout all frames, whereas S_T *(M)*=0 indicates that sector *T* is concentrated in a small cluster. A larger entropy value means urban sprawl. The increase in entropy value indicates an increase in dispersed urban growth, and that the city is experiencing expansion.

Dissimilarity Index (level of mix)

Fractal analysis was developed as an approach to measure heterogeneity or fragmentation (Batty and Kim, 1992). Mixed land use is a key characteristic of neotraditional planning, therefore, DI is used to understand the balance between different kinds of land use. In Eq. (10), DI is employed to characterize the degree of segregation and represents the variation in land use. The DI of land use T_1 and T_2 is given as

$$D_{(T_1|T_2)} = \frac{1}{2}\sum_{i=1}^{k} \left| \frac{t_{1_i}}{N_{T_1}} - \frac{t_{2_i}}{N_{T_2}} \right| \tag{10}$$

where N_T is the total number of cell pixels T found in each frame. The values $D_{(T1/T2)}=1$ imply that land uses T_1 and T_2 are fully segregated and a single land-use type dominates each frame, whereas $D_{(T1/T2)}=0$ indicates an equal division of land use throughout the frames. Thus, when a presence of 50% T_1 and 50% T_2 in seen in a frame, DI will approximate to 0, whereas when a single T_x dominates, the DI close to 1. Lastly, urban area and urban population are two significant factors in the distinction of a city. We explored the correlations among *SE, DI*, urban area, and urban population to achieve in-depth understanding of the interacting effects on urban land use.

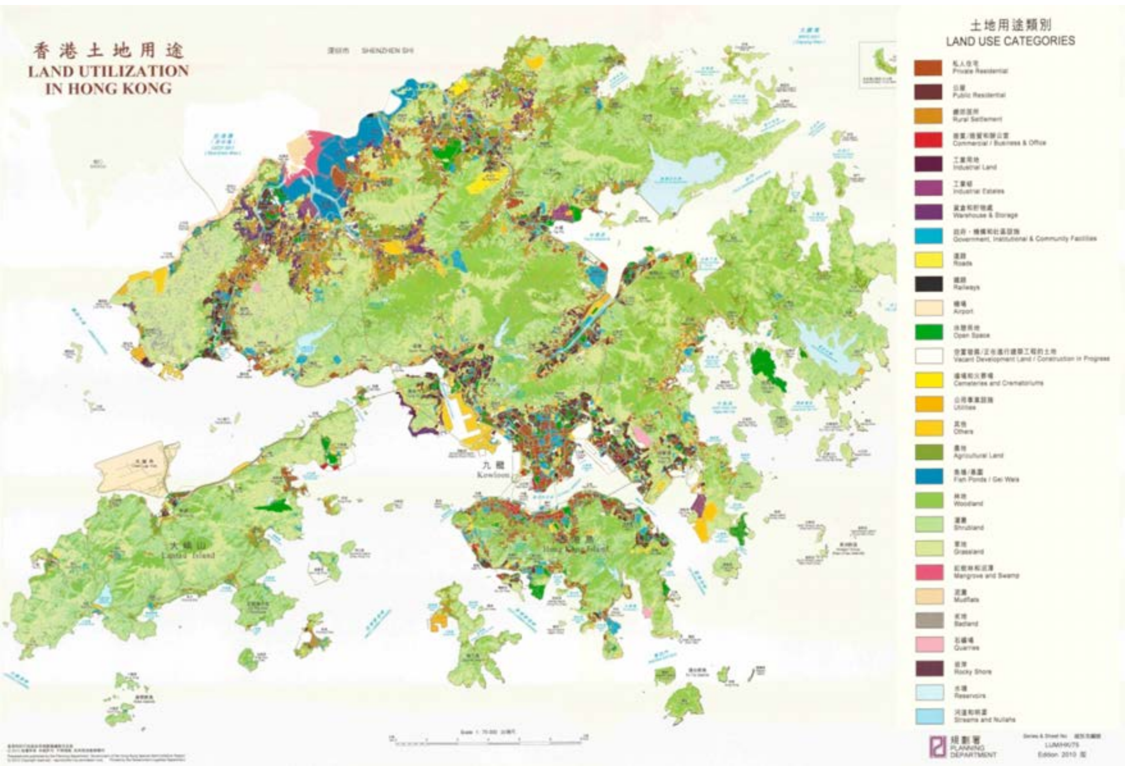


Figure 4.6a. The actual land use map of *Outline Zoning Plans* of *Hong Kong* (OZP)

Source: Town Planning Board, 2014

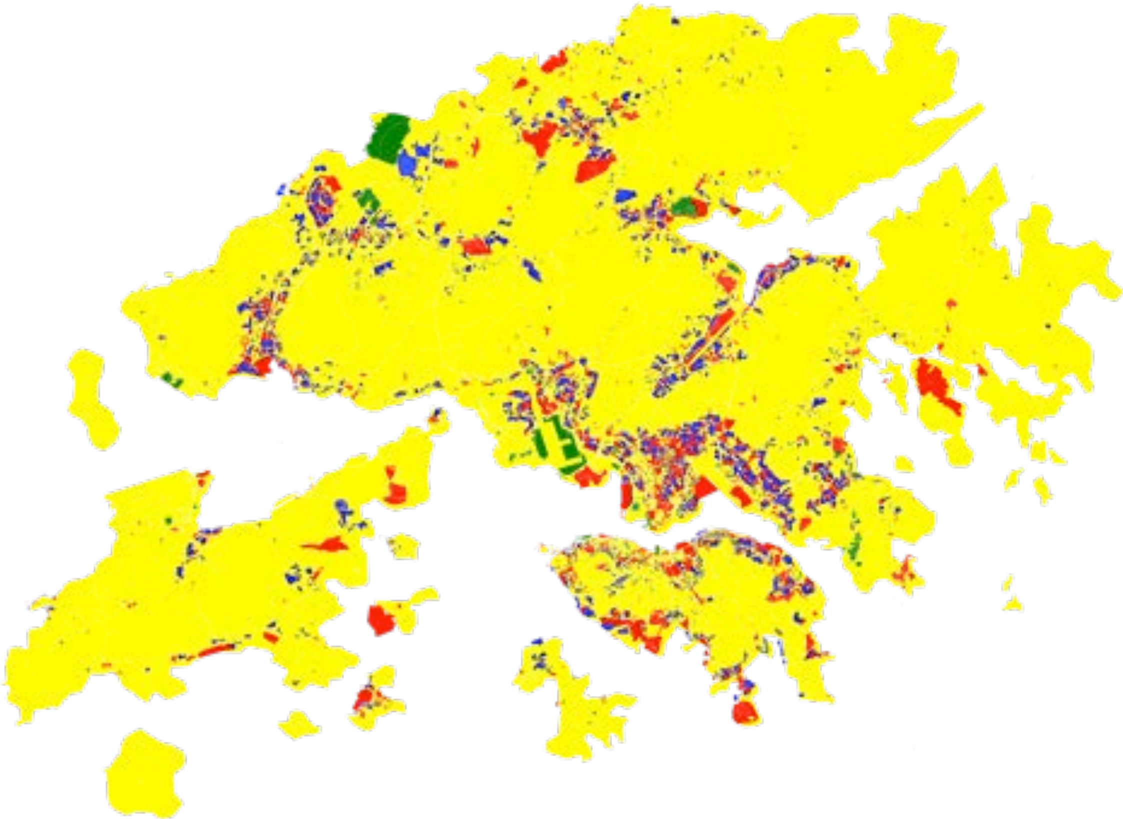


Figure 4.6b. The land use extraction model of Hong Kong map.

Figure 4.6 Land use base map-compiling model of Hong Kong.

Figure 4.6a. Actual land use map of the *Outline Zoning Plans* of *Hong Kong* (OZP) collected from the Planning Department, The Government of the Hong Kong Special Administration Region.

Figure 4.6b. Land use extraction model of Hong Kong map adapted from the OZP, which discarded land use categories not directly related to the above, and mentions major land use sectors. Blue, green, red, and yellow colored pixels correspond to residential, commercial, public, and other land use sectors (including undeveloped) respectively, where the sectors are aggregations of relevant sub-categories.

4.4.4 Measurements of spatial entropy and dissimilarity index

Urban sprawl is characterized by an uneven growth pattern in a low-density manner, leading to inefficient land resource utilization (Bhatta et al., 2010). Many researchers have analyzed urban sprawl through spatial metrics using land cover data in conjunction with census data (Bhatta et al., 2010; Schneider and Woodcock, 2008).

Some studies utilize a few assessing indices to reveal which city “sprawls” by using static and macro statistical data. However, empirical literature on spatial metrics for city wide measures is still underdeveloped. The studies failed to provide adequate information to capture differences among intra-urban areas. If three or more dimensions of land use are of interest, a multidimensional index is proposed, namely Spatial Entropy (SE) and Dissimilarity Index (DI) (Song, et al., 2013). SE is a good measure of urban spatial development (Batty, 1972; Batty, 1976), which is commonly calculated to determine the degree of urban sprawl. The classical urban theories, which are based mainly on social and economic rules, do not capture the local land use pattern. Compared to traditional spatial statistics (Thomas, 1981), SE can provide a more systematic analysis to determine whether the urbanization is moving toward being compact or expanding (aggregate or dispersed) (Yeh and Liu, 2001; Li and Yeh, 2004; Lata et al., 2001; Sudhira et al., 2004; Pathan et al., 2004). Mixing land uses need to have elevated expectations and standards for designs. After half a century of segregated zoning, most people cannot envision how their homes, shopping malls, and offices could be compatible in close proximity. Researchers have looked towards cellular automata and GIS to create urban dynamic models. The use of cellular automata (Batty, 1997) allows the modeler to use a matrix of cells whose characteristics change with repetitive application of simple rules. This process can be used to mirror the spatial development of a city, its land use, and its form. DI measures the degree of evenness of land use distribution. Decraene et al., (2013b) used SE and DI to measure the dispersion and aggregation mechanism of urban land use. The combination of these two measures provides a straightforward method to investigate urban land use patterns that result from dispersion and segregation mechanisms. This method is a cellular automata model that reconstructs cities from the bottom-up with SE and DI values.

4.4.5 Semi-structure interviews with opinion leaders

Semi-structured interviews were conducted from March to May 2016 to collect comments and suggestion from different opinion leaders and to validate the availability of the planning approach in China. Opinion leaders were defined as senior professionals within organizations in the planning or academic community. Because organizations in the public, private, and academic sectors might have different perceptions on the employment and suitability of a policy approach from smart growth, the survey sample drew from each of these sectors. Selected survey objects from organizations include municipal officials, planning department leagues, urban planning and design consultants, and academic professors (Table 4.1). Ten key individuals in those organizations were identified through web-based information as well as personal contacts. All the opinion leaders completed the survey and were identified to have significant expertise on land use regulation and planning policy from their respective cities in China. In general, the proposed set of principles lacked sufficient time and data to allow the formulation and comparison of performance assessment tracked over time across jurisdictions related to land use. Although surveys have distinct limitations, especially in sampling constraints, the findings provide a more multidimensional picture of the needs of a new policy approach in planning for the *New-Type Urbanization*.

Table 4.1 Survey Responses by cities

Cities of origin	Number of respondents	Occupations
Beijing	2	Consultant/ academia
Changsha	1	Academia
Guangzhou	2	Planning department league/ academia
Harbin	1	Academia
Hong Kong	1	Academia
Shenzhen	2	Consultant/ academia
Xiamen	1	Municipal official

The survey was structured to measure perceptions on effects of a proposed policy approach to local planning regulations on urban development, and the feasibility and applicability of the approach inherited from smart growth principles in the Chinese context. Responses were structured and compared by grouping various attitudes on the cities' planning and policy through smart growth principles with regard to mixed land use and infill development. To complete the survey, each corresponding question focuses on the inquiry based on the experts' best knowledge of local situations and impression of the effects of local regulations, which questions are presented in Chapter 3.

4.5 Chapter Summary

If urban development is not in the right place and the right form, even compact urban forms can disrupt ecological and social systems (Berke and Conroy, 2000). Current studies in China that expose the urban sprawl and control the total amount of land have only introduced the principles of and strategies based on smart growth theory in western countries. These studies have made a number of recommendations for land policy, which mainly include qualitative analysis that emphasized the theoretical learning of the smart growth concept, strategies, and technologies. With one city as a case study, most of these studies also rarely involved quantitative assessment; thus, implementing specific spatial measures for Chinese cities is difficult. Measures that can be used to quantify urban development patterns at a level that facilitates the assessment of development trends should be determined. A method to measure urbanization effects on urban form and show any similarity in urban development patterns should also be developed.

The area of focus in this study is the scaling law, which was presented to highlight and interpret urbanization in relation to a city's size, wherein the root theory lies in fractal cities and its complex system. A spatial metric with a combination of spatial entropy and dissimilarity index was given to investigate the land use pattern in terms of mixed land use and degree of sprawl. Following the base analysis, a dual logarithmic relation analysis in land use pattern study is conducted. This analysis is in conjunction with other correlation tests (correlate analysis, MNOAVA test) to explore the driving force of each urban factor in the spatial entropy and dissimilarity index. The comprehensive results and findings are delineated in Chapter 5 for the allometric scaling of city size and Chapter 6 for the land use pattern, respectively. Policy implications and recommendations based on these results are discussed in Chapter 7. This perspective is effective for urban planning and policy making.

CHAPTER 5 ALLOMETRIC SCALING OF CITY SIZE IN CHINA

5.1 Introduction

Generally, urbanization has direct and indirect effects on land use change, conversion, and evolution. To better understand urbanizing China, one has to consider the following questions: How does urbanization affect cities of different sizes? What have been the planning and policy-making programs for cities of different sizes in China? How can Chinese cities with different sizes of urban population reorganize themselves with regard to considerable shifts in national development? Less is known about the effect of urbanization on city size particularly because of the lack of necessarily supporting data and the complex nature of the analysis subject. To understand the growth dynamics of Chinese cities in the new era of urbanization, it is vital to assess the natural growth of Chinese cities and avoid the distorted/ noisy data due to administration interference, e.g. designating of new urban areas, changing urban boundaries, and eliminating/ merging existing cities. This chapter aims to investigate the allometric scaling in Chinese cities and to summarize this knowledge.

5.2 Scaling of Chinese Cities

5.2.1 Analysis of allometric scaling in Chinese cities

5.2.1.1 Allometric scaling relations of urban built-up area: Urban population

The assessments on Chinese cities have focused on the structural and dynamic relations between urban population and built-up area. In the scaling laws on log-log plots, the area grows faster than the population. The urban land use area expands in a relation of positive allometry corresponding to the urban population, which means that if the city population increases a unit, the city area will increase by more than a unit. Thus, the urban area increases more rapidly than the urban population. This trend suggests that the land use of cities in China is comparatively more than the population needs. This allometric mode of land use suggests that strong measures should be taken to restrict urban expansion. As noted in official reports, urban construction on cultivated land ranks is the second significant contributor (18.5%) for arable land loss in China (Zhang, 2000). The unprecedented increase of urban territory in the last decades has converted nearly 1.85 million hectares of cultivated land into urban built-up land (Chen et al., 2008).

The National Bureau of Statistics of the People's Republic of China (NBS) is the official source for most national statistics, including the censuses conducted every 10 years and the major statistical series published in the annual China Statistical Yearbook (CSY). The NBS has traditionally used census data to adjust the urban statistics published in the CSY. The *China Urban Construction Statistical Yearbook* (UCSY) and the *Urban Statistical Yearbook of China* (USY) are the major sources of urban data for China as they serve as summaries of national censuses.Figure 5.1 compares the allometric scaling relationship between USY (black line and dots) and census (red line and dots) data in four representative periods. The graph describes the scaling exponent β = 0.704 (USY) and 0.703 (census) in year 1990; β = 0.751 (USY) and 0.770 (census) in 2000; β = 0.876 (USY) and 0.819 (census) in 2010 and β = 0.871 (USY) in 2014. The lines in Figure 5.1(a) show the best fit to a scaling relation $A = \alpha N^{\beta}$ in 1990, Census (red), with β = 0.703 [95% confidence interval (CI), 0.632–0.774, R^2 = 0.60]; Urban Statistical Yearbook (black), with β = 0.704 [95% confidence interval (CI), 0.588–0.821, R^2 = 0.60]; and the theoretical prediction, β = 2/3 (green); The lines in Figure 5.1(b) depict the best fit to a scaling relation $A=\alpha N^{\beta}$in 2000, Census (red), with β = 0.764 [95% confidence interval (CI), 0.611–0.916, R^2 = 0.73]; Urban Statistical Yearbook (black), with β = 0.751 [95% confidence interval (CI), 0.670–0.832, R^2 = 0.65]; and the theoretical prediction, β = 2/3 (green); The lines in Figure 5.1(c) demonstrate the best fit to a scaling relation $A = \alpha N^{\beta}$ in 2010, Census (red), with β = 0.819 [95% confidence interval (CI), 0.780–0.858, R^2 = 0.86]; Urban Construction Statistical Yearbook (black), with β = 0.876 [95% confidence interval (CI), 0.798–0.953, R^2 = 0.65]; and the theoretical prediction, β =2/3 (green); The lines in Figure 5.1(d) show the best fit to a scaling relation $A=\alpha N^{\beta}$in 2014, Urban Construction Statistical Yearbook (black), with β = 0.871 [95% confidence interval (CI), 0.799–0.944, R^2 = 0.67]; and the theoretical prediction, β = 2/3 (green).

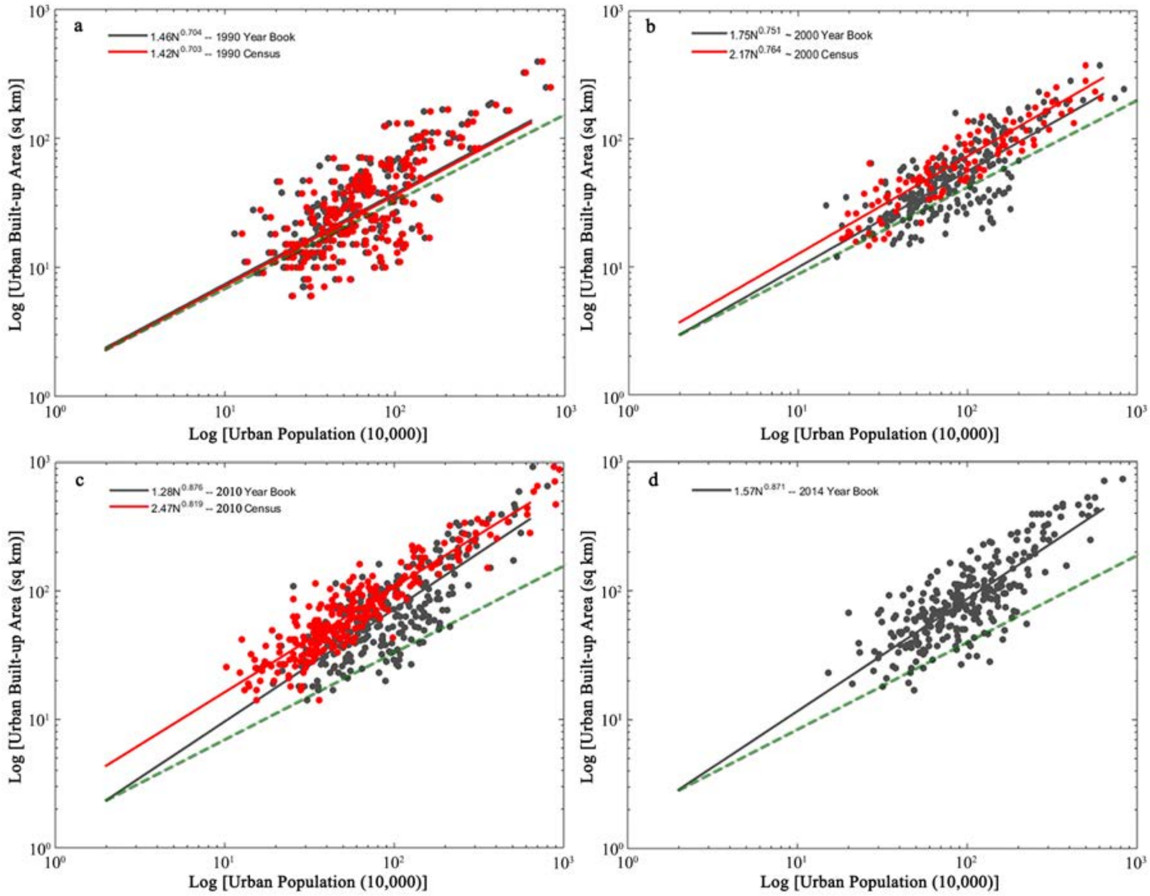


Figure 5.1 Double logarithmic plots of the allometric scaling relationship between urban area and urban population of Chinese cities.

(Notes: a. year 1990, b. year 2000, c. year 2010, d. year 2014; black line statistical yearbook, red line census, green dashed line theoretical assumption value. Census (China National Census) data section is to depict three decades urbanization for comparison with statistical yearbook. Urban Statistical Yearbook is used to compare for 1990 and 2000, and Urban Construction Statistical Yearbook is used for 2010 and 2014. Urban area applies urban built-up area data, and population applies urban population data in 1990, 2000 from USY, and urban permanent residents in 2010, 2014 from UCSY.)

5.2.1.2 Allometric scaling relations of urban GDP-urban population

The economic impact of urbanization is expressed as a scaling ratio of GDP to population changes over time. A positive economical scaling relation indicates more revenue (GDP) growth than population growth. In contrast, a negative economical scaling relation indicates more expenditure than revenue growth. GDP increase failed to catch up with this acceleration in urbanization in the past three decades. The changing scaling factors show in Figure 5.2. β best-fit values are theoretically expected at 7/6 (1.17), with an international observation ranging from 1.01 to 1.33. Thus, a drop in economic efficiency is observed at lower β values, e.g., in 1990s and 2000s.

