Doctoral Thesis

Research on Vitality and Sustainable Development of Urban Villages from the Urban Perspective

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Preface

During China's rapid urbanization process, a large number of urban villages have emerged. China's urban development has shifted from incremental development to stock development with urban renewal as the main form, and how to deal with the problem of urban villages has become the focus of urban development. Urban vitality is a key factor for sustainable urban development. The purpose of this paper is to explore the relationship between urban vitality and the existing built environment of Shenzhen cities, as well as the value of urban villages in the city and development strategies. The regression models with multi-source geographic datasets from 2017–2022 were applied to assess Shenzhen in three dimensions: economic, social, and cultural. The results show that Shenzhen’s vitality originates from multiple popular centers. Dense road networks, abundant transportation, and commercial, recreational, entertainment, sports, and leisure facilities are positive indicators of vitality, while urban villages and residential areas have the opposite effect. The model can explain 59% of vitality changes. This paper proposes a quantifiable and replicable adaptation framework for urban villages that combines urban form with data vitality assessment in order to deepen our understanding of urban villages and offer theoretical justifications for long-term urban regeneration. The findings also suggest that spatial differences should be taken into account when formulating urban regeneration responses to make them more targeted. Overall, this paper provides valuable insights for urban planners, policymaker and researchers interested in promoting sustainable urban development through vitality-based urban regeneration.

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Abstract

China's urban development has shifted from rapid urbanization to stock development with urban renewal as the main focus, but the backward facilities and inefficient allocation of public resources in urban villages make it difficult to support sustainable urban development, leading to a decline in the quality of life of residents and dissipation of urban vitality. Urban vitality is an important indicator of healthy and sustainable urban development, and it is of great significance to study the impacts of urban villages on vitality, to re-conceptualize the value of urban villages, and to explore the development path of urban villages for the sustainable development of cities.

This study takes urban villages as an indicator of the specificity of the urban built environment and uses regression modeling to study the relationship between urban vitality and the built environment, to explore the effects of urban form, urban function, and urban villages on vitality, and to demonstrate the value of vitality embodied in urban villages from an urban perspective.

In Chapter 1, the urban problems brought about by rapid urban construction and rough development are raised, the reasons for the emergence of urban villages and the importance of urban vitality in sustainable development are outlined.

In Chapter 2, the theoretical basis and current research status of urban vitality and the urban built environment are introduced. In addition, relevant studies on urban vitality and urban impact mechanisms are reviewed.

In Chapter 3, I introduce the data sources used in this study and pre-process the open-source data. The main research methodology of this paper is identified based on the literature study.

In Chapter 4, a comprehensive urban vitality measurement system is presented. Five indicators are selected from the three main components of urban vitality - economic vitality, social vitality and cultural vitality - and a comprehensive evaluation of Shenzhen's vitality is conducted based on multi-source big data, which reveals that the vitality of the central area of the city is higher than that of the peripheral areas.

In Chapter 5, the relationship between urban vitality and the influence of built environment factors is investigated. Twelve indicators were selected as independent variables. SLM model and GWR model were constructed to compare the changes of urban vitality with various explanatory variables. The results show that dense road networks, rich and diverse transportation facilities, dense commercial facilities, entertainment facilities, and sports and leisure facilities are beneficial factors that promote urban vitality. However, urban villages and residential neighborhoods have a negative impact on urban vitality, while building density has the least impact on urban vitality. The three aspects of the built environment in this study explain 44.5% of the variation in Shenzhen's vitality, and there is spatial heterogeneity in the effects. Finally, strategies to activate urban vitality are proposed.

In Chapter 6, an empirical study of urban village renewal based on vitality revitalization is presented in the example of Nantou Old Town.

In Chapter 7, the study is concluded and discussed.

In conclusion, this study takes urban villages and urban vitality as the research object and proposes a quantifiable and replicable framework for the adaptation of urban villages in Shenzhen. After assessing Shenzhen's vitality in terms of economic, social, and cultural aspects, a regression model is developed to analyze the relationship between vitality and the built environment. Finally, an empirical case study is conducted. It is hoped that this will deepen our understanding of urban villages and provide a theoretical basis for the long-term revitalization of the city.

ジャン　ペイ　博士論文の構成

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CHAPTER 1

Introduction

1.1 Research Background

1.1.1 Highlighting the issue of population mobility in the context of globalization and urbanization

Globalization is a new phenomenon that has become increasingly prominent worldwide since the 1980s and is a fundamental feature of today's era. Population mobility is increasingly becoming a prominent feature of globalization [1]. Many countries and cities have adopted active policies to attract talent and capital, promoting the migration of people worldwide. At the same time, due to the accelerated urbanization process, competition between cities is becoming increasingly fierce, which has led to further intensification of population mobility. In the past decade or so, the floating population in China has continued to grow. According to data from the National Bureau of Statistics. As of 2020, the population of separated households in China reached 492.76 million, accounting for 34.9% of the national population. Among them, the floating population reached 375.82 million, accounting for 26.6% of the national population. Compared with 2010, the number of people separated from households in China increased by 23.138 million, an increase of 88.5%, and the floating population increased by 154.39 million, an increase of 69.7%. The general trend of population mobility is from rural areas to cities, and from the west to the east. With the increase of population, big cities are facing problems such as high housing prices, traffic congestion, and environmental pollution. These issues not only affect the quality of life of urban residents, but also pose enormous challenges to the sustainable development of cities[2].

The characteristics of population mobility are reflected in the gap between the registered residence population and the permanent population [3]. The province with the highest net inflow of population is Guangdong Province, with a household separation of 28.7534 million people. In recent years, China's industry has continued to develop at a high speed, with overall industrial strength continuously increasing and significant industrialization achievements. Industrialization has driven economic growth, led to changes in population structure and upgrading of industrial structure, and also promoted the development of urbanization [4]. Economically developed cities, with high-quality social public resources and good employment opportunities, will form a strong attraction for mobile populations. According to the 2020 China Top Ten Cities with Net Population Inflow from First Financial, Shanghai, Shenzhen, Beijing, Dongguan, and Guangzhou rank among the top five in terms of total net inflows.

Rank	City	Net Inflow of Population (10,000 people)	Net Inflow Ratio
1	Shanghai	958.84	39.45%
2	Shenzhen	793.17	59.02%
3	Beijing	756.20	35.11%
4	Dongguan	595.39	70.34%
5	Guangzhou	576.87	37.69%
6	Tianjin	453.65	29.05%
7	Foshan	353.59	44.73%
8	Suzhou	352.39	32.78%
9	Ningbo	245.73	28.77%
10	Hangzhou	240.63	23.23%

Table 1-1. 2020 Top 10 Cities with Net Influx of Population (www.askci.com).

There is a close relationship between talent attraction and urban vitality. The stronger the economic vitality of a city, the more it can attract high-quality talents, and these talents can inject new impetus into the development of the city [5]. Talent is an important factor driving economic development, as they can bring innovation, create value, and improve production efficiency to enterprises. The stronger the economic vitality of a city, the more companies need high-quality talents, making it easier for the city to attract high-quality talents. The competitiveness between cities is mainly reflected in economic, cultural, technological, and other aspects. If a city can attract more high-quality talents, its competitiveness will be improved [6]. Because these talents can bring innovation and development opportunities to the city, making it more attractive. From the perspective of sustainable development, with the development of cities, the demand for high-quality talents is also increasing. If a city cannot attract enough talent, its sustainable development will be affected. Therefore, cities should take measures to enhance their attractiveness, such as optimizing the policy environment, strengthening infrastructure construction, etc., in order to attract more high-quality talents to urban development [7].

1.1.2 The importance of spatial optimization of high-density urban stock land

The rapid development of the Chinese economy has generated a huge demand for urban land development, leading to an unprecedented urbanization process. The large-scale migration of humans from rural areas to cities has brought challenges to the sustainable development of cities [8]. Since the reform and opening up, China's urban construction has gone through a rapid development stage, with unprecedented expansion of urban space. However, due to the lack of standardization in the rapid urbanization process, relying solely on urban expansion is difficult to support sustainable urban development. With the gradual end of urban growthism, urban development has shifted from incremental development to stock development represented by urban renewal [9]. New urban immigrants continue to enter the city for life, employment, and residence, forming informal living spaces. At the same time, it is accompanied by phenomena such as resource shortage, environmental pollution, public security, imbalanced employment and housing, and outdated facilities. The level of development between different urban areas is uneven, and the efficiency of public resource allocation and utilization is low, leading to a decline in the quality of life of urban residents and the disappearance of urban vitality [10]. As proposed in the 14th Five Year Plan, "accelerating the transformation of urban development mode" and "promoting the optimization and quality improvement of urban spatial structure". In the current era, it is necessary to attach importance to the rational planning and utilization of urban stock spatial resources [11].

1.1.3 Urban villages become typical representatives of various issues related to the residence of floating populations, the renewal of urban stock space, and the special built environment

The "urban village" is a typical representative of the two-way problem between the residence of floating population and the renewal of urban stock space. After the reform and opening up, urbanization entered a period of rapid development, and urban space rapidly expanded to the surrounding suburbs and rural areas. Due to the lack of reasonable planning and management, a special built environment space type of village in city has gradually formed, which is transiting from rural form to urban morphology [12]. In terms of choosing their place of residence, most of these migrant populations live in the "urban-rural fringe" areas with low rents, loose regulations, and rampant illegal construction. In large cities, urban villages have become the main transitional space for accommodating migrant populations [13]. However, the urban village space and the existing government and social operating system are currently unable to fully address the various problems caused by the rapid influx of population, resulting in increasingly prominent contradictions and contradictions between areas inhabited by mobile populations and other urban spaces. The social issues arising from high-density urban development strategies and high population concentration have become the focus of discussion among urban managers, urban planning professionals, and urban researchers today [14]. Urban villages are a unique urban phenomenon in China, closely related to cities due to the impact of urbanization. At the same time, because the internal spatial environment is "dirty, messy, and poor", it is also a typical object that needs to be "updated" [15]. Shenzhen is the city with the most urban villages and the most prominent representative. Solving the problem of urban village renewal in Shenzhen can not only provide reference for similar urban village renewal in other cities in China, but also provide strong theoretical and practical supplements for the global problem of floating population living and urban renewal [16].

1.1.4 Urban vitality is one of the important indicators of urban sustainable development, and rough urban development neglects urban vitality.

The emergence of a series of urban problems is a reflection of the imbalance between urban scale expansion and urban vitality. Urban vitality is the internal driving force of urban development and the guarantee of a city's strong vitality. Urban vitality can serve as an important indicator for evaluating the comprehensive, healthy, and sustainable development of a city at the macro scale. Studying urban vitality and its influencing factors at the meso and micro scales can help improve the quality of life of urban residents, and is also of great significance for the rational allocation of urban resources and the promotion of balanced urban development [17]. Related studies have shown that a good urban built environment, morphological structure, and other material factors play an important role in creating urban vitality [18]. Measuring the level of urban vitality and studying the relationship between its vitality and influencing factors can provide scientific reference for urban planning. Research on urban vitality is an important issue in the current new stage of urban development and transformation [14]. A new city lacking vitality is difficult to fully utilize its various functions, which is not beneficial for urbanization construction and instead leads to resource waste. How to enhance the vitality of new cities should become an important proposition in the process of urbanization [19]. However, existing empirical research has not yet formed a consensus on the measurement methods of urban vitality, and the evaluation of urban vitality mainly focuses on the economic vitality and competitiveness of cities, mostly using subjective qualitative analysis [20]. Therefore, studying the measurement and influencing factors of urban vitality through new technologies and methods is crucial for promoting urban vitality creation and sustainable development from the perspective of urban systems [21].

1.1.5 Big data era gives opportunities for urban development

Urban vitality is closely related to human behavior and activities. The spatial-temporal location big data based on ubiquitous perception has been recognized as the key data of human activity behavior characteristics and spatial pattern exploration and related applications. In recent years, a lot of practice has been carried out in demography [22], environmental science, urban science and other related research [23,24]. At the same time, the development of massive geospatial data makes it possible for us to more accurately describe the composition of urban morphology of villages in cities. Due to the fact that big data has become a hot research topic in recent years, research methods based on big data to measure urban vitality from the perspectives of building environment and population density have become mainstream [25]. Big data technology and GIS modeling technology have become core methods for describing, observing, and expressing human activities and their spatiotemporal patterns within cities. Breaking the static understanding of urban spatial patterns has made it possible for us to have a deeper understanding of human activities [26]. This has provided reliable data and methodological support for disciplines such as population geography, economic geography, ecological geography, tourism geography, etc. in analyzing human land relationships, human behavior, group needs, regional differences, spatiotemporal evolution, and other aspects in today's rapidly developing urbanization [27].

Big data is a type of information asset that can adapt to massive, high growth rate, and diversification. It has four major characteristics: large data scale, fast data flow, diverse data types, and low value density. In this study on the vitality of new cities, the time-consuming and limited nature of traditional on-site research determines the inevitability of using big data [26]. The mobile signaling data, point of interest data, location-based service data, and street view images mentioned in the previous review all belong to the category of big data [28].

Measure is a function concept in mathematics used to calculate size, volume, probability, and so on. Based on the definition of new city vitality, vitality measurement refers to the measurement of the level of activity of people in the new city and the degree of support of urban functions for users by a specified amount. In traditional research, the judgment of the vitality of new cities is usually based on the subjective feelings of investigators or by constructing an evaluation index system to test the vitality of new cities, but the weight distribution of influencing factors also has a certain subjective color. The vitality measurement based on big data can avoid subjectivity and obtain an objective reflection of the vitality of new cities [29].

1.2 Research questions

How can urban villages develop sustainably from the perspective of urban systems?

Urban villages are an independent cluster like structure that exhibits strong heterogeneity with the spatial form of surrounding cities, exhibiting special built environment characteristics. Most studies on urban villages analyze them as an independent research object, mainly focusing on the spatial characteristics, internal problems, and social forms of urban villages. In the literature on urban village renewal, there is particularly rich research on the planning and design, architectural design, and landscape design of individual projects. However, the most basic formation logic of urban villages is the rapid expansion and annexation of cities or the encirclement of rural areas, and their own development and evolution are always intertwined with the city. Since the development of urban villages, research on sustainable development and renewal needs to be expanded to a comprehensive level related to the surrounding urban environment, urban elements, and even a larger urban area, rather than just studying individual urban village projects. Based on this, simply discussing space, architecture, and models is too one-sided. Instead, urban villages should be regarded as an organic component of the city, and the internal problems and external explicit values of urban villages should be viewed relatively.

Shenzhen currently has over 1800 urban villages, making it the city with the most urban villages in China. Urban villages are spread throughout the city and have close connections and mutual influence with the city. The rapid development of Shenzhen also to some extent represents the development path of other cities in China. The complexity of urban village renewal also determines that the renewal process inevitably involves the game of stakeholders such as government, developers, village collectives, villagers, and tenants, as well as the participation of professionals from various fields such as sociologists, planners, architects, engineers, artists, interior designers, landscape designers, and community builders. Therefore, from the perspective of urban vitality, this study explores the problems and values of urban villages within the urban system, thereby analyzing the relationship between urban vitality and built environment. And by studying specific successful cases of urban village renovation, I propose differentiated renewal guidance and exploration, combining urban village renovation with urban sustainable development.

1.3 Research objectives

This article discusses the issue of how urban villages should be updated and developed from the perspective of urban systems. From the perspectives of urban vitality and urban built environment, it conducts an urban scale study on urban villages in Shenzhen, exploring their value positioning and updated development paths. First, I assess the value of urban villages from an urban perspective, study the reasons for the emergence of urban villages, assess how urban villages are built environment spaces, and assess the urban vitality of urban villages. Secondly, I study the relationship between urban vitality and built environment, explore the influencing factors of urban vitality, and find out the positive factors affecting the vitality. Finally, the special case of urban villages in Shenzhen is selected for study through relevant research, and suggestions for renewal and transformation are made from the perspective of sustainable development to provide reference for related urban villages in other cities to answer questions.

1.4 Research significance

The research of this topic is a supplement to empirical research in existing studies on urban villages and urban vitality, and has theoretical and practical significance.

1.4.1 Theoretical significance:

Behind rapid urbanization lies an extensive urban development model. Currently, high-density cities are facing problems with the renewal and development of existing land and the vitality of old cities. How to overcome the dilemma of renewal, maintain vitality, and revitalize urban villages has become a necessary issue for the development of large cities [30]. With the deepening of the transformation of the current urban development model, research on urban vitality has also received more attention from researchers. However, there is currently no clear definition of the measurement method for urban vitality [31]. Therefore, this article aims to construct a comprehensive measurement method for urban vitality that considers the urban system, explores the relationship between vitality and the urban built environment, and identifies the spatial value of urban villages. This article proposes a quantitative research method from the perspective of urban system through multi-level excavation of Shenzhen's vibrant space, in order to understand the relationship between building environmental elements and vitality at the block level, analyze the current situation of urban village blocks from the urban perspective, and propose effective improvement strategies. On the one hand, it fills the gap in the research of urban vitality in the field of urban renewal and urban villages, and on the other hand, it enriches the perspective of built environment. Using multiple data to empirically study the vitality of urban village space in China is of great significance for the theoretical system of urban renewal and sustainable development.

1.4.2 Practical significance:

The formation and development of urban space are the result of the combined effects of various factors such as society, economy, humanities, and policy guidelines. The exploration of urban village renewal in Shenzhen has a certain guiding role. After the reform and opening up, the Shenzhen Special Zone was established to construct in Luohu, Yantian, and Shekou, respectively. Later, the Futian Central District was established. These urban central areas did not originally have urban construction bases, but were demolished and rebuilt during the development process, or were built on flat land next to the village. Shenzhen is a multi-center city with the simultaneous development of nearby villages, resulting in an endemism phenomenon in Shenzhen - villages in the city spread all over the city. A large number of urban villages are facing renovation problems. The research on the renewal of urban villages in Shenzhen can not only provide reference for other cities, but also explore the unique phenomenon of urban villages in Shenzhen [32]. This article takes Shenzhen as an example, comprehensively utilizing geospatial big data and quantitatively analyzing urban vitality and its internal influencing relationships, to deeply understand the interactive relationship between the spatial form characteristics and vitality of urban villages, analyze the spatial distribution characteristics and formation mechanisms of vitality, and help discover the factors affecting the vitality of urban village development process. With the goal of improving urban vitality, it provides targeted strategic basis for urban renewal and development.

1.5 Research Framework and Technical Route

Based on the theory of spatial humanities, social perception, ubiquitous measurement and other disciplines and concepts, this paper comprehensively uses GIS spatial analysis, machine learning, big data mining and other technical methods, adopts research methods of combining qualitative research and quantitative analysis, macro and micro multi scale analysis, theoretical analysis and application verification, and uses multi-source heterogeneous big data as the data source, Construct a complete technical process from modeling individual movement processes to analyzing the distribution and application of group activities.

The two core components of urban development are the emergence of the built environment, including spatial scope, regional expansion, development, degradation, and density, and the presence and activities of humans that make a city vibrant [33]. These two components demonstrate the core urbanization processes that can lead to other urbanization processes [34]. The method of this study did not consider some influencing factors, including the connectivity between the target city and other cities, their economic potential, social composition, workplace information, and natural environment. If environmental construction and human activities do not exist, no place can be classified as a city. In a city, there may be intensity differences in the composition of these two cores, and the analysis of these differences, namely urban vitality analysis, is the theme of this study.

The analytical framework of this paper is divided into eight parts (Figure 1-1), namely, research background, literature review, data base, the measurement of urban vitality, the measurement of urban morphology and their interaction, strategic research, empirical studies, and conclusion. I propose a quantitative research method to understand the relationship between the building environment elements of Urban morphology and the vitality of urban villages at the street level. For the main body of vitality study, firstly, I measure urban vitality through open-source geospatial data and determine the weights of factors that affect vitality through entropy method, thereby determining the final comprehensive vitality value; Secondly, I excavate the building environment of the street where the village in the city is located, and define and measure the elements of Urban morphology. Finally, an econometric model is constructed using machine learning algorithms to quantitatively analyze the impact of the specific attributes of urban architectural environment where urban villages are located on urban vitality, and to analyze the differences between different elements that affect vitality from multiple perspectives, thus proposing urban renewal space optimization strategies that stimulate urban vitality.

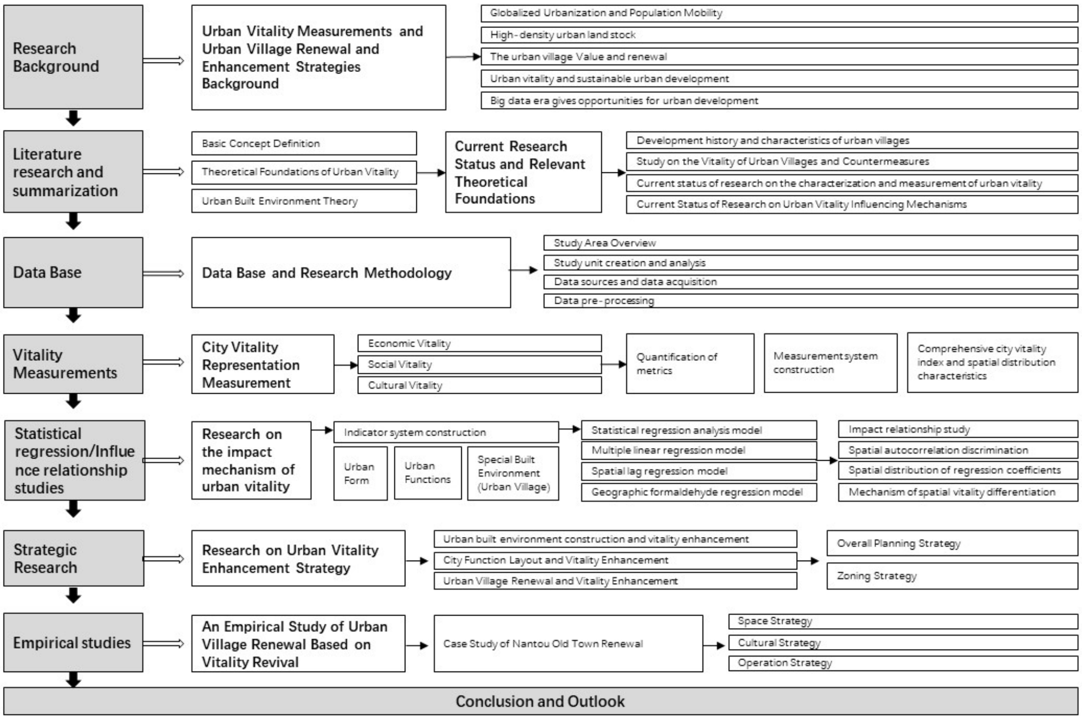

Figure 1-1. Research framework.

1.6 Organizational structure of the paper

In Chapter 1, the background of the study and the purpose of the study. The research background of the article is first introduced, including the problem of population living in the context of globalized urbanization, the problem of high-density urban development, and the context of urban villages and urban vitality. The relationship between urban vitality and sustainable development is described. Then the motivation and purpose of this study are explained, and the research framework and technical line of this paper are presented.

In Chapter 2, the theoretical foundation and literature review. The theoretical foundation and the current research status of urban vitality as well as urban built environment are introduced. The development history and characteristics of urban villages are described, and the challenges facing urban renewal are presented. Finally, relevant studies on urban vitality and urban impact mechanisms are reviewed.

In Chapter 3, the data base and research methodology. In this section, the analysis results of the geography, land use, resources and economy of the study area, Guangdong, Hong Kong and Macao Greater Bay Area, are firstly presented. Based on the analysis results, Shenzhen is selected as the study object and a spatial analysis unit is established. The data sources and pre-processing used in this study are described. Finally, the data analysis and research methods used are explained.

In Chapter 4, the comprehensive urban vitality measure. A comprehensive urban vitality measurement system is proposed to be constructed. Five indicators from the three main components of urban vitality, economic vitality, social vitality and cultural vitality, are selected to comprehensively evaluate the comprehensive vitality of Shenzhen city based on multi-source big data, and the spatial distribution characteristics of comprehensive vitality are analyzed.

In Chapter 5, the relationship between urban vitality and the influence of built environment factors is studied. The index system of the influence factors of urban comprehensive vitality based on urban built environment, which contains three primary indicators such as morphological factors, functional factors, and special built environment, and 12 secondary indicators, is designed with the definition of each indicator in different ways of index quantification. A multiple linear regression model and a geographically weighted regression model are constructed to compare the variation of urban vitality with various explanatory variables, and the geographically weighted regression model is selected to explain the influence of various variables on urban vitality. Also, the sustainable development planning strategy based on the creation of integrated urban vitality is presented. Vitality creation strategies are proposed for the built environment elements from overall and zoning planning respectively. Through the study of the influence relationship of urban built environment elements on the comprehensive urban vitality, urban vitality creation strategies are proposed for different perspectives. The impact of urban villages on the overall and zoning urban vitality is presented, and the direction of renewal is elaborated.

In Chapter 6, an empirical study of urban village regeneration based on vitality revitalization is presented. Taking Nantou Old Town as an example, I explore its historical development lineage and the impact of the two regeneration efforts on the urban village itself and on the city. Field surveys and questionnaires were conducted. A study of urban village renovation strategies is proposed from three aspects: spatial, cultural, and operational.

In Chapter 7, Conclusion and Prospect. The conclusions of the whole text are summarized and the outlook on the future work of urban village renewal and renovation is proposed.

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CHAPTER 2

Theoretical foundation and literature review

2.1 Theoretical Foundations of Urban Vitality

2.1.1 Definition of Urban Vitality

The earliest concept of urban dynamism can be traced back to the late 19th century when scholars began to study the impact of urbanization on human social and economic development in the West [1]. Among them, American economist H.W. Friedman proposed the theory of "limits to economic growth", arguing that as the economy grows, the trend of urbanization and industrialization will continue indefinitely and eventually reach a bottleneck, leading to economic stagnation and social problems [2]. This theory has drawn the attention of scholars to the issue of urban development, and they have begun to explore the potential and sustainability of urban development [3].

Jane Jacobs argues that cities should focus on meeting people's basic needs, developing public services, education, healthcare and other infrastructure, and improving the quality of life in cities [4]. At the same time, cities should also focus on environmental protection and sustainable development, and establish an urban model in which people and nature live together in harmony. In his book "The Life and Death of Great American Cities", he proposes that the vitality of cities comes from the diversity of internal life, the process of interaction between people and the spaces of their daily activities constitutes the diversity of life, and urban diversity itself brings and stimulates the creation of more diversity [5].

Kevin Lynch proposed the theory of "urban imagery", arguing that urban planning and design should focus on people's sensory and psychological experiences, so that people can feel the beauty and vitality of the city [6]. In addition, cities should be diverse and inclusive so that people of different cultures and backgrounds can coexist harmoniously. In his book "Urban Form", he outlines five indicators that influence urban spatial form, namely vitality, perception, appropriateness, accessibility and management, and makes urban vitality the primary indicator for evaluating the quality of urban spatial form [7]."

Jan Gehl believes that the vitality of cities depends on people's creativity and innovative spirit, and encourages people to innovate and create to create vibrant and creative urban communities [7]. At the same time, cities should also focus on public spaces and green environments to improve the ecological quality of the city. The earliest research scholars have focused on different theories of urban vitality, but they all emphasize the important role of urban infrastructure development, social inclusion, and cultural diversity in urban vitality [4,8-10]. At the same time, they all focused on the impact of urban management and planning on urban vitality. These theories provide important thinking perspectives for understanding and exploring urban vitality [11].

2.1.2 History of Urban Vitality Development

The historical context of urban vitality dates back to the early 20th century when cities began to experience rapid growth and development. Vitality is expressed in urban lifestyles, such as bustling streets and a variety of lively activities [11]. Jacobs first defined urban vitality as the diversity of the living environment, which includes interactions between people and the environment [4]. Montgomery emphasized that it was possible to plan and design vibrant cities through the principles of urban form, activity, street life, and urban culture. He argued that mixed use, accessibility, human scale, block density, adaptability, and permeability will facilitate the interaction between architecture and street activity [12]. As cities grow, social problems, such as overcrowding and environmental damage, appear. In the 1980s and 1990s, urban regeneration emerged in the context of urban revitalization and the focus shifted to improving the livability and attractiveness of urban areas [13]. The social dimension of sustainable urban development manifests itself in cities with highly developed human interaction, information transfer, and cultural prosperity, which are characterized by stability, equity, and dynamism [14]. Although urban areas have faced numerous challenges over the years, the creation of habitable and sustainable cities has benefited from the idea of urban vitality.

With the acceleration of urbanization and the increasing prominence of urban issues, more and more scholars are exploring the influencing factors and improvement strategies of urban vitality from different perspectives. In the 1980s, "urban economics", which focuses on transportation and housing, gradually emerged, revealing the important role of urban infrastructure construction and public services in urban vitality [15]. In the 21st century, with the rapid development of information technology and big data, the collection, analysis, and application capabilities of social and economic data have been greatly improved, providing a more solid foundation for urban vitality research[16,17].

During this period, some scholars began to use different methods and means to study urban vitality from different dimensions. Some scholars start from urban economic data and use methods such as time series analysis and spatial econometric analysis to explore the relationship between urban economic development and vitality, and propose corresponding development strategies [18-20]. Other scholars have explored the influencing factors and improvement strategies of urban vitality from the perspectives of culture, creative industries, social inclusivity, and spatial quality. Some scholars have explored the impact of urban planning and management measures on urban vitality from the perspective of urban management and planning [21].

In short, the study of urban vitality has gone through a process from theoretical exploration to empirical analysis, and from a single dimension to multi-dimensional research. With the continuous progress of technology and methods, the depth and breadth of urban vitality research continue to expand, providing more powerful support for the sustainable development of cities.

2.1.3 Current status of urban vitality research

Human activity is essential to urban planning and governance [22]. Urban vitality is the foundation of urban evolution and the driving force of urban development [23]. Urban vitality is receiving increasing attention from professionals [24]. The contribution of urban form to urban vitality has become the most common consensus among urban planners [25]. The vitality of the city is the implicit and diverse soft force of the society, which is a multidimensional complex system. Urban vitality is influenced by a variety of physical and social characteristics. The content of vitality description can be roughly divided into two aspects. One aspect is the vitality behavior itself, such as crowd performance, crowd size, density, activity type, and activity duration. The second aspect is providing a space for activities, which is directly tied to the city's built environment. Space itself is inactive; however, different spaces will guide and stimulate dynamic behaviors, reflecting the spatiotemporal distribution of dynamic behaviors.

In general, scholars concentrate on the microscopic manifestations of urban vitality, particularly the geographic dispersion of individuals and their financial, cultural, and social activities. Compared with traditional methods, big data is good at recording and analyzing human activity trajectories and communication methods and then exploring the characteristics and laws behind them. The core of urban vitality is tied to the ongoing interaction of urban society, which is intimately related to human activities and movement [26]. Population density can reflect the vitality of a region and is usually measured by data from location-based services (LBS), including cell phone signaling [20], GPS, and Baidu Heat Index, to directly represent the vitality of the city [27,28]. Commentary websites and apps are interactive platforms that integrate merchant information and consumers' feedback. This information covers areas such as food services, shopping, entertainment and recreation, and living services. Its information can well reflect economic vitality [29]. In addition, data in social media can also reflect the distribution of vitality (Sina Weibo check-in data, Twitter, etc.) [28,30]. Moreover, data from bus credit card, taxi, shared bike, and location-based food and beverage reviews are widely used to assess urban vitality [31].

