

# Measurement of Urban Sprawl

Subjects: **Area Studies**

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In the context of rapid urbanization, inefficient, disorderly, and low-density urban sprawl often leads to resource waste and ecological damage. Over the decades, many studies on the measurement, analysis, and governance of urban sprawl have emerged.

urban sprawl measurement

mechanical equilibrium model

urban agglomerations

spatial governance

## 1. Introduction

Accompanied by urbanization and industrialization for decades, urban sprawl, which is defined as an inefficient, disorderly, and low-density development mode (i.e., negative urban expansion), has emerged and developed rapidly <sup>[1]</sup>. Urban agglomeration is an aggregate of cities within certain geographic areas, which often vary in size, function, and characteristics <sup>[2]</sup>. Diverse elements, such as population, capital, and technology, are gathered in urban agglomeration areas, leading to a solid economic aggregation and radiation capacity <sup>[3]</sup>. Urban agglomeration has become an important development focus of countries and regions worldwide and is one of the main drivers of regional socioeconomic growth. For example, urban agglomeration in the New York Bay area, the Tokyo Bay area, and the London metropolitan area have been great drivers of globalization. In China, urban agglomeration in the Yangtze River Delta (YRD) region, Beijing–Tianjin–Hebei region, and Guangdong–Hong Kong–Macao Greater Bay area have also become essential carriers of China's economy, industry, and technological innovation <sup>[4]</sup>.

Despite the importance of urban agglomeration for regional development, the rapid expansion of urban space has also occupied a large amount of rural and ecological space, adding pressure to the eco-environment. In the process of urban expansion, inefficient and disorderly land construction, which is known as “urban sprawl”, has emerged for reasons such as resource mismatching, the imbalance between supply and demand, and competition among local governments <sup>[5][6]</sup>. Urban sprawl has worsened the human–land relationship, leading to negative results such as damage to biodiversity, the destruction of wetland resources, reduction of arable land resources, increased carbon emissions, and fragmentation of land use, which seriously affect the sustainable development of cities <sup>[7][8]</sup>. Therefore, measuring the spatial and temporal characteristics of urban sprawl in urban agglomeration and analyzing governance strategies are globally important issues.

To summarize the methods of urban sprawl measurement in previous studies, the metrics have expanded from one dimension to multiple dimensions, and the methods have been improved from qualitative to quantitative methods. However, existing studies lack in-depth consideration for distinguishing efficient expansion from inefficient sprawl. Especially for urban clusters, the large number and types of cities in the region require a certain amount of land space to ensure the needs of regional construction and development, which puts demands on the efficient use of land. Although some studies have considered the relationship between land use, population, and industry [\[9\]](#)[\[10\]](#), they have not clearly proposed a quantitative measurement to distinguish between effective expansion and inefficient sprawl. The development of cities involves the spatial expansion of construction land. With limited land resources, urban construction must balance the relationship between land exploitation, socioeconomic development, and ecological environmental protection. Land exploitation refers to the way and purpose for which land is utilized in different times and spaces, including construction land and agricultural land. Socioeconomic development refers to changes and developments in demographic, economic, and social activities over time. Ecological and environmental protection, on the other hand, prioritizes the protection of ecological safety and maximizes the benefits of ecosystem services in the process of land use in order to achieve the dual goals of socioeconomic development and ecological environmental protection. It is necessary to formulate a sustainable land use policy and combine it with socioeconomic development so as to realize a win-win situation for both the ecological environment and the socioeconomy. Therefore, whether urban expansion is effective or not must be distinguished.

## 2. Measurement of Urban Sprawl in Previous Studies

Urban sprawl is a spatially inefficient, disorderly, and chaotic development pattern. Therefore, studies have often measured the extent of urban sprawl by adopting indicators that reflect this spatial disorder in different dimensions. Common subdimensions include area, density, shape, and topological relationships. As shown in **Table 1**, researchers classify the indicators of urban sprawl in terms of land, function, and economy and evaluates them in terms of four aspects: area, density, shape, and topological relationship.