Figure 5.2 compares the allometric scaling relationship between the USY (black line and dots) and the census (red line and dots) data in four representative periods. The graph describes the scaling exponent β = 1.017 (USY) and 1.018 (census) in 1990; β = 1.105 (USY) and 0.927 (census) in 2000; β = 1.236 (USY) and 1.098 (census) in 2010; β = 1.221 (USY) in 2014. The lines in Figure 5.2(a) show the best fit to a scaling relation $Y\ (GDP) = \alpha N^{\beta}$ in 1990, Census (red), with β = 1.018 [95% confidence interval (CI), 1.002–1.022, R^2 = 0.65]; Urban Statistical Yearbook (black), with β = 1.017 [95% confidence interval (CI), 1.008–1.021, R^2 = 0.65]; The lines in Figure 5.2(b) depict the best fit to a scaling relation $Y\ (GDP) = \alpha N^{\beta}$ in 2000, Census (red), with β = 0.927 [95% confidence interval (CI), 0.911–0.936, R^2 = 0.60]; Urban Statistical Yearbook (black), with β = 1.105 [95% confidence interval (CI), 1.080–1.112, R^2 = 0.65]; The lines in Figure 5.2(c) exhibit the best fit to a scaling relation $Y\ (GDP) = \alpha N^{\beta}$ in 2010, Census (red), with β = 1.098 [95% confidence interval (CI), 1.083–1.118, R^2 = 0.86]; Urban Construction Statistical Yearbook (black), with β = 1.236 [95% confidence interval (CI), 1.198–1.253, R^2 = 0.75]; The lines in Figure 5.2(d) show the best fit to a scaling relation $Y\ (GDP) = \alpha N^{\beta}$ in 2014, Urban Construction Statistical Yearbook (black), with β = 1.221 [95% confidence interval (CI), 1.199–1.244, R^2 = 0.68].

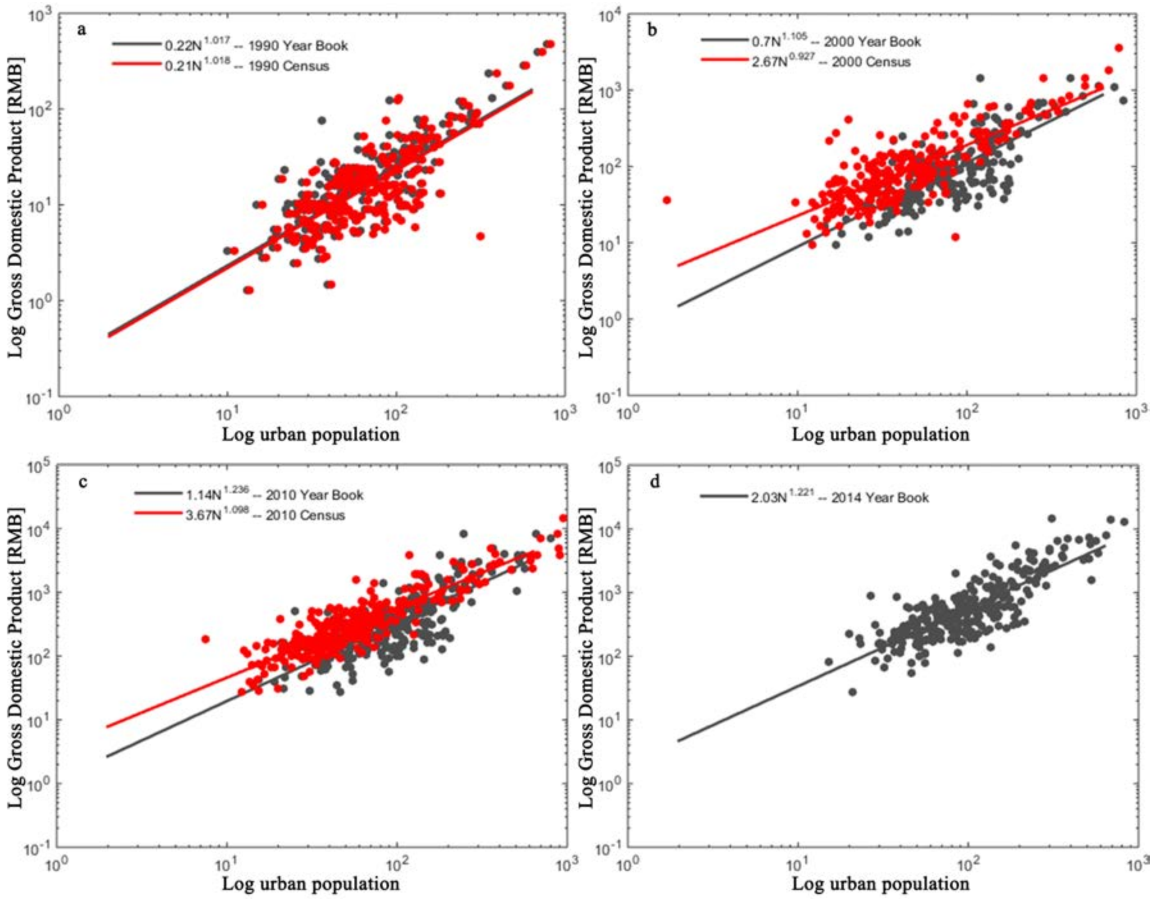


Figure 5.2 Double logarithmic plots of the allometric scaling relationship between urban GDP and urban population of Chinese cities.

(Notes: a. year 1990, b. year 2000, c. year 2010, d. year 2014; black line statistical yearbook, red line census, green dashed line theoretical assumption value. Census (China National Census) data section is to depict three decades urbanization for comparison with statistical yearbook. Urban Statistical Yearbook is used to compare for 1990 and 2000, and Urban Construction Statistical Yearbook is used for 2010 and 2014. Urban area applies urban built-up area data, and population applies urban population data in 1990, 2000 from USY, and urban permanent residents in 2010, 2014 from UCSY.)

5.2.1.3 Allometric scaling relations of urban transportation networks volume (road area)−urban population

As cities grow, part of the urban area becomes occupied by transportation networks to connect people and ship goods. This analysis underlies the dynamics of urban infrastructures against the scaling relations between transportation network volume (road area) and urban population in Chinese cities. These scaling factor β best-fit values are theoretically expected at 5/6 (0.833), with an international observation ranging from 0.74 to 0.92.

Figure 5.3 compares the allometric scaling relationship between USY (black line and dots) and census (red line and dots) data in four representative periods. The graph describes the scaling exponent β = 0.837 (USY) and 0.845 (census) in 1990; β = 0.83 (USY) and 0.781 (census) in 2000; β = 1.021 (USY) and 0.89 (census) in 2010 and β = 0.999 (USY) in 2014. The lines in Figure 5.3(a) show the best fit to a scaling relation *Y ((road area) =* αN^{β} in 1990, Census (red), with β = 0.845 [95% confidence interval (CI), 0.772–0.897, R^2 = 0.65]; Urban Statistical Yearbook (black), with β = 0.837 [95% confidence interval (CI), 0.778–0.871, R^2 = 0.65]; The lines in Figure 5.3(b) exhibit the best fit to a scaling relation *Y (road area) =* αN^{β} in 2000, Census (red), with β = 0.781 [95% confidence interval (CI), 0.661–0.836, R^2 = 0.60]; Urban Statistical Yearbook (black), with β = 0.83 [95% confidence interval (CI), 0.780–0.872, R^2 = 0.65]; The lines in Figure 5.3(c) depict the best fit to a scaling relation *Y ((road area)=*αN^{β} in 2010, Census (red), with β = 0.89 [95% confidence interval (CI), 0.883–0.918, R^2 = 0.86]; Urban Construction Statistical Yearbook (black), with β = 1.021 [95% confidence interval (CI), 0.998–1.213, R^2 = 0.75]; The lines in Figure 5.3(d) show the best fit to a scaling relation *Y ((road area) =* αN^{β} in 2014, Urban Construction Statistical Yearbook (black), with β = 0.999 [95% confidence interval (CI), 0.899–1.004, R^2 = 0.70].

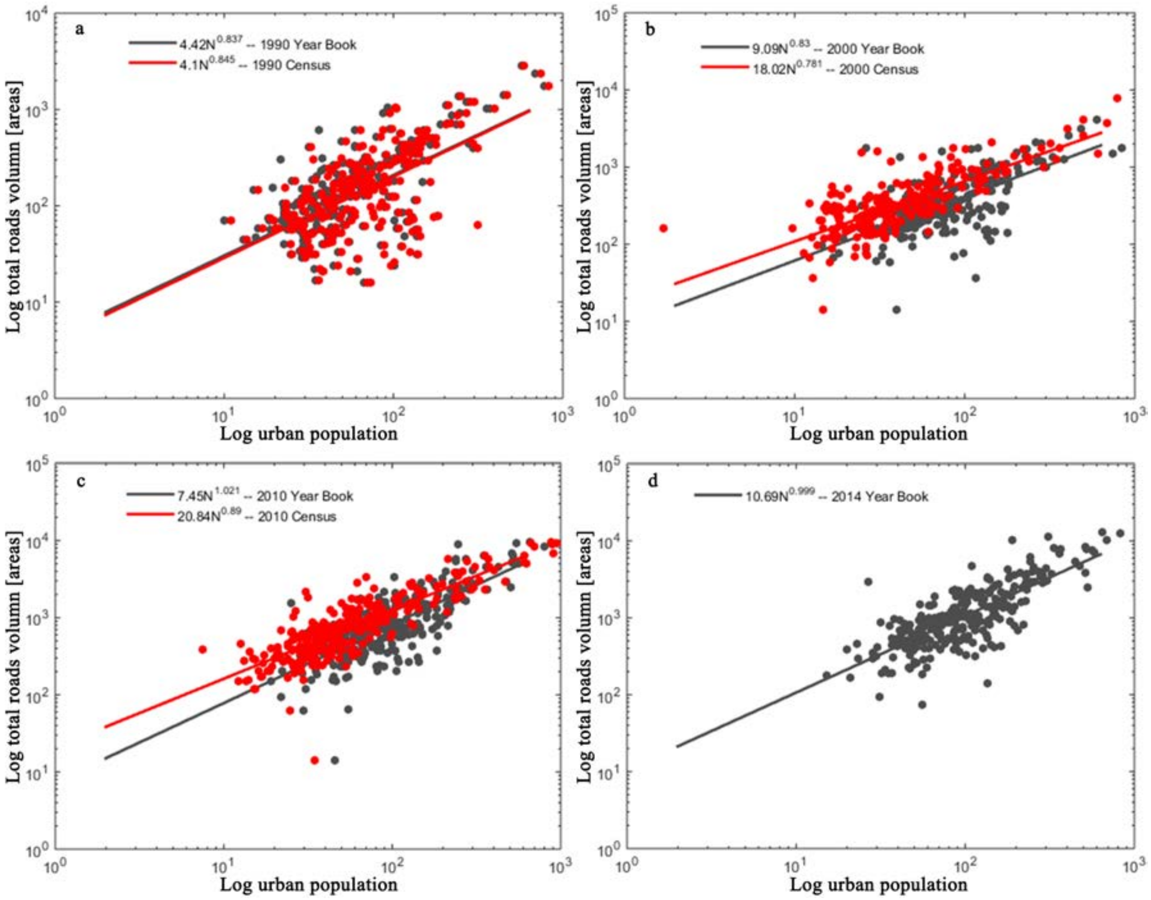


Figure 5.3 Double logarithmic plots of the allometric scaling relationship between the urban transportation network volume (road area) and the urban population in Chinese cities.

(Notes: a. year 1990, b. year 2000, c. year 2010, d. year 2014; black line statistical yearbook, red line census, green dashed line theoretical assumption value. Census (China National Census) data section is to depict three decades urbanization for comparison with statistical yearbook. Urban Statistical Yearbook is used to compare for 1990 and 2000, and Urban Construction Statistical Yearbook is used for 2010 and 2014. Urban area applies urban built-up area data, and population applies urban population data in 1990, 2000 from USY, and urban permanent residents in 2010, 2014 from UCSY.)

5.2.1.4 Allometric scaling relations of hierarchical city categories

As the urban population in all Chinese cities has increased remarkably since the economic reforms in the 1980s, the urbanization level and growth rate of different categories of cities varied significantly in terms of population, urban built-up area, GDP, and transportation network volume. The urbanization trends can be observed by looking at changing population distributions, in which different sizes of cities have different patterns. Thus, by scaling factors, the changes in the allometric scaling of cities are relatively good measures of urbanization performance. Notably, the large differences in city size related to urban factors across Chinese cities significantly affect urban spatial characters. The measured values may particularly reflect similarities within different categories of cities more than differences across cities. For this reason, focusing on the range of values across tiers or categories of cities is better than focusing on the differences of each city. According to urban population classification, cities are categorized into three groups. This categorization is also according to China's official administrative classification of city levels, i.e., cities with 0–0.5 million population are small, cities with 0.5–1.0 million population are medium, and cities with above 1.0 million population are large. Following the population-grouped categories of city sizes, this analysis has uncovered how urban built-up area, urban GDP, and transportation network volume (road area) interact with urban population in different-sized cities.

Figure 5.4 compares the allometric scaling relationship of the urban area and population among small (black line and dots), medium (green line and dots), and large cities (red line and dots) in four representative periods using the *Urban Construction Statistical Yearbook (UCSY)* data. The lines in Figure 5.4(a) show the best fit to a scaling relation *Y (urban area)* = αN^{β} in r 2000, small cities (black), with β = 0.588 [95% confidence interval (CI), 0.722–0.837, R^2 = 0.70]; medium-sized cities (green), with β = 0.620 [95% confidence interval (CI), 0.578–0.671, R^2 = 0.66]; large cities (red), with β = 1.104 [95% confidence interval (CI), 0.978–1.171, R^2 = 0.60]; The lines in Figure 5.4(b) depict the best fit to a scaling relation *Y (urban area)*=αN^{β} in 2004, small cities (black), with β = 0.773 [95% confidence interval (CI), 0.522–0.637, R^2 = 0.73]; medium-sized cities (green), with β = 0.657 [95% confidence interval (CI), 0.598–0.721, R^2 = 0.76]; large cities (red), with β = 0.954 [95% confidence interval (CI), 0.908–1.062, R^2 = 0.80]; The lines in Figure 5.4(c) demonstrate the best fit to a scaling relation *Y (urban area)* = αN^{β} in year 2008, small cities (black), with β = 0.861 [95% confidence interval (CI), 0.752–0.931, R^2 = 0.65]; medium-sized cities (green), with β = 0.610 [95% confidence interval (CI), 0.578–0.671, R^2 = 0.70]; large cities (red), with β = 0.780 [95% confidence interval (CI), 0.708–0.852, R^2 =

0.80]; The lines in Figure 5.4(d) exhibit the best fit to a scaling relation *Y (urban area)* = αN^{β} in 2012, small cities (black), with β = 0.806 [95% confidence interval (CI), 0.775–0.831, R^2 = 0.70]; medium-sized cities (green), with β = 0.732 [95% confidence interval (CI), 0.697–0.771, R^2 = 0.75]; large cities (red), with β = 0.776 [95% confidence interval (CI), 0.728–0.785, R^2 = 0.80].

Figure 5.5 compares the allometric scaling relationship of the urban GDP and population among small (black line and dots), medium (green line and dots), and large cities (red line and dots) in four representative periods using the *Urban Construction Statistical Yearbook (UCSY)* data. The lines in Figure 5.5(a) show the best fit to a scaling relation *Y (GDP)* = αN^{β} in 2000, small cities (black), with β = 0.660 [95% confidence interval (CI), 0.572–0.723, R^2 = 0.60]; medium-sized cities (green), with β = 0.084 [95% confidence interval (CI), 0.078–0.097, R^2 = 0.20]; large cities (red), with β = 1.468 [95% confidence interval (CI), 1.278–1.711, R^2 = 0.70]; The lines in Figure 5.5(b) display the best fit to a scaling relation *Y (GDP)* = αN^{β} in 2004, small cities (black), with β = 0.897 [95% confidence interval (CI), 0.792–0.923, R^2 = 0.65]; medium-sized cities (green), with β = 1.012 [95% confidence interval (CI), 0.998–1.151, R^2 = 0.66]; large cities (red), with β = 1.151 [95% confidence interval (CI), 1.108–1.256, R^2 = 0.78]; The lines in Figure 5.5(c) exhibit the best fit to a scaling relation *Y (GDP)* = αN^{β} in 2008, small cities (black), with β = 1.077 [95% confidence interval (CI), 0.872–1.131, R^2 = 0.63]; medium-sized cities (green), with β = 0.489 [95% confidence interval (CI), 0.338–0.637, R^2 = 0.48]; large cities (red), with β = 1.056 [95% confidence interval (CI), 0.889–1.067, R^2 = 0.72]; The lines in Figure 5.5(d) show the best fit to a scaling relation *Y (GDP)* = αN^{β} in 2012, small cities (black), with β = 1.031 [95% confidence interval (CI), 0.875–1.181, R^2 = 0.68]; medium-sized cities (green), with β = 0.715 [95% confidence interval (CI), 0.633–0.831, R^2 = 0.62]; large cities (red), with β = 1.072 [95% confidence interval (CI), 0.998–1.150, R^2 = 0.77].

Figure 5.6 compares the allometric scaling relationship of the urban transportation network volume (road area) and urban population of small (black line and dots), medium (green line and dots), and large cities (red line and dots) in four representative periods using the *Urban Construction Statistical Yearbook (UCSY)* data. The lines in Figure 5.6(a) show the best fit to a scaling relation *Y (road area)* = αN^{β} in 2000, small cities (black), with β = 0.577 [95% confidence interval (CI), 0.522–0.667, R^2 = 0.65]; medium-sized cities (green), with β = 0.304 [95% confidence interval (CI), 0.234–0.451, R^2 = 0.56]; large cities (red), with β = 1.159 [95% confidence interval (CI), 0.998–1.231, R^2 = 0.63]; The lines in Figure 5.6(b) depict the best fit to a scaling relation $Y\ (road\ area) = \alpha N^{\beta}$ in 2004, small cities (black), with β = 0.794 [95% confidence interval (CI), 0.662–0.837, R^2 = 0.68]; medium-sized cities (green), with β = 0.583 [95% confidence interval (CI), 0.498–0.701, R^2 = 0.65]; large cities (red), with β = 0.923 [95% confidence interval (CI), 0.908–1.062, R^2 = 0.78]; The lines in Figure 5.6(c) display the best fit to a scaling relation $Y\ (road\ area) = \alpha N^{\beta}$ in 2008, small cities (black), with β = 0.987 [95% confidence interval (CI), 0.875–0.997, R^2 = 0.65]; medium-sized cities (green), with β = 0.615 [95% confidence interval (CI), 0.588–0.669, R^2 = 0.60]; large cities (red), with β = 0.797 [95% confidence interval (CI), 0.718–0.822, R^2 = 0.70]; The lines in Figure 5.6(d) demonstrate the best fit to a scaling relation $Y\ (road\ area) = \alpha N^{\beta}$ in 2012, small cities (black), with β = 0.973 [95% confidence interval (CI), 0.675–1.023, R^2 = 0.58]; medium-sized cities (green), with β = 0.974 [95% confidence interval (CI), 0.727–1.021, R^2 = 0.55]; large cities (red), with β = 1.076 [95% confidence interval (CI), 0.942–1.215, R^2 = 0.68].

Table 5.1 summaries varying scaling factor values among different city categories generated from Figures. 5.4-5.6. These analyses reveal the differences in urbanization peculiarities among different city categories and the evolving processes of each city category. For the scaling relation of the urban population and area, small cities continued to increase in scaling exponent value alongside our study period. This finding suggests the growing power in urbanization. Hence, large cities at the same time decreased the most in land use growth with less growing power than small and medium-sized cities slightly increased their growing power in urban land use. This land use performance indicates that small and medium-sized cities have become driving forces in the urbanizing process of China recently. Moreover, this development indicates shifts from large cities in developing land use or in leading urban expansion.

Table 5.1 Changing allometric scaling factors among different city categories

Factors to urban population	Categories	2000	2004	2008	2012
Urban Area	Small cities	0.588	0.773	0.861	0.806
	Medium-sized cities	0.620	0.657	0.610	0.732
	Large cities	1.104	0.954	0.780	0.776
GDP	Small cities	0.660	0.897	1.077	1.031
	Medium-sized cities	0.084	1.012	0.489	0.715
	Large cities	1.468	1.151	1.056	1.072
Transportation network volume (road area)	Small cities	0.577	0.794	0.987	0.973
	Medium-sized cities	0.304	0.583	0.615	0.974
	Large cities	1.159	0.923	0.797	1.076

Analyzing the distribution of GDP growing power among cities of different size highlights the importance of large cities in general. A GDP comparison on a comparable longitudinal basis underscores the importance of large cities. In 2008, a time lag of capital investment and GDP generation was observed because of the global financial crisis. The upward movement of the urban economy in large cities can be attributed to the earlier concentrated investment of capital domestically and internationally. Small cities are becoming the leading force in GDP growth. Large cites remain the high driving force in GDP growth although these cities have decreased their growing power from values, which obviously outperformed small cities as indicated in the values close to small cities. However, medium-sized cities did not exhibit stable trends because those cities have gone through substantial changes in setting boundaries or administrative partition. Overall, medium-sized cities hold lower GDP growing power compared to the other two cities. This pattern further illustrates the complexity of shaping the urban economy of China, as its growth and distribution are attributed to one decisive force.