Some scholars have proposed corresponding research models from the perspectives of public space quality, urban morphological scale, and subjective feelings of urban residents. Elizabeth McDonald et al. reviewed the relevant studies on street morphology in the United States in recent years and summarized the evaluation of urban morphology into three aspects: livability, sense of place, and vitality, where vitality is measured by factors such as the diversity of activities and the density of activities occurring [32]; Apriard and Jacobs, from the perspective of urban physical morphology, argued that the diversity of residents' social life and urban physical environment and complexity can be generated or enhanced by suitable residential density and development intensity [33], and some scholars' studies focus more on quantitative analysis, measuring urban public space vitality by quantifying it as the main indicator of urban spatial development status, constructing a theoretical framework for urban vitality evaluation, quantifying various influencing factors, and revealing the main influencing factors of public space vitality [34]. Overseas research has focused on urban vitality earlier and is rich in related studies. The research direction is mainly on the relationship between urban space and urban vitality, with more emphasis on qualitative research on the quality of public space and users' feelings, and then gradually shifted to the exploration of the interaction between people and space, and the research level gradually changed from qualitative to quantitative research.

Urban space, whether it is a city or a metropolitan area, cannot be seen as a node in a network with well-defined boundaries, but as a series of processes in social space. The implication of the authors' urban theory for this study is that urbanization is an expression of people living and using space in a certain way. They have a perception of a location and use that space in a certain way. Urbanization is also an expression of population clustering and interaction. This work seeks to enhance the understanding of urban space and, at an abstract level, attempts to understand how people produce and perceive the built environment through the representation of location-based online social media messages.

2.2 Theoretical basis of urban built environment

2.2.1 Definition of built environment

Urban form is a sophisticated economic, cultural, and social phenomenon. It is the overall imagery of the city that is perceived and reflected by people in various ways. Urban morphology divides the urban built environment into interrelated and interdependent components such as buildings, streets and blocks [35]. In the book "Creating a vibrant urban center," Pamir proposes that location, size, planning, and design are the practical factors that make public places prosperous and vibrant [36]. Therefore, it is important to investigate how social and physical environmental factors, such as building size, land use, and road network density, affect urban vitality [20].

2.2.2 Built Environment Affects Urban Vitality

At its core, urban vitality is constantly related to social interactions in cities [26], while the built environment is the place where social interactions take place. Based on the measurement of urban vitality, the researcher further quantitatively explores the impact of characteristics of the built environment, such as location, functional mix, and density on urban vitality [20,37-39]. Data on points of interest (POI) describe the built environment that supports human activity and is often used to measure the density and diversity of facilities [20]. Commonly employed as urban vitality, the density of points of interest is often complemented by other measures [6]. Some studies have argued that urban vitality can be measured by food and beverage facilities [24,40]. They argue that the survival of food and beverage businesses relies on a large and active footfall and places where food and beverage businesses thrive tend to be more dynamic [41]. Urban vitality is linked to the characteristics of a cafe, such as its social connections and economic transactions [26]. These characteristics make it an "indicator business" for the area [42].

Scholars in urban sociology believe that cities play a crucial part in the growth of society and the economy. They see the city as a place where culture, society, and the economy may reflect on their own existence. Economic, social, and cultural components make up urban vitality. These traits demonstrate the city's capacity to give its citizens enough spaces and amenities [24,43]. According to academics, every element of urban form is interrelated, interactive, and inseparable [30,40,44,45]; the combined impact of form elements on vitality may be greater than their individual components [20]. Some scholars have also attempted to develop a composite indicator that serves as a stand-in for urban vitality, for instance by establishing a correlation between neighborhood characteristics, urban form and function, landscape, location, and street arrangement [46]. Other scholars have made an effort to evaluate urban vitality from a broader perspective, showing how it is connected to the economic, social, and physical environment [47]. However, most scholars still focus on the micro expressions of urban vitality; while existing research is strengthening for one aspect of economic, social, and cultural vitality of cities, comprehensive research on the three dimensions of urban vitality is still relatively rare. By defining urban vitality in our study as the integration of the intensity of various activities performed by residents in urban space, I aim to address the limitations of previous research. Three dimensions of vitality—economic, social, and cultural—were included to examine the efficacy of different urban vitality dimensions.

2.3 Development history and characteristics of urban villages

2.3.1 Definition of Urban Village

Urban villages are villages formed when all or part of rural land is expropriated in the process of rapid urban development and expansion, and villagers still live in the original village based on spontaneous construction. Its land tenure, household registration and administrative system still retain the rural model. In a narrow sense, an urban village is a residential area in which all or most of the arable land in a rural village has been expropriated in the process of urbanization, and the farmers still live in the original village after being converted to residents [48]. In a broader sense, urban villages are residential areas that lag behind the pace of urban development, are outside of modern urban management, and have a low standard of living in the process of rapid urban development [49].

In fact, the concept of urban village is only a description of a phenomenon, not a strict scientific concept, so there is no uniform definition. Different disciplines and scholars often define it from different research perspectives according to the needs of their studies. The spatial morphological characteristics of urban villages have great similarity in general, such as building density, layout methods, household type selection of the living population, etc. China's land system is a dual structure of urban and rural areas, corresponding to different property rights systems and land transfer fees in the construction process. The transfer fees of large property rights houses in cities are high, and the law of rent change is linked to this factor; while the transfer fees of small property rights houses in rural areas are low, and the rental price is the practical price of the house as a commodity. Therefore, for a large number of migrant workers and low-income people living in urban rented houses, even including college students who have just entered the labor market, urban villages that can offer lower rents form a landing place for new immigrants and low-income groups in the city [50,51].

2.3.2 Reasons for the formation of urban villages

The formation of urban villages is mainly due to the following reasons:

(1) Accelerated urbanization process. With the continuous promotion of urbanization, the urban population is increasing, and the demand for housing is also increasing, while the original housing supply cannot meet the demand, resulting in the rise of housing prices, many people can only choose to buy or rent houses in urban villages.

(2) Improper government planning. The government does not fully consider the existence and development of urban villages in the urban planning process, resulting in urban villages occupying a large amount of land resources in the city.

(3) Unbalanced economic development. The unbalanced economic development of cities is also one of the reasons for the formation of urban villages. The economic development of some cities is faster, people's living standard is higher, and the demand for housing is higher, while the economic development of other cities is slow, people's living standard is lower, and the demand for housing is reduced accordingly.

(4) Insufficient policy restrictions. The government has certain insufficient policy restrictions in the management of urban villages, resulting in the development and management of urban villages not being regulated enough, and some urban villages have problems such as indiscriminate construction, indiscriminate building and indiscriminate land occupation.

(5) Influence of social factors. Some residents of urban villages have certain difficulties in the management and development of urban villages due to their poor economic conditions, low literacy level and lack of legal awareness and social responsibility.

2.3.3 History of Urban Village Development

The development history of China's urban villages can be roughly divided into the following stages (Table 2-1).

The first stage is the budding stage (1949-1985). During this period, China's economy experienced rapid development and the urbanization process began to start. Due to the lack of urban infrastructure construction and housing supply, some peasants began to spontaneously form some informal settlements in the areas around the cities, which is the prototype of urban villages [52]. These urban villages generally consisted of several natural villages with complex population composition, dense and disorganized houses, and poor sanitary conditions, but with convenient transportation and superior location, and gradually became the main place of residence for migrant workers.

The second stage is the rapid development stage (1985-2000). During this period, with the rapid development of China's economy and urbanization, urban villages developed and grew rapidly. The government gradually increased the management of urban villages and began to renovate and improve them. During this period, many urban villages began to implement unified planning, construction and management, and gradually improved their infrastructure conditions and living environment. At the same time, with the continuous expansion of the city, many urban villages originally located in the center of the city were gradually abandoned and discarded, but some urban villages located at the edge of the city were preserved and developed [53].

The third stage is the transformation and upgrading stage (2000-2010). In this period, with the rapid development of China's economy and urbanization, city managers began to pay attention to the transformation and upgrading of urban villages. During this period, many urban villages began to upgrade and transform their industries, developing tertiary industries and commercial services, while also strengthening the remediation and improvement of the environment. The government also issued a series of policy documents to encourage the transformation and upgrading of urban villages and to improve the quality and image of the city.

The fourth stage is the prosperous development stage (2010 to present). In this period, with the rapid development of China's economy and the continuous promotion of urbanization, the development of urban villages has ushered in new opportunities and challenges. During this period, many urban villages began to undergo large-scale development and construction, and the government increased its support and investment in urban villages [50]. During this period, urban villages began to become gathering places for new industries and commercial services in the city, and also attracted a large influx of foreign population. At the same time, with the continuous development of urban rail transportation and public transportation, the distance between urban villages and urban centers gradually shrank, and some urban villages began to gradually integrate into the urban centers and become part of the prosperous urban areas.

Budding stage (1949-1985)	**Rapid development stage (1985-2000)**	**Transformation and upgrading stage (2000-2010)**	**Prosperous development stage (2010-present)**
Rapid urbanization and spontaneous formation of informal settlements	The government carries out unified planning and construction management of urban villages, improving infrastructure and living environment	City managers began to upgrade urban villages, and urban villages began industrial upgrading and transformation, focusing on urban image quality improvement	Urban villages begin to become gathering places for new industries and commercial services in the city and integrate into the city center

Table 2-1. Four stages of urban village development.

2.3.4 Representation of urban village vitality

The role of urban villages as a product of informal urbanization in the built environment is often overlooked [54]. The street space of urban villages hosts a highly complex pattern of commercial layouts, accommodates a variety of daily life behaviors, and embodies a unique spatial dynamism [32,55]. Urban villages provide affordable housing for migrants, including affordable public services and an urban environment that provides employment opportunities for migrants [50]. In terms of economic vitality, urban villages are well located and easily accessible, while the relatively low housing rents in urban villages attract a large number of immigrants and young people in search of job opportunities. Social vitality is mainly present in terms of high population density, high mobility, and complex social relationships. These people often have multiple identities, including students, white-collar workers, blue-collar workers, businessmen, etc. They have frequent interactions and interactions with each other, forming a unique social culture. The development of urban villages has so far produced a very different environment from that of villages, with a clean environment, good security, and complete public facilities. These factors have attracted many urban residents to rent, and have also provided convenient conditions for commercial activities in the surrounding area. In addition, the cultural forms of urban villages are very diverse, ranging from traditional rural culture to modern commercial culture and game culture. At the same time, as urban villages are places where young people gather, there are also many emerging cultural forces gathered here, such as independent musicians, street performers, and internet celebrities. Therefore, the manifestation of vitality in urban villages is multifaceted, both in terms of economic vitality, social vitality, environmental vitality and other manifestations of soft power such as cultural vitality. These representations reflect the various challenges and opportunities faced by urban villages in the process of urbanization, and they also provide important thinking perspectives for us to understand and explore urban development.

2.3.5 Existing Problems

Urban villages have long been criticized by city managers. Although the development of urban villages in Shenzhen has made great progress, there are still a series of spatial, social, cultural and economic problems.

In terms of spatial form, urban villages have poor living environment, poor road access, serious private connections, and backward municipal facilities. The environmental hygiene problem is one of the most prominent problems. Due to long-term unmanaged, the phenomenon of littering, piling and posting is very common, and the environmental hygiene condition is very poor; traffic is also a major problem in urban villages. The traffic problem of urban villages is mainly manifested in road congestion and inconvenient public transportation. Since the urban villages are in the center of the city, the traffic facilities around them are not perfect, resulting in serious road congestion. In addition, public transportation routes are fewer and less frequent, making it inconvenient for residents to travel.

The social problems of urban villages are also obvious, including unclear rights and responsibilities of management bodies, lack of social security, and inadequate public service facilities. Due to the high mobility of the population, security management is difficult and cases of theft and fraud occur from time to time. The living conditions in urban villages are poor, with dense housing, a messy environment, poor sanitation, and a lack of basic living facilities, such as running water, gas, and electricity. There are also social problems such as unemployment, poverty, and lack of education.

In terms of cultural forms, the native culture of urban villages is gradually weakened, and there are few displays and deeper excavations about the native indigenous culture. The historical environment is degraded, villagers' self-built houses become driven by economic interests, villagers adopt the easiest, fastest and most cost-saving way to build, and the characteristics of Lingnan traditional village style disappear. And the newborn immigrant culture is neglected. Shenzhen's urban villages have a diverse population: immigrants, indigenous people, new generation, construction workers, technology white-collar workers, self-employed people and so on. These residents in Shenzhen's urban villages come from a wide range of geographical origins and have diverse work natures, which collide with each other to form a colorful immigrant culture in urban villages.

In terms of economic form, the urban village is relatively closed, and the economic structure is very single. The industrial structure of urban villages has also gradually changed with the out-migration of factories to a purely residential service function, with some commercial support attached. These problems are related to the living environment and management of urban villages, and reflect the deficiencies in urban management.

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CHAPTER 3

Data Base and Research Methodology

3.1 Overview of the study area

3.1.1 Guangdong-Hong Kong-Macao Greater Bay Area (GBA)

As an ambitious and highly strategic regional urban integration plan of the Chinese government, the Greater Bay Area (GBA) of Guangdong, Hong Kong and Macao includes two special administrative regions, Hong Kong and Macao, and nine cities in Guangdong Province, Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing, with a total area of about 56,000 km2, a total population of over 71 million at the end of 2018, a regional production value reached US$1,642.5 billion, with a per capita GDP of US$23,342. Geospatially, the Greater Bay Area is not an entirely new geospatial concept; since the beginning of China's reform and opening up (1978), taking advantage of its geographic proximity to Hong Kong and Macau, the region has been serving as a window to the world for mainland China and is one of the most open and economically vibrant regions in China [1]. As early as 1997, Koolhaas and his team, a renowned architect and sociologist, introduced the concept of "City of Exacerbated Difference" in their book "The Great Leap Forward" to address the urban development of the region, with the intention of emphasizing the new urbanism created by the unpredictable high speed of development. The concept of "City of Exacerbated Difference" is intended to emphasize the new urban material and environment created by the unpredictable and rapid pace of development [1].

"The formalization of the "Guangdong-Hong Kong-Macao Greater Bay Area" as a national strategy comes 40 years after China's reform and opening-up policy, a reform that followed Mr. Deng Xiaoping's proposal 40 years ago to "build individual cities into special economic development zones. According to Koolhaas, the phrase that best represents the current state of urban development in contemporary China is "coordination in development, and development in coordination". The urbanization rate in China today has reached 59.58%, but the degree of development among individual cities is extremely uneven, and the trend of regional integration requires a dynamic balance between individual city development and regional synergy. The concept of the Greater Bay

Area is based on this dynamic balance. It is an exploratory model for the development of a world-class city cluster with deep regional integration proposed by the government to give full play to the comprehensive advantages of the three regions, deepen exchanges and cooperation between the Mainland, Hong Kong and Macao, and further expand openness. It is an exceptionally complex and huge concept, involving many topics such as macroeconomics, social development stages, comprehensive environmental governance, development policy research, and legal system analysis [2].

The Greater Bay Area (GBA), economy, livelihoods, and information technology are currently growing at an unprecedented rate, with changes in trends measured in years. Until 2019, the overall GDP of the GBA has surpassed that of the New York Bay Area, becoming the largest single Bay Area in the world. However, the low overall carrying capacity brought about by rapid urban expansion and population growth in the past will constrain future growth. The urban development of the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) is highly representative and exemplary [3]. A study of the development of the GBA is conducted to identify typical cases and help discover the main contradictions and problems in the process of urban development. From the perspective of urban development and infrastructure, the study is conducted from two aspects. They are land use and transportation infrastructure, respectively.

3.1.1.1 GBA Land Use Analysis

The Greater Bay Area land use pattern is moving into a dense area. The region is projected to have a population of 75.22 million and a sustained economic growth rate of 7%, but a dwindling land supply. This is an unprecedented trade-off between population and limited land resources.

The major built-up areas of the GBA are clustering towards the Pearl River Estuary (Figure 3-1). It is clear that the built-up area is growing along the coastline of the Pearl River Estuary. the GBA has initially formed a spatial structure with Guangzhou-Foshan and Shenzhen-Hongkong as the two core areas plus peripheral functional blocks [4]. With the release of the "Outline of the Development of the Greater Bay Area", industrial transfer/relocation and integration in the GBA will be accelerated. Land use will definitely develop towards de-stocking, and old renovation and urban renewal are inevitable choices. Development on the highly dense East Coast will be concentrated on existing land Resources The intensity of land development patterns within cities varies due to the different manufacturing and knowledge-based development patterns in the East and West. The east coast of the Pearl River, including Zhongshan, Shenzhen, Dongguan and Foshan, has a relatively high intensity of urban development and a more restricted space for future development, while the west coast of the Pearl River, especially Jiangmen and Zhaoqing, has a relatively low land cost and is very attractive to the core cities for industrial transfer. The undeveloped land on the west coast will serve the industrial overflow from the east coast Although cities located on the west bank of the Pearl River have more land resources to undertake the industrial overflow demand, the land development potential is lower than that of cities located on the regional development axis. However, with the gradual increase in the volume of industries in the GBA, it is inevitable that West Coast cities will become increasingly important in the development of cities in the GBA region in the future.

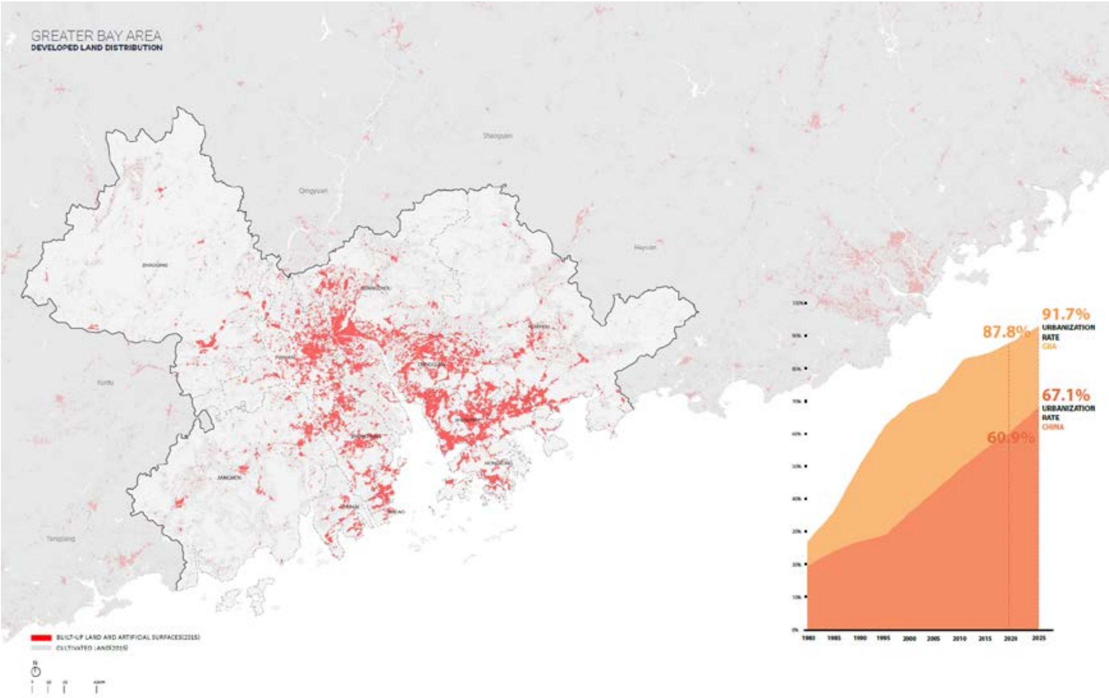

Figure 3-1. Guangdong-Hong Kong-Macao Greater Bay Area (GBA) developed land distribution.

In the context of China’s social and economic transformation and upgrading, urban space expansion has shifted from "incremental development of new district development" to "exploitation of the stock potential of urban center restructuring", and the trend of urban renewal has shifted from "dotted renewal" to "area renewal" [5]. In recent decades, China's urbanization has been in a stage of accelerated development. Cities have become the absolute center of China's economic, political, and cultural activities, and have played an important role in social development and improving people's livelihood. However, decades of extensive expansion and development have also brought about a series of derivative problems, such as traffic congestion, environmental pollution, unbalanced infrastructure construction, and relative shortage of public service resources.

After 30 years of rapid and even radical urban growth, Guangdong-Hong Kong-Macao Greater Bay Area (GBA)'s land carrying capacity has reached its limit (Figure 3-2). In the urban areas of first-tier cities such as Shenzhen and Guangzhou, urban development will focus more on urban renewal rather than new towns [6]. From 2013 to 2018, the annual land supply dropped by 40%. "With the transformation of old and new economic driving forces, the upgrading of industrial structure and the promotion of coordinated development, the carrying capacity of property carriers in the Gulf region needs to keep pace with the times. Urban renewal is to activate stock assets, release high-quality land resources and promote sustainability the best plan for economic development."——Debenham Thouard Zadelhoff China.

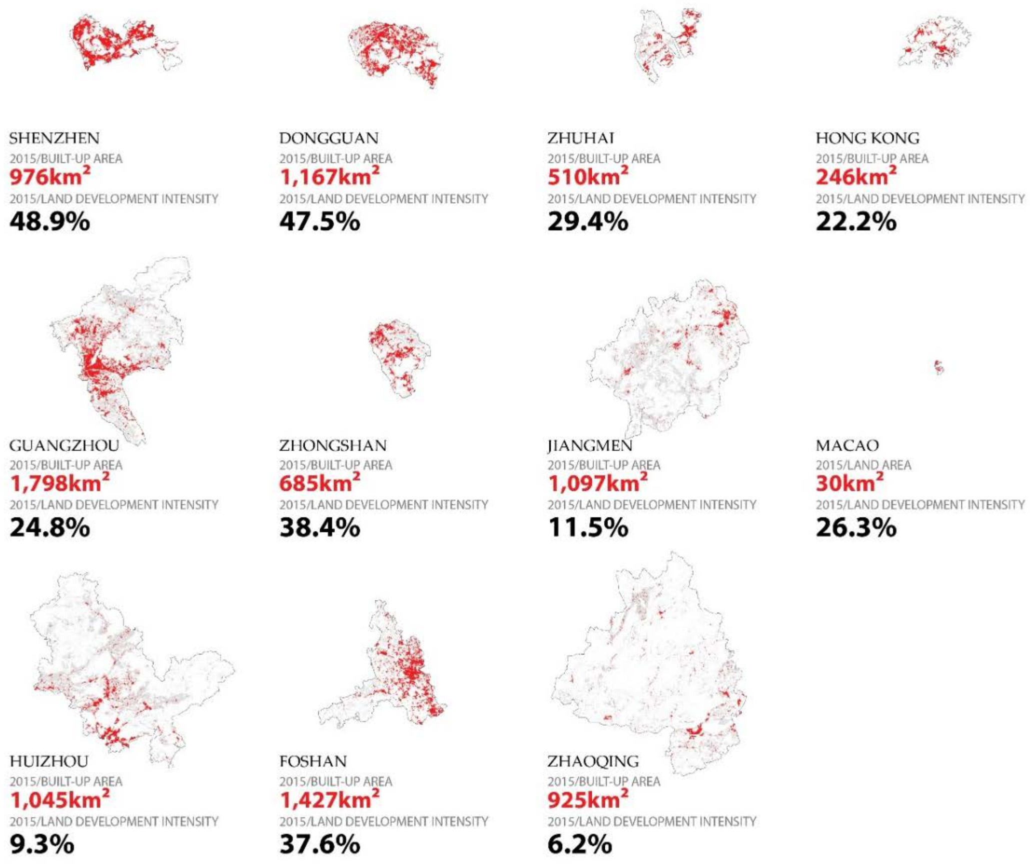

Figure 3-2. Guangdong-Hong Kong-Macao Greater Bay Area (GBA) built up land distribution.

With the rapid expansion of cities, the built-up areas in the Guangdong-Hong Kong-Macao Greater Bay Area have become saturated. According to the data in 2015, Core cities occupy leading positions in the value of built-up area, land development intensity and built-up area density. Shenzhen has the largest land development intensity, reaching 48% and nearly half of the land has been developed, far exceeding 30% (Figure 3-3). International cordon. In terms of land reserves, Shenzhen is even more stretched, and as early as 2005, Shenzhen included 974.5 square kilometers of land area as the basic ecological control line, accounting for almost 50% of the city's total land area, which means that Shenzhen has almost no land available. The scarcity of land resources has always been a huge bottleneck restricting the development of Shenzhen. Excluding a small part of the reserve land that can be reclaimed, the largest source of construction land in Shenzhen is urban renewal land. Therefore, Shenzhen, a young city, has become the first city in the country to carry out large-scale old reforms. How to transform urban construction from incremental development to stock optimization has become a major issue facing Shenzhen. For the development of Shenzhen's stock land, urban renewal is inevitable.

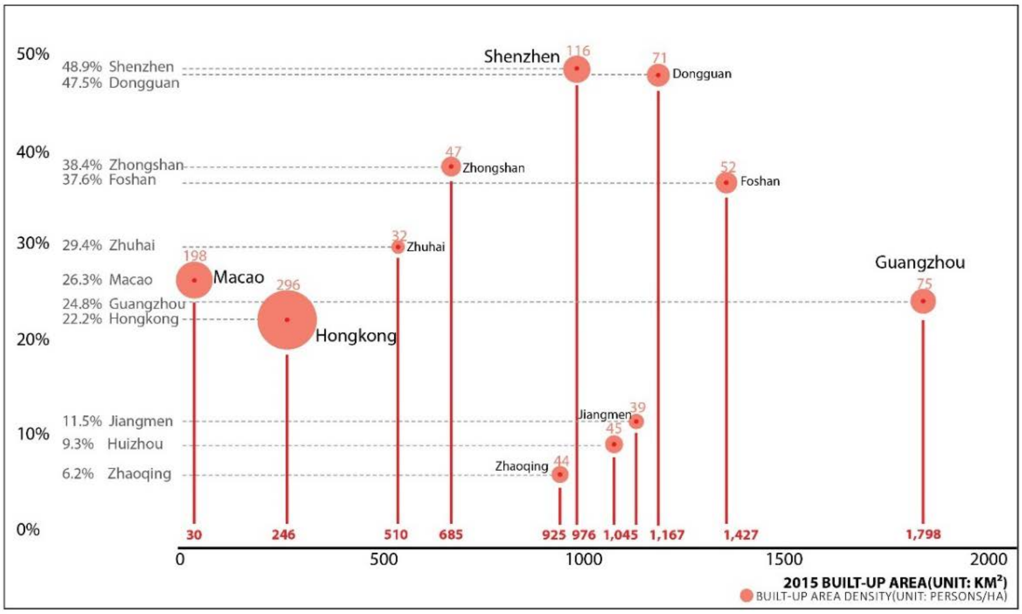

Figure 3-3. 2015 GBA land development intensity.

3.1.1.2 Connective Infrastructure Analysis in GBA

The Greater Bay Area (GBA) is widely known for its investment in connectivity infrastructure [7]. With more than 3,000 km of rail transit (including high intercity rail and metro lines) under constant construction and planning, the GBA is poised to become the largest transportation network in 2035 (Figure 3-4). Transit-only development, integrated transportation hubs, new cities and smart mobility are critical opportunities in this process, not only to review the past development of the section, but also to test multiple modes of transportation, including rail. It also provides a more convenient basis for population movement and a greater opportunity to activate urban vitality [8].

Shenzhen currently operates 286 km of rail transit, with 300 km more planned for 2022 and 749 km more planned for 2035, Shenzhen will become the city with the longest subway kilometers in the Greater Bay Area, with a total of 1,325 km planned.

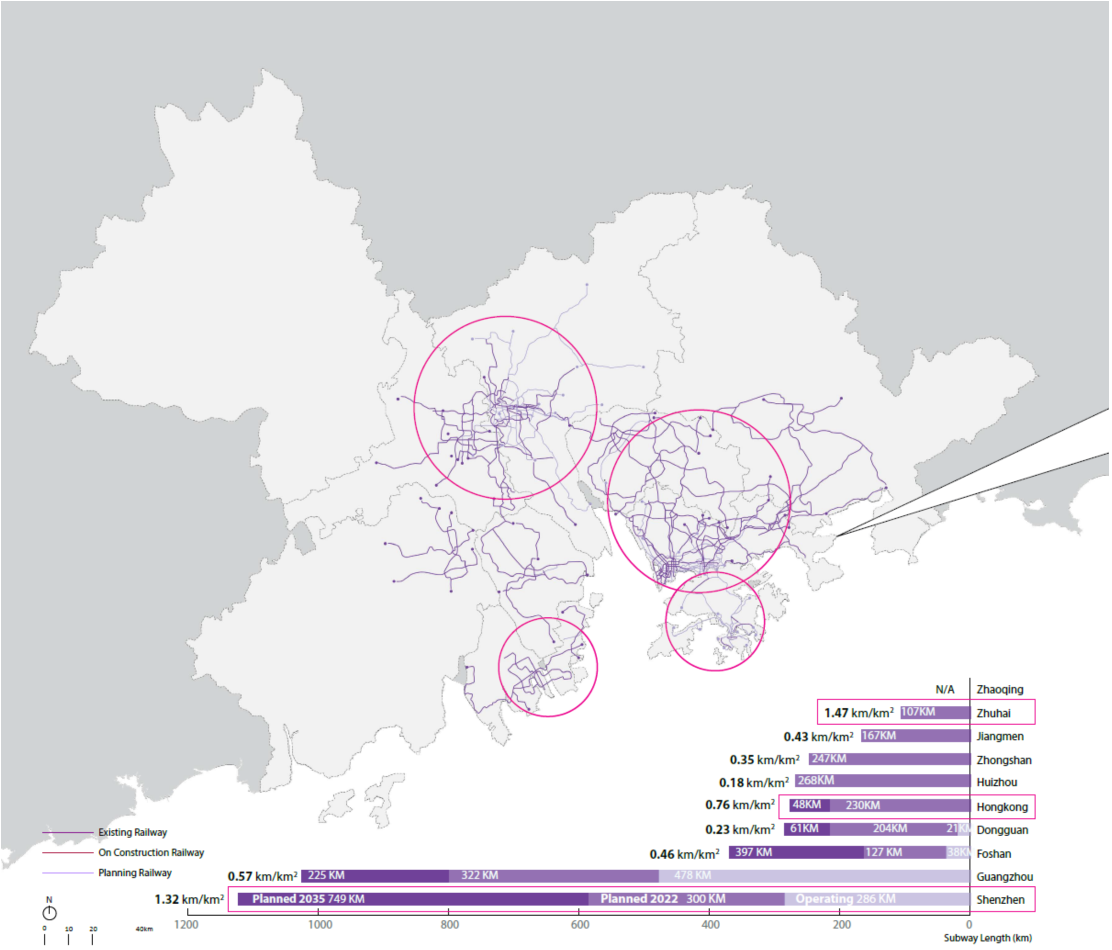

Figure 3-4. 2015 GBA transportation infrastructure outlook.

Compared to Tokyo and New York, GBA still has gaps in terms of subway density (km/km) and subway rides per 1,000 people (Figure 3-5), and GBA citizens have developed a habit of commuting by subway despite relatively limited physical facilities.

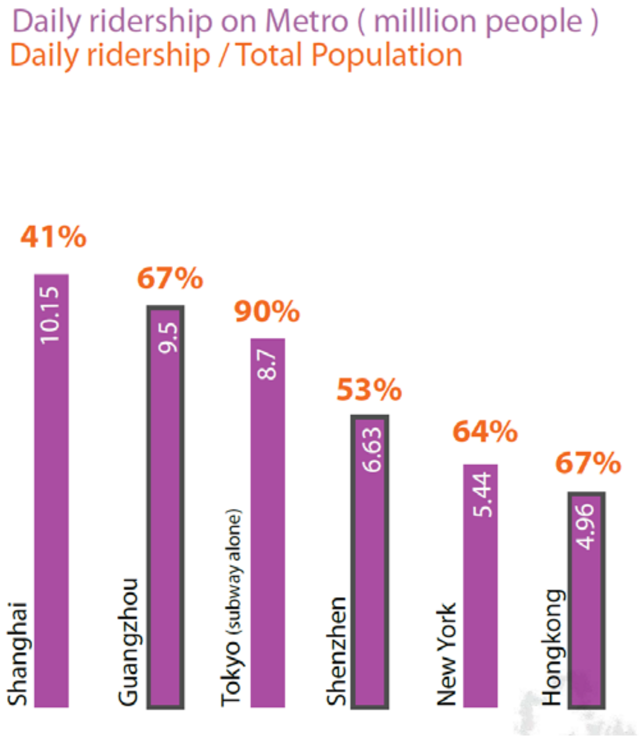

Figure 3-5. 2015 GBA land development intensity.