**Table 1.** Main urban sprawl measurements and indicated characteristics.

Category	Index	Area	Density	Shape	Topological Relation
Land	Urban elasticity index + <a href="#">[11]</a>	✓	✓		
	Population-urban expansion index + <a href="#">[12]</a>	✓			
	Built-up area per capita + <a href="#">[13]</a>	✓	✓		
	Urban sprawl index * <a href="#">[14]</a>	✓			
	Land use geospatial indices # <a href="#">[10]</a>		✓	✓	
	Urban sprawl matrix # <a href="#">[15]</a>	✓	✓	✓	

Category	Index	Area	Density	Shape	Topological Relation
Function	Compactness * <a href="#">[16]</a>		✓	✓	
	Shannon's entropy index * <a href="#">[17]</a>		✓		✓
	Expansion difference composite index * <a href="#">[18]</a>	✓			
	Landscape metrics * <a href="#">[19]</a>	✓	✓		✓
	Degree of equal distribution * <a href="#">[20]</a>	✓	✓		
Economics	Percentage of employment outside a certain distance coming from the CBD * <a href="#">[21]</a>	✓	✓		
	Residential area per capita * <a href="#">[22]</a>	✓			
	Sprawl index of the population * <a href="#">[14]</a>		✓		✓

Studies on the measurement of urban sprawl have been conducted, including single indicator descriptions, comprehensive evaluations, and entropy models. However, urban sprawl is an inefficient, low-density, and disorderly development pattern, indicating the incompatibility between socioeconomic development, urban spatial expansion, and urban function improvement. Moreover, the existing measurement methods fail to measure the balance of the indicators.

Despite the rich discussion of urban sprawl models, the following two essential aspects have been insufficiently studied: (1) Limitations to urban functions in urban construction make it difficult to meet the daily needs of residents, often causing social inequity. Therefore, the dimension of urban function must be included in the measurement framework [\[3\]](#). (2) The relationship between the different dimensions is rarely considered. Thus, the difference between sprawl and expansion is not distinguished in consideration of the needs of development and the necessity of conservation [\[23\]](#).

### 3. Spatial Planning and Urban Sprawl Control

Given that urbanization is ongoing, especially in developing countries, facing the common task of ecological civilization construction and discussing how to realize urban sprawl control through strategies such as spatial planning are critical. Planners and administrators must consider problems in accordance with the actual situation in their region. This section categorizes developed and developing countries and explores the spatial governance strategies of urban sprawl in terms of four aspects: land use policy, market economy strategy, industrial structure adjustment, and administrative division management (**Table 2**).

**Table 2.** Examples of spatial governance strategies for urban sprawl.

Developed Countries		Developing Countries
Land use policy	(1) Green belts in Western developed countries are established by government authorities and	(1) China has implemented a series of land use policies, such as the “New-type

	Developed Countries	Developing Countries
	typically demarcate areas surrounding a city or town where development is restricted. This is preserved in the green areas surrounding the urban area and prevents urban sprawl [24].	Urbanization Plan” and “Land Management Regulations”, aimed at promoting sustainable urbanization and rational land use [25]. (2) A land reserve system, which allows the government to control the supply of land for urban development, is established, thereby controlling the pace of urbanization and limiting urban sprawl [26].
Market economy strategy	(1) The private sector plays a crucial role in urban development in Western developed countries, with the government often providing incentives for private investment in urban renewal and redevelopment projects [27]. (2) The government established policies that encourage public–private partnerships in urban development, allowing the private sector to play a role in urban renewal and redevelopment projects [28].	(1) In developing countries such as China and India, special economic zones are established to attract foreign investment and promote economic growth [29]. (2) The government established policies that encourage public–private partnerships in urban development, allowing the private sector to play a role in urban renewal and redevelopment projects [30].
Industrial restructuring	(1) The development of high-tech industries, such as the IT and renewable energy sectors, is also a priority in Western developed countries, as these industries are considered key drivers of economic growth and competitiveness [31].	(1) The government encouraged the development of high-tech industries, such as the biotechnology and renewable energy sectors, to drive economic growth and improve the competitiveness of the urban economy [32].
Administrative zoning management	(1) Western developed countries have established systems of urban governance that are based on decentralized decision making and local autonomy [33]. (2) Coordination and cooperation across administrative boundaries [34].	(1) China’s urban administrative division system is based on a hierarchical model, with the central government having the power to approve the establishment of new cities and urban districts [35]. (2) Limit urban development boundaries to control urban sprawl effectively [36].

Despite numerous studies on urban sprawl governance strategies, the existing studies still have two shortcomings: (1) The current consideration is the relatively single dimension, whereas urban expansion is a complex process, and its spatial governance should also consider the coordination of the interests of multiple parties. (2) Most studies were conducted in the direction of land policy and market economic regulation for strategy enhancement, but only a few of them mentioned the strategy of urban function enhancement.

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