The allometric scaling factors of transportation infrastructure are higher in cities with large population sizes. Within the time span of the study, small and medium-sized cities generally showed increasing scaling exponents, which indicates the higher growing power of road area construction in relation to urban population growth than large cities. During the same period, from 2000 to 2008, the scaling factor values of large cities decreased. Owing to the global financial crisis, the value fell below the theoretical expected value of 5/6 (0.833) in 2008. The scaling factors lower than 5/6 (0.833) signify that the infrastructure construction does not keep up with the growing population demand. In contrast, values higher than 5/6 (0.833) suggest excessive road construction than population growth in the allometric scaling relation. As city size increases, the miles driven increase faster than built lane-miles, which affect city areas in terms of driving distance; thus, the miles driven increase faster than the road capacity of large cities (Samaniego and Moses, 2008). The number of people actually driving distances along built roads (total daily vehicle miles traveled) demonstrates a different scaling relationship to road capacities. Small and medium-sized cities maintain lower infrastructure expansion, although in later urbanization stages, their growing power ratio of road network construction to that of urbanizing population increase closer to large cities. This finding implies that infrastructure construction has recently become the dominant driving force of city development in small and medium-sized cities. More quantity of roads has to be built with population growth.

The complex system of cities is characterized by the coexistence of large cities at the one end and small and medium-sized cities at the other. In the future, both large and small urban settlements will continue to grow simultaneously, which leads to a distinct Chinese pattern of dual-track urbanization. Large and extra-large cities maintain high capital production, although small cities have taken up a growing share of the urban population. The dominance of large cities in the urban hierarchy of China has been significantly reduced because of the emergence of numerous cities to take up a growing share of urban settlements and population. Although small cities have played a growing role in the absorption of population and land uses, large cities have remained as the most efficient and productive economic centers for capital investment and production. This pattern is distinct from the norm in many market economies of the West, where the concentration of economic activities and population often go together (Timberlake, 1985; Ingram, 1998; Lin, 1994). Given the accession of China into the World Trade Organization, the flow of multinationals into the large cities of the country will create considerable employment opportunities, thereby increasing the attractiveness of large cities to rural migrants.

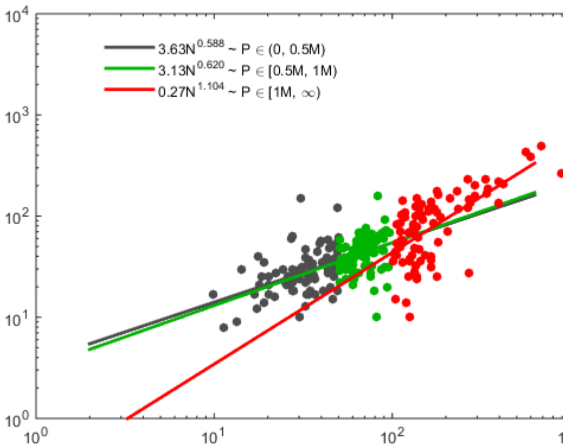


Fig. 5.4a Year 2000

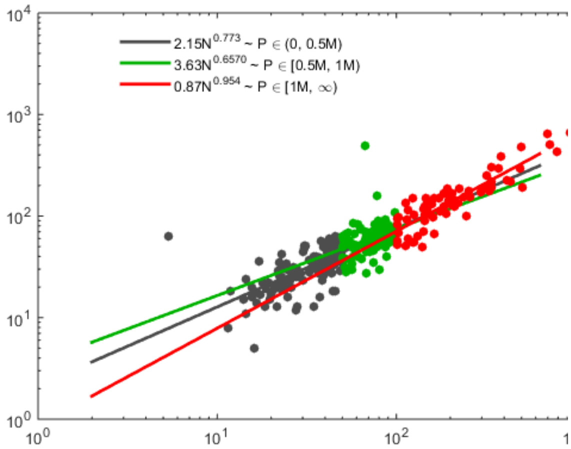


Fig. 5.4b Year 2004

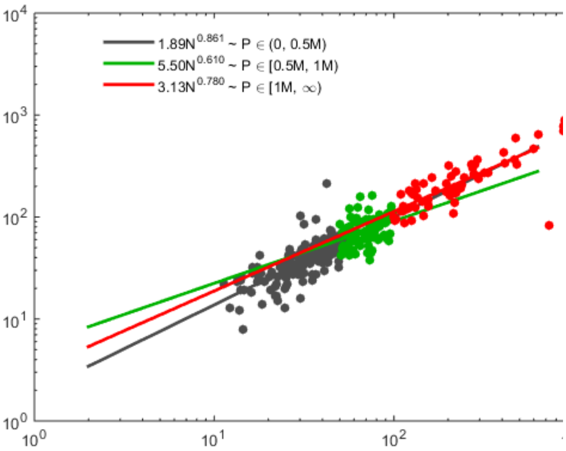


Fig. 5.4c Year 2008

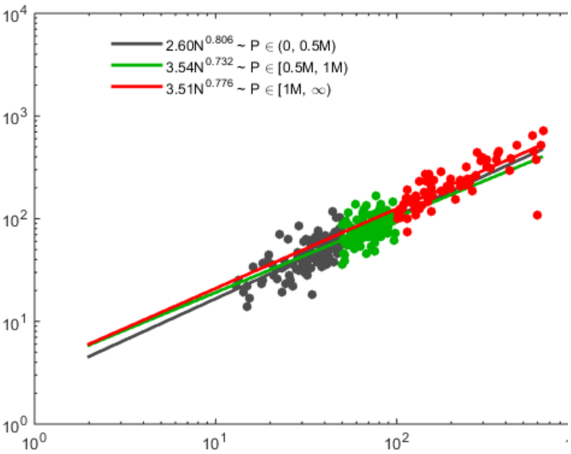


Fig. 5.4d Year 2012

Figure 5.4 Double logarithmic plots of the allometric scaling relationship between urban area and urban population in Chinese hierarchical cities.

(Notes: a. year 2000, b. year 2004, c. year 2008, d. year 2012, black line and dots as cities with 0-0.5 million of urban population, green line and dots as cities with 0.5-1.0 million of urban population, red line and dots as cities with above 1.0 million of urban population. Urban Construction Statistical Yearbook (UCSY) is used for urban built-up area data and urban population urban permanent residents data. Three clusters of cities were categorized based on their population size.)

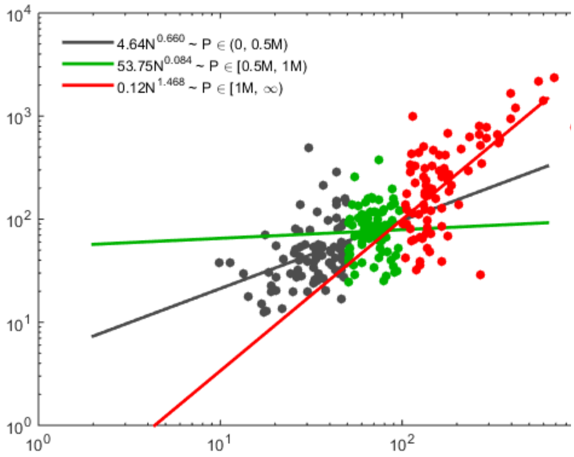


Fig. 5.5a Year 2000

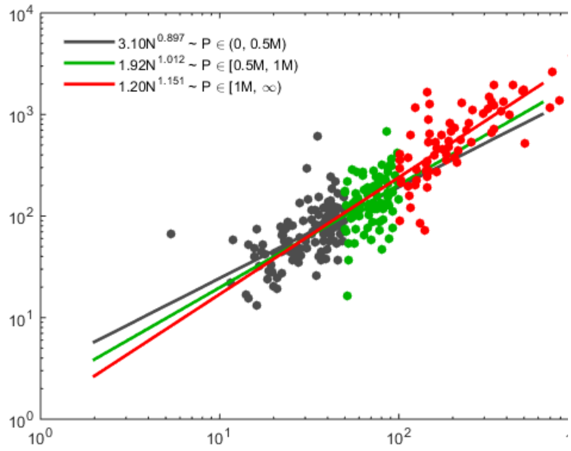


Fig. 5.5b Year 2004

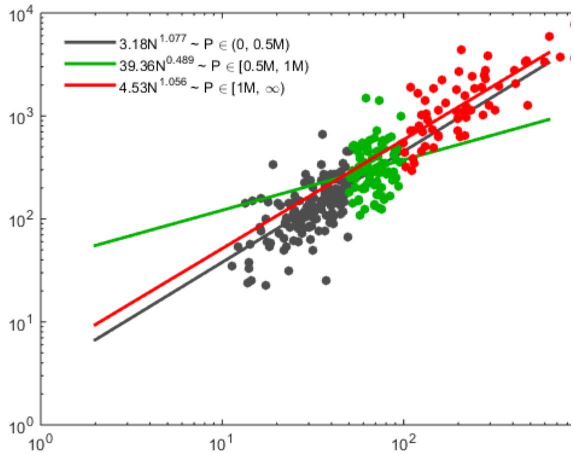


Fig. 5.5c Year 2008

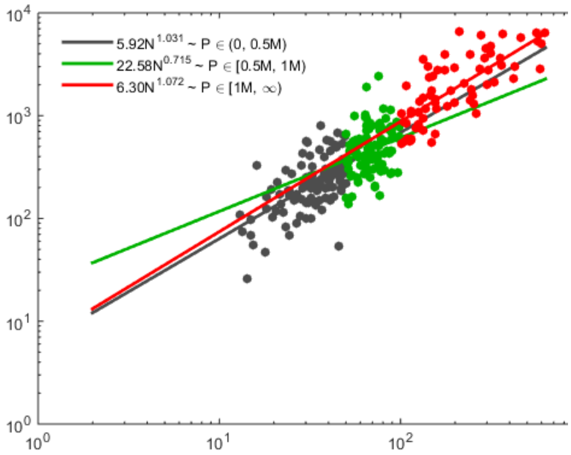


Fig. 5.5d Year 2012

Figure 5.5 Double logarithmic plots of the allometric scaling relationship between urban GDP and urban population in Chinese hierarchical cities.

(Notes: a. year 2000, b. year 2004, c. year 2008, d. year 2012, black line and dots as cities with 0-0.5 million of urban population, green line and dots as cities with 0.5-1.0 million of urban population, red line and dots as cities with above 1.0 million of urban population. Urban Construction Statistical Yearbook (UCSY) is used for urban built-up area data and urban population urban permanent residents data. Three clusters of cities were categorized based on their population size.)

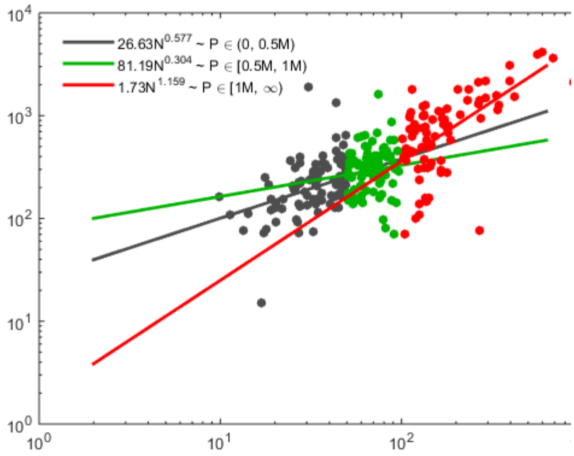


Fig. 5.6a Year 2000

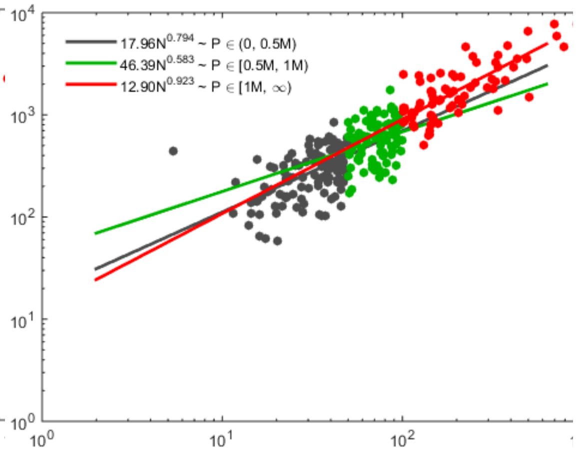


Fig. 5.6b Year 2004

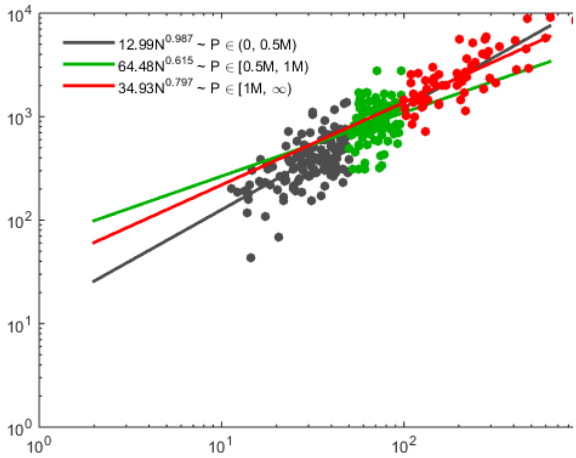


Fig. 5.6c Year 2008

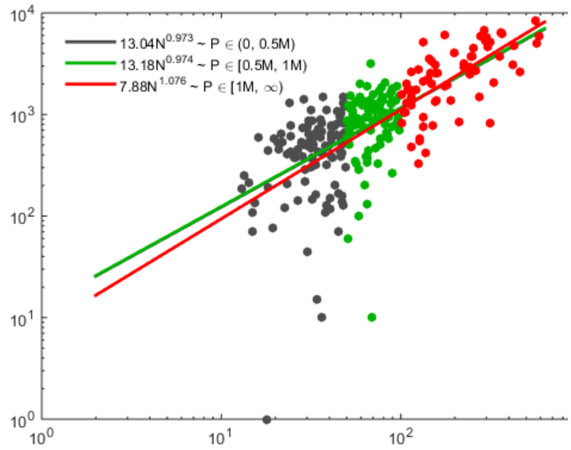


Fig. 5.6d Year 2012

Figure 5.6 Double logarithmic plots of the allometric scaling relationship between urban transport network volume (road area) and urban population of Chinese hierarchical cities.

(Notes: a. year 2000, b. year 2004, c. year 2008, d. year 2012, black line and dots as cities with 0-0.5 million of urban population, green line and dots as cities with 0.5-1.0 million of urban population, red line and dots as cities with above 1.0 million of urban population. Urban Construction Statistical Yearbook (UCSY) is used for urban built-up area data and urban population urban permanent residents data. Three clusters of cities were categorized based on their population size.)

5.2.1.5 Increase returns to scale of cities

To differentiate urbanization evolution, cities are grouped according to the orientation of their trajectories to which they belong, which may be faster or slower than that of the country as a whole. Through quantile regression (QR), cities are systematically classified into different categories according to individual scaling characteristics (Figure 5.7). Unsurprisingly, this method measures identical urbanization performance for the different tiers of cities. Hence, the method of categorizing cities is different from the last part of discussion defining three classes of hierarchical cities by administrative division according to urban population.

Population is generally more concentrated in larger cities than in small or medium-sized cities. The population in the metropolitan areas of large cities is more concentrated than the population in the metropolitan areas of small cities, and more detailed urban land-use pattern analysis are discussed in Chapter 6. This outcome can be attributed to the larger areas of urban land in these cities. As a result, these cities may have more hectares; however, from such a large base that the relative change in population is smaller. Acres of urbanized land increased more slowly relative to the population growth in large cities than in other quartile cities. Although large cities increased less urban land in absolute terms and on a per person basis, they gained a larger share of urban area. In large cities, people can access a larger number of opportunities (Levinson and Kumar 1997). Increasing returns are observed as cities grow (Bettencourt et al. 2007), as well as negative returns, such as in larger per-capita travel cost in larger cities. Large cities tend to be better managed than small cities (Yusuf and Saich, 2008), including the efficient use of energy and the halt to arable land lost.

Differences between small and large cities will change when cities dynamically evolve. Among fractal theory and spatial complexity studies on urban morphology, city size is distributed in regions under Zipf's scaling rank rule (Zipf, 1949). Figure 5.7 and Table 5.3 indicate the results of analyzing the dynamic changing scaling relations of different categories of cities. Longitudinal perspectives show the shifts in the changing scaling exponent of each city category and in leading the growth power of the scaling relation of land use and population between categories.

The lines in Figure 5.7(a) show the best fit to a scaling relation $A = \alpha N^{\beta}$ in a quantile regression (2000), quantile: 0.25 (red), with β = 0.670 [95% confidence interval (CI), 0.469–0.775, R^2 = 0.60]; quantile: 0.5 (green line), with β = 0.760 [95% confidence interval (CI), 0.662–0.834, R^2 = 0.78]; quantile: 0.75 (cyan), with β = 0.781 [95% confidence interval (CI), 0.724–0.814, R^2 = 0.88]; quantile: 0.9 (purple), with β = 0.743 [95% confidence interval (CI), 0.714–0.772, R^2 = 0.92]. Figure 5.7(b) 2004, quantile: 0.25 (red), with β = 0.853 [95% confidence interval (CI), 0.813–0.883, R^2 = 0.91]; quantile: 0.5 (green line), with β = 0.853 [95% confidence interval (CI), 0.824–0.894, R^2 = 0.91]; quantile: 0.75 (cyan), with β = 0.854 [95% confidence interval (CI), 0.808–0.902, R^2 = 0.88]; quantile: 0.9 (purple), with β = 0.847 [95% confidence interval (CI), 0.777–0.892, R^2 = 0.85]. Figure 5.7(c) 2008, quantile: 0.25 (red), with β = 0.935 [95% confidence interval (CI), 0.903–0.957, R^2 = 0.71]; quantile: 0.5 (green line), with β = 0.912 [95% confidence interval (CI), 0.864–0.937, R^2 = 0.81]; quantile: 0.75 (cyan), with β = 0.904 [95% confidence interval (CI), 0.864–0.939, R^2 = 0.83]; quantile: 0.9 (purple), with β = 0.870 [95% confidence interval (CI), 0.853–0.922, R^2 = 0.77]. Figure 5.7(d) 2012, quantile: 0.25 (red), with β = 0.904 [95% confidence interval (CI), 0.858–0.937, R^2 = 0.90]; quantile: 0.5 (green line), with β = 0.906 [95% confidence interval (CI), 0.865–0.939, R^2 = 0.90]; quantile: 0.75 (cyan), with β = 0.869 [95% confidence interval (CI), 0.816–0.924, R^2 = 0.86]; quantile: 0.9 (purple), with β = 0.872 [95% confidence interval (CI), 0.819–0.942, R^2 = 0.84]. Quantiles = 0.25 (red line), 0.5 (green line), 0.75 (cyan line), and 0.9 (purple line); the theoretical β = 2/3 (black dashed line); Data for 282 observed cities (urban built-up area and urban permanent resident population) were obtained from the Urban Construction Statistical Yearbook.

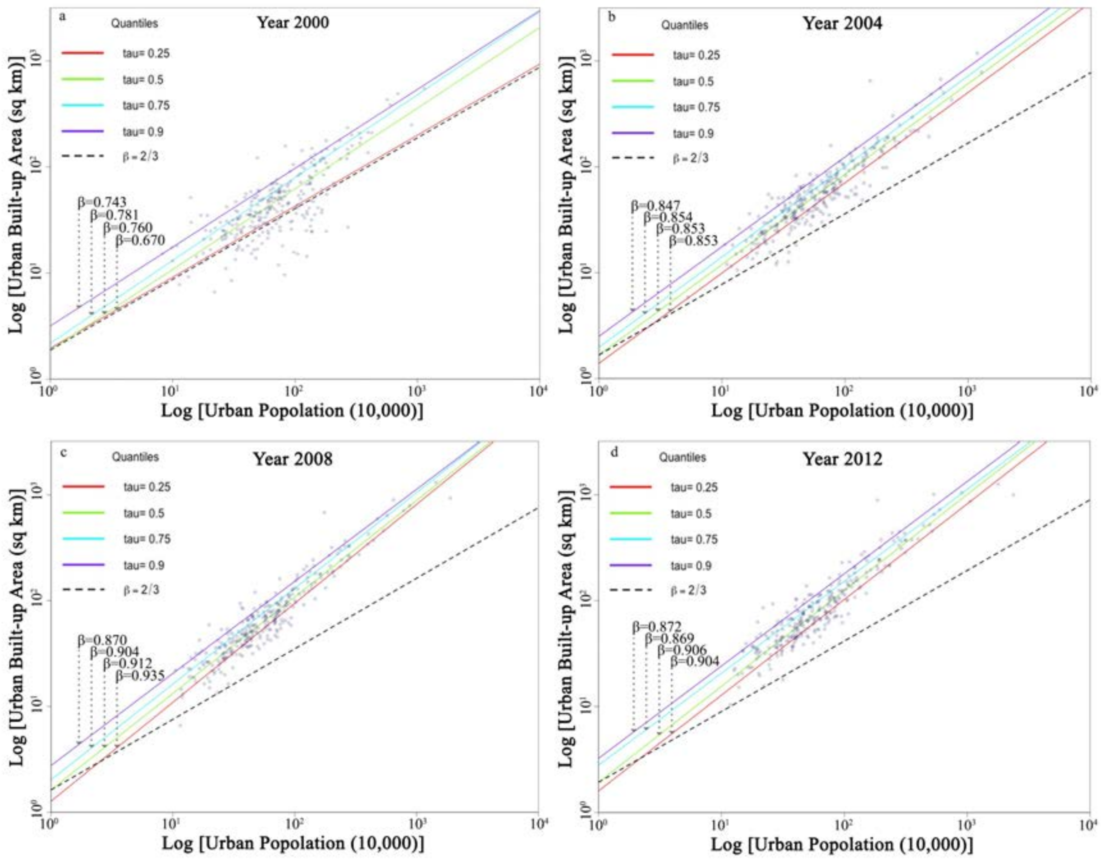


Figure 5.7 Quantile regression of double logarithmic plots of the allometric scaling relationship between urban area and urban population in Chinese cities at prefecture level.