3.1.2 **Study Subject Selection: Shenzhen**

3.1.2.1 Basic Overview of Shenzhen

Shenzhen, the only mega-city in China with a 100% urbanization rate, was the main target of this study. Shenzhen has been regarded as China's fastest-growing cities with a high level of urban vitality; it is an international metropolis that forms a special economic zone and a national economic center [9]. The city contains 10 administrative districts, including three central districts (Nanshan, Futian, and Luohu) and seven periphery districts, with an overall land area of 1997.47 km2 and an urban area of 927.96 km2 (Figure 1). The Seventh National Census figures indicate that by 1 November 2020, there were 17.56 million people residing in Shenzhen.

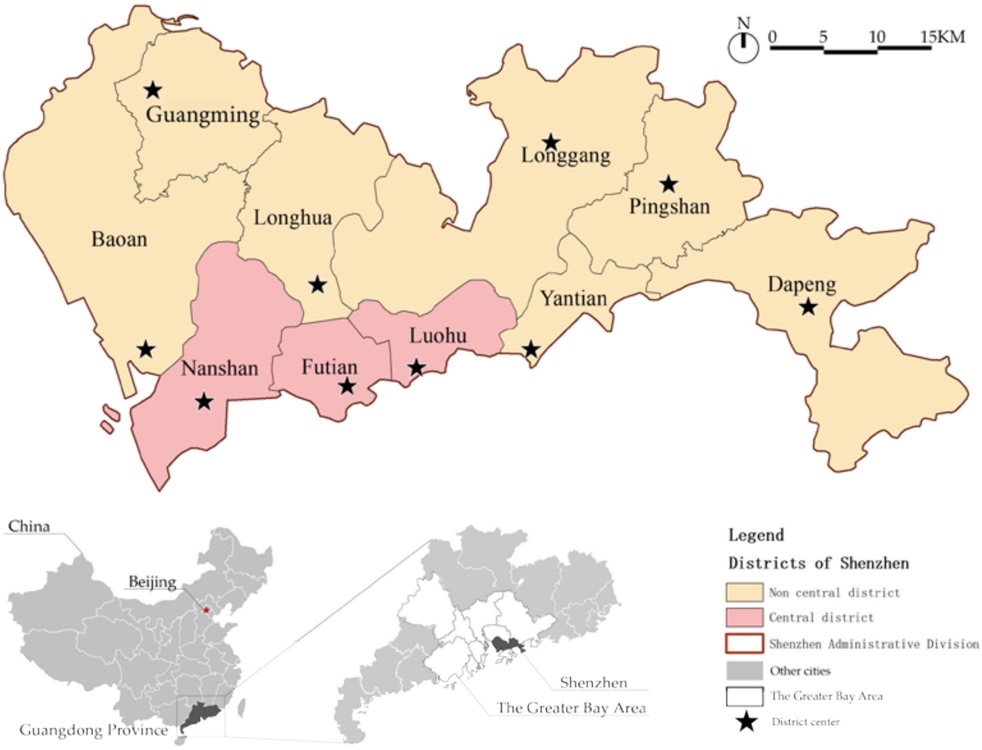

Figure 3-6. Shenzhen's administrative divisions.

Shenzhen is a seaside city in southern China, adjacent to Hong Kong. It is located south of the Tropic of Cancer, between 113°43′ and 114°38′ east longitude and 22°24′ and 22°52′ north latitude. It is located in the south of Guangdong Province, on the east coast of the Pearl River Estuary, east of Daya Bay and Dapeng Bay; west of the Pearl River Estuary and Lingding Ocean; south of the Shenzhen River and Hong Kong Special Administrative Region; north of the city borders with Dongguan City and Huizhou City. Shenzhen is an important city in the Guangdong-Hong Kong-Macao Greater Bay Area and is positioned as an important pole and core engine of the Greater Bay Area, playing an important supporting and leading role in the development of the Bay Area and maintaining a close cooperative relationship with Hong Kong. The Guangdong-Hong Kong-Macao Greater Bay Area is one of the most dynamic economic zones within China and has received global attention for its innovation, internationalization and high efficiency. As a special economic zone and a national economic center city in the Greater Bay Area, Shenzhen has leading advantages in technology, innovation and industry, and is also an important window and testing ground for China's reform and opening-up.

Shenzhen is the only mega-city in China with 100% urbanization rate and is the main target of this study. Shenzhen is considered the fastest growing city in China with a high degree of urban dynamism; it is a cosmopolitan city that forms a special economic zone and a national economic center [9]. The city has 10 administrative districts, including three central districts (Nanshan, Futian, and Luohu) and seven peripheral districts, with a total land area of 1997.47 km^2 and an urban area of 927.96 km^2 (Figure 3-6). Data from the seventh national census show that as of 2021, the city's year-end resident population in Shenzhen was 17,681,600. Among them, the resident household population was 5,563,900, accounting for 31.5% of the resident population; the resident non-resident population was 12,117,700, accounting for 68.5%.

3.1.2.2 Development history of Shenzhen city center

Shenzhen's urban development history can be roughly divided into three stages: the first stage is the early stage of reform and opening up, with the construction of the Special Economic Zone as the main feature. During this period, Shenzhen's processing trade business, mainly characterized by "three commissions and one complement" (processing with materials, sample processing, assembly and compensation trade), developed rapidly and became an important window of China's reform and opening-up and a special economic zone. The second stage is the 1990s, with the introduction of foreign investment and technology as the main features. During this period, Shenzhen increased its efforts to introduce foreign capital and technology, vigorously developed high-tech industries such as electronic information and precision manufacturing, and became one of the leading cities in the national real estate market [10]. The third stage is since the 21st century, with industrial upgrading and transformation as the main features. In this period, Shenzhen actively promoted industrial upgrading and transformation, increased investment in strategic emerging industries such as Internet of Things, new energy and life sciences, and became one of the world's important production bases for consumer electronics.

In 1981, Luohu District was established, followed by Futian and Nanshan administrative districts, etc. In the 1990s, Shenzhen started to plan for the construction of Futian Central District, which gradually formed the current urban pattern. 2009, Shenzhen started a costly urban renewal plan, focusing on the transformation of Futian Central District and in 2009, Shenzhen embarked on a costly urban renewal program, focusing on transforming the Futian Central District and Nanshan District, in an attempt to create an international and modern urban center. The transfer of Shenzhen's urban center is an important event in the city's development history. From Luohu to Futian to Nanshan, Shenzhen's urban center has advanced all the way to the west. This process started in the early 1980s, when the center of Shenzhen's development was in Luohu District, and then gradually expanded to the surrounding areas. In the 1990s, Futian became the new city center of Shenzhen with the completion of Futian Central District. After this, Nanshan District began to rise rapidly and was positioned as the main urban center of Shenzhen in 2016. The development of Nanshan District has been fueled by innovative finance, modern logistics, headquarters economy and other high-tech industries, and has become one of the important engines of Shenzhen's economic development [11].

Currently, the administrative division of Shenzhen is divided into nine administrative districts and one functional district, namely Luohu District, Futian District, Nanshan District, Bao'an District, Longgang District, Yantian District, Guangming New District, Pingshan New District and Longhua New District. Among them, the central district includes Futian District, Luohu District and Nanshan District. These three districts are more mature in development, with well-developed municipal infrastructure and complete public service facilities such as commerce, culture and education, and are home to Shenzhen's administrative, cultural, financial, information and international exhibition centers. The peripheral districts are the outer areas of Shenzhen, including Bao'an District, Longgang District, Guangming New District, Pingshan New District and Longhua New District [12].

These areas are relatively lagging behind in development, with relatively imperfect municipal infrastructure and weak public service facilities. However, the fringe areas also have development potential, and the government is increasing investment to promote infrastructure construction and industrial transformation and upgrading to facilitate the development of the fringe areas.

In general, Shenzhen's urban development has undergone a transformation from a special economic zone to a national economic center city, an upgrade from processing trade to high-tech industries, and a development process from a traditional city to a modern city. Shenzhen has always taken the central district as the core and gradually expanded to the surrounding areas, and urban planning and construction have been continuously adjusted and upgraded with the needs of urban development. In the process of continuous economic development and accelerated urbanization, Shenzhen strives to become a more vibrant and livable city.

3.1.3 Typicality and Orientation of Shenzhen Urban Villages

Among the urban villages in the country, the Pearl River Delta is the most prominent, and Shenzhen is the most representative city among them. The number of urban villages in Shenzhen has always been the highest in the PRD. According to statistics, there are 320 urban villages in Shenzhen, 277 in Guangzhou, and 275 in Foshan.1 However, compared to other cities, Shenzhen has the largest proportion of built-up areas, the most extensive urban core, and the highest density of urban villages because of its small urban area. Urban villages are essentially a conflict and convergence caused by the differences between the dual urban-rural household registration system and the state-owned and collective land management models in the context of China's rapid economic development. Both the speed of urbanization, economic development, and population inflow in Shenzhen has been the highest in the country, and the clan power of Lingnan villages is relatively strong, so the evolution of urban villages in Shenzhen is more dramatic and the problems are more representative. Therefore, almost all of the problems, contradictions, conflicts or integration contained in urban villages in other cities exist in Shenzhen, even to a deeper extent. Therefore, further exploration of urban village regeneration in Shenzhen will inevitably serve as a guide and model for similar problems encountered in other cities at present or in the future [6].

In terms of spatial distribution, urban villages in Shenzhen are more widely distributed and dispersed. Beijing, Shanghai, Guangzhou and Xi'an are big cities with a long history of urban construction and will have an old city center, although several urban sub-centers will be formed during the rapid development process, and most of these sub-centers also have traces of urban construction. However, the overall urban spatial structure development still takes the old city as the geographical center, and gradually expands to the outer circle, and urban villages are also formed in this process. Therefore, in these big cities, there are very few urban villages near the city center, especially in the old city center, there are almost no urban villages, and the location of urban villages are mostly located in the marginal area or the interval area between the central area. But Shenzhen is different, although Shenzhen is not like everyone's inherent impression - a small fishing village from the development of a cosmopolitan city, but Shenzhen's predecessor Bao'an is only a total population of only a few hundred thousand counties, excluding the original county, the territory is a large number of primitive villages.

After the reform and opening up, the establishment of the Shenzhen Special Administrative Region, respectively, in Luohu, Yantian, Shekou construction, and later set up Futian Central District, these urban centers in the region originally did not have a city building base, in the development process either demolition of the village construction, or in the village next to the flat land and rise. Therefore, Shenzhen is a multi-center and accompanied by the development of the next village at the same time, a lot of early "three to a supplement" processing industry plants distributed around the village, resulting in a unique phenomenon of Shenzhen - urban villages throughout the city [13]. Whether it is the edge of the city or the historical center of Luohu Old Street, Futian Financial Center, Nanshan Science and Technology Park or Shenzhen Municipal Government, there are urban villages around them all. Although they are partially demolished in the process of urban development, the overall spatial layout characteristics do not change essentially.

Secondly, in terms of cultural significance, the urban village is special or even unique to Shenzhen. Shenzhen is often described as "a circle drawn by an old man" or "a cosmopolitan city developed from a small fishing village", which ignores the history of Shenzhen as a county for more than 1700 years and the history of immigration of Shenzhen villages for more than 800 years [14]. Unlike other major cities that have their own historical districts in a strict sense, Shenzhen's historical and cultural information has been almost unconsciously ignored in the flood of rapid urbanization because of its special development trajectory. However, Shenzhen's urban villages are a composite of the city and the countryside, and a composite of the past and the future [15]. The urban village contains all the spatial-historical and cultural information of Shenzhen from the establishment of the county to the present, and is the original embodiment of the development process of Shenzhen as a city. So, in a sense, the urban village is Shenzhen's own unique "historical and cultural district", is the root of Shenzhen.

Finally, the nature of land in urban villages, Shenzhen also has special characteristics. Shenzhen is the first city in China without collective land, but in the process of transformation, the reform of the collective property rights system has not been fully implemented, and the ownership of land is not fully in the hands of the government [10]. The original village committee functions were replaced by the newly established village joint-stock company, so the existing urban villages in Shenzhen have both the brand of the original village in the past and the figure of modern company operation. The study of urban village renewal in Shenzhen can not only be a reference for other cities, but also a renewal exploration for the unique phenomenon of urban villages in Shenzhen in terms of personality.

3.1.4 Basic Overview of Urban Villages in Shenzhen

Shenzhen's urban villages are a unique product of a special era, the "first landing place" for migrant workers, an important part of Shenzhen's urban development, and one of the important power sources of Shenzhen's modern urban development. Shenzhen's urban villages are responsible for the living and living services of nearly 70% of the actual management population in Shenzhen [13]. According to the latest reported data from the research of Shenzhen Planning and Land Resources Committee, the total scale of land in urban villages in Shenzhen is about 320 hectares, accounting for about 16.7% of the total land area of Shenzhen. There are currently 1,892 urban villages in Shenzhen, covering an area of 12,662 hectares, with a building area of 22,398,529 square meters and a resident population of 13,438,800, 563 urban villages in Longgang District, 310 urban villages in Longhua District, 113 urban villages in Guangming District, 189 inner-city villages in Pingshan District, and 145 suburban villages in Dapeng New District. There are more than 350,000 peasant houses or private self-built houses in urban villages, with a total floor area of 120 million square meters, accounting for 49% of the city's total housing stock [14].

In 2019, the Shenzhen Municipal Bureau of Planning and Natural Resources issued the Master Plan for Comprehensive Improvement of Urban Villages (Old Villages) in Shenzhen (2019-2025), which investigates, analyzes and studies the urban villages that currently exist in Shenzhen and forms a map of the current spatial distribution of urban villages (Figure 3-7). The plan proposes to improve the quality of urban development and enhance the competitiveness of the city as the core, fully consider the elasticity of urban development, retain a certain proportion of urban villages during the planning period, carry out the renewal of urban villages in Shenzhen in a reasonable and orderly manner, gradually eliminate safety hazards, maintain urban fabric, inherit historical heritage, secure low-cost space, improve supporting facilities, enhance environmental quality, and realize the sustainable and comprehensive development of urban villages. The planning zone has established a geographic information database and incorporated it into the "one map" system for planning management [16]. Through the survey of the current population and buildings, the plan subdivides the urban village space into four types of land space, including urban village residential land, village industry, other village built-up areas and village vacant land. According to statistics, the area of urban village land in Shenzhen accounts for about 35%, or 321 square kilometers. In addition, the construction land in Shenzhen's urban villages accounts for 43% of the city's total construction, and the population of urban villages is as high as 12.31 million, with 64% of the city's population living in them [12]. In terms of land use, urban villages are more distributed in Baoan District, Longhua District, Longgang District, and Pingshan District. Compared to the central urban areas of Nanshan District, Futian District and Luohu District, the peripheral urban areas have formed a contiguous development of urban villages. Bao'an District has more villages belonging to industrial areas, so the contiguous performance is more obvious.

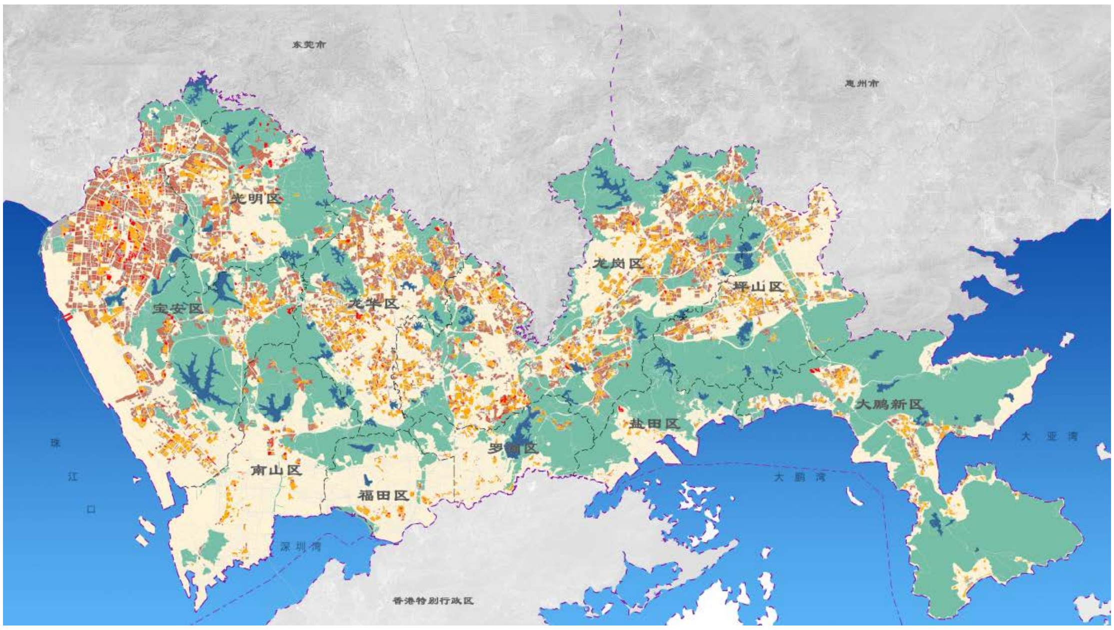

Figure 3-7. spatial distribution of urban villages in Shenzhen (source: Shenzhen Planning and Natural Resources Bureau).

According to the survey on the distribution of the number of urban villages in the city, Longgang District has the highest number of urban villages among all districts in Shenzhen. There are 294 natural villages and 51 administrative villages. Futian, Luohu, and Nanshan, as the central districts of the city, have undergone large-scale renewal and development, and the number of urban villages is significantly less than that of Longgang, Longhua, Pingshan, and Dapeng districts, which bear the overflow of residential population. Yantian District and Guangming District have fewer urban villages due to distance and industrial development.

Shenzhen is not a single center expanding outward, but a multi-center, multi-zone urban structure. In the process of development, the evolutionary form of urban villages varies according to their locations [17]. The urban villages located in the urban center are seriously affected by urbanization, and the original village form has almost disappeared, with high building density (Figure 3-8). The urban villages in the interval of the urban center area are also affected by urbanization, but not as drastically as the urban villages in the central area. Unlike the urban villages in the central area where most of the aborigines have moved out, the urban villages in the peripheral area are in a state of mixed residence of indigenous villagers and tenants, with less construction density and containing relatively mixed architectural styles (Figure 3-9). Unlike the urban villages in the central area, which are basically for residential services, the urban villages in the peripheral area assume the residential function of the mobile population, while some of them have other industries such as industry and art. The migrant culture in the urban villages in the peripheral areas is not as prominent as that in the urban villages in the central areas, and is the main soil for preserving the local culture [13,18].

Figure 3-8. Urban villages in urban center (source: Shencheng Voice).

Figure 3-9. Urban villages in the peripheral area (source: Shencheng Voice).

Comparison content	Urban villages in central areas	Urban villages in marginal areas
Space Location	Located in the central area of the city, some urban villages are located in the core of the central area and completely surrounded by the built-up area of the city	Interval areas located in central areas, usually not completely surrounded by urban built-up areas
Land Use	Mainly used as residential land, the remaining land is mostly mixed with commercial and residential land	There are both residential and commercial land, and some urban villages have industrial land
Economic and Industrial Structure	The rental economy is absolutely dominant, the service industry is well developed, and villagers mostly rely on housing rental as an economic source	The rental economy is combined with the industrial economy, and the rental income is lower than that of urban villages in the central area
Spatial Form	High construction intensity, high building density, mostly multi-story or high-rise tile houses built after the 1980s, with "handshake buildings" and "one line of sky" as its typical features	The construction intensity is low, the buildings are relatively mixed, and the phenomenon of "handshake buildings" is relatively rare
Population Composition	The mobile population occupies an absolute advantage, and their occupational backgrounds are mostly white-collar workers or other part-time workers in the urban	The proportion of local villagers has increased, but the population is still mainly transient, and their occupational background is mostly industrial workers or

	areas around the urban villages they live in, which cannot be called an absolute low-income group in terms of income.	manual laborers, with a low overall income level

Table 3-1. Comparison of urban villages in central city and peripheral city.

3.1.5 Spatial Attributes and Value Reconstruction of Urban Villages in Shenzhen

The historical background of the problem of urban villages in China is the result of the rapid expansion of the area and the absorption of the surrounding rural parts during the rapid development of cities, but the corresponding land nature has not changed. China's land system is a dual structure of urban and rural areas, which corresponds to different property rights systems and land transfer fees during the construction process [19]. The transfer fees for large property rights houses in cities are high, and the law of rent change is linked to this factor; while the transfer fees for small property rights houses in rural areas are low, and the rental price is the practical price of the house as a commodity. Therefore, for a large number of migrant workers and low-income people living in urban rented houses, including even college students who have just entered the labor market, urban villages that can offer lower rents form a landing place for new immigrants and low-income groups in the city.

From the perspective of geography, it belongs to the category of city. From the perspective of social nature, it still retains elements of traditional rural areas. The urban village, which has both urban and rural characteristics, is caused by a variety of factors, including China's urban-rural dichotomy and land ownership system. At the same time, urban villages are also considered by many scholars to be a form of slum with Chinese characteristics [20].

The development of urban villages is unconscious and spontaneous. This state of development gives freedom to the occupants, and this customization of the occupants' self-living environment redefines architecture: the unity of personality of developer, architect, builder and user. At the same time, the spatial limitations of the urban village environment bring about a struggle between the occupants for the right to use any small public space. The constantly intensifying relationship between multiple parties creates an invisible logic of construction, creating a variety of architectural opportunities and types in the urban village [21].

The "urban village" is a "seamy place" in the city, and this unique status and phenomenon inevitably brings a series of social problems. For example, urban villages have a mixed population, comprising a mix of villagers, citizens, and transients. The mobile population has become a major crime group, leading to a serious security situation. In addition, urban planning is lagging behind, resulting in a large concentration of illegal and unauthorized buildings, with a unique landscape of "one-line sky", "handshake building" and "veneer building" [22]. Due to the high housing density and poor lighting and ventilation conditions, villagers live in a poor environment.

3.1.6 Transformation of urban village renewal and construction

Early urban village regeneration focused excessively on the balance of economic interests of all parties and the creation of urban physical space effects, advocating demolition and reconstruction or easy relocation, thus transforming the original urban village into an urban landscape and increasing the economic benefits of the land, while ignoring the complex internal social and demographic problems [23]. This stage of renewal and transformation starts from case facts and less theoretical research.

In the context of the transformation of land space development from incremental to stock, the idea of urban village renewal and transformation, which has been studied by experts and scholars from all walks of life for more than a decade, is also changing: from the initial focus on the physical space and environmental problems of urban villages to the focus on the internal social space structure. Currently, the renewal of urban villages is based on in-depth renewal and improvement: areas that do not have preservation value are partially demolished and rebuilt; while those with historical significance and cultural heritage are actively guided to be renewed and rebuilt [24].

In recent years, Shenzhen has adopted the approach of "property trusteeship + rent operation + comprehensive improvement" to promote the comprehensive management of urban villages, which has solved a series of problems such as dirty environment, weak security management and inconvenient traffic. Today, these urban villages are no longer a single residential carrier, but also an important place for entrepreneurship, employment and business. At the same time, the changes of urban villages also reflect the course and characteristics of Shenzhen's urbanization process and contribute to the economic development of Shenzhen.

In general, the development process of urban villages in Shenzhen is a process of continuous transformation and upgrading, improving environmental and infrastructure conditions. Nowadays, urban villages have become a unique urban landscape of Shenzhen, and also contribute to the economic development of Shenzhen.

3.2 Study unit creation and analysis

The analysis unit of study vitality is crucial to determine how urban villages affect urban vitality and to ensure the geographical continuity and comparability of the study area [25]. According to the Shenzhen Territorial Spatial Master Plan (2020-2035), Shenzhen continues to optimize the "multi-center, cluster, and ecological" urban spatial structure on the basis of the spatial structure of the previous master plan, and deeply implements the "Eastward, Westward, Southward, Northward, and Central Superiority "The new urban development pattern of "one core, multi-center network" is formed. The "one core" is the urban core area, based on Futian, Luohu, Nanshan and Qianhai Shenzhen-Hong Kong Modern Service Industry Cooperation Zone, to build 12 urban function centers and cultivate 12 urban function nodes, "network" is to promote the city's urban function centers and urban the "networking" promotes the efficient and convenient flow of all kinds of resources and factors among the city's urban functional centers and nodes. In this paper, I choose the Shenzhen city area as the research scope, and choose a 500mx500m grid to divide into spatial units as the basic unit of the research, which contains 8581 spatial units. The basic spatial units of the study are shown in Figure 3-10. Existing studies on the vitality of Shenzhen basically use urban neighborhoods as the basic research unit [26], while this paper uses a custom 500mx500m grid space cell as the basic research unit for the following reasons:

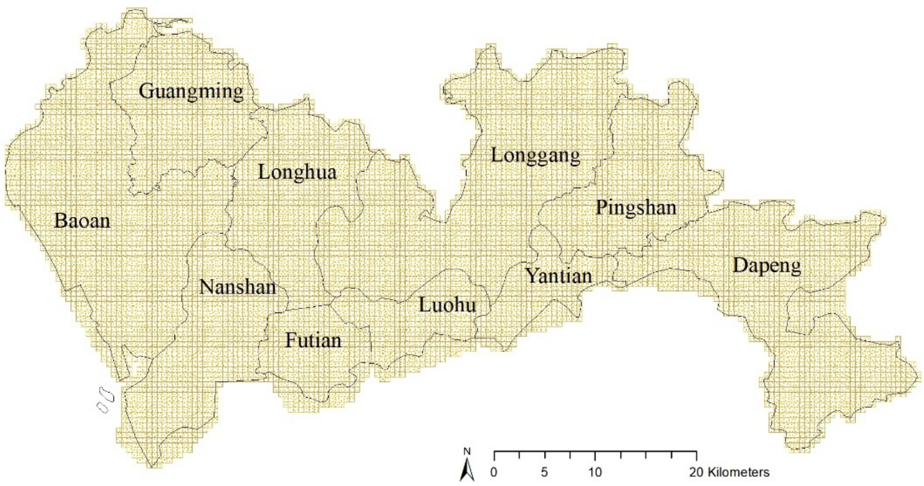

Figure 3-10. 500mx500m basic spatial units.

(1) Compared with the neighborhoods enclosed by urban roads, the spatial cells have the same area, which can avoid the extreme values of quantitative results caused by too large or too small areas of the basic cells.

(2) The existing administrative organizational units, including districts and traffic analysis zones (TAZs), have boundaries that are too large to accurately reflect the quality of vitality.

(3) This work attempts to study the impact of villages in urban collaborations on vitality using previous methods of urban vitality analysis. Typical urban villages in the central city, such as Nantou Old Town, Shuiwei Village, and Gangxia Village, have an area of 500 mx500 m (Figure 3-11). Therefore, the study area is divided into spatial units according to a 500 mx500 m grid to study the morphological elements of the urban built environment and urban vitality. It can reflect the vitality at a fine scale.

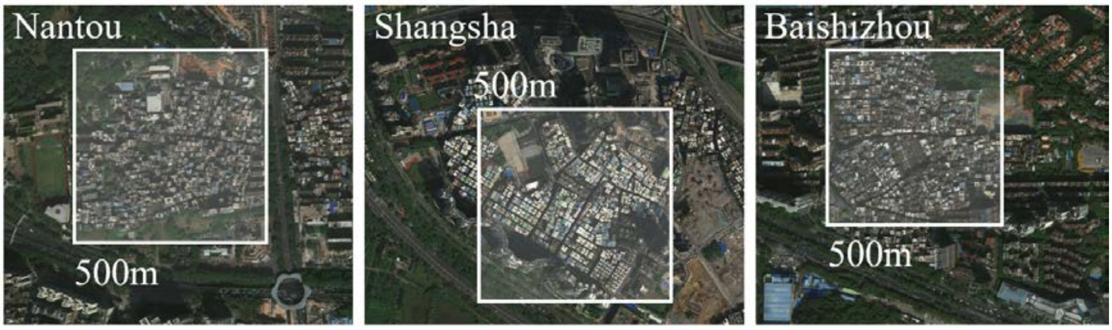

Figure 3-11. Urban village size.

In this paper, Shenzhen was gridded using tool for establishing fishing nets in ArcGIS. The tool for establishing fishing nets in ArcGIS was used to create a grid with 500 m × 500 m as a spatial unit and the administrative boundary of Shenzhen as the scope of establishing fishing nets. The point data was dropped into the grid through spatial connection, while the connection index was the unique geo-ID of each grid.

3.3 Data Sources and Data Acquisition

The purpose of this article is to investigate the relationship between urban vitality and built environment, to assess the value of urban villages from an urban perspective, and to propose possible paths and directions for urban village renewal and development. The data used in this study include: basic geographic data, planning data, urban village data, open source network data, and multi-source big data, including basic geographic and planning data including administrative boundary and surface coverage data of Shenzhen City from the National Geographic Information System, land use data of Shenzhen City, the 13th Five-Year Plan of Urban construction and land use, the Pearl River Delta Global Spatial Plan (2016-2020), the 13th Five-Year Plan for Urban Construction and Land Use in Shenzhen, the Guangdong Province Land Use Plan (2016-2035), the Three-Year Action Plan for the Construction of the Greater Bay Area, and the Guangdong Province Comprehensive Transportation System Development Plan. "Thirteen Five-Year Plan", Shenzhen Urban Construction and Land Use Master Plan (2016-2020) and other documents and data. Urban village data include the Shenzhen Urban Village (Old Village) Comprehensive Improvement Master Plan (2019-2025), and global ground coverage data. Web open-source data include the 2021 Shenzhen building vector data crawled by Gaode Map, and Shenzhen Road network data from the Open Street Map open-source map download platform [27]. Multi-source big data include POI data, cell phone signaling data, social media data, public review consumption data, and location-based bicycle sharing service (LBS) data from the Shenzhen Data Open-Source Platform [28].

According to data classification, the data involved in this paper include four categories of vitality representation, administrative division, development and construction, and transportation elements. The main contents and sources of data are as follows (Table 3-2).

Data category	Data name	Data content	Data Source	Data Period
Development and construction	Urban functional data	POI data	Amap. Available at: https://lbs.amap.com/	2021
Vitality representation	Shared bike data	Shared bike data	Shenzhen Government Data Open Platform. Available at: https://opendata.sz.gov.cn/	2021
Vitality representation	Comments data	Dianping Comments data	Dianping. Available at: https://www.dianping.com/	2017
Vitality representation	Population	Population	Shenzhen Planning and Natural Resources Bureau	2022
Administrative division	Shenzhen district boundary	Shenzhen district boundary	National Basic Geographic Information System	2021
Development and construction	Urban form data	Urban form data	OpenStreetMap. Available at: https://www.openstreetmap.org	2022
Development and construction	Urban village data	Urban village data	https://lbs.amap.com/ Shenzhen Urban Village (Old Village) Comprehensive Improvement Master Plan	2021

Development and construction	Land coverage data	Guangdong, Hong Kong, Macao and Greater Bay Area Ground Cover Data	GlobeLand30 global surface coverage data	2020
Development and construction	Landsat RS image	Landsat RS image	National Earth System Science Data Center. Available at: http://www.geodata.cn/	2022
Transportation elements data	Transportation data	Road, transportation facilities	Amap. Available at: https://lbs.amap.com/	2022

Table 3-2. Sources of data used in this study.

3.3.1 POI data acquisition and processing

POI (Point of Interest) is the point data representing the spatial geographic entities related to human activities. POI data crawled from Gaode Map, POI data for the year 2021, categories include catering, scenic spots, public facilities, companies, shopping services, transportation facilities, finance and insurance, science, education and culture, business and residential, living services, sports and leisure, medical insurance, etc., medical insurance and other 14 major categories, 152 medium categories, more than 800 small categories (Table 3-3). It covers a wide range, large quantity, easy access and high accuracy. Each POI data includes fields such as coordinates, name, and three-level category. Each POI contains information such as name, category, address, longitude, latitude, etc., which can portray the spatial location of urban elements. The POI data are processed as follows, firstly, the coordinates are screened and duplicate points and POI facility points located outside the study area are deleted.

Major category	Medium category
Food and Beverage	Chinese food, foreign food, snack fast food, coffee, cake and dessert store, cafe, other
Shopping	Shopping centers, department stores, markets, supermarkets, convenience stores, flowers, birds, fish and insects, home appliances and digital, home building materials, duty-free stores, shopping streets, cultural and sports goods, others
Business Residence	Residential area, villa area, commercial and residential buildings, dormitories, community centers, office buildings, industrial buildings, industrial parks, others
Leisure and Entertainment	Movie theaters, amusement parks, theaters, bars, chess and card rooms, Internet cafes, vacation and retirement, farmhouses, KTV, game places, others
Medical care	General hospitals, specialty hospitals, clinics, emergency centers, disease prevention, pharmaceutical sales, animal medicine, others
Sports and Fitness	Soccer, basketball, fitness center, golf, swimming, bowling, gymnasium, squash, rugby, water sports, outdoor fitness facilities, ice and snow sports, equestrian & horse racing, table tennis, billiards, taekwondo, tennis, badminton, campground, others
Science, Education and Culture	Higher education, adult education, vocational and technical education, secondary schools, elementary school, kindergartens, driving schools, training units, libraries, museums, science and technology museums, press and publication, radio and television, archives, exhibitions and exhibitions, scientific research units, art exhibitions, planetariums, cultural palaces, cultural and art groups, others

Tourist Attractions	Attractions, botanical gardens, parks, red tourism, zoos, memorials, world heritage sites, religions, squares, aquariums, others
Hotel Accommodation	Five-star hotels, four-star hotels, three-star hotels, economic chain hotels, hostels, youth hostels, others
Living Services	Public toilets, post offices, lottery sales, telecommunications offices, hairdressing, photography and printing, logistics, laundry, bath and massage, information and consultation centers, intermediaries, public utilities, others
Companies	Companies, factories, agriculture, forestry, animal husbandry and fishery, others
Transportation facilities	Public transportation, parking lots, service areas, toll stations, subways, port terminals, ports, trains, planes, ferries, coaches, others
Financial institutions	Banks, ATMs, investment and finance, insurance, others
Automobile-related	Auto sales, auto repair, auto maintenance, car wash, auto parts, auto rental, used cars, charging stations, gas stations, gas stations, other energy stations, others

Table 3-3. POI major category and medium catagory.

POI (Point of Interest) fields are often used to describe specific locations in maps or location information. POI data is essential to provide useful information in various application scenarios, such as navigation, geographic information system (GIS), route planning, etc. The acquired POI data contains 10 fields, including name, major category, medium category, minor category, latitude and longitude, and area. As shown in Figure (12).

FID	Shape *	名称	大类	中类	经度	纬度	省份	城市	区域
0	Point	东冲社区沙岗生态公园	旅游景	公园	114.580957	22.492213	广东省	深圳市	龙岗区
1	Point	深圳东冲沙滩	旅游景	其他	114.584591	22.489227	广东省	深圳市	龙岗区
2	Point	东涌水库	交通设	公交站	114.570687	22.4972	广东省	深圳市	龙岗区
3	Point	东涌浴场	交通设	公交站	114.582189	22.488976	广东省	深圳市	龙岗区
4	Point	东涌家园	交通设	公交站	114.578984	22.491514	广东省	深圳市	龙岗区
5	Point	东涌沙岗村	交通设	公交站	114.581461	22.491281	广东省	深圳市	龙岗区
6	Point	东涌	交通设	公交站	114.582024	22.489746	广东省	深圳市	龙岗区
7	Point	东涌社区工作站	交通设	公交站	114.575284	22.493188	广东省	深圳市	龙岗区
8	Point	深圳大鹏半岛国家地质生态公园	旅游景	公园	114.571314	22.521912	广东省	深圳市	龙岗区
9	Point	专用停车场	交通设	停车场	114.582585	22.48866	广东省	深圳市	龙岗区
10	Point	东冲海柴角	旅游景	景点	114.624673	22.508155	广东省	深圳市	龙岗区
11	Point	芭芭拉山庄	酒店住	经济型连锁	114.578201	22.493389	广东省	深圳市	龙岗区
12	Point	公厕	生活服	公厕	114.600895	22.537603	广东省	深圳市	龙岗区
13	Point	东涌沙岗固定公厕	生活服	公厕	114.580654	22.491672	广东省	深圳市	龙岗区
14	Point	无障碍公厕	生活服	公厕	114.571893	22.493049	广东省	深圳市	龙岗区
15	Point	鹿雁科考线	旅游景	其他	114.602853	22.536027	广东省	深圳市	龙岗区
16	Point	天后宫	旅游景	宗教	114.582226	22.488103	广东省	深圳市	龙岗区
17	Point	东涌海滩	旅游景	其他	114.585842	22.48946	广东省	深圳市	龙岗区
18	Point	深圳东涌遇见三米民宿酒店	酒店住	旅馆	114.582161	22.491926	广东省	深圳市	龙岗区
19	Point	深圳东涌遇见三米民宿酒店	购物消	其他	114.581734	22.491891	广东省	深圳市	龙岗区
20	Point	东涌码头	交通设	港口码头	114.583218	22.487343	广东省	深圳市	龙岗区
21	Point	新豪方东涌豪华酒店	酒店住	其他	114.582873	22.491655	广东省	深圳市	龙岗区
22	Point	深圳蓝斯精品度假豪华酒店	酒店住	旅馆	114.58247	22.488113	广东省	深圳市	龙岗区
23	Point	深圳东涌Blue冲浪民宿酒店	酒店住	其他	114.582741	22.488617	广东省	深圳市	龙岗区
24	Point	深圳星淋沐屋	酒店住	其他	114.582558	22.489657	广东省	深圳市	龙岗区
25	Point	深圳东游记民宿酒店	酒店住	其他	114.576855	22.492903	广东省	深圳市	龙岗区
26	Point	深圳潜舍旅馆	酒店住	旅馆	114.581469	22.491935	广东省	深圳市	龙岗区
27	Point	深圳木马旅馆	酒店住	旅馆	114.581912	22.487771	广东省	深圳市	龙岗区
28	Point	深圳好友富民宿酒店	酒店住	其他	114.58193	22.491923	广东省	深圳市	龙岗区
29	Point	山海盈居	商务住	住宅区	114.583106	22.487413	广东省	深圳市	龙岗区
30	Point	东涌小区	商务住	住宅区	114.573521	22.492856	广东省	深圳市	龙岗区

Figure 3-12. POI data content.

Coordinate correction was performed on all kinds of POI data to obtain the data under the earth coordinate system (WGS84), and imported into ArcGIS for projection. And connect all kinds of POI data with Shenzhen administrative district boundary data, give information of the area to which each POI data belongs, and delete the data outside the boundary of Shenzhen urban area, the final data statistics total 685,217 items, including 169913 items in central urban area and 515,304 items in non-central urban area (Figure 3-13).

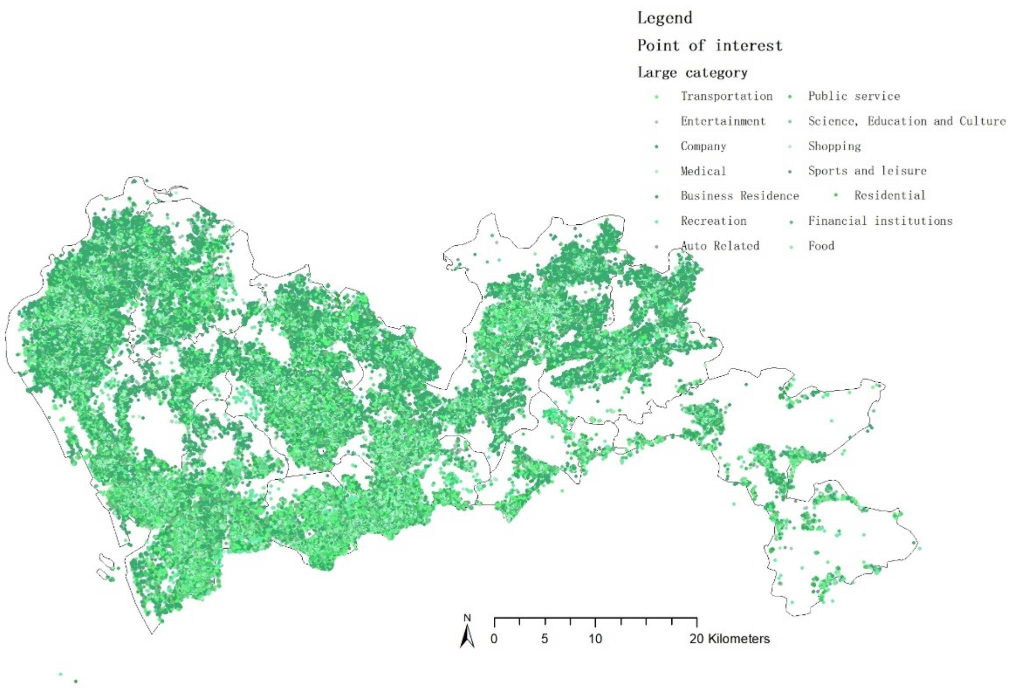

Figure 3-13. POI visualization distribution.

3.3.2 Social interaction data acquisition and processing

3.3.2.1 Shared bike data

Shared bike data is a new type of transportation based on the sharing economy model, in which users can rent bicycles through a cell phone app and park them at designated parking spots when needed. The emergence of shared bicycles aims to solve the urban travel problem and improve the efficiency and convenience of travel, while also having the characteristics of environmental protection and low carbon. Shared bicycles usually use smart locks, GPS positioning and other technologies to achieve vehicle management, and users can unlock, pay and return the bicycle through cell phone app [29]. Bike-sharing companies usually place and manage vehicles based on factors such as market demand and operating costs, and also cooperate with city governments to develop relevant policies and regulations to ensure the safe and orderly operation of shared bikes.

There is a close connection between bike-sharing data and city vitality. By collecting and analyzing bike-sharing data, I can better understand the travel conditions, traffic congestion, and user behavior of cities, thus providing decision support for urban planning and management. Related studies show that bike-sharing has an impact on cities in terms of improving travel efficiency, promoting green urban mobility, improving urban traffic conditions, and driving urban economic development, providing an important reference basis for urban planning and development.

Shared bicycles are widely used in studies such as urban spatial linkage because of their wide coverage, all-weather coverage, and precise spatial-temporal characteristics of the data, which can show the travel information of residents more objectively. This study obtained daily data of 1884312 shared bicycles from February 14, 2018 to February 15, 2021 by calling the API interface of shared bicycle data from Shenzhen Data Open Platform. Since people use bike-sharing trips on weekdays mainly for commuting, and most of their autonomous activities take place on weekends, the weekend data are chosen to reflect the active level of social dynamics. The amount of data is too large, and I clean and filter the data. I selected data from January 30 and 31, 2021 for the study, and the processed data totaled 384,879 items, including data on unlocking time, unlocking latitude and longitude, bike ID, unlocking time, and unlocking latitude and longitude (Figure 3-14, 3-15).

2021/1/31 23:56	22.53632138	2021/1/31 23:59	113.9202	bfc1fccb652cf	113.91792	22.53908
2021/1/31 23:44	22.61302112	2021/1/31 23:59	114.0372	ab0da44f6c04	114.03237	22.60146
2021/1/31 23:55	22.5475821	2021/1/31 23:59	114.1257	6c55add7692	114.12772	22.54379
2021/1/31 23:51	22.54949922	2021/1/31 23:59	114.1323	9278460de36	114.12838	22.55208
2021/1/31 23:51	22.54945472	2021/1/31 23:59	114.1323	723f7efa1aab	114.12833	22.55203
2021/1/31 22:27	22.6013626	2021/1/31 23:59	113.8469	4ebd7f9cd8c2	113.84679	22.59773
2021/1/31 23:55	22.6411485	2021/1/31 23:59	113.8494	a630e89f0c0f	113.83183	22.72353
2021/1/31 23:52	22.5497445	2021/1/31 23:59	114.1276	0d976395b89	114.12141	22.54331
2021/1/31 23:55	22.66402184	2021/1/31 23:59	114.0251	4b6a33fbb0d	114.02851	22.66017
2021/1/31 23:55	22.66402184	2021/1/31 23:59	114.0251	0a5a967d937	114.02851	22.66017
2021/1/31 23:58	22.53848099	2021/1/31 23:59	114.1244	a9b0c019b3cf	114.12321	22.5368
2021/1/31 23:42	22.60774787	2021/1/31 23:59	114.1515	bca4d4e49cf6	114.13148	22.60684
2021/1/31 23:49	22.5090797	2021/1/31 23:59	113.9146	ae91f8ea15a9	113.91805	22.5123
2021/1/31 23:53	22.54789761	2021/1/31 23:59	114.1247	3340239bfd3	114.12189	22.54329
2021/1/31 23:54	22.7967689	2021/1/31 23:59	113.8707	320a1c55911f	113.8632	22.79587
2021/1/31 23:24	22.6793932	2021/1/31 23:59	113.7844	bd8068964e4	113.80184	22.67644
2021/1/31 23:47	22.5542356	2021/1/31 23:59	113.8933	652d1f57eca0	113.88652	22.56151
2021/1/31 23:42	22.55572001	2021/1/31 23:59	114.0379	b73a31b81e4	114.03773	22.55602
2021/1/31 23:42	22.55576101	2021/1/31 23:59	114.038	a9db01be12b	114.03777	22.55606
2021/1/31 20:43	22.6153608	2021/1/31 23:59	113.926	df56bd90692	113.83726	22.58211
2021/1/31 23:44	22.6790243	2021/1/31 23:59	113.7974	4209377f10d	113.79783	22.67771
2021/1/31 23:55	22.7618221	2021/1/31 23:59	113.8383	f537ee07b726	113.79946	22.77236
2021/1/31 23:52	22.5560286	2021/1/31 23:59	113.8047	c6a15aacc9b1	113.94839	22.71521
2021/1/31 23:56	22.56103315	2021/1/31 23:59	114.113	4f5f08365127	114.10668	22.56506
2021/1/31 23:47	22.67764286	2021/1/31 23:59	113.9525	ea2d0cd7821	113.93535	22.67894

Figure 3-14. Shared bike data content.

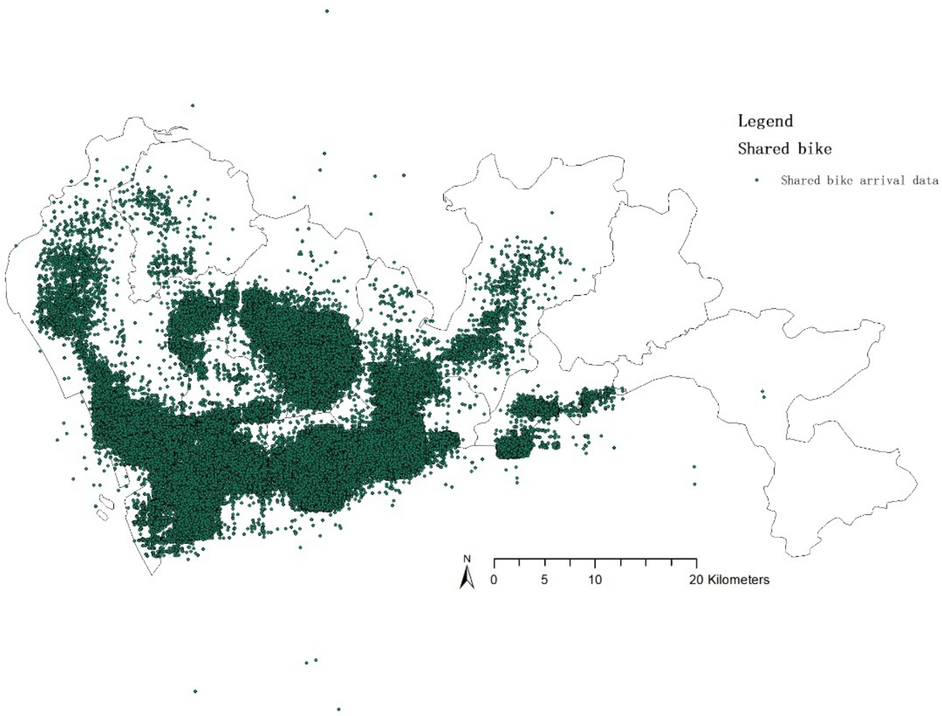

Figure 3-15. Shared bike arrival data distribution.

3.3.2.2 Mobile phone signaling data

Cell phone signaling data is the communication data between cell phone users and transmitting base stations or micro stations. As long as the two conditions are satisfied that the phone is turned on and the word operator (China Mobile, China Unicom, China Telecom) is shown on the screen, the signaling data will start to be generated. After that when you use your cell phone to make and receive calls, send and receive SMS, surf the web and all other communication behaviors, you will send communication relationship with the base station near your cell phone. Since the location of the communication base station is fixed and known, the location information of the base station reflects the user's location, so the cell phone signaling data field always carries information such as time and location. Therefore, cell phone signaling data is a good reflection of the movement and distribution of the population [30].

Mobile phone signaling can be used to analyze the vitality of a city. By collecting and analyzing the mobile phone signaling data, the number of people in the city, the population density, the movement of people and other information can be deduced to assess the vitality of the city. At the same time, cell phone signaling data can also be used to assist in decision making in urban planning and traffic management to improve the overall efficiency of the city. In urban planning, cell phone signaling data can be used to analyze the flow of people in different areas, thus providing more accurate data support for urban planning. And in traffic management, cell phone signaling data can be used to analyze road congestion, thus providing more accurate information support for urban traffic management. As a big data technology, cell phone signaling can reflect social interactions and provide powerful support for studying social networks and social relationships, as well as vitality analysis and decision making in cities.

China Unicom was established on January 6, 2009 through the merger and reorganization of the former China Netcom and the former China Unicom. The company has branches in 31 provinces (autonomous regions and municipalities directly under the Central Government) and many countries and regions outside China, as well as more than 130 overseas access points, with a modern communication network and global customer service system covering the whole country and the whole world. Currently, the number of "Big Connect" subscribers exceeds 850 million. In this article, I obtained 2019 cell phone signaling data from Unicom to obtain information on the spatial location and spatial and temporal trajectories of users in Shenzhen during daytime and nighttime. The data content includes information such as connected base station ID, time, etc (Figure 3-16).

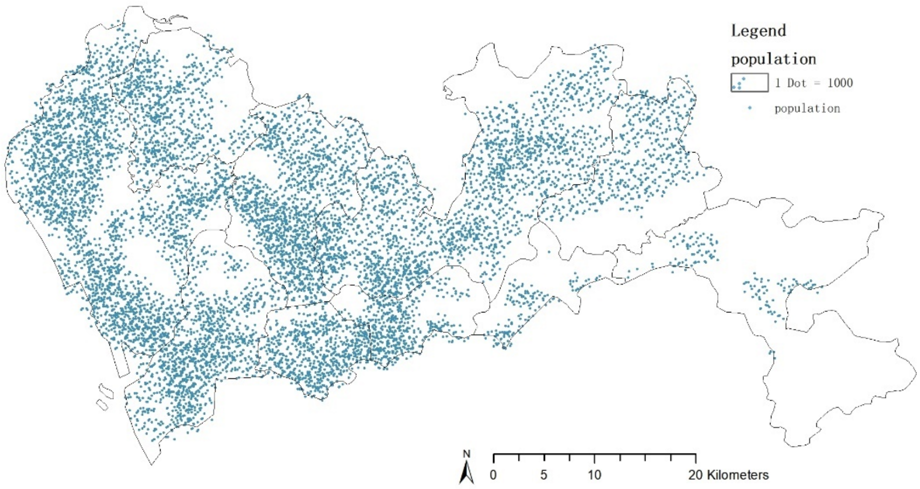

Figure 3-16. Population distribution.

3.3.3 Consumer behavior data acquisition and processing

This paper selects data from Dianping, one of the most influential platforms in the local life field in

China, as the basis. Founded in 2003, Dianping is a comprehensive life service platform aiming to provide users with information and consumption experiences in restaurants, food, shopping, leisure and entertainment. Dianping's main business includes information release and user reviews of restaurants, gourmet food, hotels, KTV, movie theaters, beauty salons, bath and massage places, and also provides consumer services such as group purchases and coupons. Users can search and browse business information on Dianping, view other users' ratings and reviews, and make online reservations and purchases. Dianping has a very large market share in China and is one of the largest local lifestyle service platforms in China. Acknowledged as a consumer guide to Chinese cities, Dianping data proved to be very useful in understanding China’s urban geography [31]. It has a wide range of user groups, including young people, white-collar workers, housewives and other various age groups and occupational groups. It can reflect data on how active people are in leisure and entertainment.

An increase in the number of reviews may mean that the store receives more attention and reviews from more people, which may make more people interested in the store and thus increase the customer traffic and turnover. However, the vitality of a store is also related to its food quality, service quality, environment and other factors, and the increase in the number of reviews alone does not fully indicate the vitality of a restaurant. The number of reviews can be used as a reference indicator to assess its vitality level, but other factors also need to be taken into account. In this paper, I select review data as a reference for economic vitality.

Therefore, this paper obtained the review data from the public review website https://www.dianping.com/ (accessed on February 21, 2022). The data content is shown in Fig. (), which contains 14 fields such as restaurant name, star rating, number of reviews, type, administrative district, rating, latitude and longitude (Figure 3-17). A total of 56658 data were obtained.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
饭店名	星级	评论数	人均消费	饭店类型	行政区	商圈	地址	口味评分	环境评分	服务评分	纬度	经度	城市
浙礼(龙华	四星商户	2114	75	江浙菜	龙华新区	民治	人民路202	8	8.3	7.9	22.62772	114.0213	Shenzhen
六千馆(茂	四星商户	1310	58	江浙菜	龙华新区	东门商业圈	和平路300	7.7	7.7	7.5	22.54419	114.1139	Shenzhen
六千馆(龙	四星商户	935	71	江浙菜	龙华新区	龙华	丰益路1号	8	8.1	8.1	22.65396	114.02	Shenzhen
二小姐的店	准四星商户	534	73	江浙菜	龙华新区	龙华	东环二路8	7.4	8.4	7.9	22.65605	114.0377	Shenzhen
鱼米香家常	准四星商户	428	69	家常菜	龙华新区	雁栖开发区	雁栖经济开	7.7	7.9	7.6	40.36285	116.6744	Shenzhen
西湖小馆(观	准四星商户	31	71	江浙菜	龙华新区	观澜	观澜湖新城	7	7.5	7	22.72269	114.0751	Shenzhen
江南小调	准四星商户	103	70	江浙菜	龙华新区	民治	民治大道优	7.1	8.3	7.5	22.62811	114.0367	Shenzhen
疯味肉蟹煲	准四星商户	38	95	江浙菜	龙华新区	龙华	汇海广场3	7.4	7.8	7.7	22.65753	114.0277	Shenzhen
阳澄湖大闸	三星商户		60	江浙菜	龙华新区	龙华	三联路美丽365花园华园道103号				22.66454	114.0313	Shenzhen
厨子印象(	三星商户	1170	66	江浙菜	龙华新区	民治	梅龙路2号	6.3	6.9	6.5	22.60261	114.0461	Shenzhen
江南印象(	三星商户	228	65	江浙菜	龙华新区	深圳火车北	深圳北站东	6.4	6.9	6.6	22.61157	114.0326	Shenzhen
鹰鹏草原	准四星商户	121	82	烧烤	龙华新区	龙华	龙华东环二	7.4	7.2	7.4	22.6602	114.0312	Shenzhen
湘江小厨	准四星商户	7		江浙菜	龙华新区	龙华	龙华街道东	7.2	7.2	7.3	22.65444	114.0437	Shenzhen
大红灯笼(	准四星商户	1		江浙菜	龙华新区	民治	民治街道人	7	7	7	22.6282	114.0238	Shenzhen
食寨美味(	准四星商户	8	33	江浙菜	龙华新区	大浪	大浪浪口金	7	7	7	22.68127	114.0188	Shenzhen
农家小厨	准四星商户	1		江浙菜	龙华新区	观澜	松元社区旭	7	7	7	22.71969	114.0644	Shenzhen
化州B记鸡	三星商户	1		江浙菜	龙华新区	龙华	花园新村9	6.9	6.9	6.9	22.66119	114.0185	Shenzhen
紫金人家	准四星商户	1	89	江浙菜	龙华新区	龙华	联康一路和	6.9	6.9	6.9	22.66053	114.0186	Shenzhen
天天爱吃猪	准四星商户	1		江浙菜	龙华新区	民治	民治大道白	6.9	6.9	6.9	22.60519	114.0385	Shenzhen
廉怡小菜市	准四星商户	1		江浙菜	龙华新区	大浪	华繁路附近	6.9	6.9	6.9	22.67686	113.99	Shenzhen
民新饭店	三星商户	1		江浙菜	龙华新区	龙华	三联路锦绣	6.9	6.9	6.9	22.66086	114.0255	Shenzhen
实惠饭店	三星商户	1		江浙菜	龙华新区	龙华	乐家福百货	6.9	6.9	6.9	22.65754	114.0458	Shenzhen
竹知味	三星商户			江浙菜	龙华新区	龙华	龙华镇龙观路郭吓村7巷3栋1楼				22.66304	114.0172	Shenzhen
美味鲜	三星商户			江浙菜	龙华新区	梅林关	梅龙路与民乐路交叉口东				22.60506	114.0449	Shenzhen
龙华潮客	三星商户			江浙菜	龙华新区	龙华	龙华街道景华新村西区12栋101商铺				22.65448	114.0226	Shenzhen
常德土菜馆	三星商户			江浙菜	龙华新区	民治	民福南路郭府				22.61515	114.0388	Shenzhen
重庆天天	三星商户	1		江浙菜	龙华新区	龙华新区	龙华区民治	6.4	6.4	6.4	22.62527	114.0375	Shenzhen
湘味菜馆	准四星商户	1		江浙菜	龙华新区	大浪	华兴路与	7	7	7	22.67869	113.9933	Shenzhen
巴澄牌阳澄	该商户暂无星级			江浙菜	龙华新区	龙华新区	民治街道民丰路127号				22.61165	114.0443	Shenzhen
井冈山庐陵	该商户暂无星级			江浙菜	龙华新区	观澜	新湖北街星源楼旁				22.70367	114.0921	Shenzhen
顾家豫厨	该商户暂无星级			江浙菜	龙华新区	龙华	油松路与工业路交叉口				22.63838	114.0434	Shenzhen
老友私房土	该商户暂无星级			江浙菜	龙华新区	民治	龙华民治大道水尾二区22栋一楼				22.62645	114.0374	Shenzhen
大闸蟹	该商户暂无星级			江浙菜	龙华新区	龙华新区	龙华新区龙华街道花园新村沿河路47栋24号				22.65942	114.0193	Shenzhen
名海餐厅	该商户暂无星级			江浙菜	龙华新区	龙华新区	观湖街道下湖社区樟坑径下围北三巷1号1楼				22.68849	114.0766	Shenzhen
大红灯笼	该商户暂无星级			江浙菜	龙华新区	深圳火车北	民治龙悦居				22.60346	114.0305	Shenzhen
雷州羊肉馆	该商户暂无星级			江浙菜	龙华新区	龙华	华龙路与和平路交叉口西				22.65391	114.026	Shenzhen
老上海大馆	该商户暂无星级			江浙菜	龙华新区	龙华	龙华街道福茂新村42-1号铺				22.66247	114.0342	Shenzhen

shop_id	mall_id	verified	is_closed	name	alias	province	city	city_pinyin	city_id	area	big_cate	big_cate_i	small_cate	small_cate	address	business_a	phone	hours	avg_price	stars
521772		FALSE	TRUE	满泉楼中餐厅		广东	深圳	shenzhen	7	宝安区	美食	10	粤菜	g103	深圳国际机	宝安中心区	0755-27300888转			
521773		FALSE	TRUE	南尚海鲜酒楼		广东	深圳	shenzhen	7	宝安区	美食	10	粤菜	g103	松岗镇楼岗	松岗	0755-27098111转			
521774		TRUE	TRUE	晶都城渔港		广东	深圳	shenzhen	7	龙岗区	美食	10	粤菜	g103	龙岗区平湖	平湖	0755-28851888			
521775		FALSE	TRUE	香蜜湖东座酒店		广东	深圳	shenzhen	7	福田区	美食	10			深南大道香	香蜜湖	无			
521776		TRUE	TRUE	中山银苑酒楼		广东	深圳	shenzhen	7	南山区	美食	10	粤菜	g103	南山大道中	南头	0755-26969688,0755-26968988			
521777		FALSE	TRUE	广食坊		广东	深圳	shenzhen	7	福田区	美食	10	粤菜	g103	福华路326	岗厦	无			
521778		FALSE	TRUE	广食坊		广东	深圳	shenzhen	7	福田区	美食	10	粤菜	g103	福民路石厦	石厦	0755-83862669			
521779		FALSE	TRUE	锅加锅		广东	深圳	shenzhen	7	宝安区	美食	10	火锅	g110	34区雅兰	宝安中心区	无			
521780		FALSE	TRUE	锅加锅		广东	深圳	shenzhen	7	福田区	美食	10	火锅	g110	沙嘴路53	新洲	无			
521782		TRUE	FALSE	锅加锅		广东	深圳	shenzhen	7	南山区	美食	10	火锅	g110	南山大道1	南油	0755-264	10:00——	78	
521783		TRUE	FALSE	谭鱼头		广东	深圳	shenzhen	7	福田区	美食	10	火锅	g110	深南中路2	华强北	0755-836	10:00-22:0	82	
521784		FALSE	TRUE	巴蜀饭庄(福安街店)		广东	深圳	shenzhen	7	福田区	美食	10	川菜	g102	福安街79	皇岗	无			
521786		FALSE	TRUE	三湘人家(华侨城店)		广东	深圳	shenzhen	7	南山区	美食	10	湘菜	g104	华侨城西	华侨城	无			
521787		FALSE	TRUE	三湘人家(南山店)		广东	深圳	shenzhen	7	南山区	美食	10	湘菜	g104	南山大道	南油	无			
521788		FALSE	TRUE	裕发煲煲店		广东	深圳	shenzhen	7	福田区	美食	10	粤菜	g103	上步中路	华强北	0755-83755948			
521789		FALSE	TRUE	一加长沙粉面馆		广东	深圳	shenzhen	7	福田区	美食	10	小吃快餐	g112	八卦三路	八卦岭/园	0755-25915768			
521790		FALSE	TRUE	罗浮客家王食府		广东	深圳	shenzhen	7	福田区	美食	10	粤菜	g103	同心路103	荔枝公园	0755-82063446			
521791		FALSE	TRUE	飘满地带		广东	深圳	shenzhen	7	福田区	美食	10	西餐	g116	东园路33	荔枝公园	0755-82243282			
521792		FALSE	TRUE	梦都中西餐		广东	深圳	shenzhen	7	福田区	美食	10	小吃快餐	g112	巴登街11	荔枝公园	无			
521793		TRUE	FALSE	顺德渔村		广东	深圳	shenzhen	7	福田区	美食	10	粤菜	g103	上步同心	荔枝公园	0755-822	10:00-22:3	69	3.
521794		FALSE	TRUE	新兴饺子馆		广东	深圳	shenzhen	7	福田区	美食	10	东北菜	g106	景田北路	景田	0755-83932666			
521795		FALSE	FALSE	挪亚西餐厅		广东	深圳	shenzhen	7	福田区	美食	10	西餐	g116	新闻路57	景田	0755-333	尚无营业时间		3.
521796		FALSE	TRUE	巴蜀苑		广东	深圳	shenzhen	7	福田区	美食	10	川菜	g102	景田北路	景田	0755-83932434			
521797		FALSE	TRUE	东方明珠大酒楼(罗湖		广东	深圳	shenzhen	7	罗湖区	美食	10	粤菜	g103	爱国路100	翠竹路沿	0755-25671668			
521798		TRUE	FALSE	印尼海鲜酒家		广东	深圳	shenzhen	7	南山区	美食	10	粤菜	g103	福清街2号	华侨城	0755-269	7:00-22:00	91	
521799		FALSE	TRUE	东方明珠大酒楼		广东	深圳	shenzhen	7	宝安区	美食	10	粤菜	g103	宝安31区	宝安中心区	0755-27850666,0755-27851111			

Figure 3-17. Dianping comment data content.