Population growth differed significantly among cities. These differences reflect the recent pace of economic development in cities of different size classes. Large cities generally have higher shares of population growth in urban areas, whereas small cities account for a relatively lower share of growth. Large cities have higher densities than small cities, and both large and small cities tend to be decentralized with population densities that decline slowly as distance from the city center increases. In contrast, the population densities of small cities drop off rapidly as distance from the center increases. The population growth in large cities usually promotes the densification of less-developed areas. In addition, the population distribution in large cities is more variegated than in small cities (Ingram, 1998), e.g., larger cities exhibit polycentrism. Large cities in both industrial and developing countries usually have an original center for central business district (CBD), as well as a number of sub-centers, which combine to form a polycentric development pattern (Dowall and Treffeisen, 1991). Small cities, especially in developing countries, are more likely to have a single, well-defined center (Ingram and Carroll, 1981).

A large city gains an edge from agglomeration and urbanization economies. For the importance of cities given different population or land use sizes and locations as regional economic development centers, large cities obviously emerged as capital investment centers. As a result of the intrinsic benefit of economic agglomeration, larger cities generally secured fixed assets investment more than 60% among all cities in the 1990s, suggesting that the Chinese government chose large cities as fixed asset capital investment centers (Lin, 2002). In a manner similar to the distribution of fixed asset investment, utilized foreign investment displayed a tendency to favor large cities whose total investment share received significant increase in the 1990s. Compared to continuing concentration of investment on fixed assets, a majority of foreign investment (94.5%) initially located in the eastern cities, but decreased much to 87.4% afterwards, suggesting that foreign investments began to spread across the inner regions of China.

Since new China was established, the central government has attempted to promote a policy for the growth of smaller urban settlements (towns and small cities) that has not achieved its intended effects. The economic reforms and the state owned rights relaxation over urban development by the end of 1980s, have approved a huge quantity of rapidly expanding small and medium-sized cities at the bottom to take shape and characterize urban development and urbanization of China (Lin, 2002). The burst in the quantity of small and medium-sized cities has duplicated industrial facilities and infrastructures. As the economy of China continues to globalize under market reforms, the competitive competence of large cities is more and more motivated by the realization of economic agglomeration effects within urban areas. A lot of Chinese cities, notably large cities with more than 1 million population, are currently encountering a complex process of urbanization under both "centrifugal" and "centripetal" forces. Shanghai, Beijing, Chongqing, and Tianjin, as well as the small urban areas, such as Nanjing, Changsha, and Wuhan are showing the both types of driving forces. Cross-country experience shows that good land planning, regulation, and coordination by bureaucracies, as well as administrative subdivisions enable cities to reap the benefits of size and to avoid most pitfalls.

5.2.2 Scaling of Chinese cities along longitudinal evolution timeline after the economic reform

Urbanization stages are evolving along with the economic development of China since 1978 reform. These stages are divided into three main periods:(i) post-national programming age, (ii) starting urbanizing movement, and (iii) dramatic urbanization. Based on the urban population and urban built-up area data from UCSY and USY from 1982 to 2013 (Figure 5.8), a longitudinal analysis through log-log plot of the allometric scaling relation is carried out in this section. The changing dynamics of scaling factors among different city categories reflect the macro policy of China and the evaluation of urbanization stages. The variation is every now and then brought by administrative or political factors instead of urban development itself. The urban area is sometimes expanded quickly by governmental intervention or political will rather than natural urbanization. As administrative factors disturb urban development, urban land use is strongly manipulated, which resulted in the urban areas of some cities not being proportional to their population sizes.

Generally, during the early years of urbanization, large cities led the growth power of scaling in land use, GDP, and road area. However, small and medium-sized cities have recently grown closer to such activities. In terms of GDP production, large cities remain the leading force compared to other two city categories. We can infer that although small and medium-sized cities are catching up to the urbanization of large cities by expanding infrastructure construction and land use, they cannot surpass the urban agglomeration of economic development. In other words, size is a plus. The urban economic development in cities, associated with the scale of growth should be based on higher productivity, more opportunities, and increased employment (Jing and Qian, 2013).

The interests of rural industrialization and town development were primarily prioritized during China’s urbanization in the 1980s and early 1990s. Since the mid 1990s, large cities attempted to reaffirm their prominent role in development and growth through city-based urbanization in China. In 2010, the government responded with the “Go West” campaign to build infrastructure (roads, rail lines, dams, and power grids) that brought western China into the economic mainstream. However, the likely environmental impact of China's western development vision, which is to be achieved in over 20 years, was similar in scale to the U.S. development of the American West in the first 7 decades of the 20th century (Grumbine, 2007). The increasing scaling factors of road area and land use of all cities reveal relatively lower urban land utilization against the population in China compared to the world average (Nian and Yao, 2002).

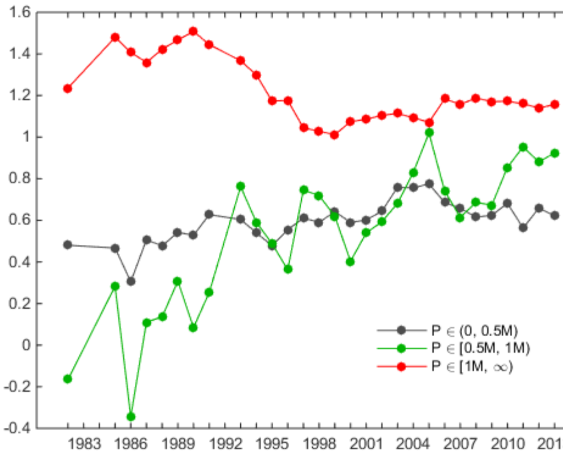


Fig. 5.8a Urban Land Area ~ Population

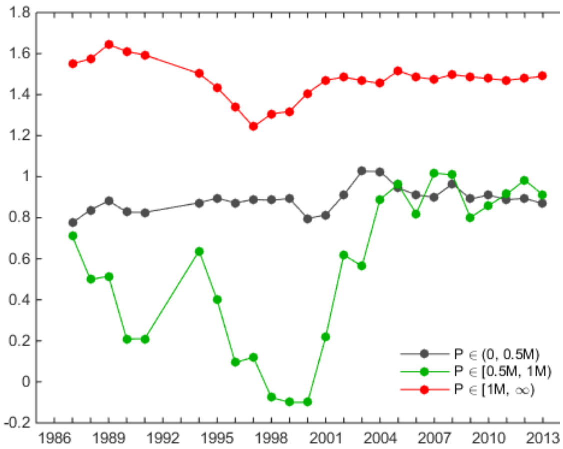


Fig. 5.8b Urban GDP ~ Population

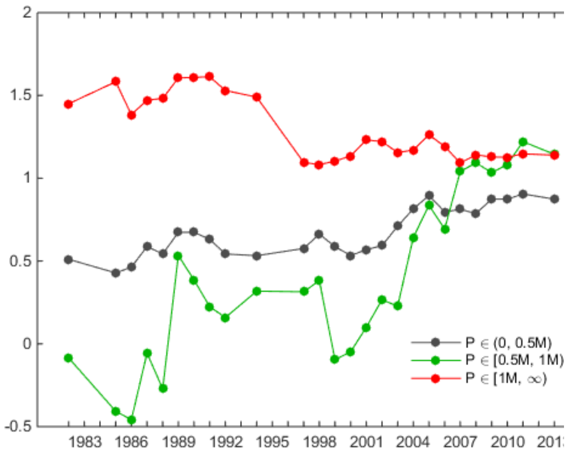


Fig. 5.8c Urban Roads Area ~ Population

Figure 5.8 Longitudinal analysis of allometric scaling relation of China's urbanization from 1982 to 2013.

Figure 5.8a urban built-up area ~ urban population,

Figure 5.8b urban GDP ~ urban population,

Figure 5.8c transportation network volume (road area) ~ urban population.

Three category cities based on population size (<500,000, 500,000-1million, >1million), urban built-up area and urban population (permanent residents) from UCSY and USY.

5.2.3 Scaling exponent

All evidence generally explains the universal nature of city development across time and nations. Empirical evidence from other cities lends support to the scaling relation between urban area and population (Lo and Welch, 1977; Chen and Lin, 2009). The findings of this study manifest that the relationship among the urban population, urban built-up area, GDP, and transportation network volume of China's urban system are allometric. The allometric relations through the growth function clearly characterize the evolution process of urban systems. The allometric analysis reveals the complexity of urban and structure evolution efficiently. Planned cities are always the exception rather than the rule, and when directly planned, they only remain for very short periods. Self-similar structures are seen across many scales, but grow organically from the bottom up. The elements of the system scale are relative to one another, and their system hierarchies have become useful in showing how local actions and interactions lead to spatial patterns, which can only be predicted, from bottom up (Miller and Page, 2007).

The set of scaling factors implies a special order in urban systems (Table 5.2). The theoretical meaning of the scaling factors of allometric growth provides significant information on the relative growth rate and development trend of elements under fractal structure. Evidence across countries and urbanization levels shows the scaling relation of several variables within urban systems. From the U.S., U.K., and Sweden to China, this scaling relation to urban development has been discussed over the past 70 years. Although researchers assume that the scaling exponents are theoretically independent of time (Bettencourt, 2013), the variety of all attributes α is considerably high over the study periods.

Table 5.2 Comparison of historical allometric urban development in the U.S. and U.K. (Evidence of allometry between area and population size)

	Years	Exponent α	Reference
U.S.	1940s	0.75	Stewart, 1947;
	1950s	0.75	Stewart and Warntz, 1958;
	1960s-1970s	0.8598	Nordbeck, 1965; Woldenberg, 1973;
		0.8621	Boyce, 1963;
		0.8651	Lee, 1989;
		0.8803	Nordbeck, 1965; Woldenberg, 1973; Tobler, 1969
	1980s	0.8598	Veregin and Tobler, 1997;
		0.8540	Lee, 1989
	1990s	0.65	Sutton et al., 1997;
	2000s-2010s	0.63	Paulsen, 2012;
U.K.	1950s	0.7502	Stewart and Warntz, 1958;
	1960s	0.8382	Jones, 1975
	1980s	0.96	Longley et al., 1991
	1990s	0.9587	Batty and Longley, 1994;
	2000s-2010s	0.7716	Batty et al, 2008

The allometric coefficients estimated in this study support the possible hypothesis of a dynamic changing value for the urban system rather than a fixed and stable value.

Such interpretation from allometric perspective is consistent with the existing empirical evidence that describes the nature of growth of a system toward an optimal alternative form. Urban systems characterized by allometric growth will always be evolving into an optimal state of environmental, social, and economic efficiency. This allometric urbanizing process presents a mechanism in which open systems are in dynamic equilibrium or in a tendency to approach steady optimal state. Therefore, the steady state of an open system is equivalent to the equilibrium state of a closed system (Warntz and Woldenberg, 1970).

Cities are highly organized with respect to their form, city size, and activity clusters on all scales, or in short, fractal (Batty and Longley, 1994). This urban development volume implies exponential population growth. Urban growth represents the scales through time, and the processes of growth implied the scale stability changes radically. A system soon grows to its upper limits with exponential growth initially, which then becomes logistical or capacitated (Batty, 2009). However, few counterexamples or exceptional cases are insufficient to doubt the scaling law, which is supported by many empirical studies and observational data. For instance, if a city at a certain stage of urbanization fails to follow this law, the city is regarded as wrong, instead of the scaling law (Chen, 2010). The main question of empirical work should be how well a theory fits, rather than whether or not the theory fits perfectly (Gabaix and Ioannides, 2004; Chen and Jiang, 2009).

A little change in a system may result in an huge and disproportionate change in the size of corresponding attributes in the system (Chen and Jiang, 2009). The relative change in city area is always greater than the relative change in urban population. As administrative areas in the cities have more than disproportionate population, the higher allometric coefficients associated with average densities will fall (Batty and Ferguson, 2011). On the contrary, isometric scaling denotes urban growth does not correlate to any disproportionate alteration in a geometric system. The population density in the center decreases over time, as does the population gradient. However, an area that is of a distance from the city center will have a population density that will remain relatively unchanged. This observation implies a change in the average population density of the urbanized areas caused by land area growth that exceeded population size increase. When the gross land-area increases faster than the gross population-size, larger urbanized areas have lower average population density than that of smaller urbanized areas. Furthermore, the population density of urbanized areas has been decreasing as population size increases over time.

The urban density of urbanized area is no longer a fixed value; instead it varies from lower to higher standards compared to internal experiences. American cities define being urbanized in census block groups with a density of more than 1,000 persons per square mile (Ingram et al., 2009). Density classification defines urban area and its population in the following 3 tiers: 1000 p/sq km in the early 1980s and the 1990s by the Chinese government, 2000 p/sq km (Zhou et al., 1995) for urban statistical area from the mid 1990s to the early 2000s, and 4000 p/sq km in recent years according to the Japanese high dense urbanized areas (Long et al., 2013). In this study, 1000 and 2000 p/sq km do not make any difference in classifying urbanized areas according to adjustments in scaling factor (exponent α). However, when the threshold value is set at 3000 and 4000 p/sq km, α tends to be closer to the international experience value for city scaling (Batty, 2013; Bettencourt, 2013), and 5000 p/sq km is a screen value that makes α almost the same theoretically predicted exponent, 2/3.

5.3 Allometric Scaling And Urban Development

5.3.1 Magnitude of city size and rapid urbanization speed in China

Urbanization (expansion) of China, outside of the already developed cities, has been the trend over the last 35 years. Enormous changes in city size have been brought to Chinese cities with the accelerated industrialization and urbanization progress (Wu and Yeh, 1999). Rapid urban land expansion is caused by fast urban population growth, high-speed economic development, massive urban housing and infrastructure investments, and green-field and prime agricultural land conversion into industrial and residential use (Rousseau and Chen, 2001). Based on the above analysis results, Figure 5.9 demonstrates a geographical difference in the changing allometric scaling growth of Chinese cities over the past 35 years. This allometric scaling result of land use expansion in relation to urban population growth shows large-scale urban expansion of Chinese cities above prefecture level. The circle size denotes the degree of variance in their scaling factor of actual growth from the theoretical scaling growth over the past 35 years. Blue color indicates a negative scaling factor of actual growth to theory value, whereas red color indicates a positive scaling factor of actual growth to theory value. Most cities have proportionately over used their land, and only a few cities have consumed their land less in the scaling relative to population growth.

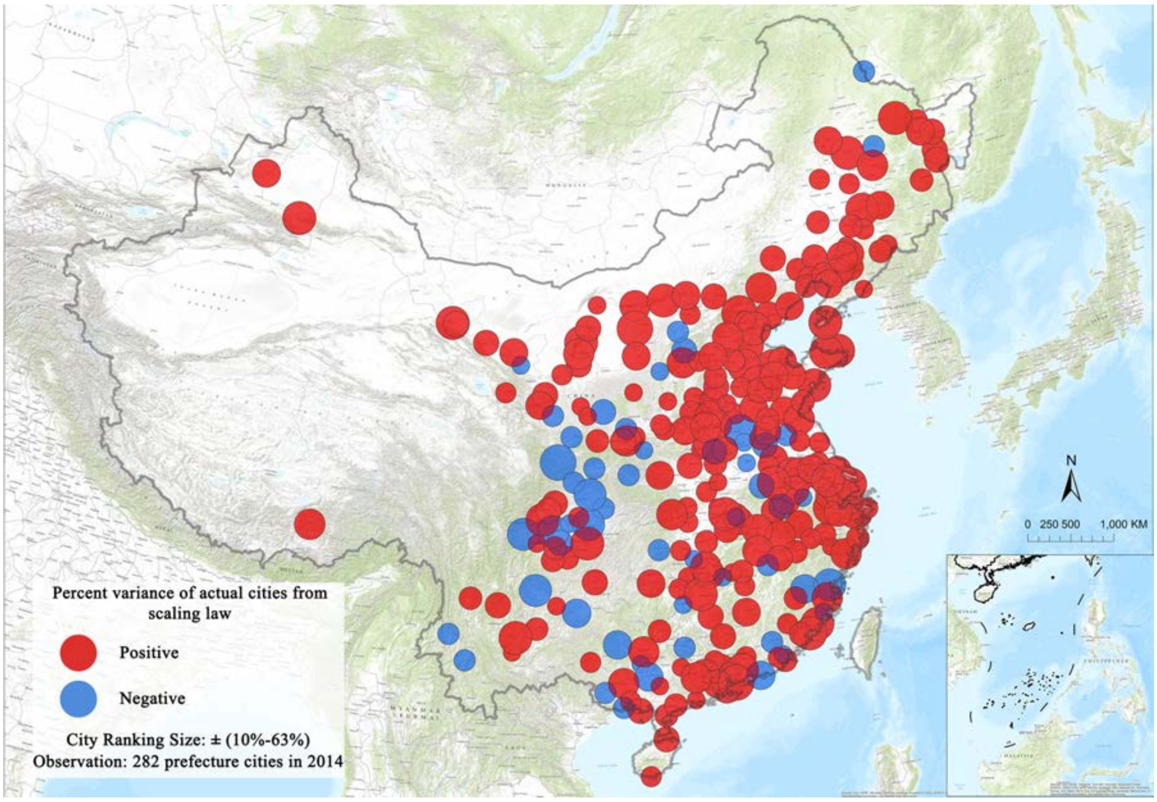


Figure 5.9 Changing degree of allometric scaling relation of urban area and urban population in 282 prefecture level cities from 1982 to 2014. Percentage variance of scaling factors of actual value over theoretically expected value, positive (red), negative (blue), and size range: ± (10%−63%).

The spatial characters of China's urbanization over the past 35 years have considerably different structures compared to cities in North America and Europe in a century span. Western cities traditionally grow outwards with tremendous flows of migrants and large-scale suburbanization. In China, people have more mobility constraints to traveling around cities for decades, which extremely limited location preferences. Furthermore, housing market limits mobility and administrative allocation of inner urban land to state-controlled enterprises at no cost meant that, up until very recently, no economic incentive was given to these firms to relocate to lower-cost suburban sites. Therefore, in the formal urban areas of cities in China, households and firms have been subjected to significant location and mobility constraints absent in North American and European cities.

Two key forces have driven this significant urban land expansion, namely, increase in the number of cities and enlargement of existing city territory caused by dispersed urban growth (Tan et al., 2004). Unlike the suburbanization process in western cities, urban expansion in China is driven by a reluctant movement of lower-income people, who have lost their domiciles in the city when large-scale urban renewal and industry restructuring were conducted (Liu, 2003). Owing to the low mobility of the relocated individuals and the insufficient infrastructure investment in suburban areas, new developments have tended to be in locations in the immediate urban fringe for a more convenient employment of existing urban facilities, like public transport. As a result, urban expansion in China is characterized by its short-distance (normally within 10 km) and by it homocentric outspread (Chen et al., 2008).

Population densities have been generally decreasing as the decentralized urban growth of Chinese cities continuously expands. Urban populations have become more decentralized because of the influence of increased expansion at the urban fringe (Meyer and Meyer, 1987). The development toward the periphery was driven by low land prices and development costs (Meyer and Gomez-Ibanez, 1981). Hence, building on vacant land was less costly than redeveloping encumbered sites, which required the resource expenditure to destroy existing physical assets and the loss of the assets as well. This strategy is economically feasible when shifting a parcel from residential to commercial or industrial use, but this movement is rare. In the suburbs of Chinese cities, where agricultural land is in collective ownership and lower regulation, informally transforming farmland into commercial uses is almost easy. The relative ease of industrial enterprise formation takes much from agricultural land in the peripheral areas of cities to convert fast into suburban zones.

Among the contributing factors to rapid land use was the decision of the state to decentralize the financial capacity and to approve land market for free economic investments (Ho and Lin, 2003; Lin and Ho, 2005). Although the socialist administration on land allocation remains to certain extent, land use market is in shape. Redevelopment of existing urban areas is becoming more financially infeasible than new land development in the suburbs. This lucrative asymmetry between state-owned urban and collectively owned rural lands gives one of the critical reasons for describing the continuing land use expansion (Lin, 2007). The economic reforms of China over the past decades have given rise to the development of an urban land allocation system, in which land lease rights can be acquired by paying land-use fee (Cheng et al., 2006).

5.3.2. Drivers of urbanization of China

A comparative evaluation revealed the distinct driving-forces of urbanization at work in China that simultaneously and dynamically transforms with changes among different city categories. Table 5.3 summarizes the quantile regression results for different city categories that best describe the dynamic changing urbanization driving forces at various urbanization stages. In addition, Figure 5.10 further elaborates this changing process in the allometric scaling growth of Chinese urbanization. These changing scaling exponents clearly illustrate the driving forces of urbanization shifting among different category cities and the land use development status at various urbanization stages for each city category. Whereas large cities were the leading forces in land use in the first place, small and medium-sized cities have recently driven toward urbanization. The results in Table 5.3 and Figure 5.10 reveal an obvious shift in growth power gradually moving from large- to medium-sized cities, and then to small cities over time.

Table 5.3 Urbanization driving force tendency through scaling exponents shift

Quantiles	2000	2004	2008	2012
0.25	0.670	0.853	0.935*	0.904*
0.5	0.760*	0.853	0.912*	0.906*
0.75	0.781*	0.854*	0.904	0.869
0.9	0.743*	0.847	0.870	0.872

* indicate significant driving force, which scaling exponents were achieved from

quantile regression, also see Figure 5.7 and Figure 5.10.

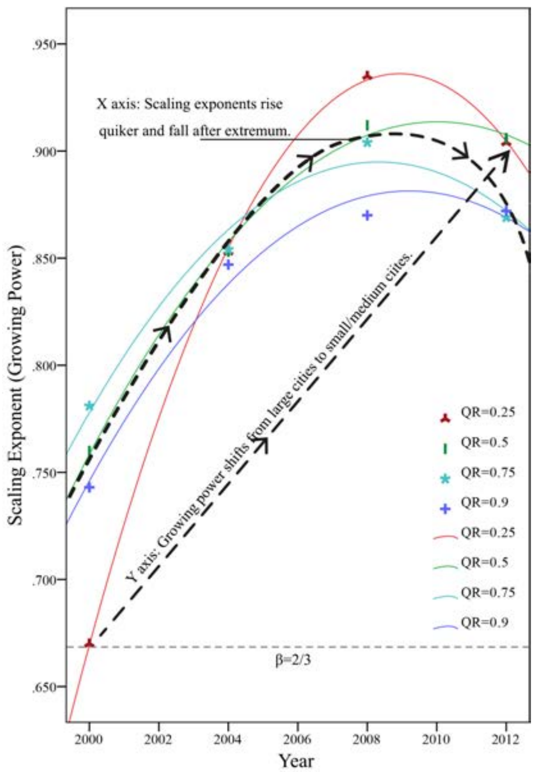


Figure 5.10 Driving force shifts among different categories of cities in the allometric scaling of urbanization in China.