The data were imported into ArcGIS and pre-processed by removing missing values, filling blank areas, and correcting coordinate errors to eliminate errors, duplicate items, or inconsistent data. Then the projection to the unified WGS1984 coordinate system of this study and the topology tool was used to perform operations such as element linking to obtain the spatial distribution map (Figure 3-18).

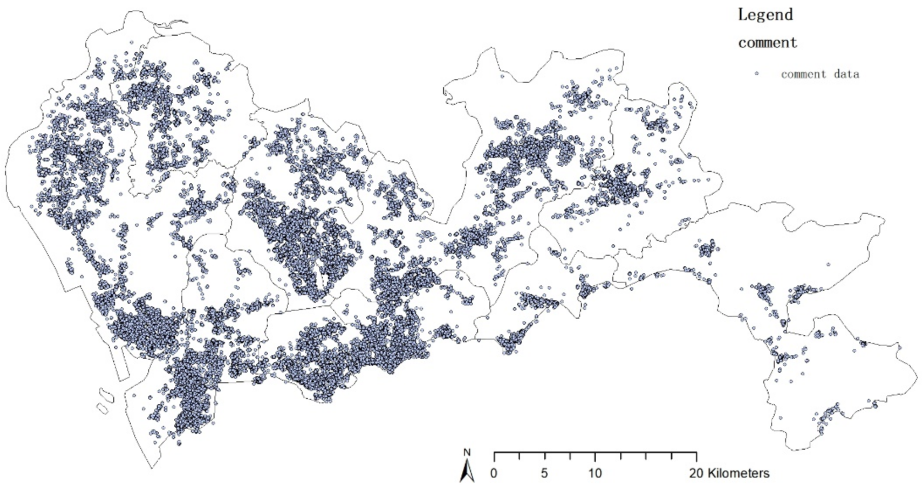

Figure 3-18. Dianping comment data distribution.

3.3.4 Urban morphology data acquisition and processing

Urban morphological data are data used to describe the characteristics of urban spatial layout, architectural style, land use type, etc. The urban morphology data mainly used in this study include map data, remote sensing data, building data and ground cover data. The map data were obtained from Sky Map (https://map.tianditu.gov.cn/). Remote sensing data were obtained from http://www.geodata.cn/ (accessed on 21 February 2022). The building spatial distribution data were mainly obtained from the OpenStreetMap web public dataset, and the OpenStreetMap current topographic map data contained building contour lines and building height information. ArcGIS is further used to check the coordinate system and visualize the collected results, and the vector surface data of Shenzhen administrative district is used to crop them to obtain the building distribution data of Shenzhen (Figure 3-19). The surface coverage data is obtained from GlobeLand30 global surface coverage data, which also includes data recording the location, area, height and other information of various surface coverage types (such as roads, buildings, green areas, etc.) in the city, and can help city managers better understand the surface coverage of the city and make more effective urban planning and policies by acquiring them through geographic information systems (GIS).

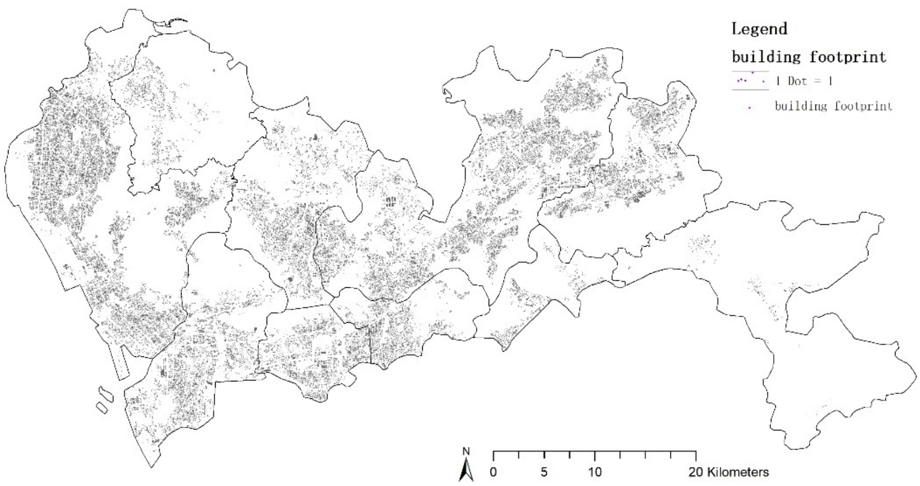

Figure 3-19. Building distribution in Shenzhen.

3.3.5 Traffic data acquisition and processing

The traffic data in this paper are mainly obtained from the Shenzhen Road network data (http://download.openstreetmap.fr/extracts/asia/china/?C=M;O=A) obtained from the OpenStreetMap web public dataset. Subsequently, the ArcGIS platform is used to import the basic data to construct the traffic network model of Shenzhen (Figure 3-20). The traffic network is mainly composed of four levels: high trunk roads, secondary roads, tertiary roads and feeder roads. Pre-processing of the road network data, the road network vector data obtained from the OSM open platform has a large number of duplicate roads and broken roads, delete duplicate roads, and combine remote sensing images to complete broken roads, interrupt all road intersection lines in ArcGIS to form road intersections. After the topological check of the road network, the basic attributes of the roads are set according to the relevant specifications [32].

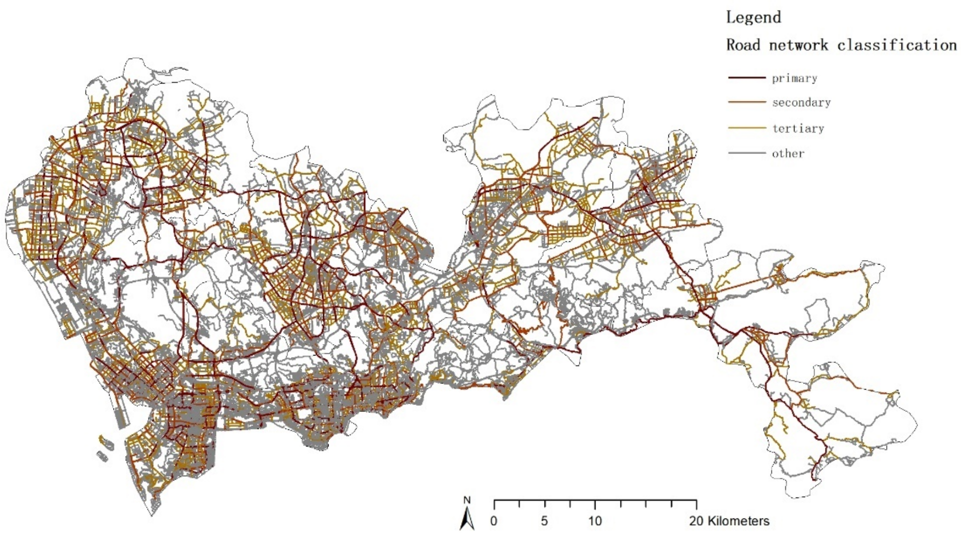

Figure 3-20. Building distribution in Shenzhen.

The construction goal of Shenzhen Road network is to build "eight horizontal and thirteen vertical" high speed road network system, with a total mileage of about 998 kilometers. At present, the total length of Shenzhen's roads has exceeded 13,000 kilometers, including highways, trunk roads, secondary roads, feeder roads and other types of roads. In the construction of the urban road network, Shenzhen focuses on improving road density and road quality to meet the needs of rapid urban development. At the same time, Shenzhen also actively promotes the construction of intelligent transportation and introduces advanced traffic management systems and intelligent facilities to improve the efficiency and safety of traffic operation.

In addition, Shenzhen also focuses on the development of public transportation and has built public transportation facilities such as subways, buses and railways to provide a convenient way for the public to get around. In recent years, Shenzhen is also actively promoting bicycle travel and pedestrian travel by building numerous bicycle paths and pedestrian trails to encourage citizens to choose low-carbon and environmentally friendly travel modes. Therefore, the analysis of the transportation network is crucial to the development and construction of the city. As shown in Figure (3-21). Shenzhen has a high density of transportation facilities, with a relatively even distribution in each district.

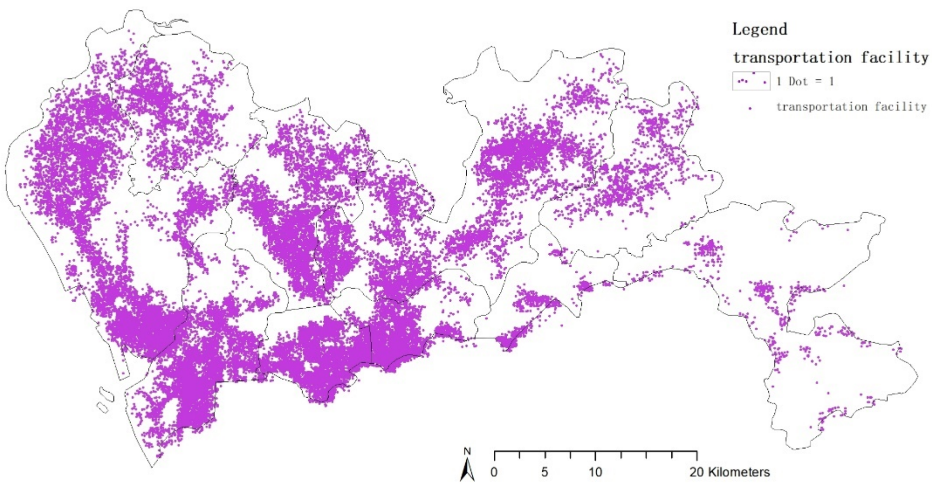

Figure 3-21. Transportation facilities distribution in Shenzhen.

3.3.6 Acquisition and processing of urban village data

Since the descriptions of the basic profiles of urban villages in the previous paper were obtained from the Shenzhen Bureau of Planning and Natural Resources, direct vector and data with geographic information were not obtained, only graphic records were available. Therefore, in this paper, from the perspective of big data, I adopt the way of crawling data from Gaode Map to obtain the point data of urban villages for analysis. Finally, a total of 2460 urban village point data were obtained, and the data were mainly urban village point data, and the data were obtained in 2021, containing 11 fields (Figure 3-22). The urban village point data were processed and analyzed in ArcGIS. Including eliminating irrelevant fields, visualizing the distribution of urban villages in Shenzhen based on latitude and longitude data (Figure 3-23). Combined with the sky map high-definition satellite image map, information such as the plan layout overview of each urban village can be captured (Figure 3-24).

FID	Shape *	name	address	adname	pname	cityname	tel	type	lon	lat
0	Point	大望村	新平大道	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名|商务住宅;住宅区;	114. 166879	22. 605837
1	Point	向西村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 120581	22. 545319
2	Point	莲塘	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 163914	22. 56566
3	Point	田心村	宝岗路168号	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名|商务住宅;住宅区;	114. 107941	22. 56964
4	Point	文锦渡	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 121416	22. 543252
5	Point	水贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 120551	22. 574605
6	Point	独树	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 119228	22. 578856
7	Point	附城	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 126491	22. 546465
8	Point	新桥	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 139595	22. 545333
9	Point	新湖	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 11269	22. 537565
10	Point	田贝村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 117926	22. 566036
11	Point	湖贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 124101	22. 548709
12	Point	大坪	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 173061	22. 60471
13	Point	向东	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 122191	22. 544335
14	Point	大径	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 165677	22. 597162
15	Point	长岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 178967	22. 557747
16	Point	怡景花园	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 13374	22. 55855
17	Point	梅岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 19433	22. 59695
18	Point	坳下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 164257	22. 569826
19	Point	西岭下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 152446	22. 555729
20	Point	旧围	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 103784	22. 547619
21	Point	茅径	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 096736	22. 57801
22	Point	上田贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 116879	22. 567156
23	Point	洪岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 102547	22. 5572
24	Point	田心村牌坊	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 107816	22. 569765
25	Point	上下坪	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 080508	22. 596159
26	Point	新田村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 172211	22. 604678
27	Point	新屋下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 110126	22. 59191
28	Point	大望耕作口	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 162838	22. 606643
29	Point	禾塘岗	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 182597	22. 597222
30	Point	落马石	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 176395	22. 613309
31	Point	马水凤	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 192335	22. 589193
32	Point	坷河顶	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 200718	22. 58949
33	Point	沥婆嘴	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 178835	22. 589353
34	Point	甜竹桥	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 192225	22. 595568
35	Point	布心村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 134483	22. 581659
36	Point	金鹏社区	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 126635	22. 588347
37	Point	湖南围	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 115856	22. 544092
38	Point	禾塘光	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 180181	22. 597924
39	Point	怡景中心	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 126529	22. 55611
40	Point	草埔吓屋村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 113269	22. 588264
41	Point	黄獠寮顶	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 198216	22. 602874
42	Point	溪头下厝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 132254	22. 559215
43	Point	横排岭村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 192809	22. 596539
44	Point	蔡围屋	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 101213	22. 547193
45	Point	黄咪楼	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 104548	22. 587388
46	Point	曼妥思	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 130983	22. 545773
47	Point	清水河	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 109784	22. 585944
48	Point	城工场	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 189228	22. 592007
49	Point	塘坑仔	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 181823	22. 599145
50	Point	长盛庄家	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114. 105137	22. 553711

Figure 3-22. Urban village data content.

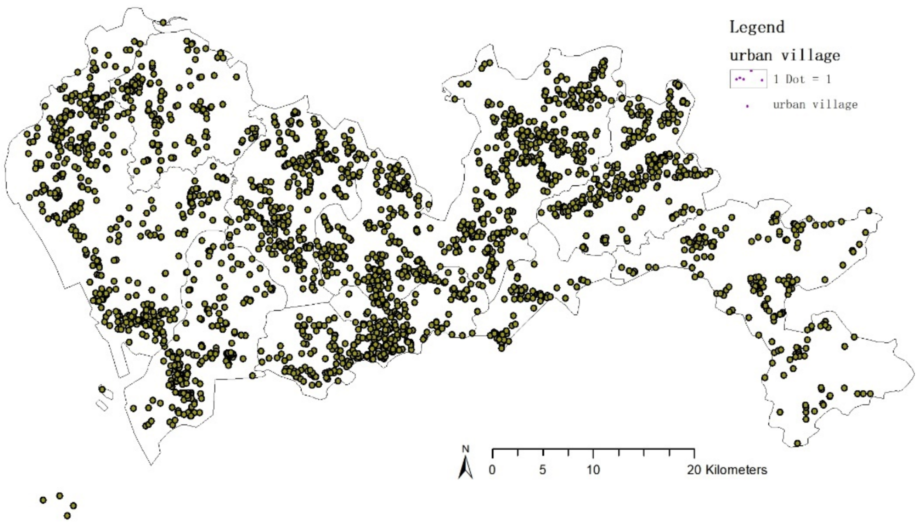

Figure 3-23. Urban villages distribution in Shenzhen.

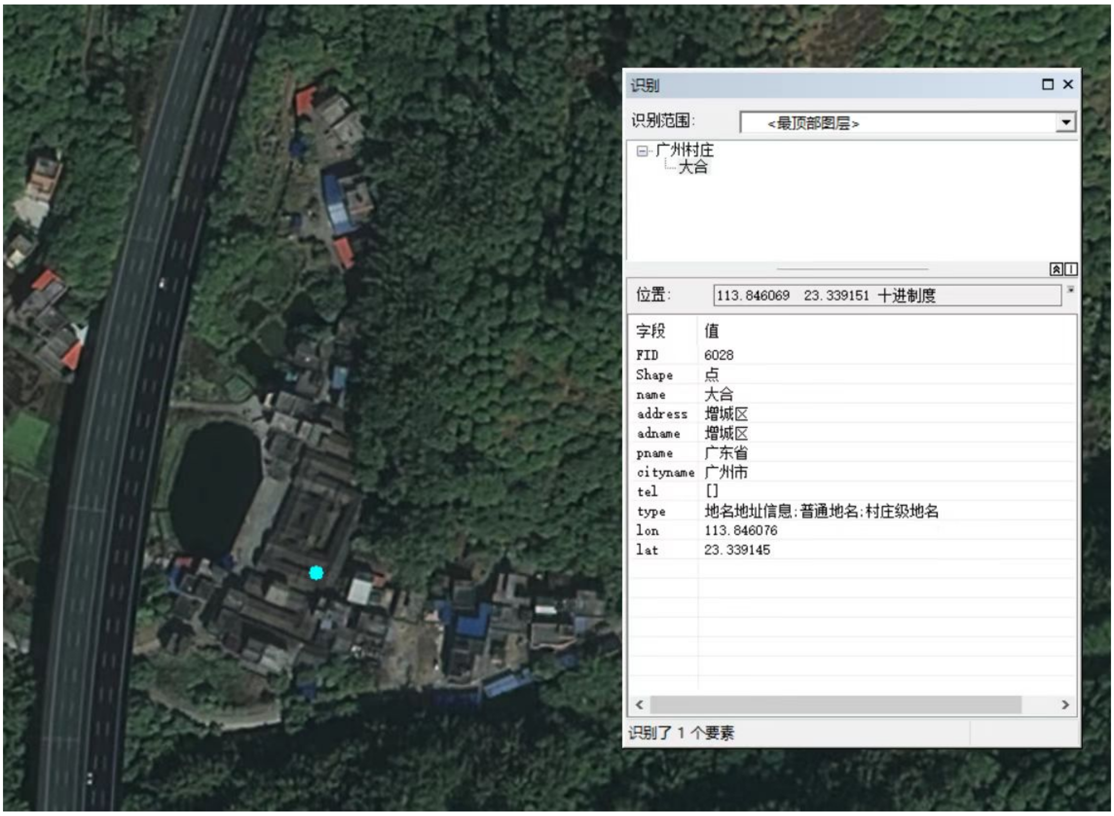

Figure 3-24. Plan layout overview of urban village.

3.4 Data pre-processing

This paper uses a large amount of data for support, especially the acquired big data, because of its large amount of data, poor data quality, different data sources, and different needs of data analysis, before data analysis, modeling and mining, a series of operations such as cleaning, conversion, integration and statute of the original data are needed to improve the accuracy, integrity, consistency and usability of the data. All data are processed in a uniform WGS1984 geographic coordinate system with Universal Transverse Mercator projection (UTM) [33].

The main data processing software used includes ArcGIS and Jupiter notebook. the processing process mainly includes importing data, checking data, filtering data, and linking with the spatial unit of fishery network data divided. For example, POI data are imported into GIS software, appropriate fields are selected for linking, and the data are spatially aligned according to geographical location, and problematic data are eliminated and other operations [34]; the road network vector data obtained from OSM open platform has a large number of duplicate roads and broken roads, duplicate roads are deleted and combined with remote sensing images to complete broken roads, and topological relationships are established with the cleaned road layers to generate intersections [35]. Obtain the distribution of road intersections, etc. Do the data preparation work before data analysis.

3.5 Research methods

3.5.1 Entropy value method

Entropy Value Method (EVM) is a comprehensive evaluation method with multiple indicators. The basic principle of the Entropy Value Method is the concept of information entropy. Information entropy represents the degree of uncertainty or chaos of a random variable. In information theory, information entropy is a measure of uncertainty, which indicates the magnitude of uncertainty or randomness in a message. In a decision problem, I want to find a set of options such that their uncertainty is minimized. Therefore, the goal of the entropy method is to maximize the information entropy value of each solution in order to find the optimal decision solution. The entropy method is commonly used as a non-parametric method for multi-attribute decision problems. It provides an objective and comprehensive evaluation criterion for decision making by calculating the entropy value of each solution to compare the differences between different solutions. The entropy method is currently widely used in the evaluation of indicator weights for urban vitality measurement [36,37], and the calculation method is shown in Equation below:

$$H_j = -\frac{1}{\ln y}\left(\sum_{i=1}^{y} \frac{b_{ij}+1}{\sum_{i=1}^{y}(b_{ij}+1)} \ln \frac{b_{ij}+1}{\sum_{i=1}^{y}(b_{ij}+1)}\right)$$

$$w_j = \sqrt{\frac{1 - H_j}{n - \sum_{j=1}^{n} H_j}}$$

Where: y is the number of evaluation objects; b_{ij} is the *jth* indicator of the *ith* evaluation object after normalization and standardization, and w_{ij} is the indicator weight value.

3.5.2 Global Moran Index

The Global Moran Index (GMI) is a non-parametric index used to assess the diversity and complexity of geographic regions. It is used to measure whether a sample has spatial autocorrelation. It is based on the Moran Index and allows a comprehensive evaluation of an entire geographic area, rather than just a single location or region. It was proposed by Australian statistician Moran in 1950. The global Moran index can reflect the degree of data dispersion or aggregation, and can be used to assess the degree of dispersion of spatial data as well as the degree of dispersion of time series data. The calculation formula is:

$$I = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij}$$

$$z_i = x_i - \overline{x}$$

Where: S_0 represents the sum of spatial weights between so sample points, ω_{ij} represents the spatial weights between element i and element j, n is the total number of elements, and z_i represents the deviation of an attribute value of sample point i from the mean. The value of Moran index ranges from -1 to 1. The closer to 1 indicates that the sample is spatially clustered, 0 indicates a random distribution, and tends to -1 indicates a discrete distribution.

The spatial weights are usually calculated using a distance matrix where the diagonal is 0 and the cell elements are the reciprocal of the distance. If other distance calculation methods are used, they need to be modified to suit the specific situation. The global Moran index can be used for various types of data analysis, including spatial data and time series data. If the distribution of the data is concentrated, the global Moran index is positive; if the distribution of the data is discrete, the global Moran index is negative.

GMI has a wide range of applications, including ecosystem research, urban planning, geographic information systems (GIS), and resource management. It can be used to assess the diversity and stability of ecosystems, the diversity and complexity of cities, construct GIS models, and evaluate the sustainability and efficiency of natural resources use. It helps city users, designers, and government personnel to understand geospatial data and provides effective support for resource management. In conclusion, GMI is a very useful tool to help us better understand the complexity and diversity of geospatial data, and thus provide decision support for various application scenarios [38].

3.5.3 Least squares regression model

Ordinary least squares regression model (OLS) is the most popular technology to study the relationship between urban vitality and urban morphology. It explains the connection between the dependent and independent variables [39,40]. Multiple linear regression models were used to help explore the relationships between incompatible parameters [41]. The dependent variable in this paper was the composite vitality value determined through economic, social, and cultural vitality, while the built environment indicators were the independent variables. The formula is as follows:

$$y = \beta_0 + \sum_{j=1}^{m} \beta_j x_j + \varepsilon$$

where y is the dependent variable, x_j is the jth independent variable, β_j denotes the corresponding estimated coefficient, and ε is the residual.

However, the relationship between geographic variables usually varies with location, which affects the accuracy of regression models. The spatial dynamics of the interaction between spatial variables cannot be explained by the OLS model since it ignores the spatial influence of variables [42].

3.5.4 Spatial lag regression model SLM

SLM (Spatial Lag Model) model is a spatial econometric model for analyzing spatial dependence. It is an extension of SAR (Spatial Autoregressive Model) to deal with spatial dependence and spatial heterogeneity. Autoregressive Model (AR) is easily understood in time series analysis, i.e., the dependent variable is correlated with its time lag (Lag), which also means that the autoregressive model abandons the assumption of independence of the dependent variable. In spatial econometric models, the spatial lagged values are considered as the attribute (weighted) values of neighboring spatial units.

Spatial Lag Model (SLM) is a classical model in spatial econometrics used to study the spatial dependence or spatial contagion of an indicator in a region. The spatial lag model focuses on the effect of the value of an indicator in a neighboring region on the value of that indicator in the current region, also known as the spatial autoregressive effect. The urban form elements were spatially inter-related because urban planning had the characteristics of spatial continuity. For example, roads and communities were connected in adjacent space units. Therefore, the spatial element studied may have been affected by its adjacent elements. The ordinary least squares (OLS) model based on independent assumptions has limited ability to analyze this type of data. However, spatial lag multiple regression model (SLM) can weaken the deviation of autocorrelation, thus reducing the mutual interference of adjacent units [43].

In the spatial lag model, the explanatory variable is associated with a spatial lag variable that is a weighted average of the current regional variables with weights of the spatial weight matrix *W*. The basic form of the SLM model is as follows:

$$Y = \beta_0 + \rho WY + \sum_i \beta_i X_i + \varepsilon$$

where *Y* denotes the dependent variable, X_i represents the explanatory variable *i*, β_0 is the intercept, β_i is the estimated coefficient of the explanatory variable, *W* is the spatial weight matrix, *ρ* is the spatial autoregressive coefficient, and *ε* is the error term. In this paper, the dependent variable was the urban vitality and the explanatory variable was the factors of the built environment.

Spatial lag models can be used to study various spatially dependent problems, such as international trade, economic growth, crime rates, environmental issues, etc. It is also widely used in fields such as geographic information systems (GIS) and remotely sensed imagery (RS).

In the SLM model, the spatial weight vector w describes the spatial dependence among the independent variables. It can be calculated by multiplying the path-dependent effects of each independent variable (i.e., their time series) by a weight. This weight can be used to weight the effects of each independent variable to better capture the spatial dependence among them. The advantages of the SLM model include the ability to handle spatial dependence and spatial heterogeneity, and to control for spatial correlation among the independent variables.

3.5.5 Spatial Error Model Regression Model SEM

Spatial Error Model (SEM) is another classical model in spatial econometrics, which focuses on the effect of the explanatory variables on the explained variables and whether there is spatial dependence of this effect. In the spatial error model, the explained variable y is related to an error term ε, which may contain some exogenous variables but does not contain any spatial dependence. Specifically, the spatial error model can be expressed as

$$y = X\beta + \varepsilon$$

where X is an $n \times k$ matrix of exogenous variables, β is a $k \times 1$ vector of endogenous variables, and ε is an $n \times 1$ error term.

The spatial error model is suitable for studying those cases where there is spatial dependence, but this dependence is mainly in the error term. In contrast to the spatial lag model, the spatial error model does not contain any spatial autoregressive effects. Spatial error models can be applied in fields such as geographic information systems (GIS) and remotely sensed imagery (RS) for studying various spatially dependent problems, such as international trade, economic growth, crime rates, environmental issues, etc.

In the SEM model, the spatial weight vector w describes the spatial dependence among the independent variables. It can be calculated by multiplying the path-dependent effects of each independent variable (i.e., their time series) by a weight. This weight can be used to weight the effect of each independent variable to better capture the spatial dependence between them.

Some assumptions need to be satisfied when using the SEM model, such as that the path-dependent effects of each independent variable capture the effects of the other independent variables, that the spatial weight vector describes the spatial dependence among the independent variables, and that the effects of independent variables in neighboring regions on the dependent variable are properly captured and measured. Meeting these assumptions can improve the accuracy and reliability of SEM models.

3.5.6 Geographically weighted regression model

Geographically weighted regression (GWR) is a spatial analysis technique that is widely used in geography and related disciplines involving spatial pattern analysis. GWR explores the spatial variability of a study object at a given scale and the associated drivers by establishing a local regression equation at each point in the spatial scale, and can be used for the prediction of future results. It has the advantage of higher accuracy because it takes into account the local effects of spatial objects.

According to Tobler's first law of geography: everything is spatially correlated, and the closer things are to each other, the greater the spatial correlation [44]. Therefore, unlike traditional cross-sectional data, spatial correlation of spatial data leads to spatial non-smoothness (spatial heterogeneity) of the regression relationship. To explore the spatial non-smoothness of spatial data, Brunsdon et al. first proposed a geographically weighted regression model [45], set as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_{j=1}^{p} \beta_j(u_i, v_i)x_{ij} + \varepsilon_i$$

where $\beta_j(u_i, v_i)$ is a spatial geographic location function that reflects the variation of housing prices with geographic location.

The GWR model is suitable for some cases where a generic or global model does not describe the spatial data well, but is applicable to some spatial regions where a proper local model calibration can provide a better description. The method uses a moving window weighting technique to find the local model at a target location. Here, for a single model at a target location, I weight all neighboring observations according to some distance decay kernel function, and then apply the model locally to that weighted data. The size of the window in which this local model may be applied is controlled by the bandwidth. When some objective function exists (e.g., the model is predictable), the optimal bandwidth can be found using cross-validation and correlation methods.

3.5.7 Questionnaire survey

Questionnaire survey is a commonly used survey research method, refers to the investigator according to the purpose and requirements of the study, the design and production of a questionnaire to mail, in person to the respondents to fill out a form of survey. Questionnaire method is also a very common method in user research or market research, can collect a large number of responses in a short period of time, can be used to disseminate research with the network and reduce costs, with a wide range of applications. Questionnaire design is a key part of the questionnaire method, the questionnaire design directly affects the validity and reliability of the questionnaire.

3.6 Summary

This chapter has analyzed the concepts and technical methods related to urban vitality modeling and built environment measurement, including the latest research results on vitality weights, geospatial data, urban built environment data, and relational modeling, and summarized and reviewed the development and limitations of related technologies. In addition, the data preparation work that will be involved and used in the study of spatial patterns of urban vitality is introduced, mainly describing the sources, characteristics and selection basis of large-scale human activity data and urban geospatial related data, and including the organization and pre-processing of these data.

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CHAPTER 4

Measurement of Urban Comprehensive Vitality

4.1 Urban Vitality Representation Measurement

The measurement of urban vitality in this paper is assessed in three main aspects. An extensive assessment was conducted through previous literature and case studies of vibrancy prediction to understand the inner meaning of a city's vibrancy in terms of its combined economic, social, and cultural performance. Existing administrative organizational units, including districts and Transportation Analysis Zones (TAZs), are too large a boundary area to accurately reflect the quality of vitality. The aim of this work was to investigate the impact of villages on the vitality of the urban collaborative urban built environment using previous methods of urban vitality analysis as the object of study [1]. Typical urban villages in the central city, such as Nantou Old Town, Shuiwei Village, and Gangxia Village, cover an area of approximately 500 m × 500 m. Therefore, a 500 m × 500 m grid is considered the best basic spatial unit for studying the morphological elements of the built-up urban environment and urban vitality [2]. In order to accurately perceive the regional vitality distribution, this study divides Shenzhen into 8581 cells and constructs vitality indicators.

Existing administrative organization units, including districts and traffic analysis zones (TAZ), were too large a boundary area to accurately reflect the qualities of vitality. This work sought to investigate the effects of the village on the vitality of the city collaborative urban built environment using the prior urban vitality analysis method as the research object [1]. The typical urban villages in the central urban areas, such as Nantou Ancient City, Shuiwei Village, and Gangxia Village, cover an area of approximately 500 m × 500 m. Therefore, a 500 m × 500 m grid was considered the best basic spatial units to study the morphological elements of the urban built environment and urban vitality [2]. Accordingly, in this study Shenzhen was divided into 8581 units.

In this paper, Shenzhen was gridded using tool for establishing fishing nets in ArcGIS. The tool for establishing fishing nets in ArcGIS was used to create a grid with 500 m × 500 m as a spatial unit and the administrative boundary of Shenzhen as the scope of establishing fishing nets. The point data was dropped into the grid through spatial connection, while the connection index was the unique geo-ID of each grid.