The migrants from rural population to urban population and the fast transformation of suburban areas into districts of cities are the two essential forces driving urbanization in China. The expanding urban built-up area is characterized by both the exterior extension of urban transportation networks and the new designation of *Economic and Technological Development Zone* adjacent to existing urban areas. Moreover, urban expansion is one of the most important influential attributes in city size (urban land area) increase. In the meanwhile, continuous industrialization in the rural area and urbanization of countryside has widely increased urban land use at the expense of agricultural land with a spreading mode. Collectively, city-centered urban sprawl and rural-based industrializing disperse turn out to be two paralleling progresses that led to land use expansion under the background of fast urbanizing Chinese cities.

If urban population of China doubles, will cities also double their size? This relationship suggests that Chinese cities are likely to grow less in size than in proportion to overall urban population. If the growth patterns reach a stable equilibrium state, population stabilizes with no land use change. Cities with significant population growth relative to those with minimal growth are expected to urbanize more resource land. However, if the population is growing more quickly than the increase in land area, then this suggests that these cities are using less additional land to accommodate new residents. Thus, a decline in the urbanized land growth relative to population growth rate supports the change in that trend for the future. All cities in the later period of their urbanizing stage will get close to theoretically assumed situations in the allometric scaling growth, similar to the evolutionary process shown in Figure 5.10. To summarize, the three key drivers (scale of development, land use, and government policy), along with urbanization, are rapidly transforming China.

5.4 Chapter Summary

This chapter reveals an increasingly stable, but more complex network of hierarchy of cities in assessing the magnitude of urbanization. Growth is measured in terms of population changes, which indicates the degree to dual relations in urban built-up area, GDP, and transportation network volume (road area). These factors are relative in size with respect to urban population, i.e., the allometric scaling relations under power law. The four-period set of socioeconomic data is used to determine the co-terminous urban areas in China. For comparability, all data are collected from government data from 1982 to 2014. The analysis compares the changes in the performance of urbanization from 1980 to 1990, from 1990 to 2000, and from 2000 to 2014. Methodologically, urban spatial and demographic data over time are utilized in analyzing the determinants of city size and more precisely in decomposing the changes in the allometric scaling growth of cities. Theoretical advancement in understanding the complex processes of urban change and in explaining the growth of cities is noticeably limited because of rearticulating and reconfiguring national political strategies and polices for economies. The expansion of cities is a complex process, and the inclusion of all factors to measure the spatial size of cities is difficult. Chinese planners should systematically assess cities' sizes of different population/ land use area in respect of evolutionary urbanization process. Moreover, special attention should be paid to the growth of large cities in the era of new urbanization in order to understand and to plan the city and town systems for economically viable, socially stable, and environmentally sustainable growth.

CHAPTER 6 URBAN LAND-USE PATTERNS IN CHINA

6.1 Introduction

After exploring the driving factors of urbanization in China in Chapter 5, the current chapter attempts to use spatial metrics to characterize urban land-use patterns through a new method integrating the use of CA, Python, ArcGIS, and Mat Lab. In this study, 61 sets of urban land-use images from 2011 were extracted, and three integrated categories ($T_{Residential}$, $T_{Commercial}$, and T_{Public}) were selected to analyze urban land-use patterns in China. The study applies a new method to compare the differences of urbanization in 61 cities and investigates its dynamics using a quantitative approach. This chapter addresses the following research questions:

(i) How are urban land-use patterns quantified using spatial entropy and dissimilarity?
(ii) What is the relationship between the interconnected urban factors (urban population, urban land area, GDP, and paved road area) for the formation of land-use patterns?
(iii) What factors govern urbanization to enlighten planning and policymaking?

This introduction is followed by the identification of urbanization and land-use patterns in Chinese cities. Section 6.2 discusses the analysis and modeling of land-use patterns. This section also describes the measurements in detail, including their mathematical formulae. Section 6.3 presents the findings, beginning with an interpretation of land-use patterns and followed by an analysis of the corresponding influence factors. Section 6.4 presents a discussion and the implications drawn from the mechanisms of urbanization in selecting appropriate planning policies. Section 6.5 presents the concluding remarks.

6.2 Distinguishing Range of Urban Land-Use Patterns

A fundamental activity of urban land-use research is the quantitative characterization of city morphology and dynamic growth (Jiao, 2015). If three or more dimensions of land use are of interest, a multidimensional index must be applied, e.g., Spatial Entropy (SE) or Dissimilarity Index (DI) (Song et al., 2013;

Decraene et al., 2013b). In particular, the following analyses were made to help identify spatial patterns in urban development, which shows the shapes and indicates how the relative differences of urban land use at a time period vary among cities: sprawl–aggregation (SE) and segregation–mixed land use (DI).

SE measures how dispersed the urban land use is within a city, whereas DI helps define the efficiency of mixing land-use sectors ($T_{R,}$ $T_{C,}$ $T_{P,}$ T_O). T_R, T_C, $T_{P,}$ and T_O denote the land use of a residential sector, commercial sector, public sector, and other sectors, respectively. SE is a good measure of urban spatial development (Batty, 1972, 1976), which is commonly calculated to determine the degree of urban sprawl. Classical urban theories, which are mainly based on social and economic rules, do not capture local land-use patterns. Compared with traditional spatial statistics, SE provides a more systematic analysis to determine whether urbanization occurs in a compact or expansive (aggregate or dispersed) manner (Li and Yeh, 2004). DI measures the degree of evenness in land-use distribution. Decraene et al. (2013b) used SE and DI to measure the dispersion and aggregation mechanisms of urban land use. The combination of these two measures provides a straightforward method to investigate urban land-use patterns resulting from dispersion and segregation mechanisms. This cellular automata (CA) model emphasizes the reconstruction of cities through a bottom–up approach with SE and DI values. Thus, in the present research, we are adopting Decraene et al.'s (2013b) CA model to study a selection of Chinese cities.

6.3 Quantitative Analysis of Land-Use Patterns in Chinese Cities

6.3.1 Generalization of land-Use patterns

To reflect the balance and patterns of land use, two quantitative approaches, namely, SE and DI, were used to classify and analyze urban features. Figure 6.1 provides a general representation of the typical land-use classifications for the selected cities in this study. The classifications clearly depict the features of each city that were extracted from the base map, where the residential, commercial, and public land-use sectors are the aggregations of relevant sub-categories in which land-use categories indirectly related to the aforementioned sectors were discarded. The blue, green, red, and yellow pixels correspond to residential, commercial, public, and other and undeveloped functioning sectors, respectively. Lower SE values indicate aggregated development, whereas higher SE values indicate dispersed development. DI is a distinctive characteristic that clearly highlights land-use segregation. See Figure 6.2 for details and the model concept.

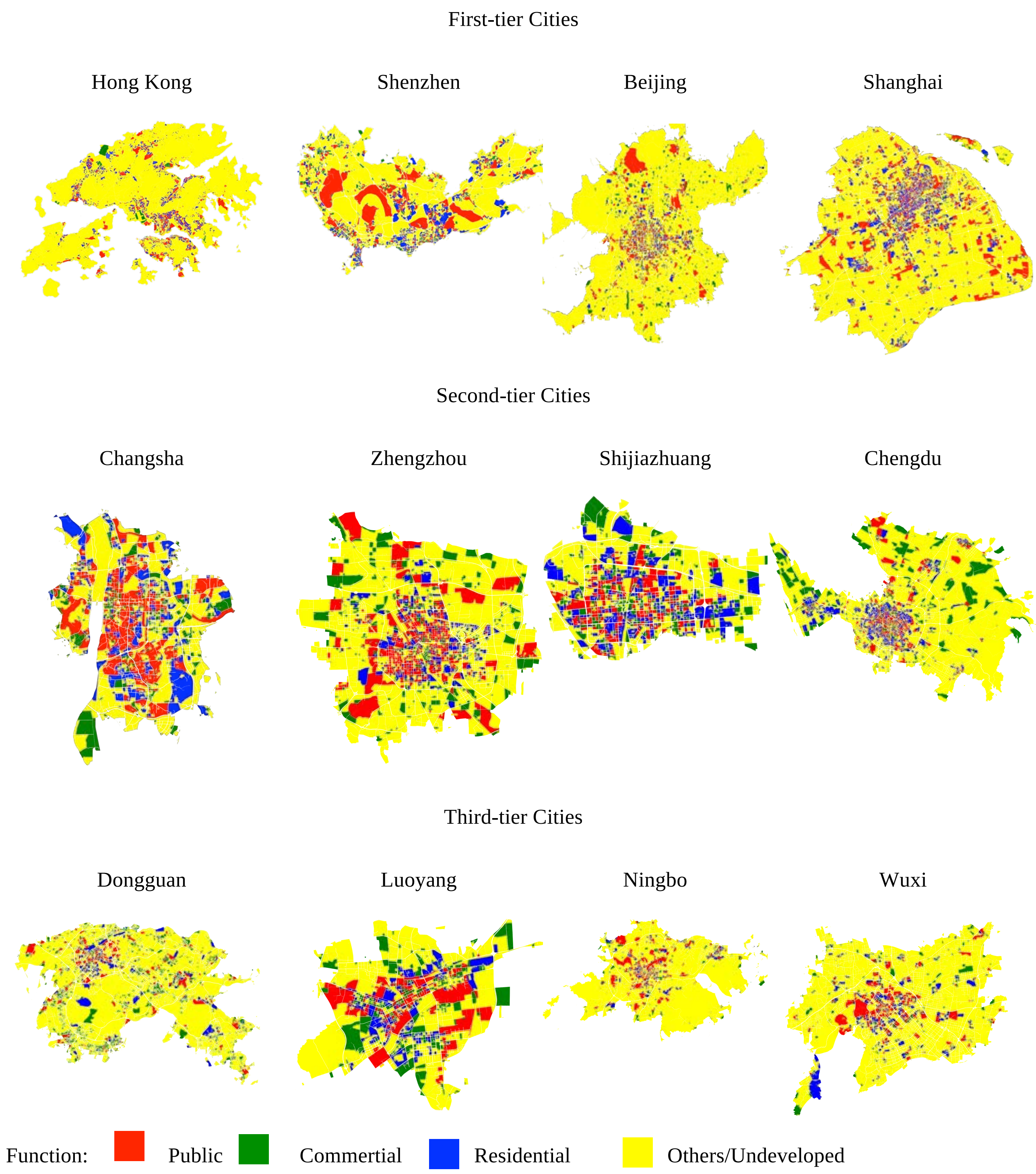


Figure 6.1 Typical classifications of land-use patterns.

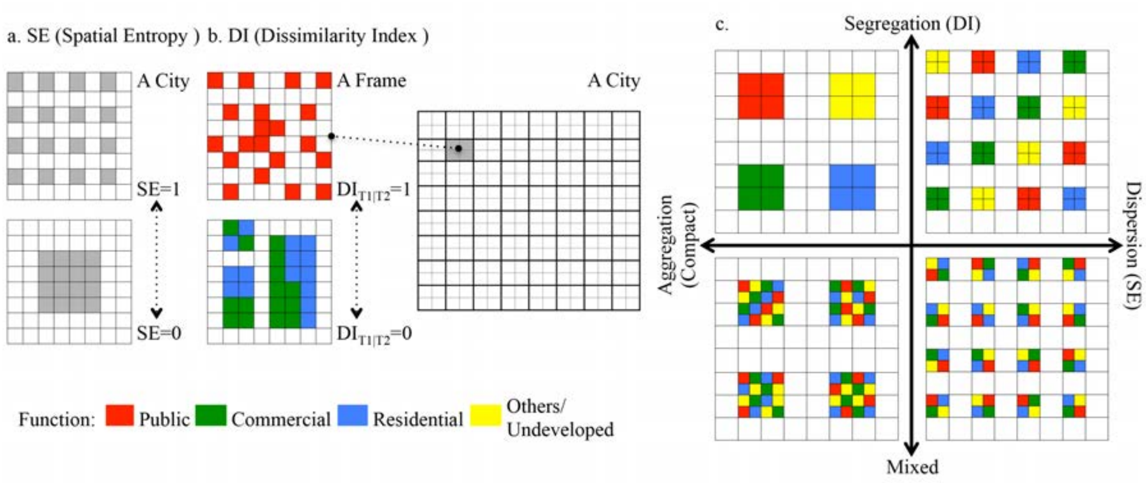


Figure 6.2 Geometric prototypes of land-use patterns

(a) the degree of SE denotes aggregate (compact) land use; (b) the degree of DI indicates segregation/mixed land use ($DI_{T1|T2}$=1 implies the presence of a singular type of land use, such as T_{Public} dominates a given frame rather than $T_{Commercial}$ or $T_{Residential}$. $DI_{T1|T2}$=0 entails mixed land use, such as $T_{Commercial}$ evenly distributed with another type of land use, such as $T_{Residential}$.); and (c) multi-dimensional indices.

Table 6.1 lists the top 10 cities in each category based on their actual SE and DI values. The appearance of each city widely differs. A relatively low DI is observed among large cities, such as Beijing and Shanghai. By contrast, smaller cities, namely, Xiangyang, Tangshan, and Guiyang, present higher DI values. Although Chongqing is a large city in terms of population and urban area, it has a high DI value. In addition, Chongqing is the Chinese city with the most segregated development. Its $D_{R|P}$ and $D_{R|C}$ are relatively high, of which T_R to T_P and T_R to T_C are more segregated than the rest of the Chinese cities. The primary reason for this result is the implementation of a planning layout emphasizing the segregation of land use, e.g., zoning, which has been rigidly enhanced by planning authorities at the national and local levels. Historically, the early stages of the development of China’s programming economy and the mode of the Soviet planning system shaped the current situation, although China has begun to adjust and reform its planning and administration system. Distinctively, Hong Kong consistently exhibits a lower degree of DI (less segregated) but higher degree of SE (more spread out) compared with other cities. In addition, Hong Kong exhibits a higher SE value but has developed a highly concentrated urban space because of limited land availability. This city is wellattested to be the most densely populated city worldwide with a highly concentrated city center and sub-centers. Developable lands are dispersed throughout the territory. The pockets of developed areas in Hong Kong have been scattered and spread throughout its entire urban area, even though most parcels of built-up lands are characterized by high density. Thus, with respect to developed-area distribution, Hong Kong has a sprawl, and its SE value is relatively high. Its populated sub-centers are separated by country parks and conservation areas. Therefore, Hong Kong is recognized as a unique case.

Table 6.1 Results summary for the top 10 cities under each variable

SE_R	SE_C	SE_P	SE_{Mean}	$DI_{R\|C}$	$DI_{C\|P}$	$DI_{R\|P}$	DI_{Mean}
Hong Kong	Dongguan	Hong Kong	Hong Kong	Chongqing	Xiangyang	Chongqing	Chongqing
.158	.143	.093	.101	.995	.990	.989	.989
Wenzhou	Shijiazhuang	Shijiazhuang	Dongguan	Xiangyang	Wuhan	Tangshan	Xiangyang
.121	.095	.082	.093	.995	.987	.989	.989
Lanzhou	Shanghai	Dongguan	Shijiazhuang	Changchun	Datong	Xiangyang	Tangshan
.103	.090	.064	.088	.993	.987	.982	.985
Changzhou	Zhongshan	Shanghai	Shanghai	Haikou	Changchun	Jiangmen	Guiyang
.093	.088	.061	.081	.992	.986	.981	.983
Shanghai	Beijing	Changzhou	Wenzhou	Guiyang	Qingdao	Yangzhou	Changchun
.092	.077	.058	.080	.992	.983	.980	.982
Baotou	Shenzhen	Urumqi	Changzhou	Zhanjiang	Chongqing	Weihai	Luoyang
.089	.076	.055	.075	.991	.982	.978	.978
Shijiazhuang	Changzhou	Qingdao	Beijing	Wuhan	Haikou	Xuzhou	Wuhan
.088	.075	.051	.070	.990	.981	.977	.978
Beijing	Wenzhou	Suzhou	Suzhou	Tangshan	Guiyang	Luoyang	Jingzhou

.086	.073	.050	.065	.990	.981	.976	.977
Nanjing	Suzhou	Lanzhou	Lanzhou	Jingzhou	Luoyang	Guiyang	Xuzhou
.086	.070	.049	.065	.988	.981	.975	.974
Suzhou	Baotou	Beijing	Baotou	Datong	Zhanjiang	Yancheng	Langfang
.075	.064	.048	.065	.983	.980	.974	.973

Note: SE (spatial entropy), DI (dissimilarity index), R (residential), C (commercial), P (public), M (mean).

Table 6.2 provides an overall understanding of the top 10 cities ranked in each category of aggregation to dispersal and segregation to mixed land use according to the mechanism elaborated in Figure 6.2. For example, Dongguan is widely dispersed but retains a highly even land-use distribution. Meanwhile, Shijiazhuang shows dispersal but mixed land use. Large cities exhibit higher degrees of dispersal than small cities, despite the importance of topographic considerations as in the case of Hong Kong. Finally, Hong Kong is notably the only selected city that does not follow a Chinese zoning map (Urban Master Plan and Regulate Detailed Planning). The potential implications of this fact require further investigation.

Table 6.2 City ranking of top 10 cities according to aggregation vs. dispersion, and segregation vs. mixing

Aggregation	**Disperse**	**Segregation**	**Mix**
Luoyang	Hong Kong	Chongqing	Shanghai
Guiyang	Dongguan	Xiangyang	Shijiazhuang
Hohhot	Shijiazhuang	Tangshan	Changzhou
Xiangyang	Shanghai	Guiyang	Shenzhen
Jingzhou	Wenzhou	Changchun	Hong Kong
Liaoyang	Changzhou	Luoyang	Dongguan

Tangshan	Beijing	Wuhan	Beijing
Nantong	Suzhou	Jingzhou	Baotou
Weihai	Lanzhou	Xuzhou	Wenzhou

6.3.2 Differences of Distribution in Urban Land-Use Patterns

The analysis of the SE–DI combination best differentiates the cities in terms of urban land-use patterns. Figure 6.3 differentiates the selected cities by combining SE and DI in terms of degree of segregation and dispersion. The blue dashed line signifies the mean value of SE and DI that divides cities into four distribution zones and reflects the distinct characteristics of land-use patterns. Cities in the upper-right zone show a pattern of dispersion and segregation; cities in the upper-left zone exhibit a pattern of concentration but segregation; cities in the lower-left zone show a pattern of concentration and mixed land use; cities in the lower-right zone display a pattern of mixed but dispersed land use. Apparently, the dispersal of cities is accompanied by a decrease in segregation. Most of the cities are located in the lower-right and upper-left zones, which imply that spread-out cities have mixed land use and vice versa. Beijing, Shanghai, Shenzhen, Guangzhou, and Hong Kong are relatively spread-out urban areas with highly mixed land use. Chongqing also has a high DI value but has no evident spread-out urban area because of the restrictions of the natural environment, which surrounds the territory with continuous mountains and rivers (see Table 6.2).

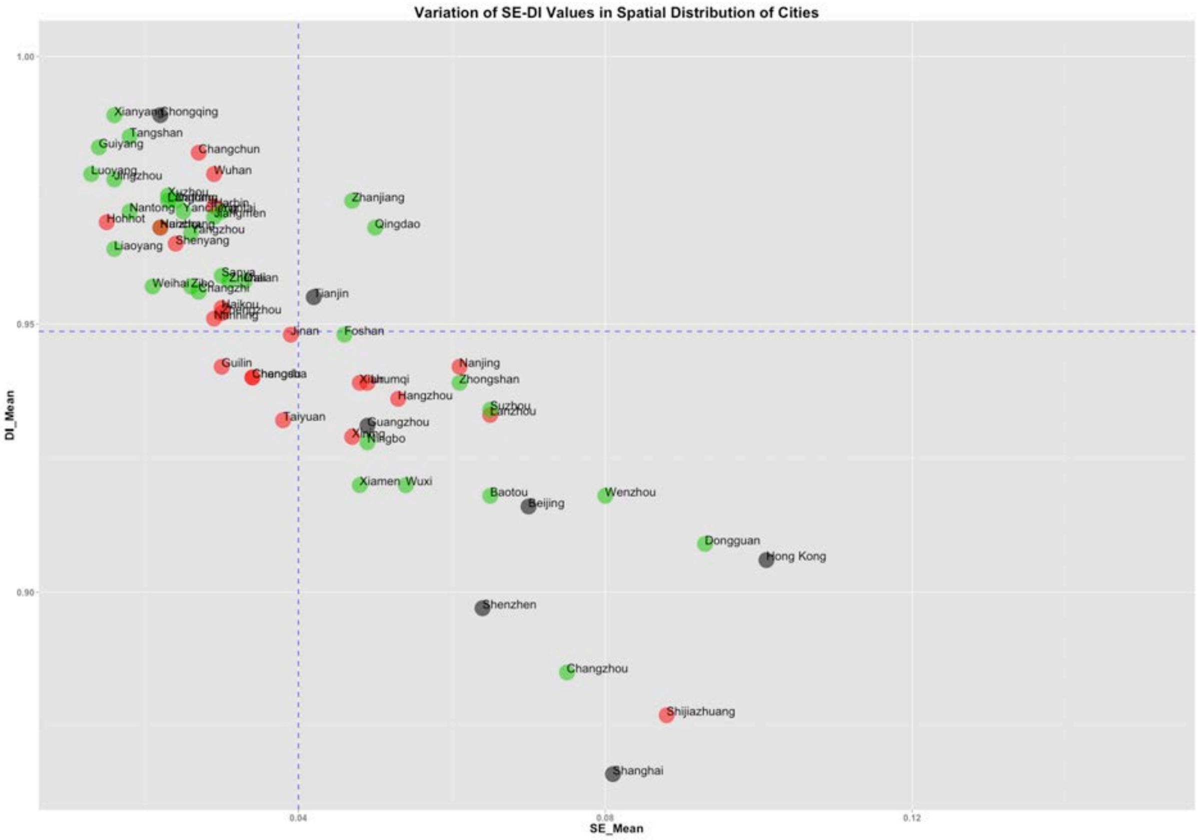


Figure 6.3 Variation of SE–DI values to evaluate spatially differentiated cities. First-tier city (black dots), second-tier cities (red dots), third-tier cities (green dots).