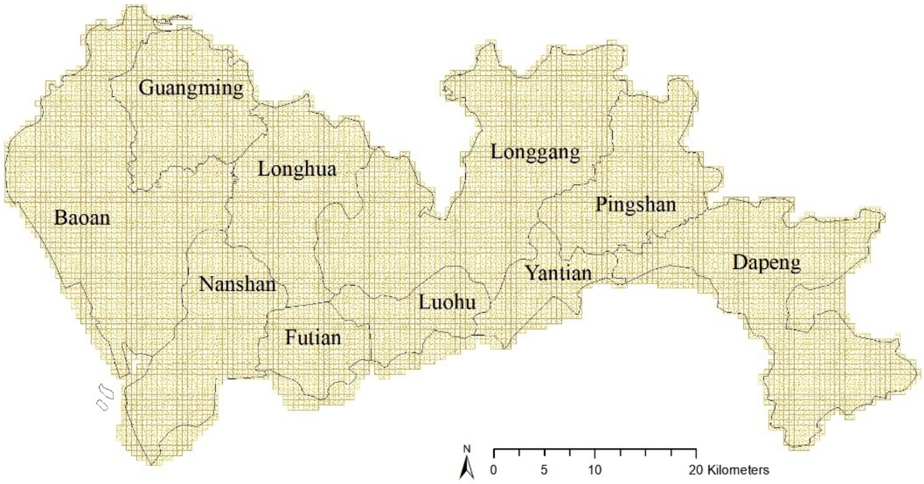

Figure 4-1. 500m x 500m grid spatial units.

4.1.1 Selection of economic vitality indicators

Economic dynamism is an important component of urban dynamism, so the study of urban dynamism usually includes the analysis of economic dynamism as well. Economic vitality is closely related to urban development. A vibrant economy can bring more jobs, investment opportunities and financial revenue to a city, thus promoting its development. At the same time, a vibrant economy can also attract more talent and technology, which improves the competitiveness of a city [3]. Economic-aware data refers to various data related to economic activities, including but not limited to consumer behavior, market size, number of companies and firms, industry trends, macroeconomic indicators, etc. Acquiring and processing these data is essential for making economic policies and business decisions.

Urban economic vitality is used to describe a city's ability and potential for economic growth. Conventional economic indicators such as GDP (Gross Domestic Product) are often used to describe the overall economic activity of a country or region, including aspects such as production, consumption and investment. However, GDP is not the only indicator of economic dynamism, as it only reflects the size of the total economy, but not its quality and efficiency. Chinese cities are currently expanding rapidly, and their economic dynamism is mainly expressed in their ability to attract capital and attract highly qualified labor [4]. In this paper, from the perspective of city operation, two data with geographical information, the data of Dianping comment and the number of company enterprises, are selected as indicators of economic vitality.

4.1.1.1 Dianping comment data measurement

Dianping is the top lifestyle information and trading platform in China that can provide reference data to measure economic growth [5]. It is an interactive platform for online users to provide information on providers, consumer offers and post-consumer reviews [6]. There is a relationship between the number of popular reviews and economic dynamism. On the one hand, the stronger the economic vitality of a region, the higher the living standard and consumption power of people, and therefore they are more likely to post reviews and comments on mass reviews. On the other hand, the number of reviews on public reviews can also reflect the economic development of a region. Specifically, when the economic vitality of a region is stronger, people's spending power increases and they have more money to spend, including in the areas of dining, travel, and entertainment. These consumption behaviors are usually reflected in the public reviews, so the number of reviews in the region will increase accordingly. In addition, when a region has better economic development, it will also attract more companies and businesses to the region, and these companies and businesses usually open stores and provide services on Dianping, thus increasing the number of reviews in the region.

饭店名	星级	评论数	人均消费	饭店类型	行政区	商圈	地址	口味评分	环境评分	服务评分	纬度	经度	城市
浙礼(龙华	四星商户	2114	75	江浙菜	龙华新区	民治	人民路202	8	8.3	7.9	22.62772	114.0213	Shenzhen
六千馆(茂	四星商户	1310	58	江浙菜	龙华新区	东门商业圈	和平路300	7.7	7.7	7.5	22.54419	114.1139	Shenzhen
六千馆(龙	四星商户	935	71	江浙菜	龙华新区	龙华	丰益路1号	8	8.1	8.1	22.65396	114.02	Shenzhen
二小姐的	准四星商户	534	73	江浙菜	龙华新区	龙华	东环二路8	7.4	8.4	7.9	22.65605	114.0377	Shenzhen
鱼米香家	准四星商户	428	69	家常菜	龙华新区	雁栖开发区	雁栖经济开	7.7	7.9	7.6	40.36285	116.6744	Shenzhen
西湖小馆(	准四星商户	31	71	江浙菜	龙华新区	观澜	观澜湖新城	7	7.5	7	22.72269	114.0751	Shenzhen
江南小调	准四星商户	103	70	江浙菜	龙华新区	民治	民治大道仿	7.1	8.3	7.5	22.62811	114.0367	Shenzhen
疯味肉蟹煲	准四星商户	38	95	江浙菜	龙华新区	龙华	汇海广场3	7.4	7.8	7.7	22.65753	114.0277	Shenzhen
阳澄湖大闸	三星商户		60	江浙菜	龙华新区	龙华	三联路美丽365花园华园道103号				22.66454	114.0313	Shenzhen
厨子印象(	三星商户	1170	66	江浙菜	龙华新区	民治	梅龙路2号	6.3	6.9	6.5	22.60261	114.0461	Shenzhen
江南印象(	三星商户	228	65	江浙菜	龙华新区	深圳火车北	深圳北站东	6.4	6.9	6.6	22.61157	114.0326	Shenzhen
鹰鹏草原破	准四星商户	121	82	烧烤	龙华新区	龙华	龙华东环二	7.4	7.2	7.4	22.6602	114.0312	Shenzhen
湘江小厨	准四星商户	7		江浙菜	龙华新区	龙华	龙华街道东	7.2	7.2	7.3	22.65444	114.0437	Shenzhen
大红灯笼(	准四星商户	1		江浙菜	龙华新区	民治	民治街道人	7	7	7	22.6282	114.0238	Shenzhen
食寨美味(	准四星商户	8	33	江浙菜	龙华新区	大浪	大浪浪口金	7	7	7	22.68127	114.0188	Shenzhen
农家小厨	准四星商户	1		江浙菜	龙华新区	观澜	松元社区旭	7	7	7	22.71969	114.0644	Shenzhen
化州B记鸡	三星商户	1		江浙菜	龙华新区	龙华	花园新村9	6.9	6.9	6.9	22.66119	114.0185	Shenzhen
紫金人家	准四星商户	1	89	江浙菜	龙华新区	龙华	联康一路和	6.9	6.9	6.9	22.66053	114.0186	Shenzhen
天天爱吃猪	准四星商户	1		江浙菜	龙华新区	民治	民治大道白	6.9	6.9	6.9	22.60519	114.0385	Shenzhen
廉怡小菜市	准四星商户	1		江浙菜	龙华新区	大浪	华繁路附近	6.9	6.9	6.9	22.67686	113.99	Shenzhen
民新饭店	三星商户	1		江浙菜	龙华新区	龙华	三联路锦绣	6.9	6.9	6.9	22.66086	114.0255	Shenzhen
实惠饭店	三星商户	1		江浙菜	龙华新区	龙华	乐家福百货	6.9	6.9	6.9	22.65754	114.0458	Shenzhen
竹知味	三星商户			江浙菜	龙华新区	龙华	龙华镇龙观路郭吓村7巷3栋1楼				22.66304	114.0172	Shenzhen
美味鲜	三星商户			江浙菜	龙华新区	梅林关	梅龙路与民乐路交叉口东				22.60506	114.0449	Shenzhen
龙华潮客轩	三星商户			江浙菜	龙华新区	龙华	龙华街道景华新村西区12栋101商铺				22.65448	114.0226	Shenzhen
常德土菜馆	三星商户			江浙菜	龙华新区	民治	民福南路郭府				22.61515	114.0388	Shenzhen
重庆天天见	三星商户	1		江浙菜	龙华新区	龙华新区	龙华区民治	6.4	6.4	6.4	22.62527	114.0375	Shenzhen
湘味菜馆	准四星商户	1		江浙菜	龙华新区	大浪	华兴路与二	7	7	7	22.67869	113.9933	Shenzhen
巴澄牌阳澄	该商户暂无星级			江浙菜	龙华新区	龙华新区	民治街道民丰路127号				22.61165	114.0443	Shenzhen
井冈山庐陵	该商户暂无星级			江浙菜	龙华新区	观澜	新湖北街星源楼旁				22.70367	114.0921	Shenzhen
顾家豫厨	该商户暂无星级			江浙菜	龙华新区	龙华	油松路与工业路交叉口				22.63838	114.0434	Shenzhen

Figure 4-2. Dianping data content.

Dianping data included information such as restaurant name, number of reviews, per capita consumption, restaurant type, address, and latitude and longitude (Figure 4-2). This study examines the overall status of each data before quantitatively analyzing urban vitality to discover the differences in vitality levels between central and non-central urban areas. I extracted the geographic information of latitude and longitude from the review data to visualize the data of the number of reviews in the study area. The spatial distribution of review volume was obtained by borrowing ArcGIS platform (Figure 4-3). Utilize ArcGIS to spatially connect comment data with research scope boundary data and research unit data, and further calculate the number and density of comments in each spatial unit. Due to the same area of all research units in this article, the number of units can intuitively reflect density information.

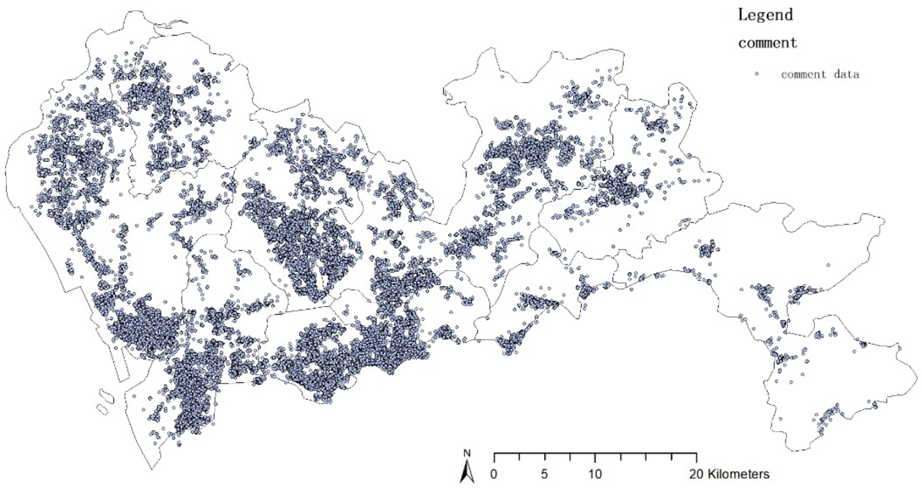

Figure 4-3. Dianping data distribution in Shenzhen.

Calculating the density of Shenzhen Dianping comment data by spatial unit, the review number activity roughly shows the characteristics of contiguous distribution in central city and scattered distribution in peripheral city (Figure 4-4). The overall vitality of Luohu Center, Futian Center, and Nanshan Center is relatively high. Data above 65000 appears in the central urban area. Among them, Houhai area, Futian exhibition area, and Huangbeiling area have values ranging from 65000 to 110000, making them the gathering areas with the highest consumption activity in Shenzhen. The overall store activity in Guangming, Pingshan, Yantian, and Dapeng districts is weak.

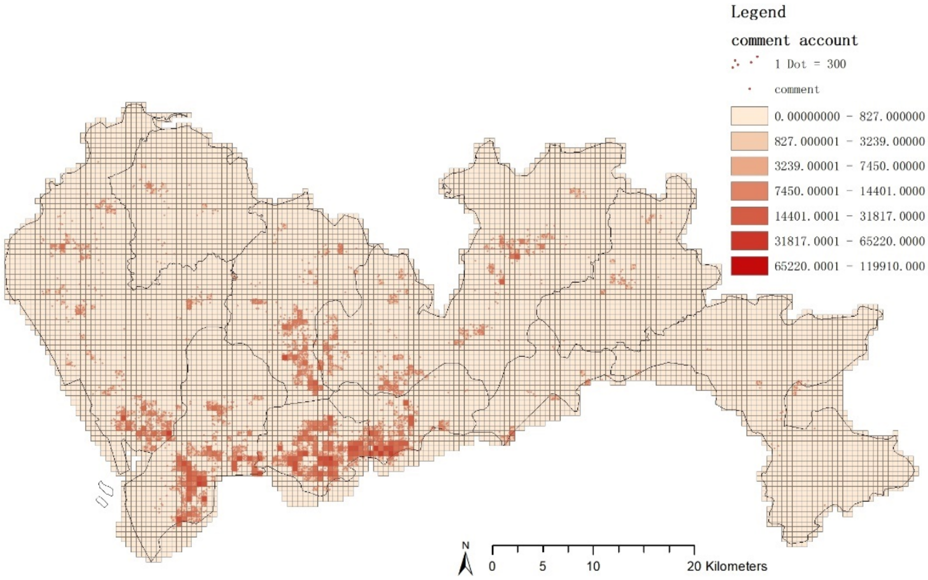

Figure 4-4. Dianping comments in spatial units.

4.1.1.2 Corporate enterprise data measurement

Related studies have confirmed that an increase in creativity, such as an increase in the number of patents and firms, has a greater driving effect on urban economic growth [7]. There is a relationship between the number of firms and economic dynamism. Typically, the higher the number of firms in a country or region, the higher its economic dynamism is likely to be relatively. A higher number of enterprises means more employment opportunities, higher levels of technology and productivity, more demand for investment and infrastructure development, and more businesses and individuals paying income taxes. Thus, the number of enterprises reflects the people's living standard and consumption ability, the city's innovation and technological progress, the government's economic investment efforts, policy tilt, and other elements related to economic vitality.

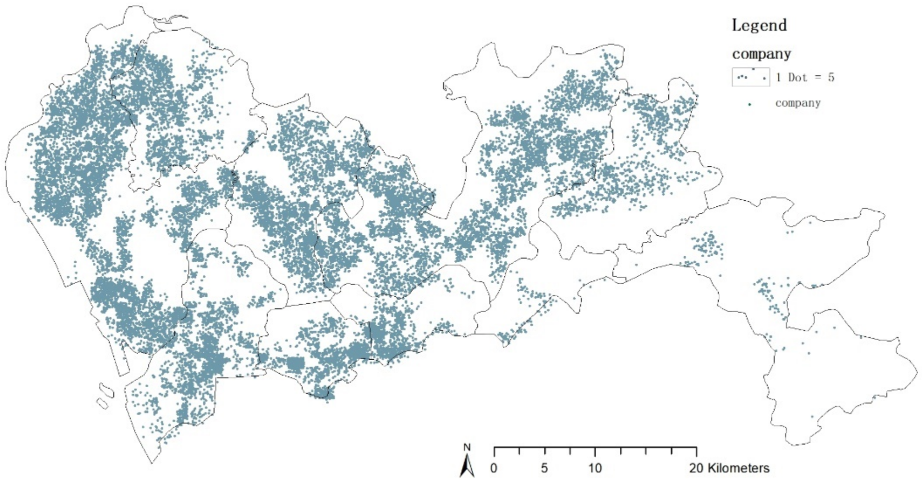

Figure 4-5. Corporate enterprise data distribution in Shenzhen.

Therefore, this study crawled the 2019 data of registered addresses of listed companies and the geographic information data of corporate enterprises from enterprise search and Gaode map (Figure 4-5), respectively, and spatially connected the corporate enterprise data with the spatial unit data through ArcGIS to count the number and density of corporate data in each unit to characterize the vitality. The formula is as follows:

$$LBS_i = \frac{C_i}{area_i}$$

where LBS_i is the data density of companies in cell *i* (pcs-km²); C_i denotes the number of companies in cell *i* (pcs); and area *i* denotes the area of the spatial cell (km²).

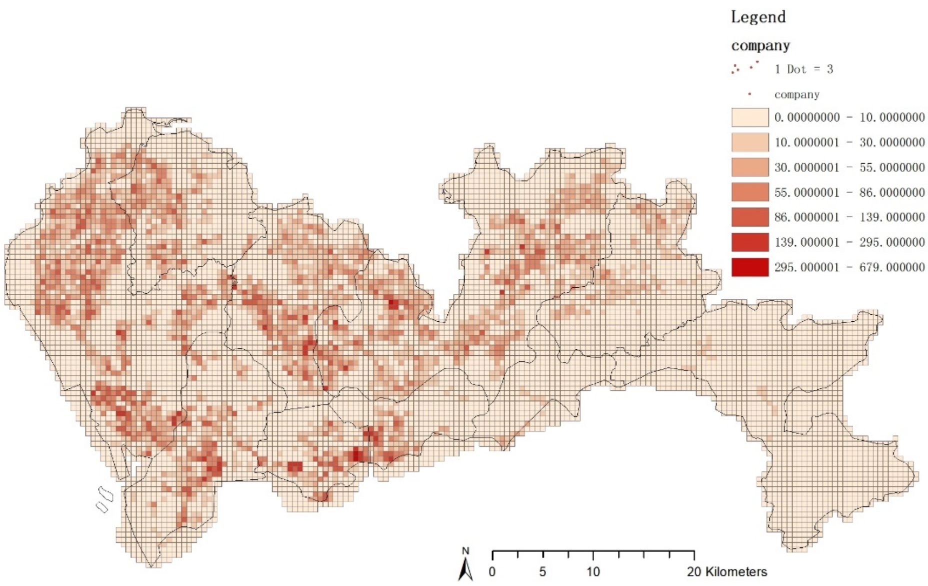

Figure 4-6. Corporate enterprise data in spatial units.

The results of calculating the economic vitality characterized by the data of firms in the city vitality unit are shown in the figure (Figure 4-6). The distribution of companies in Shenzhen shows an obvious scattered multi-point distribution, indicating that the development of companies in Shenzhen is more balanced and less influenced by geographical location factors. This is in line with the Shenzhen government's planning for industrial layout. In order to promote the high-quality development of Shenzhen's industries, Shenzhen has formulated the industrial planning of each district to assume different functions and attract corresponding corporate enterprises to move in to help the balanced economic development (Figure 4-7). Among the city's central districts, Futian District is the commercial and financial center of Shenzhen, with the Shenzhen Convention and Exhibition Center and many international corporate headquarters. The industrial planning of Futian District focuses on the development of finance, modern service industry, high-end business offices, cultural and creative industries. Nanshan District is the technology and innovation center of Shenzhen, with many high-tech enterprises and R&D institutions. The district's industrial plan focuses on the development of electronic information, biomedicine, artificial intelligence, new energy and other fields. In addition, Nanshan District is committed to building an international gathering place for financial, cultural and creative industries. Luohu District is the historical city of Shenzhen, with Shenzhen Railway Station and Shenzhen Convention and Exhibition Center. The industrial planning of Luohu District focuses on the development of commerce, logistics, tourism, cultural and creative industries. In recent years, Luohu District is also actively developing the digital economy and cross-border e-commerce industry.

Among the non-city centers, Bao'an District is the manufacturing base of Shenzhen, with many famous electronic manufacturing enterprises such as Huawei and Foxconn. Baoan District's industrial planning focuses on the development of advanced manufacturing, intelligent manufacturing, aerospace and new materials industries. Longgang District is the industrial town of Shenzhen, with many industrial parks and production bases. Longgang District's industrial planning focuses on the development of manufacturing, logistics and warehousing, electronic information and other industries. In recent years, Longgang District is also actively developing modern agriculture and tourism. Yantian District is located in the eastern coastal area of Shenzhen, with two major ports, Shenzhen Port and Yantian Port. Yantian District's industrial planning focuses on the development of port logistics, marine economy, electronic information and other industries. In addition, Yantian District is also committed to the development of green energy and environmental protection industries, etc.

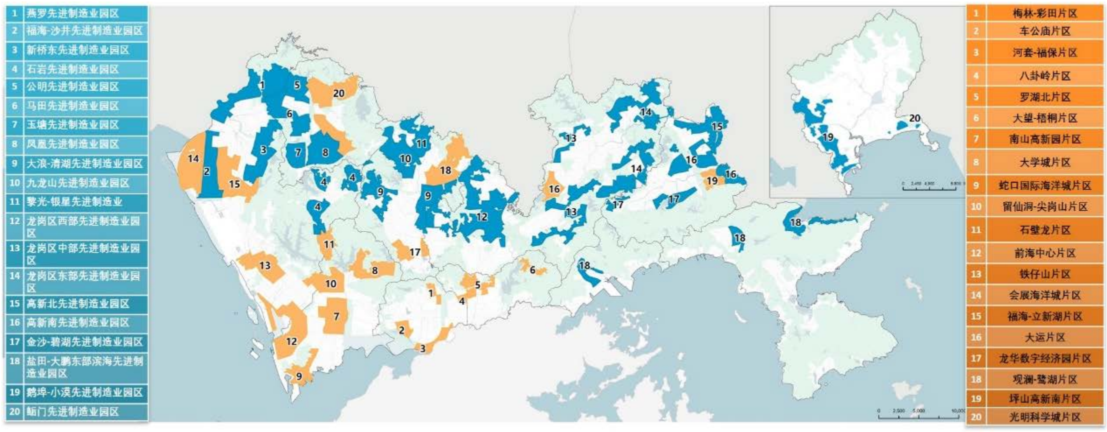

Figure 4-7. Shenzhen key development area distribution (source: Shenzhen Planning and Natural Resources Bureau).

4.1.2 Selection of social vitality indicators

Urban social vitality is related to human activity and mobility, while the core of urban vitality is related to constant urban social interaction [7]. The increase of population brings vitality to cities, and population density can be considered the most intuitive reflection of urban vitality. Currently, urban spatial vitality is mainly determined by "spatial social interactions", which are generated by people's social needs [8]. In addition, bicycle sharing has been widely used in previous studies such as urban spatial linkage because of its wide coverage, all-weather availability, and precise spatial-temporal characteristics of data, which can show more objective information about residents' travel. However, areas with high arrival rates may also have other problems, such as parking difficulties and road congestion. Therefore, multiple factors need to be considered to assess the social vibrancy of an area. In this paper, I choose population density data and bike-sharing data to measure social vitality.

4.1.2.1 Population density data measurement

The cell phone signaling data are obtained from China Unicom, collected in June 2019, and

Shenzhen is covered by 21,995 base stations, and the call data are counted based on the base stations. The data content includes information such as connected base station ID, time, etc. It is necessary to establish the mapping relationship between base station area and spatial unit, construct Tyson polygon based on base station points, calculate the communication data density of base station area, overlay analysis with spatial unit layer, calculate the area of overlap between each base station area and establishment unit, and get the communication number of people in the overlap part by communication data density, and summarize to get each establishment Although there may be discrepancies with the actual distribution, it can be a more approximate statistics of the number of communications in each spatial unit. Taking the planning spatial unit as the basic unit, the call data is counted in hours.

The cell phone signaling data obtained in ArcGIS is linked with the spatial unit data to make a visual representation of the population distribution shown in Fig. (4-8).

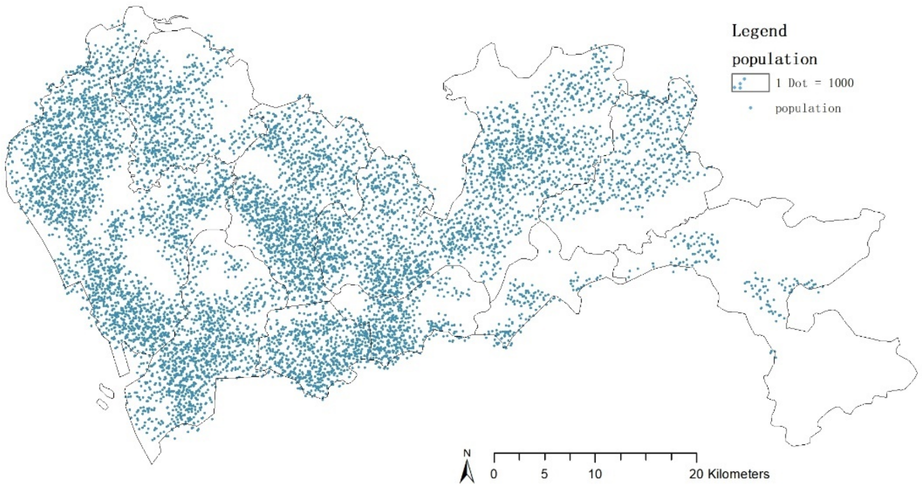

Figure 4-8. Population distribution.

4.1.2.2 Shared bike arrival data measurement

Bike-sharing arrival data can reflect the social dynamics of different areas in a city. An area with a high rate of bike-sharing arrivals may have more population density, more commercial activities, or more transportation demand. In addition, bike-sharing arrival data can also be used to study the patterns of traffic flows and patterns in cities, providing a reference for urban planning and traffic management.

Based on bike-sharing arrival location data for one weekend in Shenzhen in 2021, this study measures the vitality of travel through the average weekly hourly bike-sharing arrival density within the study unit. People mainly travel to commute on weekdays, while weekend activities are mostly active; therefore, weekend data are selected to reflect the active social dynamics. Based on this, this paper selects population density data and bike-sharing data to measure social dynamics. Figure (4-9) shows the statistical distribution of shared bicycle reaches in each cell after processing.

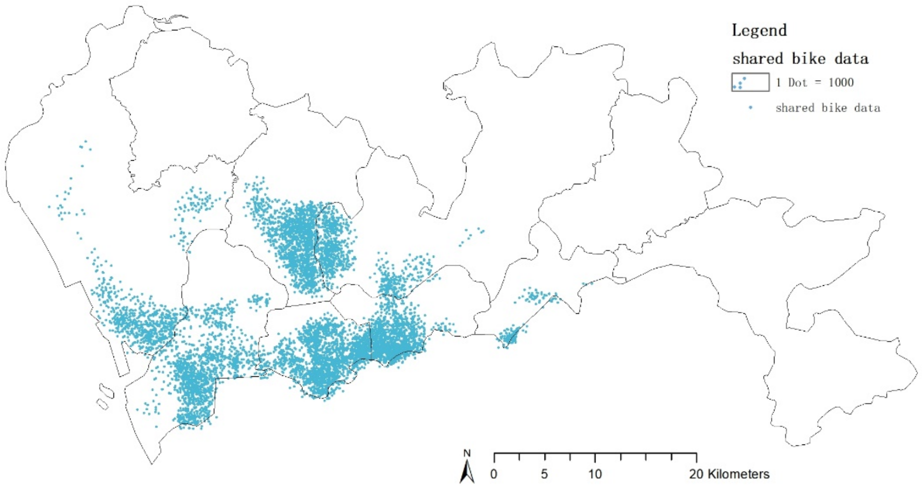

Figure 4-9. Shared bike arrival data distribution.

4.1.3 Selection of cultural vitality indicators

Cultural vitality is essential to urban vitality. Employment, income generation, innovation, and regional competitiveness are all influenced by culture [9]. Cultural vibrancy includes two interrelated components: facilities and people flow [10]. Data on the people flow of venues is difficult to obtain; thus, this paper referred to existing studies and used the POI density of cultural facilities as a measure, where cultural venues and facilities are attractive to the crowd and become an extension of the concept of cultural vitality [10]. The region's cultural facilities include theaters, music halls, exhibition halls, libraries, planetariums, art galleries, museums, planetariums, and conference centers.

The higher the density of cultural facilities, the richer the cultural resources of the area and the relatively stronger the cultural vitality. There is a certain positive correlation between the density of cultural facilities and cultural vitality. On the one hand, an increase in the density of cultural facilities can promote people's access to more cultural resources, thus increasing their cultural knowledge and literacy and raising the cultural level of the whole society; on the other hand, the cultural vitality of a region can also influence the development and construction of its cultural facilities. For example, a city full of innovation may attract more cultural institutions to move in, thus promoting the construction and development of local cultural facilities. Therefore, this paper selects the density of cultural facilities as a reference indicator of cultural vitality. Figure (4-10) shows the distribution of the density of cultural facilities in Shenzhen.

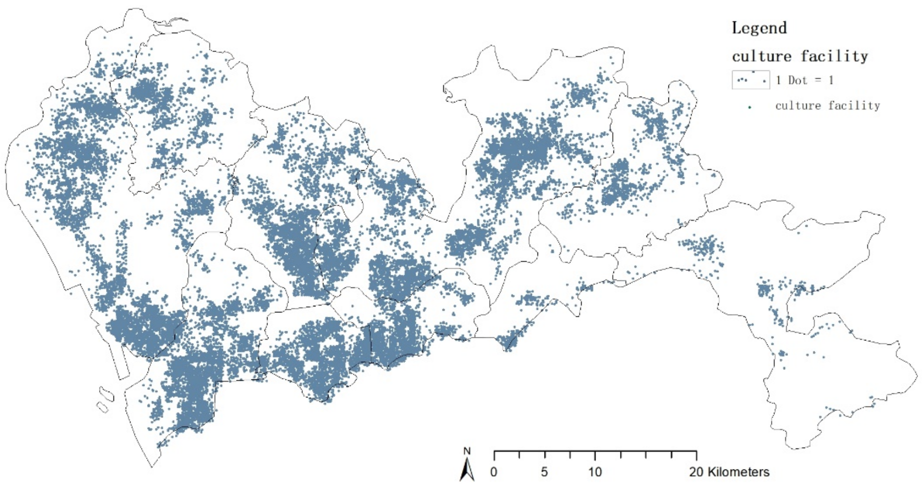

Figure 4-10. The distribution of the density of cultural facilities.

4.2 Measurement system construction

Through the above three aspects of economic, social and cultural vitality indicators selected and integrating the details and contents of each indicator in the Table (4-1), I get the indicator system to measure the vitality of the city.

Component	Name	Description
Economic vitality	Company density	The number of companies divided by the space unit area, reflecting the distribution of enterprises
	Comments number	The total comments number of amenities in the unit
Social vitality	Population density	Population divided by space unit area, reflecting population characteristics
	Shared bike data	Weekly average density of shared bike arrivals per hour in the unit
Cultural vitality	Cultural facilities density (science/culture & education services)	Cultural facility POI density of space unit

Table 4-1. T Description of indicators for urban vitality.

To determine the total vitality value (V value) of the city, I employed the entropy approach. The entropy approach was used to explain the level of indicator dispersion. The impact of the indication on the overall evaluation increases with the degree of dispersion [11]. This method determined the indicator weights of subsystems and constituent elements and, in the case of the integrated vitality indicator, entropy was derived from the data and effectively avoided the shortcomings of the subjective weighting method. In previous study, 22 indicators were subjected to entropy weighting by Liu et al. to calculate a composite vitality assessment value [12]. For this work, the social, economic, and cultural vitality values were standardized and calculated in the following steps using the entropy method:

Firstly, the original data were processed and collected to form the initial matrix of the evaluation system. I assumed that the urban vitality of m spatial unit grids needed to be evaluated; the evaluation system had n indicators. The matrix is as in Formula:

$$X = \begin{Bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & . & \vdots \\ x_{1m} & \cdots & x_{\mathrm{mn}} \end{Bmatrix} \mathrm{x} = \left\{ \mathrm{x_{ij}} \mid 1 \leq \mathrm{i} \leq \mathrm{m}, 1 \leq \mathrm{j} \leq \mathrm{n} \right\}$$

I then performed data translation using Formula below. To avoid the nonsense of logarithms when finding the entropy value, the data were panned.

$$x'_{\mathrm{ij}} = x_{\mathrm{ij}} + 0.01$$

Next, I used formula below to calculate the proportion y_{ij} of index j in the spatial unit i.

$$y_{\mathrm{ij}} = \frac{x'_{\mathrm{ij}}}{\sum_{i=1}^{m} x'_{\mathrm{ij}}} \left(0 \leq y_{\mathrm{ij}} \leq 1\right)$$

Formulas below were used to determine the index information entropy value e_j, K value and information utility value d_j.

$$e_j = -K \sum_{i=1}^{m} y_{\mathrm{ij}} \ln y_{\mathrm{ij}} , \left(K = \frac{1}{\ln m}\right)$$

$$d_j = 1 - e_j$$

The weight w_j was calculated using Formula:

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_i}$$

Finally, I calculated the comprehensive vitality value by using the weighted summation Formula:

$$V = \sum_{i=1}^{n} y_{ij} w_j$$

4.3 Comprehensive urban vitality index and spatial distribution characteristics

4.3.1 Distribution of urban vitality centers

Using a Geographic Information System (GIS), this study illustrates how the variables are spatially distributed. Figure (4-11) depicts the geographical spread of the composite urban vitality. Urban vitality is observed to have an uneven spatial distribution. The central district of Shenzhen, consisting of Nanshan District, Futian District and Luohu District, has a high-level vitality. The central district of Bao'an in the west, the central district of Longhua Shenzhen North Railway Station, and the central district of Long-gang in the northeast also show high levels of vitality. This is consistent with the map of Shenzhen's urban development pattern. Other non-focused peripheral areas show lower levels of urban vitality.

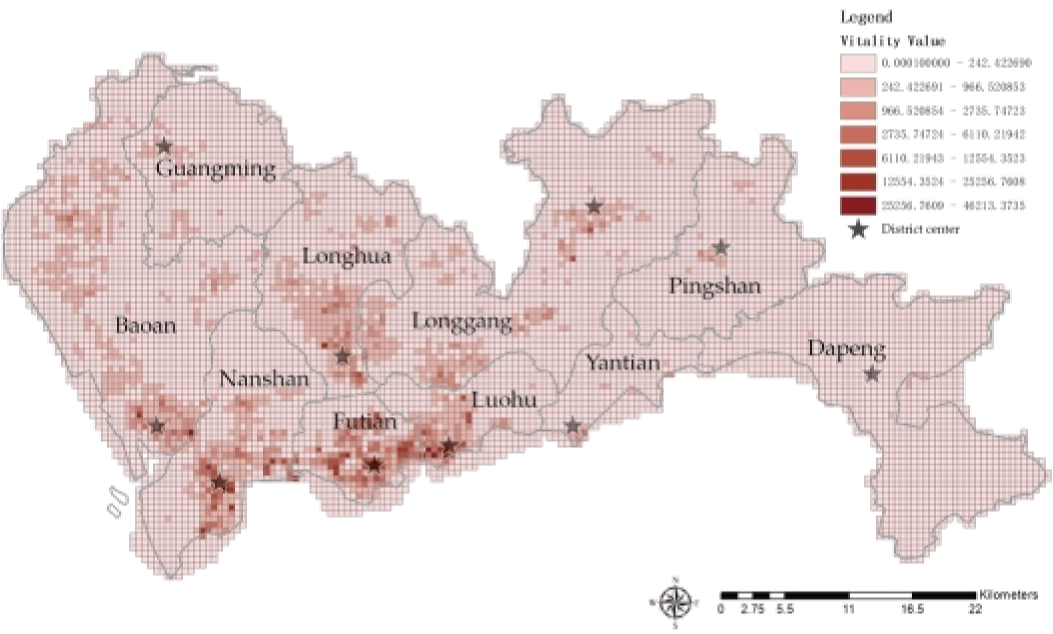

Figure 4-11. Spatial distribution of urban vitality (V value) in Shenzhen.

In order to further analyze the distribution characteristics of vibrancy centers in Shenzhen, the hotspot analysis tool of ArcGIS was used for the identification of urban integrated vibrancy centers and the hotspot analysis of urban integrated vibrancy intensity, and Figure (4-12) shows the results of the hotspot analysis. It can be found that the distribution of hotspot areas is relatively concentrated, mainly in the spatial units of Luohu District, Futian District, Nanshan District, and a few Baoan and Longhua-Longgang. There are 349 spatial units with 90% or more confidence interval. The hot units with confidence interval above 99% are 41 in Luohu District, 94 in Futian District, 76 in Nanshan District, 15 in Bao'an District, 14 in Longhua District and 3 spatial units in Longgang District.

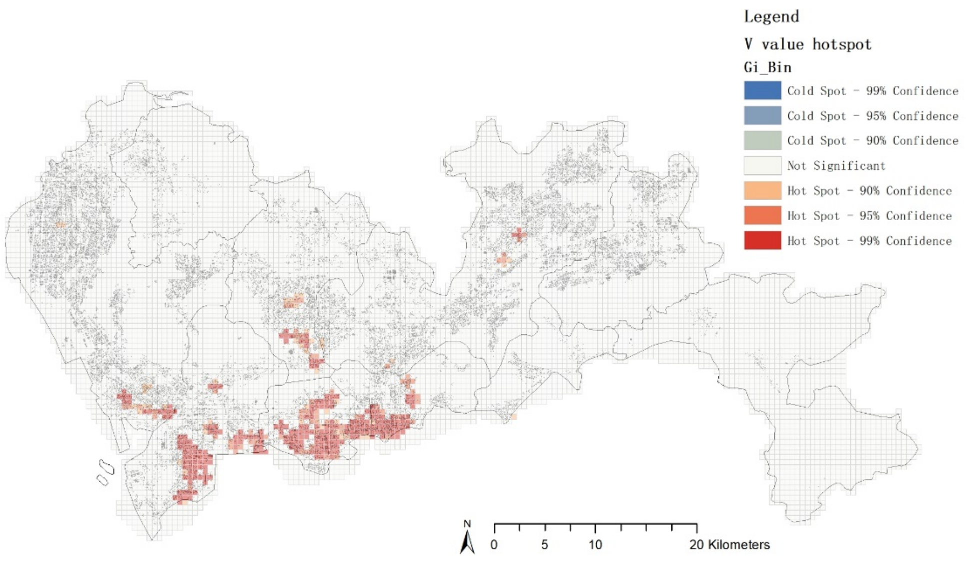

Figure 4-12. Hotspot analysis of urban vitality (V value) in Shenzhen.

Superimposed on the development plan of each district, specifically, the hot areas are mainly concentrated in the spatial units of Luohu District, Futian District, Nanshan District and a small part of Bao'an and Longhua Longgang. Among them, the Luohu District to the "Golden Triangle" international consumption core area, shoot Gang special business area, as well as the core of the Shennan East fashion dynamic business area to the north radiation. Futian District is the most densely populated, with the Civic Center area, Chegongmiao and most of Meilin area showing a high level of vitality. The hot spots in Nanshan District are mainly concentrated in OCT, Houhai District, and Shekou District. In addition, Longhua Center North Station area and Baoan Center area also show hot units, indicating the overflow of vitality from the central city. Longgang Center also has a small number of vitality hotspots, probably because Baoan Center, Longhua Center and Longgang Center focus on humanization, ecology and intelligence in urban planning and design, creating a series of high-quality living facilities and services, such as parks, shopping malls, hospitals, schools and so on. These facilities provide residents with a convenient and comfortable living environment, attracting more people to live and work in these areas.

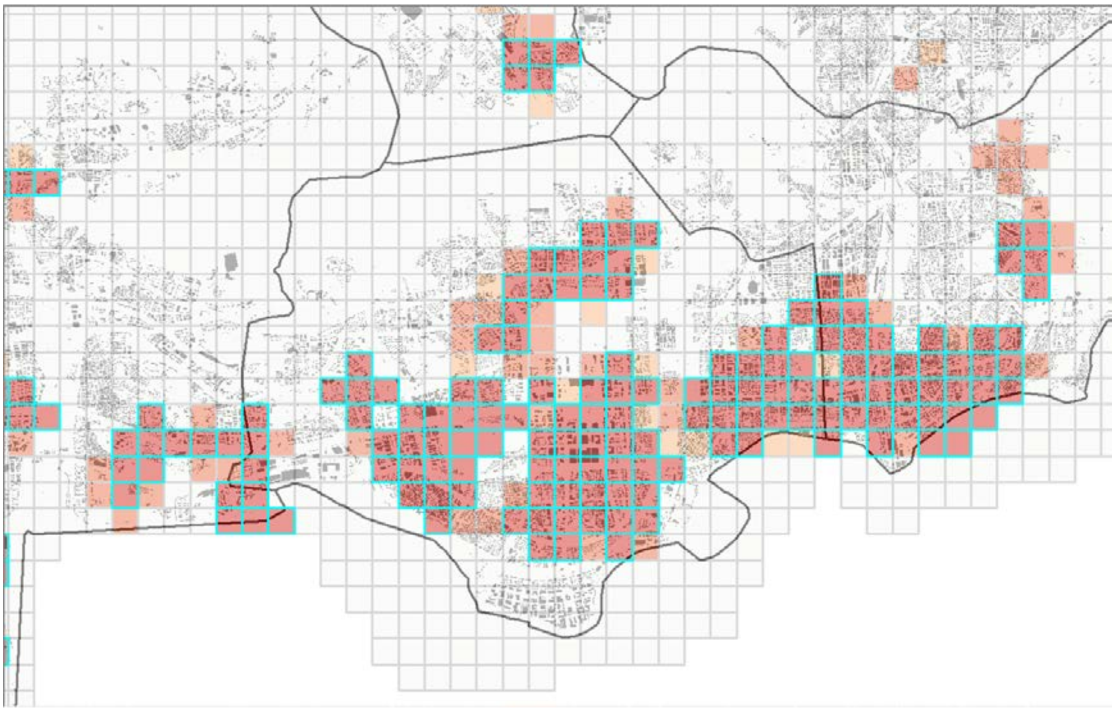

Figure 4-13. Vitality hotspot units in Futian.

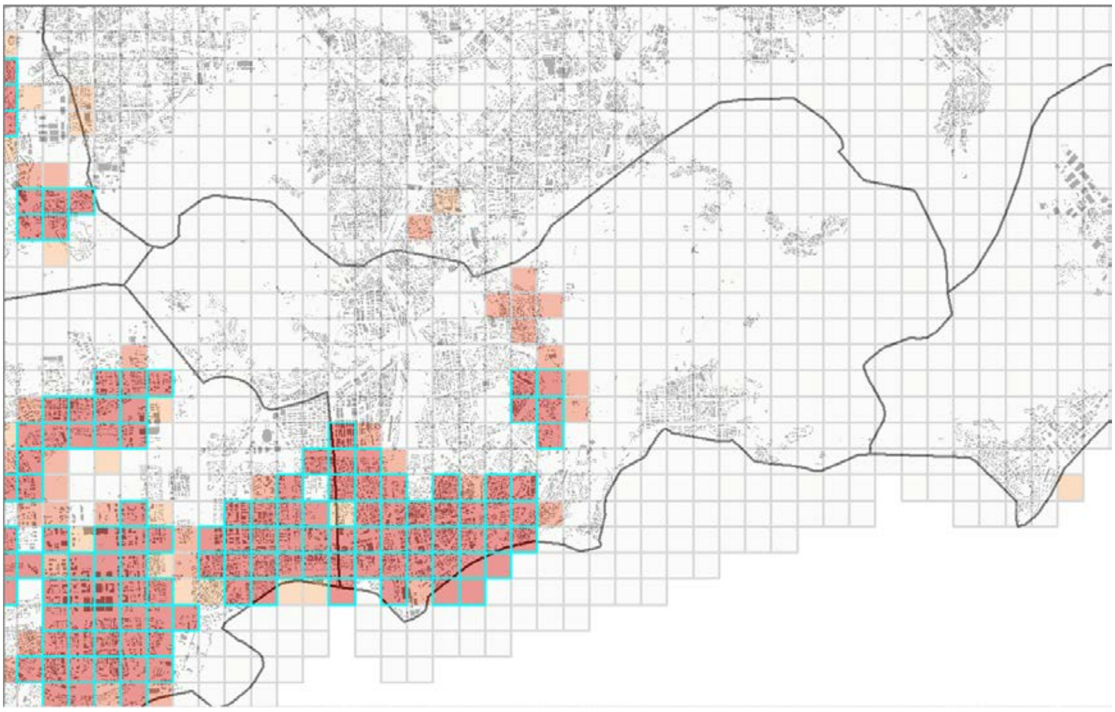

Figure 4-14. Vitality hotspot units in Luohu.

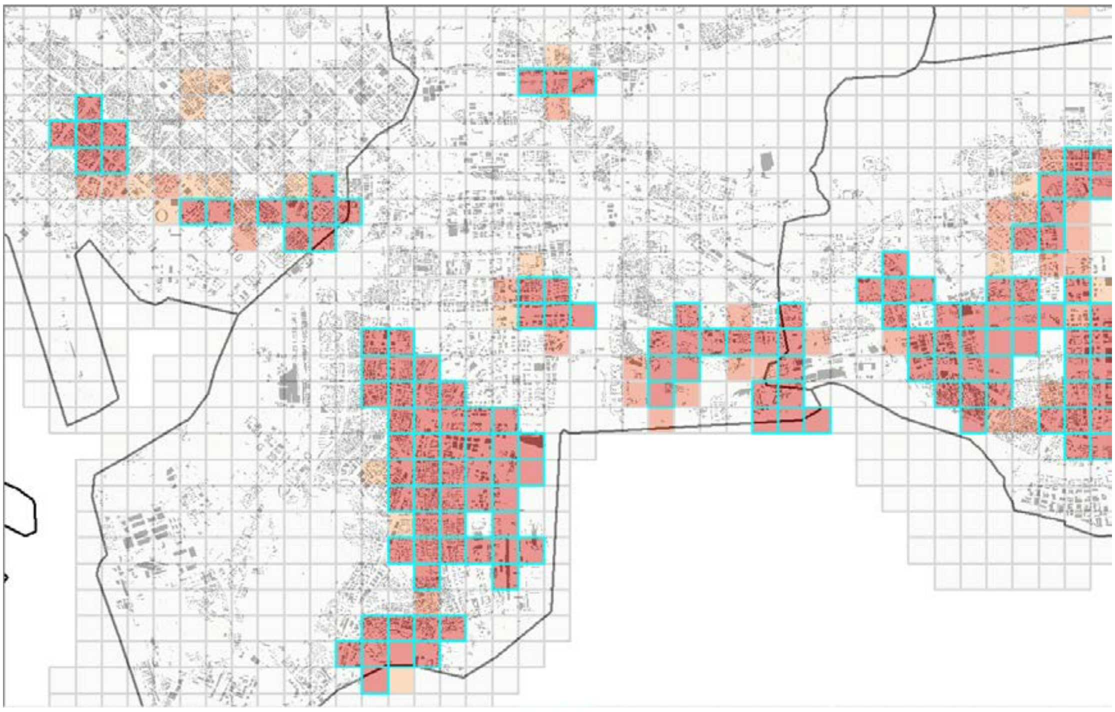

Figure 4-15. Vitality hotspot units in Nanshan.

Luohu, Futian and Nanshan are three important areas in the central city of Shenzhen, and their higher vitality may be due to the concentration of industries as well as the strong cultural atmosphere, and they all have bustling businesses. Luohu, Futian, and Nanshan are all part of the industrial center of gravity in Shenzhen, with numerous enterprises and industrial parks. These enterprises and parks provide abundant employment opportunities and economic vitality, attracting a large influx of people to these areas and further contributing to their development. All three regions have a long history and rich cultural heritage, such as the Cultural Village in Luohu, the Art Museum in Futian, and the Cultural Square in Nanshan. These cultural facilities provide citizens with a variety of cultural activities and experiences, and attract more people to live and work in these regions. Luohu, Futian and Nanshan are all commercial hubs in Shenzhen, with numerous shopping malls, shopping centers, restaurants and entertainment venues. These commercial facilities attract a large number of consumers to shop and spend money, and bring great economic vitality to the areas. With the core geographical location and convenient transportation, the development of the region is further promoted.

4.3.2 Spatial autocorrelation discrimination of urban vitality

I conducted a spatial autocorrelation analysis of the city's vitality values using GeoDa version 1.20.0.20 software and created a weight matrix using the Queen's continuum. As shown in Figure (4-16), after using 9999 permutation tests, the Moran Vitality Index has a value of 0.366, which is highly positively correlated at a significance level p-value of 0.001.

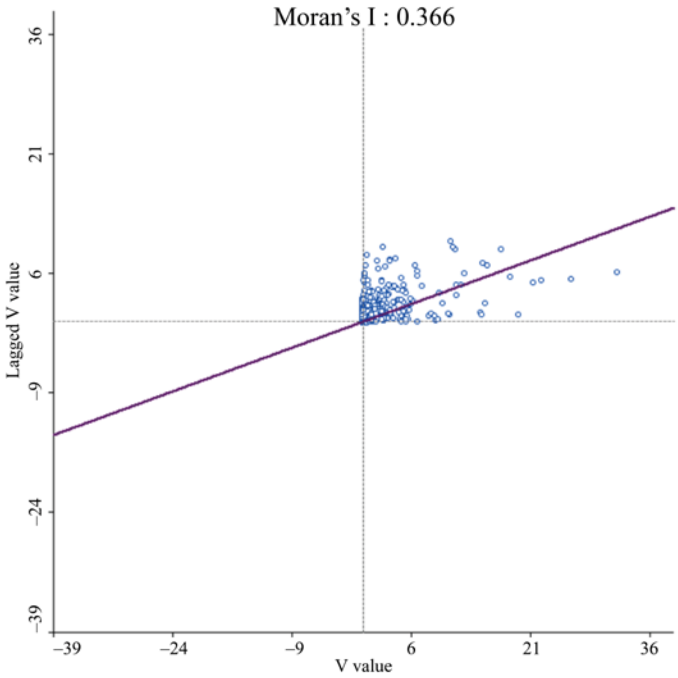

Figure 4-16. Global Moran's I of urban vitality value in Shenzhen.

The local Moran's I was also utilized to locate geographic clusters with statistically low or high urban vitality (Figure 4-17); the outcomes support the idea that urban vitality is unequally spatially distributed. As shown in Figure 4, there are clusters of high vitality in the centers of Bao'an and Nanshan, as well as Futian and Luohu districts. However, the overall scale of urban dynamism is much lower in Yantian and Dapeng districts on the eastern coast, as well as in localized areas in the north.

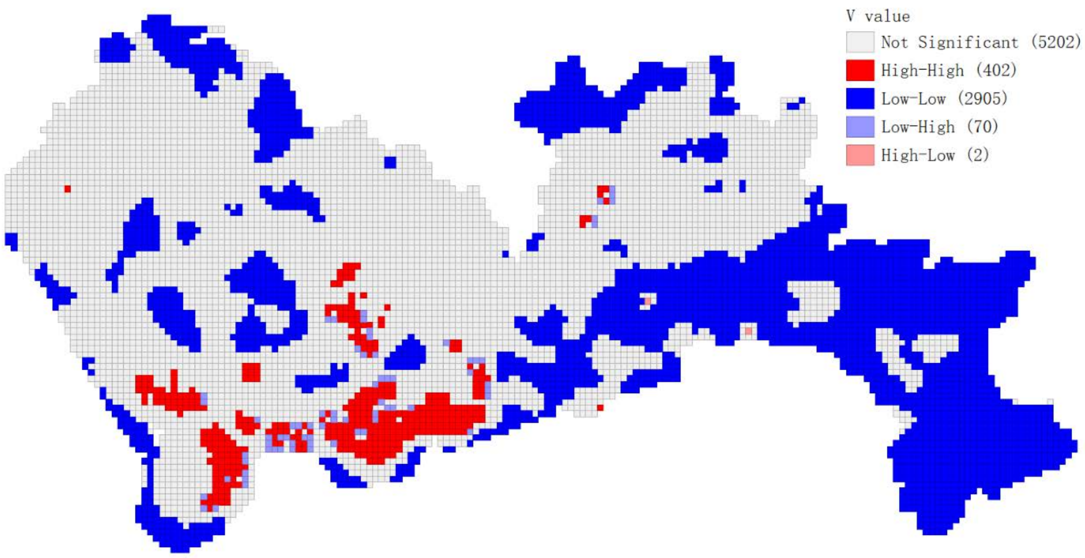

Figure 4-17. Local indicator of spatial association (LISA) map of urban vitality.

4.4 Summary

This chapter proposes three main components of urban vitality, economic vitality, social vitality, and cultural vitality. Based on multi-source big data, five indicators of company enterprise density, number of social platform reviews, population density, number of shared bicycle arrivals, and density of scientific and cultural facilities are proposed to comprehensively evaluate the comprehensive vitality of Shenzhen city and analyze the spatial distribution characteristics of comprehensive vitality. The hot spot analysis of comprehensive vitality and the distribution of vitality centers show that the vitality of the city is spatially scattered. The hotspot distribution pattern of urban vitality is formed with the "Golden Triangle" international consumption area, Futian central area, Nanshan Houhai, OCT area, Bao'an central area and Longhua central area as the core.

Overall, the study of the comprehensive vitality level and the spatial distribution characteristics of vitality centers in Shenzhen reveals that there is a more significant uneven development in the spatial distribution of vitality in Shenzhen at present. In general, the vitality centers are mainly concentrated in the three main centers of the city, Luohu, Futian and Baoan, while the seven peripheral urban areas have lower vitality levels and uneven distribution among different regions, with the Futian region having the most integrated urban vitality hotspot units, followed by Nanshan district as well as Luohu district. The Baoan Center and Longhua Center are closer to the city center due to their geographical location, so their vitality performance is also very good, making them secondary urban vitality centers. However, Guangming District, Pingshan District and Dapeng District lack hotspot vitality units, and their overall vitality is weak.

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CHAPTER 5

Study on the relationship between urban vitality and the influence of built environment factors

5.1 Built Environment Index System Establish

Many scholars have explored the influencing factors of urban vitality. For example, Jane Jacobs, when proposing the concept of urban vitality, believed that mixed functions, small neighborhoods, buildings of different ages and high population density are necessary conditions for constituting urban vitality, and subsequent studies have shown that the influencing factors of urban vitality mainly include built environment, urban morphology and spatial structure [1,2], among which the elements of built environment are more specific, easy to quantify, and controlled by urban planning, and the research on them is easy to apply in practice.

The built environment, as an integral part of overall well-being, is a spatial reflection of urban design and construction; its importance is currently increasing. There is an increasing variety of methods for measuring the built environment. All cities can be conceptualized as urban form elements, usually consisting of three main components: streets, blocks, and buildings [3]. Researchers have investigated several indexes to determine neighborhood morphological traits from morphological components (roads, blocks, buildings, and POIs) [3-6]. In 2020, Li summarized the built environment characteristics into two dimensions: formal and functional. Urban village acts as a specific spatial component of the city; on one hand, the urban form of the urban village has been described as inefficient [7]. On the other hand, the ability of urban economic and social life is significantly impacted by the mixed-use buildings and fine-grained street networks of urban villages [8]. Urban villages assume a wealth of urban functions. Therefore, this paper used urban villages as a third morphological dimension based on traditional formality and functionality. A total of 12 indicators were selected from the three morphological dimensions to measure the urban built environment. As shown in Table (5-1), it contains three primary indicator classifications and 12 secondary indicator classifications. Explanation of the changes in the combined vitality of the city.

Primary Indicators	**Secondary Indicators**

Urban form	Road network density (RND)
	Transportation facilities density (TFD)
	Building density (BuD)
Urban village	Distance from urban villages (DUV)
POI	Food facilities density (FoD)
	Shopping facilities density (ShD)
	Public service facilities density (PuSD)
	Recreation & Entertainment density (REnD)
	Residential facilities density (ReD)
	Medical facilities density (MeD)
	Outdoor and recreation density (ORD)
	Sports and leisure density (SLD)

Table 5-1. Built environment indicators.

5.1.1 Urban Form Factors

The urban form factors are mainly based on the Kevin Lynch Urban Elements to select factors that can influence the spatial form of the city. For example, the transportation network elements and the architectural elements. The urban road network and architecture have a profound influence on urban form, and together they form the skeleton and face of the city. Transportation construction is the foundation that drives the dynamic development of new cities. A dense urban road network not only provides more convenient transportation, but also divides urban land into smaller units, which helps increase the mix of urban functions [9]. The construction of public transportation system further influences the land use and development of new cities, and is a prerequisite for the formation of urban vitality [10]. There are complex interactions between road networks and buildings. For example, in the process of urban renewal and renovation, a rational road network design can promote the preservation and utilization of buildings in old urban areas; at the same time, new construction projects can optimize and improve the existing road network. In addition, the design of buildings can also influence the use of the surrounding roads, such as a reasonable design of parking lots can reduce the congestion of the surrounding roads. Therefore, in terms of form, this paper selects Road Network Density (RND), Transportation Facility Density (TFD) and Building Density (BuD) as indicators to reflect the basic state of the urban built environment.

5.1.1.1 Road network density

Road network density is an important indicator in urban planning and transportation planning to measure the size and layout of urban road networks. Higher road network density usually leads to better traffic mobility and accessibility, thus promoting economic development and social activities in cities [11]. For example, a high-density road network can improve traffic efficiency in central business districts, shorten commuting times, and attract more business and population movements. In addition, a high-density road network can improve the safety and emergency response capabilities of a city. However, too high road network density may also bring some negative effects, such as congestion and traffic accidents. Therefore, in urban planning and transportation planning, the size and distribution of road network density need to be considered according to the characteristics and needs of different cities in order to achieve the best urban transportation and social development benefits.

The road network in a city determines the distance and location relationship between buildings, which in turn affects the overall shape of the city. For example, in urban planning, reasonable street width and traffic flow can provide more display space and access to buildings, thus facilitating the development of commercial and residential buildings. In addition, the layout and connection of roads can also have an impact on the overall morphology of the city, such as circular roads and linear parks, which can change the morphological characteristics of the city. This study uses the total number of roads in a spatial unit divided by the area of the unit to calculate the road network density (RND) (Figure 5-1).

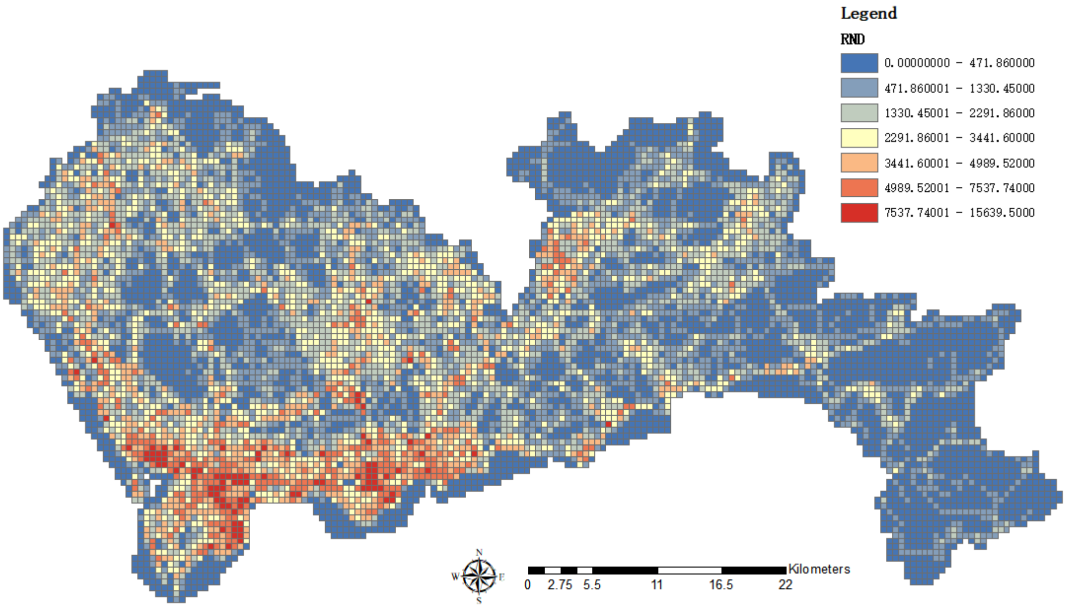

Figure 5-1. Distribution of road network density for each spatial unit.

5.1.1.2 Transportation facilities density

The higher the coverage of public transportation in an area, the easier it is for this area to develop urban vitality. The density of transportation facilities directly affects the vitality and development of a city [12]. Higher density of transportation facilities can lead to better traffic mobility and accessibility, thus promoting economic development and social activities in the city [13]. On the contrary, lower density of transportation facilities may lead to traffic congestion, traffic accidents and other problems that affect the economic and social activities of the city. Therefore, in urban planning and transportation planning, the size and distribution of transportation facility densities need to be considered according to the characteristics and needs of different cities in order to achieve the best urban transportation and social development benefits.

In this paper, the data of bus stops and metro stations are used for the calculation of public transportation stop density comprehensively (Figure 5-2). This data was obtained to a total of 6275 bus stops and 1307 subway stations in Shenzhen, and the public transportation stops are laid out in combination with roads, so they are clearly distributed in a linear pattern in space. I calculate the total number of transportation facilities within a unit to describe the transportation facility density (TFD). The results of the public transportation station density analysis show a relatively uniform distribution across the city, with high value aggregation spilling over to the edges with each urban center as the core.

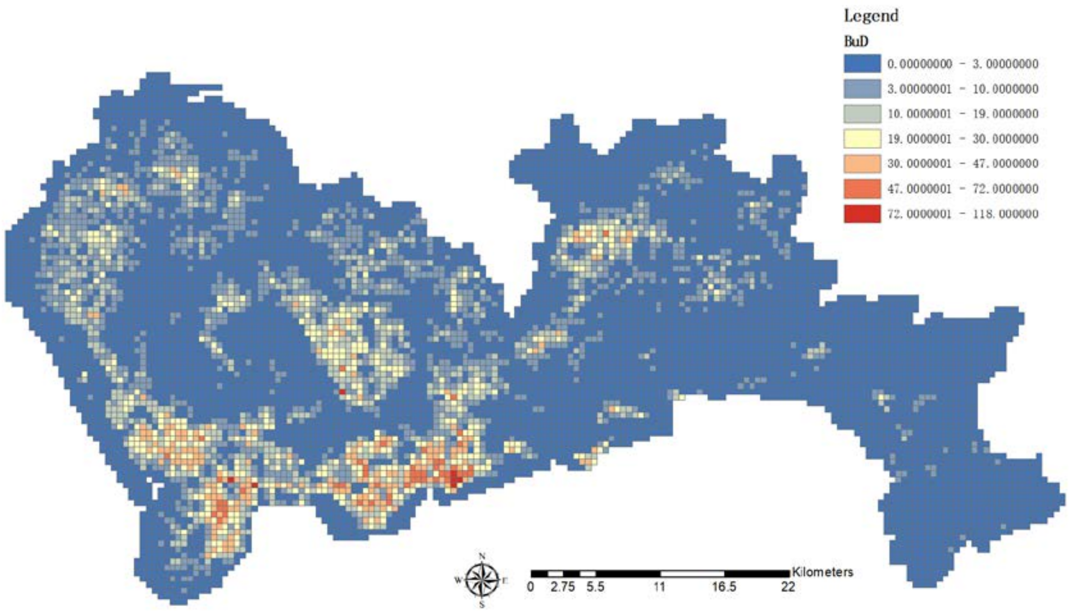

Figure 5-2. Distribution of transportation facilities density for each spatial unit.

5.1.1.3 Building Density

The height, density and form of buildings can also have an impact on the overall form of the city [14]. For example, high-rise buildings take up more road area, thus limiting the width and number of roads, while dense residential areas create narrow streets and complex block structures that require more elaborate traffic management and planning. In addition, the exterior design and style of buildings can reflect the cultural characteristics and historical background of a city.

Building density is an important indicator in urban planning and construction to measure the scale and layout of a city's buildings. High-density residential areas can provide more housing supply to meet the housing needs of urban residents; high-density commercial centers can attract more businesses and consumers and promote the economic development of the city. In addition, high-density buildings can also improve the cultural atmosphere and urban image of the city. Higher building density can bring more population and commercial activities, thus promoting the economic development and social vitality of the city.