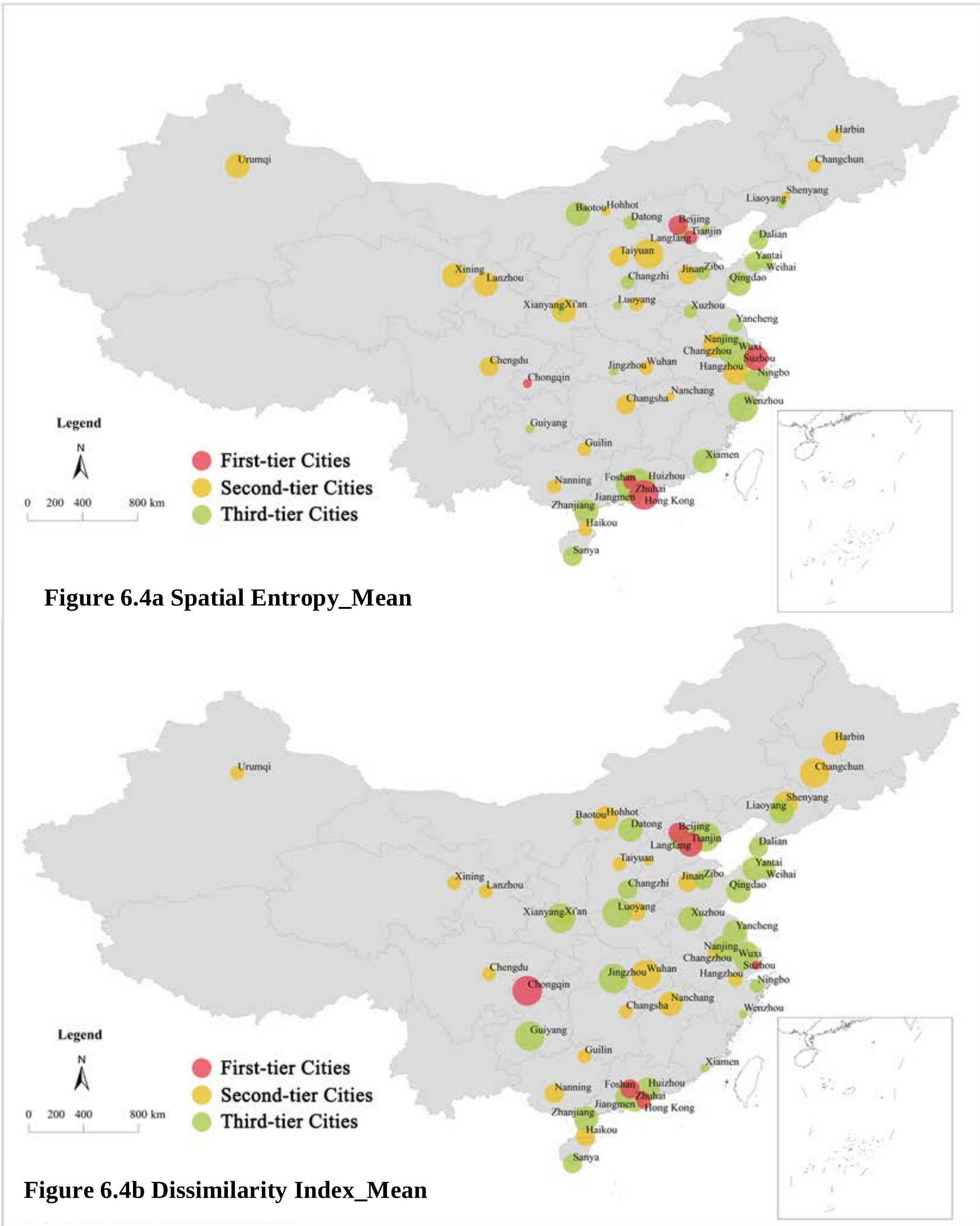


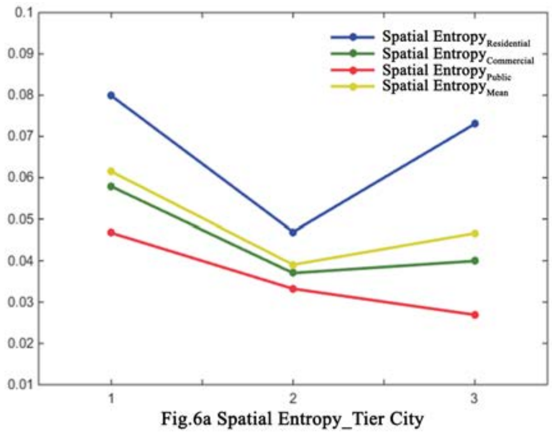
Figure 6.4a Spatial Entropy_Mean

Figure 6.4b Dissimilarity Index_Mean

Figure 6.4 Geographic distribution of cities indicating SE–DI values.

Numerous Chinese cities have experienced rapid and unbalanced development. To promote or restrict urban growth, the central government has divided cities into different tiers for decision-making and management. The structural hierarchy of the administrative divisions of China includes three classifications for cities and excludes the county-level cities as follows: 1) Directly controlled municipalities of China (megacities), identified as first-tier cities 2) Provincial capital cities (large-medium cities), representing second-tier cities; and 3) Prefectural-level cities (medium cites), identified as third-tier cities. First-tier cities represent the most developed areas of the country with the most affluent and sophisticated growth that typifies the driving forces of China's urbanization. These first-tier cities have the most potential to attract growth. Second-tier cities represent some of the fastest growing areas with growth trends mimicking those of first-tier cities. Third-tier cities generally lag behind the other two tiers in terms of economic growth and urban development, although many of them are considered to be economically and historically important.

Figure 6.4 further shows the geographical distribution of the differently tiered cities according to the SE_{Mean} (Figure 6.4a) and DI_{Mean} (Figure 6.4b) values. Based on a multi-factor assessment, Figure 6.4 depicts the three tiers of Chinese cities differentiated by their SE and DI values. Figure 6.4a presents megacities and prefecture cities, which have more residential lands because first-tier cities must absorb a large number of migrants and provide enough residences for them. On the other hand, third-tier cities need to attract investment, and residential-district development is the fastest and most direct way of increasing local GDP. Similarly, first-tier cities are the most vibrant because of their economic functions and show a high SE_C in Figure 6.4a. Meanwhile, as detailed in the previous section, first-tier cities emphasize government-led development by increasing public functions in new areas. Unsurprisingly, Figure 6.5a reveals that a more stable urban land-use pattern is observed among provincial cities. Figure 6.5b shows that mixed land use is prominent in all land sectors in first-tier cities. By contrast, the urban land-use patterns of second- and third-tier cities with higher DI values do not manifest mixed land use. Large cities tend to have low DI values. Multiple urban and functional districts are observed in relatively large cities because of the presence of multiple city cores, whereas small cities exhibit a distinct singular city core.



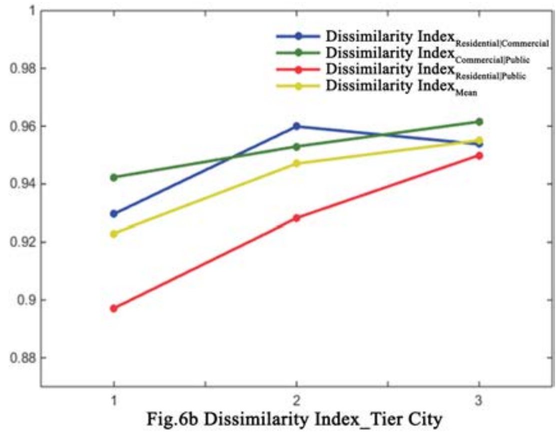


Figure 6.5a Spatial Entropy_Tier City

Figure 6.5b Dissimilarity Index_Tier City

Figure 6.5 Variations in urban land use among Chinese tiered cities.

6.3.3 Relationships Between Urban Land-Use Patterns and Their Driving Factors

Figure 6.6 shows plots of SE and DI values in relation to urban land area, urban population, GDP, and paved road area. The plots estimate how dispersed the urban land use of Chinese cities are in relation to urban factors. An increase in the SE value of a city means that the compactness of a city is decreasing, and the city is possibly sprawling. By combining the results shown in Figure 6.6 and bivariate correlate analysis, Table 6.3 shows the correlation degree of dual relations. The SE values of cities in the upper-left area of the plot are larger, and the corresponding cities are characterized by a more expanded form (Figure 6.6a–6.6d). Particularly, cities with high SE values can be inferred to have a large footprint. SE_R has a relatively higher positive correlation with population, GDP, and paved road area than with urban land area. Meanwhile, SE_P development is fundamentally driven by urban population, GDP, and paved road area. In other words, residential and public sectors are equally dispersed throughout the cities. Specifically, residential districts are consistently developed based on the amount of public land-use development. This consistent development occurs because land use in the public sector generally serves as a catalyst for the promotion of residential investment for the development of new urban areas, or for the provision of supplementary services to the existing residential communities. Furthermore, the commercial sector is the sector least influenced by population and urban land areas; however, GDP and paved road areas are closely related to SE_C. In other words, the commercial sector is generally a relatively concentrated development with easy access to road networks, which in turn attracts more economic activities. Cities with larger populations will not spread their commercial development to the same extent as residential or public sectors. Therefore, regulating the development of residential sectors and concentrating the populations in cities is a more effective way to preserve land resources.

With respect to the DI values shown in Figure 6.6e–6.6h, higher DI values denote aggravated segregation. Given that DI introduces the degree of segregation of different types of land use, the evenness or unevenness of urban land use can be evaluated. The results of $DI_{R|C}$, $DI_{C|P}$, and $DI_{R|P}$ indicate GDP to be the most influential factor in reducing the segregation of land use, and paved road area has an average significant correlation to those values. $DI_{R|C}$ and $DI_{C|P}$ have no correlation with urban population and urban land area, whereas $DI_{R|P}$ exhibits a mid-range significant correlation with urban population. $DI_{R|P}$ displays a low degree of segregation and relatively homogeneous distribution of residential and public sectors, which leads to accumulative public land use around the residential areas. On the other hand, urban population is associated with the $DI_{R|P}$ value, which would require various types of public services and induce diversified behavior in multifunctional districts (see Table 6.3).

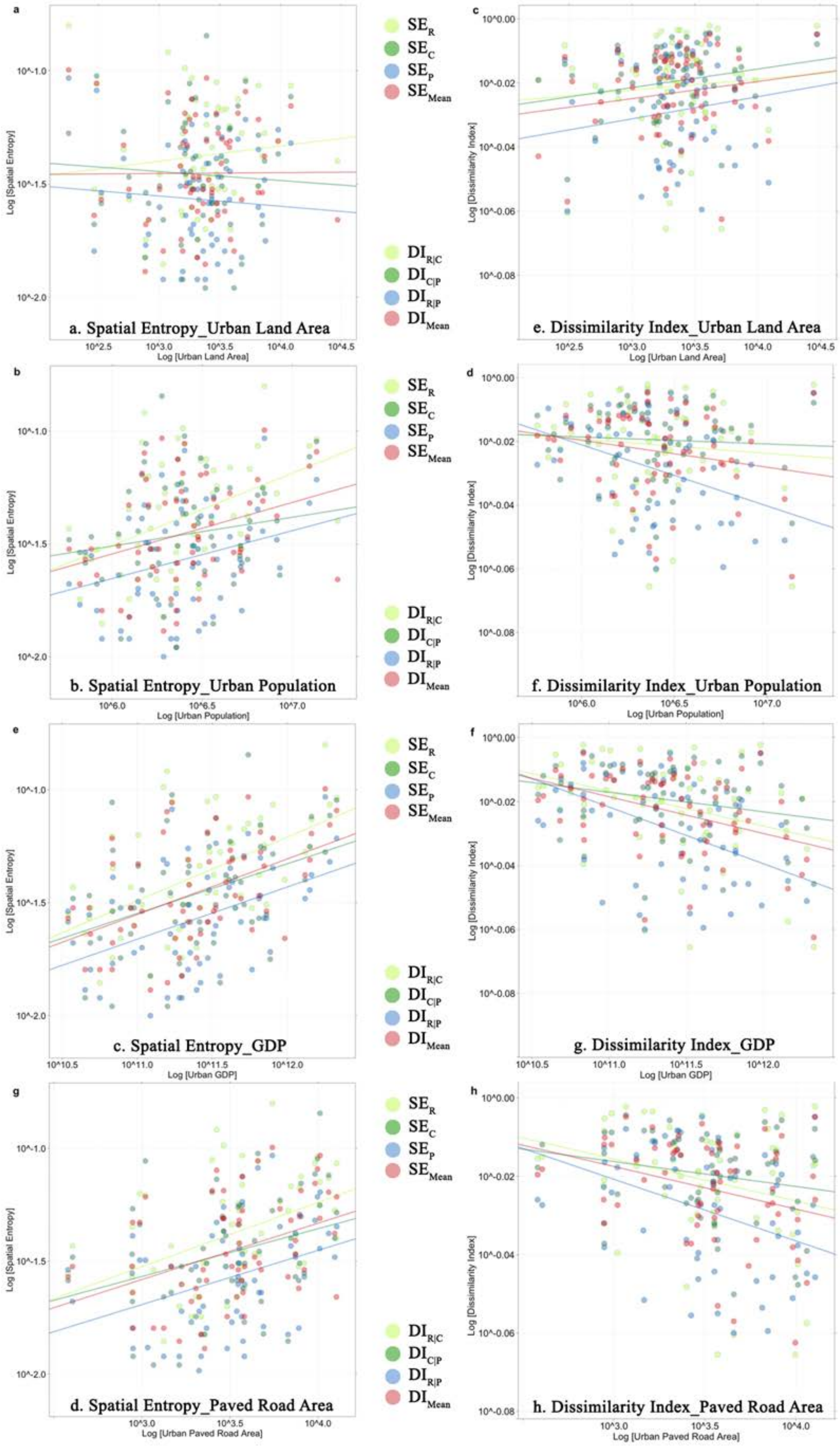


Figure 6.6 Double logarithm plots of the comparison of SE and DI values of cities (x-axis: urban area, population, GDP, and paved road area; y-axis: SE and DI values).

Table 6.3 Summaries of significance and correlation analysis

		Urban population	Urban land use area	GDP	Paved Road Area
$SE_{Residential}$	Pearson Correlation	.310*	.040	.532**	.365**
	Significance (2-tailed)	.015	.759	.000	.004
	Log-log R-squared	.184	.012	.287	.189
	Log linear p-value	.000***	.393	8.61e-06***	.000***
$SE_{Commercial}$	Pearson Correlation	.125	-.074	.397**	.341**
	Significance (2-tailed)	.337	.570	.002	.007
	Log-log R-squared	.026	.004	.157	.094
	Log linear p-value	.212	.635	.002**	.004**
SE_{Public}	Pearson Correlation	.218	-.054	.474**	.353**
	Significance (2-tailed)	.092	.677	.000	.005
	Log-log R-squared	.080	.006	.191	.1338
	Log linear p-value	.027*	.569	.000***	.00375**
SE_{Mean}	Pearson Correlation	.244	-.026	.516**	.387**
	Significance (2-tailed)	.059	.844	.000	.002
	Log-log R-squared	.104	.252	.242	.1619
	Log linear p-value	.012*	.959	5.65e-05***	.0013**
$DI_{Residential\|Commercial}$	Pearson Correlation	-.082	.136	-.370**	-.226
	Significance (2-tailed)	.530	.295	.003	.080
	Log-log R-squared	.009	.008	.107	.067
	Log linear p-value	.472	.493	.010**	.044*
$DI_{Commercial\|Public}$	Pearson Correlation	-.065	.144	-.297*	-.202

	Significance (2-tailed)	.620	.267	.020	.119
	Log-log R-squared	.004	.043	.063	.045
	Log linear p-value	.626	.110	.050	.102
$DI_{Residential\|Public}$	Pearson Correlation	-.277*	.099	-.529**	-.308*
	Significance (2-tailed)	.031	.447	.000	.016
	Log-log R-squared	.113	.022	.195	.100
	Log linear p-value	.008**	.252	.000***	.013*
DI_{Mean}	Pearson Correlation	-.178	.140	-.474**	-.288*
	Significance (2-tailed)	.170	.280	.000	.024
	Log-log R-squared	.043	.026	.195	.094
	Log linear p-value	.106	.211	.001**	.016*

Note: Correlation significance level is at the *** <0.001, ** <0.01, * <0.05.

Table 6.4 summarizes the correlations among SE–DI variables and urban factors, specifically land area, population, GDP, paved road area, and tier cities. In addition to Figure 6, the multivariate correlation analysis (parameter estimates) clearly demonstrates that SE_P is strongly correlated with the city scale, namely, urban land area, urban population, and GDP. First-tier cities are driven by SE_P, whereas second- and third-tier cities do not have a relationship with SE_P. SE_R indicates a high correlation with third-tier cities. Meanwhile, GDP shows higher correlation with SE_R and the highest correlations with SE_P and SE_M. $DI_{R|P}$ has the highest correlations with urban land area, urban population, and GDP. $DI_{R|C}$ and $DI_{C|P}$ have high correlation with urban land area. $DI_{R|C}$ shows a high correlation with GDP. First-tier cities have high correlation with $DI_{R|P}$, which imply that larger cities have more mixed residential and public land uses. Furthermore, this result also shows that public sectors stimulate city size, and residential sectors are associated with public sectors in a reciprocal relationship based on volume and location (see Figure 6.7).

Table 6.4 Multivariate correlation analysis

Dependent Variable	Parameter	Standardized Coefficients	Std. Error	t	Sig.
SE_R	Intercept	.073	.030	2.465	.017
	Urban Population (1,000)	.56	9.044E-6	.271	.788
	Urban Land Area (sq km)	.030	6.772E-6	.158	.875
	Urban GDP (10,000 RMB)**	3.632E-010	1.027E-010	3.536	.001
	Paved Road Area (sq km)	-8.273E-007	1.455E-006	-.569	.572
	First-tier Cities	.006	.057	.110	.913
	Second-tier Cities	-.038	.036	-1.045	.301
	Third-tier cities*	.026	.005	-.657	.050
SE_C	Intercept	.037	.006	6.715	.000
	Urban Population (1,000)	.125	1.695E-6	1.648	.105
	Urban Land Area (sq km)	-.072	1.269E-6	-1.644	.106
	Urban GDP (10,000 RMB)	1.722E-010	9.745E-011	1.767	.082
	Paved Road Area (sq km)	6.735E-007	1.381E-006	.488	.628
	First-tier Cities	.017	.011	1.576	.121
	Second-tier Cities	-.004	.007	-.572	.570
	Third-tier cities	.028	.004	-1.246	.499
SE_P	Intercept	.027	.004	7.222	.000
	Urban Population (1,000)**	.218	1.122E-6	2.869	.006
	Urban Land Area (sq km)*	-.055	8.404E-7	-2.321	.024
	Urban GDP (10,000 RMB)***	1.797E-010	6.557E-011	2.741	.008
	Paved Road Area (sq km)	-1.028E-007	9.289E-007	-.111	.912
	First-tier Cities*	.015	.007	2.179	.034
	Second-tier Cities	-.001	.004	-.218	.828
	Third-tier cities	.015	.003	-1.293	.161
SE_{Mean}	Intercept	.046	.010	4.425	.000
	Urban Population (1,000)	.103	3.152E-6	.888	.379
	Urban Land Area (sq km)	.006	2.360E-6	-.415	.679

	Urban GDP (10,000 RMB)***	2.384E-010	7.881E-011	3.025	.004
	Paved Road Area (sq km)	-8.553E-008	1.117E-006	-.077	.939
	First-tier Cities	.013	.020	.644	.522
	Second-tier Cities	-.014	.013	-1.131	.263
	Third-tier cities	.021	.004	.355	.301
$DI_{R\|C}$	Intercept	.958	.007	131.616	.000
	Urban Population (1,000)	-.083	2.214E-6	-1.858	.069
	Urban Land Area (sq km)*	.134	1.658E-6	2.122	.038
	Urban GDP (10,000 RMB)**	-3.232E-010	1.282E-010	-2.521	.014
	Paved Road Area (sq km)	1.303E-006	1.816E-006	.718	.476
	First-tier Cities	-.021	.014	-1.483	.144
	Second-tier Cities	-.001	.009	-.060	.953
	Third-tier cities	.031	.006	-.221	.352
$DI_{C\|P}$	Intercept	.961	.005	178.055	.000
	Urban Population (1,000)	-.064	1.642E-6	-1.868	.067
	Urban Land Area (sq km)*	.146	1.229E-6	2.229	.030
	Urban GDP (10,000 RMB)	-1.718E-010	9.751E-011	-1.762	.083
	Paved Road Area (sq km)	4.157E-007	1.381E-006	.301	.765
	First-tier Cities	-.014	.010	-1.410	.164
	Second-tier Cities	-.005	.007	-.780	.439
	Third-tier cities	.022	.004	-.002	.143
$DI_{R\|P}$	Intercept	.951	.007	129.791	.000
	Urban Population (1,000)***	-.277	2.229E-6	-4.460	.000
	Urban Land Area (sq km)***	.099	1.669E-6	3.912	.000
	Urban GDP (10,000 RMB)***	-5.669E-010	1.366E-010	-4.148	.000
	Paved Road Area (sq km)	2.607E-006	1.936E-006	1.347	.183
	First-tier Cities*	-.032	.014	-2.304	.025
	Second-tier Cities	-.002	.009	-.262	.794
	Third-tier cities	.030	.006	.230	.285
DI_{Mean}	Intercept	.957	.006	167.306	.000

Urban Population (1,000)**	-.178	1.739E-6	-3.302	.002
Urban Land Area (sq km)**	.141	1.302E-6	3.294	.002
Urban GDP (10,000 RMB)***	-3.539E-010	1.034E-010	-3.424	.001
Paved Road Area (sq km)	1.442E-006	1.465E-006	.985	.329
First-tier Cities*	-.022	.011	-2.062	.044
Second-tier Cities	-.003	.007	-.361	.720
Third-tier cities	.025	.005	.001	.302

Note: * indicates a significant level according to MANOVA, significance tested at $p<0.05$ for multiple comparisons (*** highest correlation, ** higher correlation, * high correlation).

6.3.4 Relationship between Urban Land-Use Patterns and Urban Development

Land-use patterns reflect the arrangement of different types of land use and indicate where to allocate land for city development. The government has played an important role in stimulating, restricting, and allocating land use. The findings clearly prove that cities experience crucial dispersion of land use in the public sector (high SE_P), given that most of the new urban areas are initially urbanized through public investment. Many Chinese cities released their peripheral land or rural land for real estate development of residential clusters (high SE_R). Hereafter, the land use of urban fringes was adjusted from agricultural land to built-up area leading to a more dispersed landscape of central urban areas. The results also reveal the essential origin of Chinese urbanization. For instance, Beijing, Shanghai, and Hong Kong have high SE (see Table 6.1). These cities have powerful municipal authorities, where the government determines land release or acts as a catalyst for development in new districts. Nonetheless, with lower SE in the commercial sector (SE_C), Hong Kong has concentrated its commercial centers in a few districts, such as Tsim Sha Tsui, Central, and Causeway. This concentration arises from the city's aims to provide people with more housing and support public services under highly limited land resources.

The current separation of land-use patterns is a result of traditional planning and economic marketization and exacerbated by environmental restrictions. Notably, office and commercial developments have an economic advantage in locations close to the city center, whereas industrial development is pushed farther away toward suburban areas. Residential development tends to take place in between the city center and the industrial areas. This evidence suggests the strong influence of market-driving forces on the spatial separation of urban land-use patterns. Furthermore, cities with environmental restrictions on urban development have several dispersed developed areas, each with independent functions. For example, Dongguan has not divided its city into towns with urban administrative districts (shixiaqu) nor set up counties (shixiaxian); however, the municipality has direct jurisdiction over towns (shixiazhen). Accordingly, each independent town urbanizes alone, separating the entire city domain and resulting in well-balanced functions. Consequently, Dongguan is on both lists of high dispersion and mixed land use (see Table 6.2).

Our analysis of the variations in urban land use in major Chinese cities shows that each individual city has a distinct land-use pattern, ranging from more mixed (Beijing, Shanghai) to less segregated (Xiangyang, Tangshan, and Guiyang), and the most segregated (Chongqing). From the above analysis, the spatial characterization of urban land-use patterns in China can be categorized into three typical types: (1) economically led (Shanghai), (2) government led (Dongguan), and (3) geographically constrained (Hong Kong and Chongqing). Analysis on land use patterns in Hong Kong indicates more compact urban form than in any other cities. Among fastest-growing Chinese cities, Hong Kong posted a decade-long lower increase in developed land per capita. Hong Kong is the only city where population increased and land-use did not increase excessively compared to other Chinese cities. In addition, it was the only city where population became more concentrated and land-use de-concentrated the least during the study period.

6.3.5 Characteristics of Urban Land-Use Patterns Among Cities of Different Tiers

In China’s urban system, tiered cities defined by the State Council have a major impact on land-use patterns because of the spatial distribution of land resources and population mobility. Administrative intervention in city development, particularly through land acquisition and fiscal support, is in line with the national policy for urban hierarchy systems. Furthermore, the strict hierarchy of the land-use planning system and the restriction on population migration resulted in relatively undifferentiated urban land-use patterns within the same tier of cities (Seto and

Fragkias, 2005). Some subtle differences are observed among cities. First- and third-tier cities remain the most dispersed and the most segregated, respectively, in terms of land-use pattern. First-tier cities have a higher degree of mixing but also have higher dispersion than the two other tiers. Third-tier cities are more driven by residential sectors (SE_R), which require increased real estate development to guarantee their fiscal resources and stimulate city growth.

In general, large cities will eventually acquire a more mixed urban land-use pattern. Lands in cities with large urban populations, land area, GDP, and paved road areas tend to have mixed land-use areas (highly correlated with lower DI values). In particular, Chinese cities originally have significantly more separated functional layouts. However, cities have been developing at a highly rapid rate in the last three decades, particularly among the first-tier cities. They have either absorbed a variety of land-use areas within the existing city layout or added a large amount of additional land-use areas of various types. The process of mixing land use in large cities is generally faster than that in small cities because of the influx of migrants into large cities. We can assume that land-use mixing declines from the city cores to the outskirts. Meanwhile, despite being a first-tier city, Chongqing is a mountainous city surrounded by undevelopable land, which limits expansion compared with other first-tier cities. Chongqing is divided into different land-use clusters, thereby explaining its high DI and SE values.

6.4 Survey Results of Evaluation of Opinion Leaders

As above-mentioned, an interview/survey was conducted with opinion leaders on questions identified in the various research methods. Based on the evaluation of 10 local opinion leaders, five major topics related to local governments to apply a policy approach built on smart growth principles for new urbanization have been carefully addressed. The views of opinion leaders in the survey correspond well with the perceptions of planning regulations. The strength of government regulatory regimes was affirmed in terms of government specification for land use regulatory. They also emphasized the essential role of local governments who have constitutional power to carry out smart growth policies over land use planning should actively involve in policy adoption and implementation. Clearly, they perceived overall regulation is a combination of municipal government and local planning authorities. It is also noted that when municipal government imposes certain requirements, planning department may dampen the motivation for additional professional regulation. The policy priority of government forces plays a greater role in the distribution of land use for urbanizing population in the cities and generally intervenes in three direct ways: limiting sprawl development and encouraging urban infill development, and promoting mixed land-use.

In general, the survey results show that a policy approach to planning built from smart growth principles of mixed land use and infill development are perceived to be more effective on top of traditional planning systems in achieving sustainable urbanization goals. Local governments, however, have become more active in trying to manage and regulate growth in their cities. The policy approach seem to achieve a particular case of planning through the effective use of regulation, sanctions, and incentives, meanwhile it is also perceived to have higher development costs in social consensus and administration approval.

Involvement and observation for critical urbanization challenges

In view of the experts interviewed, although all levels of Chinese government need to address a wide range of challenges in urbanization, they came to agree that the key challenge are recognized as the effective and efficient allocation of land use in a proper urban scale, which the sizes of cities and patterns of urbanization should be refined, realigned, or re-designed. *The New-type Urbanization Plan* has made a turning point in China from the old investment-led quantity growth mode to efficiency, resource protection, and quality of growth. The interviewed opinion leaders believe that the quantitative assessment presented in this study can profoundly inform China’s decision-makers by realizing the objective situation of the two key challenges. In addition to traditional way of qualitative recognition of city size and land use pattern, the findings of this study can also provide new considerations from urban planners’ side, even if the analysis may not be integrated into planning systems. They have faith in that the new development can gradually shift from expanding growth to urban rejuvenation, as long as a policy approach of planning could be formed to advance the performance and rationality of urban land use in the populous and fast urbanizing China.

Effectiveness in achieving goals through special planning discretion

Respondents perceive principles adopted from smart growth to be significantly effective in achieving *New-Type Urbanization* goals. The two goal of this study, infill development of existing urban areas and mix of land-use is perceived in high performance. The administration of China's conventional urban planning system is key factor. Urban planning is not an exact science but has to proceed by trial and errors, with which spatial side effects are often unexpected. The evidence presented here does not sustain that citywide statute planning systems are sufficient to attain all out performed development, and conventional planning programs hardly make progress on sustainable urbanization. This is not to say that Chinese cities do not deliver better planning regulation, although the measures may make a strong case for that claim. In addition, it is not necessarily the case that some cities are doing a better planning job than others, which some of the measures presented here may suggest. The opinions suggest that in the absence of legislation for providing adequate administration support, local government may actively manage special and specific growth through a highly articulated and integrated system with traditional planning system.

Employment and applicability with coordination across jurisdictions

In general, opinion leaders believe that any new programs or policies must be implemented over a long period to achieve tangible and visible results, which requires credible governmental commitment to their policies. They regarded the design of a new policy approach as a procedure that should take account of interactions among policies and coordinate well across relevant agencies. The applicability across jurisdictions apparently leads to increased local government activism for the perceived effective a policy approach. In some cases, a new policy approach is put in place that focuses narrowly on a specific objective, which is part of a larger framework and may have potential synergies or antagonisms with other policies. They take for that, for example, infill development requires government approval of the possibility that such easements can be inconsistent with existing statutory plans.

Cost to regulatory compliance

Several survey respondents wrote in comments on issues related to costs, notably about the planning authorities or municipality's ability to use capital expenditures or regulation discretion to shape urban development. Respondents from the investment organizations (e.g. developers) were more likely to believe that the costs of applying privileged principles and the time required to complete the review process had become a lot higher than projects examined and approved through conventional channel. A planner suggested that the municipal government has to influence land-use through budget and regulatory authority over infrastructure planning and land control to exercise authorities and responsibilities. Respondents perceived the use of incentives and sanctions as significantly more effective than strict prescription control, presumably reflecting the greater effect of discretion of this policy approach in local development.

Government role in guiding land use

In this set of survey questions, respondents were asked to rate the extent to which they agreed or disagreed with a set of statements concerning government regulation of land use development. Respondents agreed that government has a responsibility to guide the development of land in rapidly growing areas to protect the public interest. Similarly, respondents felt that the government incentives will help to initiate a paradigm shift from more statutory based traditional planning to administrative-based mechanisms, using their planning and zoning capacity. Respondents strongly supported strong limits on land use and urban growth. Local government should not dictate specific land uses per se but instead should provide a framework to provide a mix of land use alternatives. Without these mechanisms, the government role has low effect. 7 answered local government while 2 answered developers; 1 felt that citizens should be responsible to get involved in public participation for policy enhancement. Opinion leaders generally had similar views about the role of government in this policy approach, except that those from the planning and design consultancy were more likely to believe that municipal governments should defer to local planning departments on such issues.

6.5 Chapter Summary

Understanding how cities urbanize is vital and can be accomplished using a computer model that can reconstruct cities through a bottom–up approach to investigate fundamental urbanization mechanisms. Most of the existing literature has discussed the negative effects of the proliferation of urbanization. However, research on the development of methods to quantify and compare land-use patterns shaped by urbanization is generally limited. The present study filled this gap and proposed an integrated and quantitative method to investigate urban land-use patterns through automatic categorization, identification, and characterization of the existing land-use patterns in Chinese cities. By linking planning data, particularly through ordinance survey, Python, ArcGIS, SPSS, Mat Lab, and CA modeling with statistical data sets, the spatial metrics of SE–DI were developed to capture, quantify, and understand urban land-use patterns and link them to the urban planning background. This study has explored the characteristics of land-use patterns in China and explained how urban land-use patterns are shaped.

A comparative evaluation of land-use patterns reveals the distinct driving forces of urbanization that are simultaneously at work and can lead to far-reaching policy implications. We have compared the spatial patterns of cities by studying eight independent attributes (SE_R, SE_C, SE_P, SE_{Mean}, $DI_{R|C}$, $DI_{C|P}$, $DI_{R|P}$, DI_{Mean}) of actual land use, followed by integration with the statistical data. The findings indicate that SE_R has relatively higher positive correlations with population, GDP, and paved road area compared with urban land area; SE_P development is fundamentally driven by urban population, GDP, and paved road area; and SE_C is closely related to GDP and paved road area. Furthermore, the key to linking urbanization and land-use patterns lies in the recognition of the spatial relationships of urban hierarchies. The changing land-use patterns in China have been influenced by the natural environment, administrative adjustment, entrepreneurial governments, and the spatial arrangement of Chinese zoning districts. However, such a government-led urbanization approach in China relies on both the will of decision makers and government intention, but neglects the following fundamental law: peripheral areas have close and dependent relationships with relevant core areas. Planning initiatives that somehow lead to a short-term disequilibrium facilitates gradual shifts in land-use patterns from disequilibrium to equilibrium.

Besides, in the views from survey of opinion leaders obtained from the survey, overall, the implementation strategy of a policy approach mostly addresses legal, administrative means to put forward a series of planning policies and measures from legislative and regulatory point of view, applying in development projects and optimal allocation of land resources. Notably, they deemed that both the central government and local governments play an active role in this assumptive policy approach of planning to future China's intensive development. In the raised questions of this study, they agreed on the standpoints that the ineffective planning systems and land-use policies have induced the current city spatial formation and the allocation of land resources in China. The overly rigescent and hysteretic governance of urban planning has resulted in inefficient land use enforcement. Policy-makers or decision-makers at distinctive management levels are believed to have neglected the nature of the city. The next chapter summarizes the major findings of this research and its contributions to knowledge. It also provides policy implications and recommendations for a policy approach of planning in Chinese cities under the era of new-type urbanization, and identifies its limitations as well as directions for future research.

CHAPTER 7 CONCLUSION

7.1 Introduction

The four research objectives were achieved in this dissertation. To gain new insights into the efficacy of urbanization that started in the 1980s, this study examined three sets of measures and analyzes the city size and scale, land-use mixture, and urban expansion of preferred cities. Three strands of research on urbanization and planning policy are most relevant to the present study. The first body of research deals with urbanization, smart growth policy, and fractal city theory. The second one explores the measurement of urban development patterns and spatial characters, and the third one examines the approaches to land use and the effects of policy approach. This study initially examined the drivers of urban land use change and its spatial pattern in China by combining high-resolution digital data with the compendium panel data generated from socioeconomic and demographic data. This approach is adopted to estimate relations among urban factors. The evaluation then measured the performance of urbanization to inform related parties toward intensive development goals in the stage of a new of urbanization. This evaluation suggests that policy responses to the critical challenges of urbanization should differ from old policies.

This chapter presents the concluding remarks of this study. First, the major findings of this study are summarized in the following section. Second, contributions to the knowledge of the study are presented. Finally, recommendations are made for future studies.

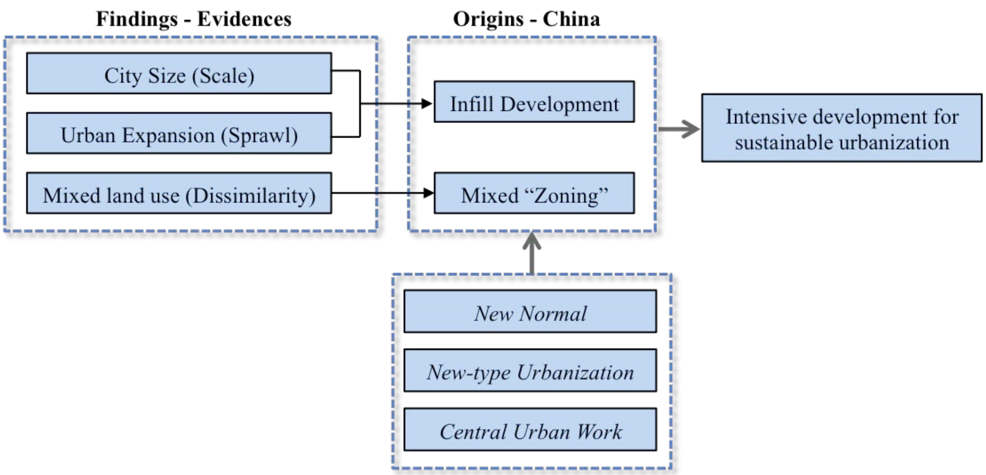


Figure 7.1 Framework of Chapter 7.

7.2 Implications, Discussions, and Recommendations

7.2.1 Urbanization and its spatial characters of city size

Only a few studies were conducted on the complex system of urban evolution in China that consider the law of allometric growth, scaling parameter, and fractal theory. The quantifications of previous urban studies were never compiled in the past. Thus, these studies were able to offer new information on China's urbanization issues. This allometric study provided clear and strong implications for urban planners in understanding urban structure and dynamics.

Investigations on changing city size from allometric scaling consideration

Changing size of cities is to be found as common issues in fast urbanizing countries. Urban factors should be relatively consistent over time and across geography. In order to investigate how urban scaling laws emerge and relates to the population size of cities in China, based on existing studies, this study, reveal the evidence of how Chinese cities are allometric scaling during decades of urbanization movement. It selectively looks at the allometric relations among urban population, GDP and transport networks volume, and urbanized areas, in particular linking spatial to socio-economic factors that have shown unstable allometry other than static state or isometric.

Allometric scaling relations of Chinese cities between urban built-up areas and

urban populations

China's urbanization reflects a series of reactions relationships. The area of urbanized land most relevant to city size and administration levels rapidly increased in every city since the economic reform of China in the 1980s. Scholars argue that land urbanization does not correspond to the speed of population urbanization. Land-use contains more increments than the population of Chinese cities in the past decades. An area grows faster than population, which means that if the population of a city increases in a unit, the city area will increase more than a unit in the scaling relations. Over the past 35 years since China's economic reform and open economy, urban area expanded by 2 to 3 times until 2014 and urbanization rate reached 53.7%. However, urbanization rates in the U.S. and South Korea are about 90% and 80%, respectively. A gap exists between space urbanization and real population urbanization. China's urbanization demonstrated the fastest development stage in history from 2000 to 2010. During this period, urban construction in domestic land expanded to 83% along with the increase in urban population, including migrant workers, which increased by only 45%. This finding suggests that population urbanization lags behind land urbanization. This finding indicates that the population of most metropolitan areas decreases, which implies urban expansion. Only a small number of cities achieved a rate of accommodation of population increases faster than that of land use per capita expansion. This outcome generally counters the objectives of new-type urbanization.

Allometric scaling of Chinese cities between GDP and transportation networks volume (road area) in relation to urban population

The economic impact of urbanization is expressed as a scaling ratio of GDP changes to population changes. GDP increases in the past three decades lag behind the acceleration of urbanization. Changes in scaling factors are described as follows: a drop in economic efficiency is observed at lower β value, such as those in the 1990s and 2000s. β best-fit values are theoretically expected at 7/6 (1.17), with an international observation that ranges from 1.01 to 1.33. As cities grow, transportation networks occupy a certain part of urban area for connecting people and shipping goods. This analysis indicates the dynamics of urban infrastructures against the scaling relations between transportation network volume (i.e., road area) and urban population of Chinese cities. The β best-fit values of scaling factor are theoretically expected at 5/6 (0.833), with an international observation that ranges from 0.74 to

0.92. The land revenues in several Chinese cities are used to finance infrastructure thereby leading to increased urban spatial expansion.

Allometric scaling relations of hierarchical city categories between urban built-up areas and urban populations

The significant differences in city size in relation to urban factors across Chinese cities significantly affect urban spatial characters. The measured values may reflect similarities more than differences within different categories across cities. Generally, the population is more concentrated in larger cities than in small or medium-sized cities. In terms of the scaling relation of urban population and urban area, small cities show continuous increase in the exponent value of scaling. This finding indicates the growing power of urbanization. For example, the land-use growth of large cities decreased to a level lower than that of small cites, whereas the growth of medium-sized cities slightly increased. Small and medium-sized cities increasingly become the driving forces of China’s urbanization. This process originated in large cities thereby leading to urban expansion.

Allometric scaling relations of hierarchical city categories between GDP and urban population

The circulation of GDP among cities with different population/ land use area sizes generally highlights the importance of large cities. The upward movement of the urban economy of large cities may be the consequence of the condensed domestic and international investment in finance and market. Small cities are becoming the leading forces of GDP growth, whereas large cites remain the driving forces of GDP growth. The growing power of large cities decreased, but they visibly continue to outperform small cities. Medium-sized cities did not exhibit a stable trend because these cities have undergone substantial change in boundaries or administrative partition. Overall, the power of medium-sized cities to increase GDP is lower than that of the two other city categories.

Allometric scaling relations of hierarchical city categories between transportation networks volume (road area) and urban population

The allometric scaling factors of transportation infrastructure are higher in cities with large population sizes. Small and medium-sized cities show an increasing trend of scaling exponents. This finding indicates high growth power in road area construction in relation to urban population growth. The value of scaling factors in large cities decreased from 2000 to 2008. In particular, 2008 demonstrated a level below the theoretical expected value of 5/6 (0.833) because of the global financial crisis. Generally, scaling factors lower than 5/6 (0.833) signify that infrastructure construction lags behind the demand of growing population. By contrast, values higher than 5/6 (0.833) imply excessive road constructions compared with population growth in allometric scaling. The growing power ratio of road networks construction to urbanizing population in small and medium-sized cities increased and achieved a level close to that of large cities. This finding implies that infrastructure construction has become a dominant driving force of city development in small and medium-sized cities. The number of built roads increased with population growth.

Changing allometric scaling factors among different city categories

Differences between small and large cities will change when cities dynamically evolve. The general growth trend from 1982 to 2015 is similar in all studied cities. Population is more concentrated in large cities than in small and medium-sized cities. Over the study period, large shares of population growth in larger cities resided in existing urban areas, which suggests a rate of infill development higher than in other cities. Relatively smaller shares of newly urbanized population in larger cities lived in newly urbanized (i.e., urban peripheral/rural) areas thereby indicating low expansion. In the 1980s to 2000s, developed land per capita increased more rapidly in larger cities than in smaller cities, whereas in the 2000s to 2010s, land use in small and medium-sized cities increased more dramatically than in large cities. Urban spatial structures as the consequences of such dynamic evolution process are path-dependent. The spatial structure of large cities evolves slowly and can evolve only in a few directions (Bertaud, 2003). For example, decrease in population density is easier to achieve than an increase in density. Moreover, a monocentric city can more easily become polycentric rather than the opposite. Dominant monocentric cities tend to become less monocentric. Therefore, sub-centers that emerge as a city becomes large, whereas the degree of monocentricity decreases with size. The city center becomes large as cities expand. However, expansion causes a city center to lose accessibility.

Driving factors of China’s Urbanization in the allometric scaling growth

The quantile regression demonstrates shifts in scaling exponents in each city category and the growth power of scaling relation of land use and population. Large cities have high shares of population growth in urban areas, whereas small cities achieve a relatively low share of growth. The competitiveness of large cities will increasingly gain an edge from agglomeration and urbanization economies. Large cities are the leading force in land use, whereas small to medium-sized cities are the drivers of urbanization. An obvious shift in growth power was observed in large cities to medium-sized cities and small cities. Small and medium-sized cities are catching up with the urbanization of large cities in expanding infrastructure construction and land use. However, these cities cannot engulf the urban agglomeration of economic development.

7.2.2 Urbanization and its spatial characters of land-use pattern

Given the large differences in land-use composition, all case studies show that the land types of cities significantly differ. These fundamental differences in landscapes provide simple comparisons among cities. This study focusses on existing land use pattern, which reflects the traces of the past policies and jurisdictions. The current levels of various factors (e.g., urban population, urban land area, GPD, and paved road area) are the results of the cumulative effects of the past policies. Thus, the analysis focuses on the evaluation of land use pattern with respect to driving factors. The results show that cities exhibit distinctive spatial differences of fragmentation. Cities are expanding rapidly and are becoming less compact and increasingly dispersed. The findings prove that cities have been experiencing crucial dispersion of land use in the public sector because most new urban areas are initially urbanized with public investment. Office and commercial developments have an economic advantage in locations closer to the city center, whereas industrial development is pushed farther away toward the suburban areas. The results indicate that land use patterns are affected by the natural environment, administrative adjustment, and the spatial arrangement of Chinese zoning districts (e.g., Urban Master Plan and Regulate Detailed Planning).

In terms of land pattern, large and small cities remain the most dispersed and the most segregated. Large cities will eventually acquire mixed urban land use pattern. Lands in cities with large urban populations, land area, GDP, and paved road areas are likely to acquire mixed-use areas, which are highly correlated with low DI values.

The process of mixing land use in large cities is generally faster than that in smaller cities because of the influx of migrants in large cities. Large cities have a high degree of mix and high dispersion. Small cities are driven by residential sectors (SE_R). These cities require increased real estate development to guarantee their fiscal resources and stimulate city growth. The current separation of land use is a result of traditional planning and economic marketization and worsened by the natural environment. This study shows prevailing inefficient development patterns that directly or indirectly resulted from the following factors: 1) malfunction of planning institutions; 2) economic growth-oriented local authorities' officials; 3) substantial incentives of land use for promoting city economic growth; and 4) single-minded urban planning practice. This phenomenon demonstrates that city policy and planning can formulate the spatial structure and development features of a city.

7.2.3 Mixed and infill development towards *New-type Urbanization*

China is progressing to a level of sustained growth since the government focused on the transformation of its economic model. Government concerns on urban development vary significantly because of the urbanization stages since the economic reform. The analyses of city size and land use pattern in Chapters 5 and 6 indicate: 1) high the total land use per capita for each city, which should be adjusted to sustain improved relation among population, land-use area, GDP, and road areas; 2) the proportional designation of land use sectors of a city is excessively rigid, out of sense for a particular city, and should be reconsidered with adjustment or special treatment in a particular case; 3) conventional planning system (i.e., statutory plans and planning laws) are immutable and hardly allows special discretion for infill development and mixed land use.

The intensive concept of urban spatial development has gained considerable attention and sustained China's national policy forum on *Central Urban Work Conference* in 2015. The intensive development mode of urbanization actively advocates mixed land use and strengthens prescribed minimum control of land for infill development. Land use for new development has two major sources of supply, namely, stock land and newly incremental construction land. The former is obtained by consolidating idle land use, mining inner potential land for intensive use, and improving land utilization, whereas the latter is gained by expropriating agricultural and undeveloped lands through outward expansion. These lands are often subjected to ecological environments. To realize intensive urban development, cities should encourage efficient mining of relative stock land, regulate expansion, and ultimately control the construction land increment by timely adjustment of land use function and revitalization of brownfields. The strategy of infill development and mixed land use can be realized, unless a host of new planning approach is identified that can resolve various weaknesses in planning control and land use governance. The government should introduce a new policy planning approach to effectively enforce regulation that pursues the of a new type of urbanization. The new policy approach is an alternative to traditional planning. This approach implements the objectives of infill development plans and mixed land use areas.

The results of this study show that the new approach for mixed and infill development should include the following aspects:

The land use per capita prescribed for each city in the planning code should be adjusted to facilitate improved relation among urban factors, such as population, land use area, GDP, and road areas.

2) The proportional designation of land use sectors of a city should be reconsidered that includes adjustment or special treatment as a particular case in the planning system.

3) Given the presence of urban spatial characters and land use, a wise approach is to continuously infill newly urbanized populations and new construction projects that are strongly limited in the present urban footprint. The relations of urban factors will reach equilibrium more closely than the theoretical prediction. Land use pattern will achieve increased mix of urban space and sprawl or expansion will be compromised thereby increasing the potential to urbanize the population (20% to 30% of the total Chinese population).

4) To allow exceptions, a mechanism on top of conventional planning system and code should be established. This approach can be achieved by breaking traditionally prescribed restrictions to encourage mixed features of construction land and to control suitable city size with infill development;

6) Infill development is usually accompanied by mixed land use. The policy approach can stimulate their mutual enforcements and the expected effects of

China's urbanization.

7) Changes in land-use systems are necessary and should allow increased mix of land use and permit flexible land-use categorizations and changes.

7.2.4 Adjustment of planning and codes for the new policy approach

From Increment planning to inventory planning

The objective of alternative planning approaches is the most important concept that should be considered to overcome typical static planning process and planning driven by increment growth. Urban planners should design tools that will help shape the new policy planning approach for urbanization by supplementing a part of land use regulations and planning codes as special discretion. This approach can integrate the new policy planning approach into traditional planning to encourage mixed land use and infill development. The policy approach prohibits cities from altering development practice and certain aspects of traditional urban planning systems and codes. The imperfect performance of China's planning systems also reflects its priority to specify a new approach and the effort of the government to facilitate its implementation. Therefore, the new policy approach should be framed in a new code. A new regulatory tool should be used as a supplement to improve plans and dynamic planning processes.

Adoption and application of a new code

A new regulatory tool with a new code can help achieve the goals and principles of implementing a new type of urbanization that focuses on city size and function mixture. The Chinese planning codes often result in overly strict segregation of land uses and extensive consumption of land use. Thus, planners and local decision makers aim to change this planning system and codes. To avoid rigid restrictions on land use and to allow a variety of functions that can host mixed land use, cities should resolve major codes or issues ordinances when considering this new policy planning approach that employs combinations of maps, plats, charts, diagrams tables, text, and images. Similar to smart growth programs that strengthened regulatory controls on development in the U.S., local governments can positively influence rigorous planning to support such an approach by inspiring and motivating policies, rules, incentives, and regulations. At present, the Chinese government can regulate and prioritize planning and bring forth the standards for urban development that facilitates its enforcement.

A new code can be used by cities that struggle with sprawl, as well as cities that are dealing with the rigidities of conventional zoning and those that need to implement new urbanization principles. This approach is a more effective way of regulating physical development than conventional zoning. This approach added simple standards that can dramatically improve a city’s land use and planning competence. The new code offers an option to influence the separation of land use. As a means to achieve implementation of the new regulatory tool, the new code can be added to a city's municipal codes that are not mutually exclusive. The new policy approach with new supplement code should also supplement conventional code or land use zoning on land use and new development allocation allowing accommodating informality.

7.3 Contribution of Knowledge

Urbanization is a dynamic, complex phenomenon that involves large changes in land use. The direct and weighty effort to acknowledge such urbanization and environmental concerns should gain recognition. China exhibits a complex, allometric and multidimensional urban form because of the complexity of top-down urbanization. This study reveals the complex spatial characterization of urbanization in China. The features of China’s urban evolution are discussed. The conclusion has implications on planning optimization. To improve our understanding of the dynamics of urban systems, a multidisciplinary complex spatial analysis will help characterize and address urbanization in a greater detail. Measures of city sizes are constructed to quantify allometric scaling relations of urbanizing cities in a logarithmic model to include multiple urban factors under power law growth, such as population, land use, GDP, and transportation network volume (i.e., road area). Measures of urban form are developed to quantify urban land use patterns in a spatial model to include additional detailed information about land use dynamics, such as dispersion/aggregation, segregation/mix, and the relationship among the interconnected urban factors (i.e., urban population, urban land area, GDP, and paved roads area) for the formation of land use patterns.

The contributions of this research is mainly summarized as follow:

- Observations on changing growth exponents of scaling law illustrate urbanization regularities of Chinese cities with respect to urban land area, GDP, and volume of transportation network in urban population;
- Spatial metrics provide an effective tool for comparing the structural and functional differences of cities through land use pattern. Spatial metrics quantify the spatial characters and properties of urbanization and present the effects of urban expansion.
- Contextual evidence enriches international knowledge on the allometric scaling growth of cities. Human disturbances may interrupt the natural order of urban development, such as government interventions and political administrations, but cities are always evolving towards theoretically optimized development.
- Exploring the factors govern urbanization and its driving forces through city classification and longitudinal comparison and strengthening the finding that urbanization is a dynamic evolution of time axis and urbanization is path-dependent in different states.
- Quantitative analysis of different city categories through classifications at the administrative level and quantile regression consolidate the understanding of the differences in urban development and evolution process that provides additional detailed information of allometric scaling growth in cities.
- Longitudinal analysis comprehensively demonstrates the history of urbanization process and its objective law.
- This study introduced a new measurement to quantify urban land use pattern at city level through spatial entropy and dissimilarity index.
- This study explored the relations and correlations between urban factors (i.e., population, GDP, urban land area, and transportation network volume) and land use.
- Calculation of land use pattern to determine the degree of urban sprawl and land use mix that supplements classical urban theories on social and economic rules.
- Information of empirical exercises to provide supplementary analysis dimension to spatial metrics.

- Recommendations on solutions of a policy approach of planning for enlightening mixed land use and infill development.

7.3.1 Methodologically contributing to literatures

7.3.1.1 Allometric scaling of complex cities

This study characterized fractal cities and the allometric scaling urbanization in China. We utilize urban spatial and demographic data over time during the analysis of the determinants of city size and more precisely decompose changes in the allometric scaling growth of cities. Evidence across countries and urbanization levels in the double logarithmic regression shows the scaling relation among variables within the urban systems. The shares of incremental growth of each urban factor that occurred in different city categories were calculated to provide a summary of measurement of statistic changes in the distribution of urban development. In the process of differentiating the evolution of urbanization in the longitudinal analysis at selected year breakpoints, cities are grouped according to the orientation of their trajectories to which they belong, including their administration levels, which may be faster or slower than that of the country. Through quantile regression (QR), cities are systematically classified into different categories according to individual characteristics of scaling. This approach addressed the following:

- Assessing scaling relations among key urban development factors by log-log regression at different stages of urbanization;
- Categorizing cities in terms of administration division and self- trajectory in quantile regression;
- Synthesizing changing exponents of allometric growth among different category cities and summarizing their development mechanisms;
  Discovering urbanization driving forces at different urbanization stages through quantile regression.

7.3.1.2 Spatial entropy in a combination of multi-dimensional data and analytic methods

The urbanization of cities should be explored. The key to linking urbanization and land-use patterns lies in the recognition of the relationships among urban factors. Cities can be reconstructed in terms of spatial entropy (SE). SE can provide increased systematic analysis to determine whether urbanization is compact or expanding. Dissimilarity index (DI) measures the degree of evenness of land use distribution. To characterize the local features of urban land use, this study employed multi-measurements to model and compare the spatial dynamics of urban form in China. The combination of these two measures provides a straightforward method of investigating urban land use patterns that resulted from dispersion and segregation mechanisms. This study combined cellular-automata (CA) modeling and linked planning map data, transportation survey maps (Ordnance Survey), Python programming, ArcGIS, SPSS, Mat Lab, and land parcels of point of interests (POIs) and statistical yearbook with statistical data sets. This approach facilitated the development of a spatial metrics of Spatial Entropy and Dissimilarity Index (SE-DI) to capture, quantify, and understand the patterns of urban land use and link them to the urban planning background.

The SE-DI approach reported in this study provided an effective tool and useful means for exploring land use patterns. Various indicators (i.e., SR, SC, SP, DR|C, DC|P, DR|P) can be used to characterize urbanization and explicitly describe the basic properties of an urban form. Spatial entropy confirms the dispersed urban growth of a city. DI helped to define the efficiency of mixing land sectors (i.e., TR, C, P, O). These measurements explain how urban land use patterns are shaped. This approach is rarely used in China, but this can improve our understanding of land use pattern and improve planning and governance. This study contributes to a practical approach of

- Illustrating a practical method of calculating the complexity of urban form and presenting a new framework of spatial analysis;
- Quantifying and calculating land use pattern to illustrate the spatial characteristics of cities;
- Applying multidimensional analytic methods according to the data available, from raster image maps of cities, annual statistics, to regression models;
- Exploring the interconnection of urban factors and revealing the driving forces of land use;

  Supplementing the correct urban planning policy response to improve land use patterns.

7.3.2 Theoretically contributing to literatures

7.3.2.1 Dynamic evolution of urban scaling rations

The scaling exponent of allometric growth emphasizes on an evolutionary process or spatial relations. The value of growth exponents of scaling attracted a long debate in western urban development, but the context of China has not been investigated. The allometric coefficients estimated in this study support the possible hypothesis of a dynamic changing value for urban system rather than a fixed and stable value. Such an interpretation from allometric perspective is consistent with existing empirical evidence that describes the nature of system growth toward an optimal alternative form. Urban systems characterized by allometric growth will continually evolve into an optimal state of environmental, social, and economic efficiency. This allometric urbanizing process also presents a mechanism, wherein open systems are in dynamic equilibrium or tend to approach a steady optimal state. Therefore, a steady state of an open system is equivalent to an equilibrium state of a closed system.

7.3.2.2 Changing urbanization driving forces

The dual interrelated relation of urban factors in relation to population is a fundamental basis for determining city size, whereas their coordinating relation is associated with the economic and social development stage of a city. This study shows the allometric scaling of urbanization in China along the time axis, which extends Bettencourt's and Batty's theory of embracing the spatially historical evolution of Chinese cities based on statistical data. The scaling factors (exponent) are a dynamic stable index along with the changing stage of urbanization. Urban spatial structures attributed to dynamic evolution process are path-dependent. These scaling exponents illustrate that the driving forces of urbanization are shifting in the different categories of cities and development status of land use at different urbanization stages.

7.3.2.3 External man-made influences on the urban systems

Planning initiatives or government intervention plays a vital role in land resources usage thereby leading to a short-term disequilibrium and shifts in land use pattern from disequilibrium to equilibrium. Scientific conclusions of empirical analysis based on objective data inevitably include the effects of endogenous government behavior. The discrepancy between changing actual value and theoretical expected value of the scaling exponent is attributed to the evolution of urban systems at different urbanization stages. This discrepancy is also due to the external impacts of administrative or political power imposing on planning and government decision-making. Variance is mainly observed on each individual city rather than on the theory itself. For instance, Chinese national and local government has more direct or indirect influences on new development project, urbanized land use, or construction compared with their counterparts in the U.S. municipal and federal government.

7.3.2.4 Interlink impacts and formation between city size and land use pattern

External impacts also play a decisive role in the formation of land use pattern. The government enforces planning through political intervention and administration of land use in cities. This approach directly leads the development in each land use sector from the top–down thereby emphasizing residential development, industrial investment, commercial districts, and CBD or indirectly resulting in land use through the interposition of urban factors, such as population, GDP, and land area. Another influencing factor is the existing planning system and codes, which are mostly are responsible for the formation of land use pattern of Chinese cities, such as segregation of land use function. This finding induces onward expansion of increasing obstacles to reusing land in built-up areas. Land use pattern is a group-based spatial character shaped by different city categories, such as tier cities by categorized by administration level in terms of population or statistical classification based on self-similarities of spatial characters. These patterns are the differences between natural growth cities and anthropogenic influence-planned and influence-constructed cities. City size/urban scaling and land use pattern are two interlinked factors that mutually affect each other to determine a city's development features and urbanization characteristics.

7.3.3 Practically contributing to planning policy

Urbanization policy evolved from a determinedly anti-urban stand from 1950s to 1960s to measure favored small and medium-sized cities three decades ago and recognize the agglomeration attractions of metropolitan regions in China. Chinese cities can manage land use into economic and intensive resources that drive innovation and change extensive development to a connotative one development. Despite the attempt to solicit support for growing intensive work, this study requires further interpretation.

New-type Urbanization indicates "scientific and rational urban development" and focuses on an intensive model of mixed land-use and dense infill development. This concept is a pioneer work in China's official planning policy, but a principles similar to smart growth has been adopted as a standard in the U.S. Policy planning approach can enable China to address issues in quality urbanization. This approach should articulate the means of achieving objectives and specifying implementation mechanisms instead of merely declaring objectives. The goals of the approach are not to stop or slow down growth, but rather to manage its pace and location, which should be implemented through planning. The policy planning approach should integrate planning systems and codes to determine a common ground and facilitate unconventional projects. However, many aspects of plans and codes remain incompatible and contentious. Conventional planning systems allow a supplement provision of special planning discretion to encourage new development that meets the criteria of mixed and infill characters.

This special approval or incentives usually abide by statutory plans, such as technical terms, environment limitations, and rationale. To enhance this approach, the planning code embedded in conventional planning systems should be given discretion. Existing statutory planning codes are recommended to adjust prescriptions on land use per capita, proportional divisions, and per capita of land use sectors to reduce quotas in the natural law of scaling relations among urban factors. The results of this study may encourage relevant parties to revise legal documents and empower local planning authorities. However, these changes must be adopted under the strong supervision and monitoring of the government and the public to ensure its effectiveness. This approach is can be used by planning departments and encourage them to re-consider the adjustment of indices and standards of planning codes in the next round of review and rectification.

7.4 Limitations and Future Studies

7.4.1 Limitation of the study

Data on population and urban land use re collected for geographic areas that underwent boundaries changes. The data are authoritatively sourced from government statistics. However, the statistical methods, coverage areas, and term definitions differ from those obtained through precise quantitative information, such as differences in the trends and characters of urban built-up areas. Most economic and demographic data of statistics are drawn from governmental files that are derived or estimated from the assumed trends and conditions of census data. The time series analysis of urban scaling chose different time periods with different data resources because of data constraints and the key representative time of urban development. Data are for land use that are consistent over time and across cities are readily available, but obtaining comparable data was difficult.

Prominent obstacles for smart growth include resistance to change in urban structure, institutions, and development preferences in status quo, economic pressure, institutional limitations, statutory reforms in local government, insufficient planning or coordination incentives, and counterproductive planning policies. Reconfiguration of zonal systems to facilitate consistency is costly for individual studies and should be conducted in a unified platform. Researchers should consider these limitations when referring to these results in further studies. However, data limitation does not diminish the merits of this study. Considerable effort was exerted to standardize and format data that may affect the comprehensive comparability for several reasons.

7.4.2 Area of future study

Further progress is needed to develop and refine policies that build on past experience. New approaches to policy implementation should be established that are politically feasible, technically sound, and economically efficient. A comparative study of land development patterns could lead to far-reaching policy implications. Future research can establish direct causality between specific policies, such as smart growth principles and desirable land-use outcomes.

Hundreds of millions of newly urbanized families settle in cities. This development requires sustained and stable increase in urban construction land as a basic living demand. However, the biggest constraint to such expansion is the reline restriction on a minimum 1.8 billion mu (Chinese acre) of arable land. Thus, increased efforts should be exerted to develop explicit approaches of promoting sustainable and measureable urbanization. This assessment can be longitudinally compared for several years until a new urbanization process becomes more prevalent.

Another approach to in-depth investigation is cross-sectional comparisons to determine how planning practice should respond to reshaping smarter spatial development pattern.

7.5 Concluding remarks

A city is a complex system. This complexity is compounded by its constantly evolving shape and structure. Changes in the urbanization of Chinese cities is consistent with the evolution of complex urban systems. The spatial structure of a city can be defined by two complementary components, namely, spatial distribution of land use and urban factors that form city size. This study provides a tool that can be used by planners to identify the type of spatial organization that is compatible with municipal strategy and regulatory tools. Spatial characters of urbanization are assessed by relative changes in city size and land-use patterns. This study presents an overview of the main urban issues interrelated in Chinese cities. This study also proposes a policy approach to resolve urbanization issues and investigates the regulatory mechanisms for implementation in China’s planning systems. This study also examined how leaders perceive the effectiveness of policy approach to planning and how implementation can be realized under the Chinese context. To our knowledge, only a few studies quantified these urbanization factors and raised recommendations on planning codes and regulations for Chinese cities.

Contribution to the overall success of mixed land use and infill development is only possible when a policy planning approach is in place. A major objective of this policy approach is to alter the spatial distribution of population and land-use by principally increasing the density and intensity of development and by promoting compactness. This approach encourages infill development in urbanized areas and reduces the spread of development to adjoining rural areas. To address the challenges to achieving these objectives, policy makers should endorse legislation through planning system and code. The new policy approach should be framed in a new code and new regulatory tool as a supplementary to the improvement of plans and dynamic planning processes. Urban development has no win-win urban spatial strategies. Most urban development policy involves trade-offs. A land use optimization approach cannot be formed by a single technical measure. Thus, research in this area should be enhanced to identify an effective and operational implementation strategy for optimization and allocation of a new type of urbanization.

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