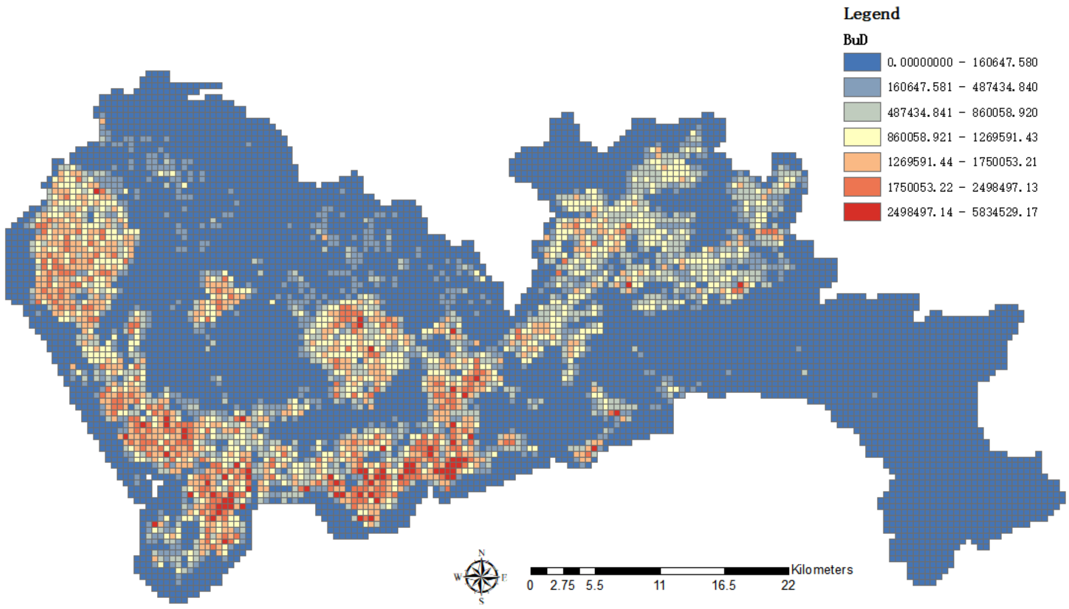

Figure 5-3. Distribution of building density for each spatial unit.

The building density (BuD) of the spatial unit in this paper can be calculated by dividing the total building area of the unit by the area of the unit. Since the spatial unit I set is a 500x500m cell grid with the same cell area, this study directly calculates the total building area in the spatial unit, which can visually reflect the building density information. The building density can reflect the building density and open space rate in the cell. The higher the building density, the higher the degree of development of urban space. The overall building density in Shenzhen is high. It shows the characteristics of circle differentiation (Figure 5-3). The building density in the central area is higher than that in the peripheral urban areas. There are 79 units with a total building area of more than 2,498,500 square meters, mainly in Luohu, Futian, Nanshan and Baoan districts (Figure 5-4).

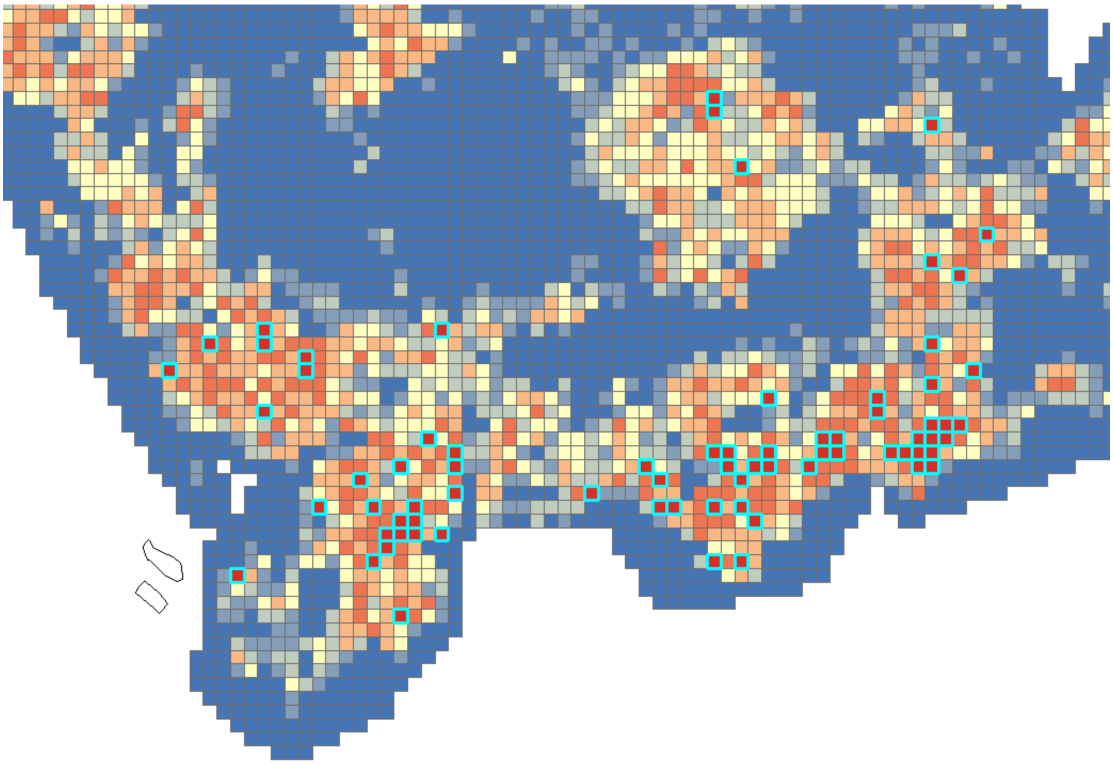

Figure 5-4. Distribution of building density for each spatial unit in Futian and Nanshan.

5.1.2 Urban Functional Factors

The type and density of functional facilities in an area represents the type of functions and convenience that the area can provide, which is closely related to urban vitality [15]. The function of a district not only affects the residents who use it, but also determines the role it plays in the operation of the urban system, how and how often it is used by residents, and the types of activities it may generate, all of which have a close influence on urban vitality. As Jane Jacobs argues, the rich diversity of life in small-scale neighborhoods is an important manifestation of urban vitality, and a mix of basic functions is one of the conditions essential to maintaining urban vitality [16]. Therefore, the functional facilities of the area are also important influencing elements of urban vitality. For the functions of spatial units can be measured by POI data, which are characterized by large quantity, much information, and update over time, etc. Based on this, I choose to use various types of functional density, functional mix, and other indicators to quantify the functional attributes of the urban built environment.

Functionally, various types of POI data were used as indicators to identify city functions and sort out the internal spatial structure of a city [17]. In this paper, eight common categories of POI data that highly correlated with human were selected as indicators: food facilities, shopping facilities, public service facilities, recreation and entertainment, residential facilities, medical facilities, outdoor and recreation, and sports and leisure. Specific facilities and classifications can be found in Table (5-2). I then figured out the density of each POI within the unit.

Component	Variables	Description	Mean	Std.	Max	Min
POI	Food facilities density (FoD)	The total number of food facilities in a unit divided by the area of the unit	14.64	34.49	415.00	0.00
	Shopping facilities density (ShD)	The total number of shopping facilities in a unit divided by the area of the unit	19.75	47.97	1112.00	0.00
	Public service facilities density (PuSD)	The total number of public service facilities in a unit divided by the area of the unit	10.07	21.14	236.00	0.00
	Recreation & Entertainment density (REnD)	The total number of recreation & entertainment facilities in a unit divided by the area of the unit	0.83	2.34	72.00	0.00
	Residential facilities density (ReD)	The total number of residential facilities in a unit	3.59	6.99	164.00	0.00

	divided by the area of the unit				
Medical facilities density (MeD)	The total number of medical facilities in a unit divided by the area of the unit	2.49	5.98	62.00	0.00
Outdoor and recreation density (ORD)	The total number of POIs in the outdoor and recreation category divided by the area of the unit	0.47	2.01	74.00	0.00
Sports and leisure density (SLD)	The total number of sports and leisure in a unit divided by the area of the unit	0.89	2.16	29.00	0.00

Table 5-2. Urban functional built environment indicators.

5.1.2.1 Density of various types of facilities

There is a close relationship between the functions of a city and its vitality. The functions of a spatial unit not only have an impact on the city residents who use it, but also influence the attractiveness of the unit to the surrounding environment, which is crucial to the creation of urban vitality. The higher the density of functions, the more it can meet the daily needs of urban residents, and the easier it is for the area to gather popularity and enhance vitality.

In this study, the spatial unit is a 500x500m cell grid with the same cell area, so the total number of POIs in the spatial unit is calculated directly to reflect the information of POI density.

$$\mathrm{fd}_t = \frac{N_i}{S_i}$$

The functional density represented by each type of POI is calculated separately. The spatial cell set in this study is a 500x500m cell grid with the same cell area, therefore, this study directly calculates the total number of each type of POI in the spatial cell to reflect the information of each type of POI density.

(1) Food facilities

Knowing the location and number of different types of food facilities can help us better understand the local business activities and consumption habits. Food facilities usually refer to places that provide food and beverage services, and the POI data include restaurants, cafes, fast food restaurants, dessert stores, etc. Food facility POIs are relatively evenly distributed in Shenzhen, with no obvious clustering. the number of POIs is large and covers a wide range (Figure 5-5).

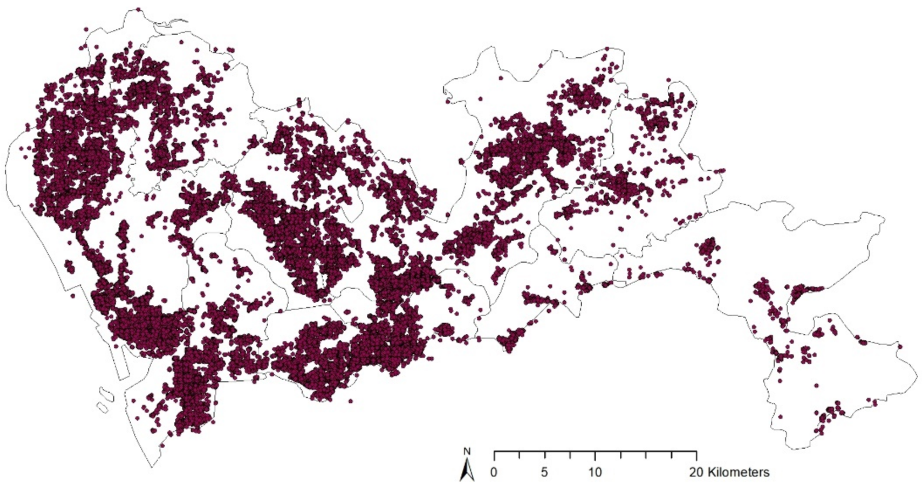

Figure 5-5. Distribution of food facilities in Shenzhen.

(2) Shopping facilities

The POI data obtained in this study contains 169,684 shopping facilities. Shopping facilities usually refer to places that provide shopping services, such as shopping malls, department stores, etc. Knowing the location and number of different types of shopping facilities can help us better understand the local business activities and consumption habits. In terms of the distribution of commercial facilities, all urban built-up areas have a high density of commercial facilities (Figure 5-6). The density is higher in urban centers, and the peripheral areas of cities have a high demand for commercial facilities and high coverage due to the large number of residents' demand.

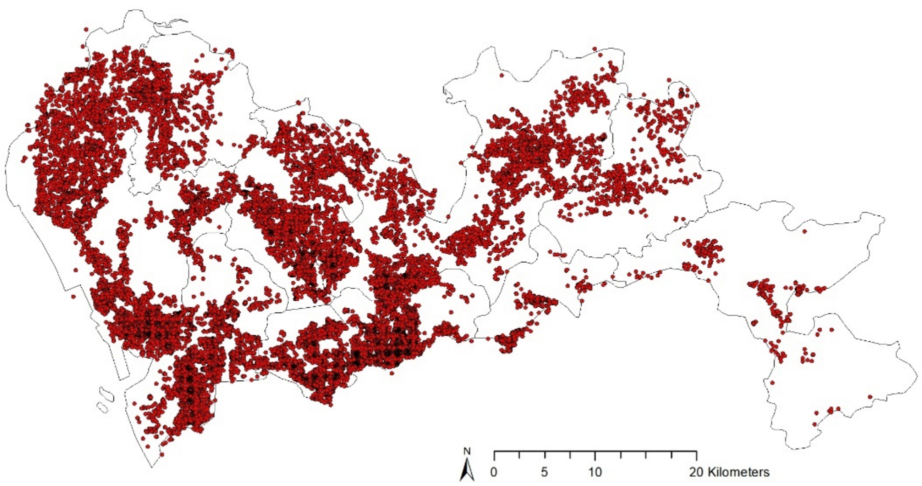

Figure 5-6. Distribution of shopping facilities in Shenzhen.

(3) Public service facilities

The POI data obtained in this study contains 86,541 public service facilities. The location and number of different types of public service facilities reflect the local social service and cultural atmosphere. Public service facilities usually refer to places that provide public affairs services, such as government agencies, hospitals, schools, etc. Public service facilities are unevenly distributed in Shenzhen, with a significantly higher density in the urban center than in the peripheral urban areas (Figure 5-7).

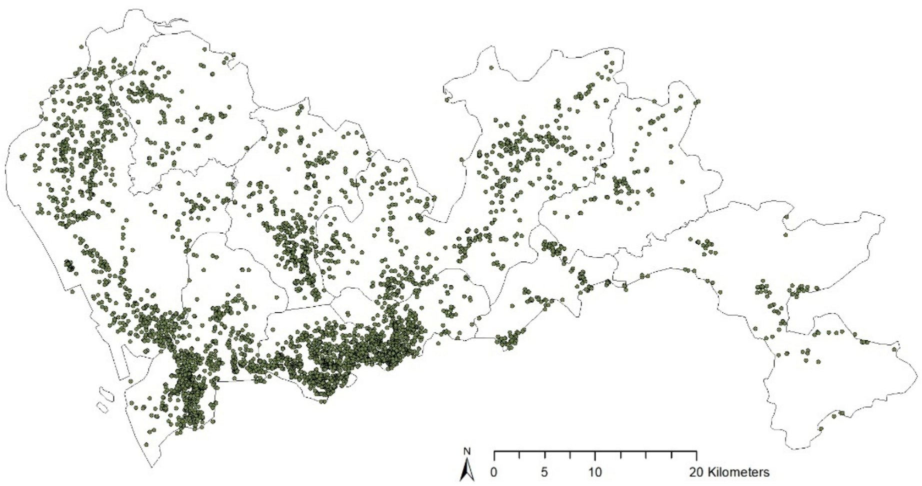

Figure 5-7. Distribution of public service facilities in Shenzhen.

(4) Recreation and entertainment

The POI data obtained in this study contains 7,145 recreational facilities (Figure 5-8). Recreation and entertainment facilities usually refer to places that provide entertainment and leisure services, including cinemas, amusement parks, KTVs, etc. Knowing the location and number of different types of recreation and entertainment facilities can help us better understand the local cultural and entertainment activities and consumption habits.

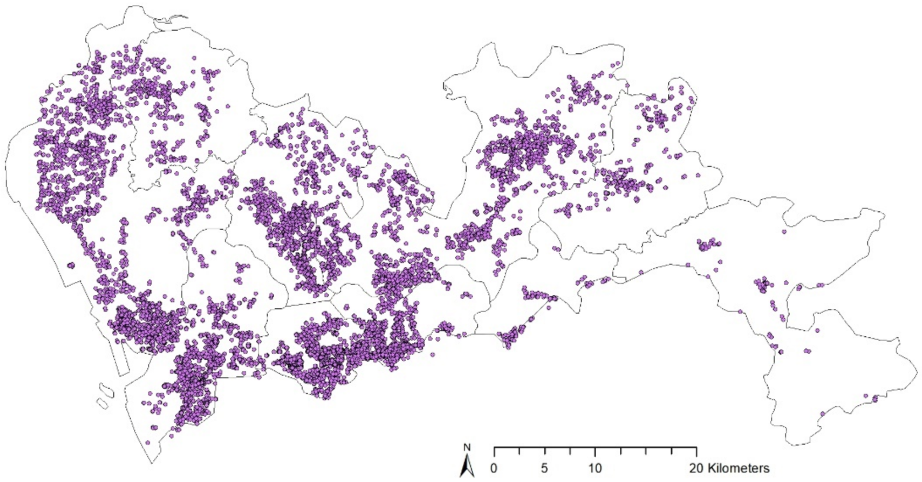

Figure 5-8. Distribution of recreation and entertainment facilities in Shenzhen.

(5) Residential facilities

The POI data obtained in this study contains 30,825 residential facilities (Figure 5-9). Residential facilities are usually composed of residential buildings, neighborhoods, villas, etc. Residential areas are one of the most basic living units in cities and villages, and they are also important places for people's daily life. The construction and management of residential areas have an important impact on people's health and quality of life. A good living environment can improve people's quality of life and happiness, while a bad living environment may lead to health problems and social problems.

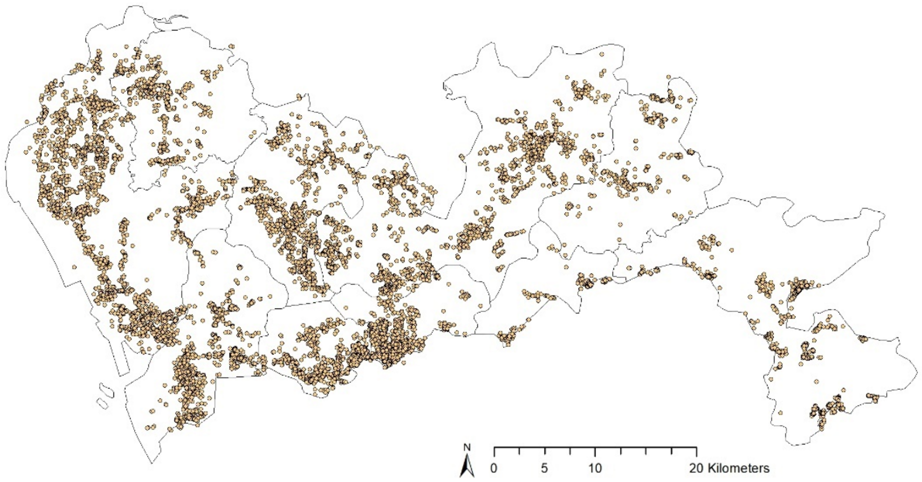

Figure 5-9. Distribution of residential facilities in Shenzhen.

The distribution structure of residential areas in Shenzhen is characterized by dense central areas and sparse peripheral areas. This is in line with the "4+2+4+1" distribution structure of residential areas as disclosed by the Ministry of Housing and Construction of Shenzhen [18]. The distribution of residential facilities differs from other POI facilities in that there is no obvious clustering, and the density of residential facilities in Longgang, Longhua and Bao'an regions shows high values. The "4" refers to four mega-residential areas, namely Bagua Ling, Yuanling, Shangbu and Meilin. These residential areas are large in scale and population, and are concentrated in the three administrative districts of Futian, Luohu and Nanshan. "2" refers to two large residential areas, namely Longgang Center City and Bantian Yangmeibulong. These two residential areas are large and densely populated, mainly in the Longgang and Bantian districts. "4" refers to four medium-sized residential areas, respectively, Baoan Xixiang, Baoan Xin'an, Longhua Minzhi and Dalang. These settlements are small in size and moderate in population, and are mainly located in Baoan, Longhua and Longgang Districts. "1" refers to the central district of Pingshan. This residential area is smaller in scale and less populated, mainly distributed in Pingshan District.

administrative region	Residential area	Residential proportion
Futian District (9.3%)	Meilin area	2.6%
	Bagualing area	2.1%
	Yuanling area	1.9%
	Futian central district	1.4%
	Shangbu area	1.2%
	Shatou area	0.7%
Nanshan District (14.1%)	Qianhai area	13.2%
	Shenzhen Bay Port Area	0.9%
Longgang District (14.7%)	Phuket area	3.5%
	Bantian area	3.3%
	Pinghu area	2.8%
	Henggang area	1.8%
	Longgang central city	1.6%
	Dayun area	0.6%
	Pingdi area	0.4%
Baoan District (21.3%)	Xixiang	3.8%
	Bihai	3.6%
	Xin'an	3.5%
	Fanshen	2.3%
	Baozhong	2%
	Fuyong	1.8%
	Shajing	1.6%
	Songgang	1%
	Shiyan	0.9%
Guangming District (10%)	Gongming central district	5.8%
	Fenghuang city area	4.2%
Longhua District (25.8%)	Minzhi	3.5%
	Dalang	2.9%
	Longhua central area	2.8%
	Guanlan	2.6%
	Yangmei Bulong	2.4%

	Hongshan	1.8%
	North foot of Yangtai Mountain	1.6%
	West side of Longhua Lu Lake	1.3%
	Guanhu Songping Village Zone	1%
Pingshan Central Area Pingshan District (7.9%)	Pingshan Central Area	2.8%
	Biling	2.3%
	Shijing	1.5%
	Kengzi	1.2%
	North foot of Maluan Mountain	0.4%

Table 5-3. Residential ratio of each district in Shenzhen.

(6) Medical facilities

There are 21,406 medical facilities included in the POI data obtained for this study (Figure 5-10). Medical facilities usually refer to organizations that provide medical services, such as hospitals, clinics, pharmacies, etc. By querying the information of medical facilities in POIs, users can quickly find nearby medical service providers and understand their specific service contents and contact information to facilitate medical treatment or consultation.

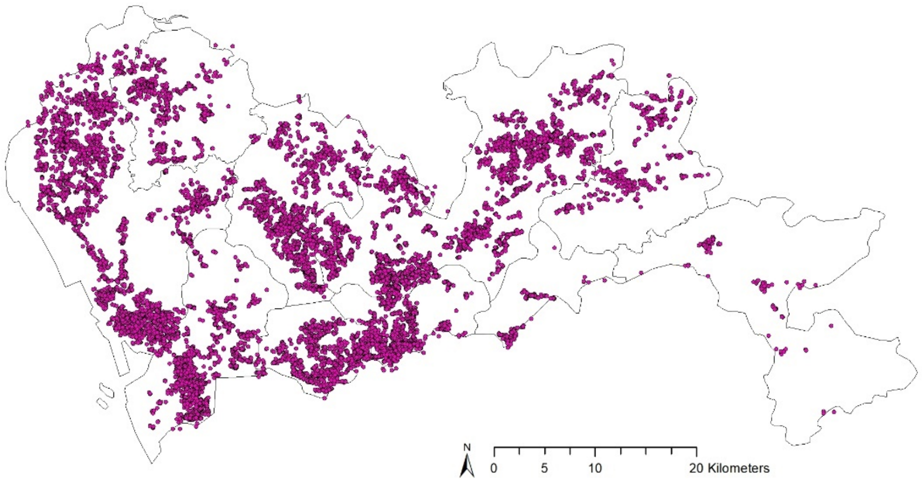

Figure 5-10. Distribution of medical facilities in Shenzhen.

(7) Outdoor and recreation

There are 4082 outdoor and recreational facilities included in the POI data obtained for this study. Outdoor and recreational facilities are usually located in public places, including parks, plazas, recreational facilities, etc. facilities that provide outdoor sports and recreation services to the public. As shown in Figure (5-11), the facilities are more distributed in the old city including Luohu and Futian, and the distribution decreases outward, probably because the urban periphery is in the process of development and the green infrastructure has not yet kept up with the progress of urban development.

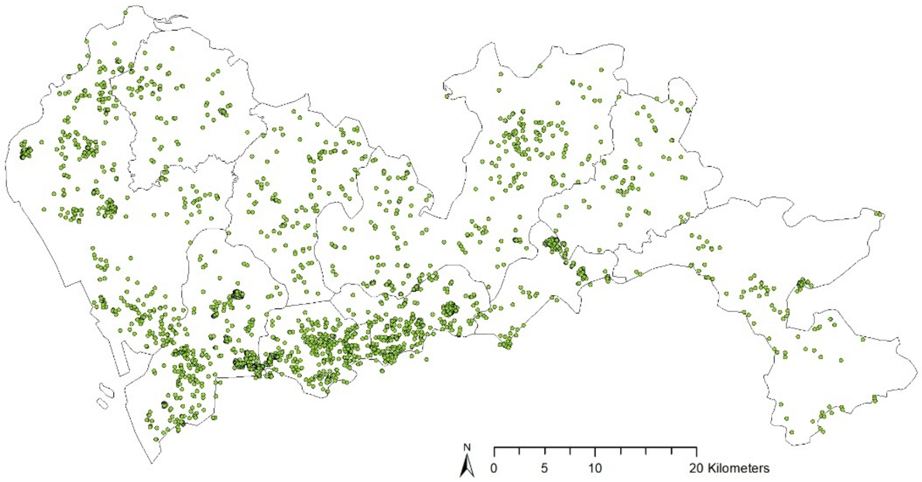

Figure 5-11. Distribution of outdoor and recreation facilities in Shenzhen.

(8) Sports and leisure

The POI data obtained for this study contained 15,049 sports and recreation facilities. Sports and leisure facilities usually refer to places that provide various sports and recreational activities, such as parks, stadiums, swimming pools, gyms, golf courses, etc. These facilities are usually marked on the map to facilitate users to find and use them. The map shows that the sports and recreation facilities in Shenzhen are widely distributed, dense and covering a wide area, so that people can exercise or recreation at any facilities near the city or community (Figure 5-12).

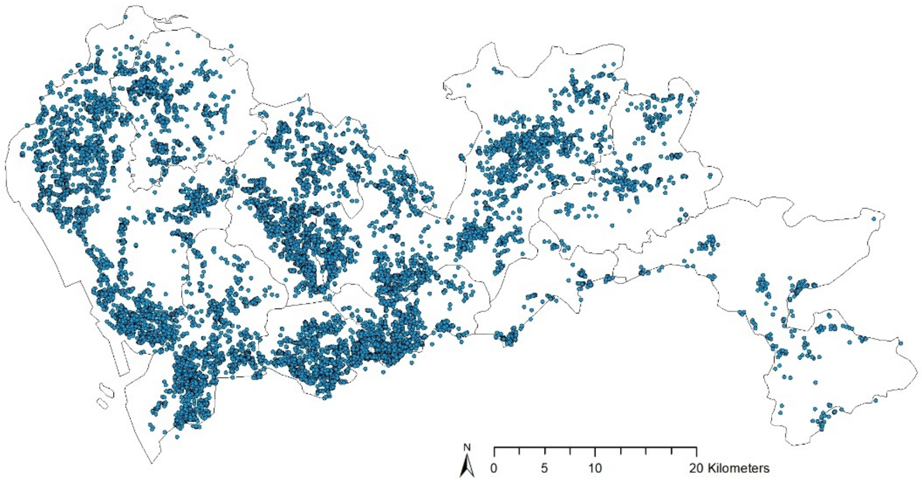

Figure 5-12. Distribution of sports and leisure facilities in Shenzhen.

5.1.2.2 Distribution characteristics of various POI

The statistical analysis of POI in 10 administrative districts of Shenzhen, as shown Figure (5-13), shows that restaurant facilities, sports and leisure facilities, and public service facilities account for the largest proportion in each district, indicating that the use of such facilities is in high demand and better promotes urban vitality. In terms of the number of facilities, Longgang and Baoan districts have a high number of facilities, which is related to the area of each district. However, the three central districts of the city, Luohu, Futian and Nanshan, which are relatively small in terms of administrative area, also show a rich number of facilities of various types.

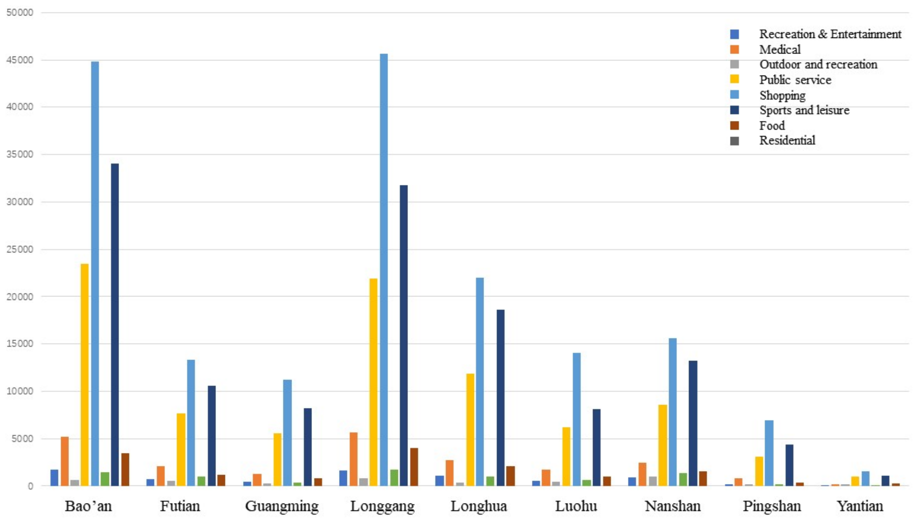

Figure 5-13. Distribution characteristics of various POI.

I use Kernel Density Estimation to explore the food facility POI, public service facility POI, and sports and leisure facility POI data to identify POI dense areas, and Kernel Density Curve (KDC) can show the density value of each data point.

Kernel Density Estmation (KDE) believes that in a certain spatial range, a certain event can occur at any location, but the probability of occurrence is different in different geographical locations, if the number of events in a certain area is high, it is considered that the frequency of this event in this area is high, and vice versa is low. In addition, according to the first law of geography, that is: the closer things are associated more closely, the closer the location with the core elements to obtain the greater the value of density expansion. I can consider each occurring event as a core element, then the stronger the correlation between the core elements in the region where the events occur more frequently. And the kernel density estimation reflects this idea by a function. Using the relevant software this function is presented in the form of an image. The formula is as follows:

$$\mathrm{fd}_t = \frac{N_i}{S_i} f_{\mathrm{n}}(x) = \frac{1}{nh}\sum_{i=1}^{n} k(\frac{x - x_i}{h})$$

where k is the weight function of the kernel, h is the bandwidth, i.e., the width of the surface extended in space with x as the origin, and the value of h affects the smoothness of the graph; x-x_i is the distance between the density valuation point x and x_i.

Food facilities are most concentrated in Luohu Center, Futian Chegongmiao Area, Futian Central District and Nanshan Houhai Area, with Longhua North Station Central District, Longgang Buji Area and Baoan Central District forming a secondary concentrated core (Figure 5-14).

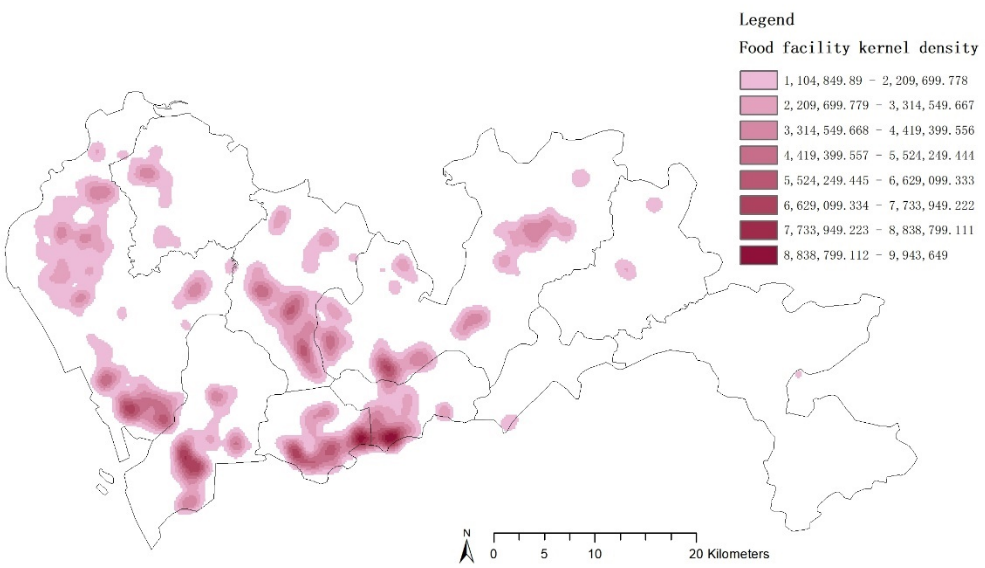

Figure 5-14. KDE analysis of food facilities.

In terms of public service facilities, the overall public service facilities in Shenzhen are unevenly distributed. The central city has the highest and most concentrated density of public service facilities

(Figure 5-15). This reflects the unequal distribution of social resources.

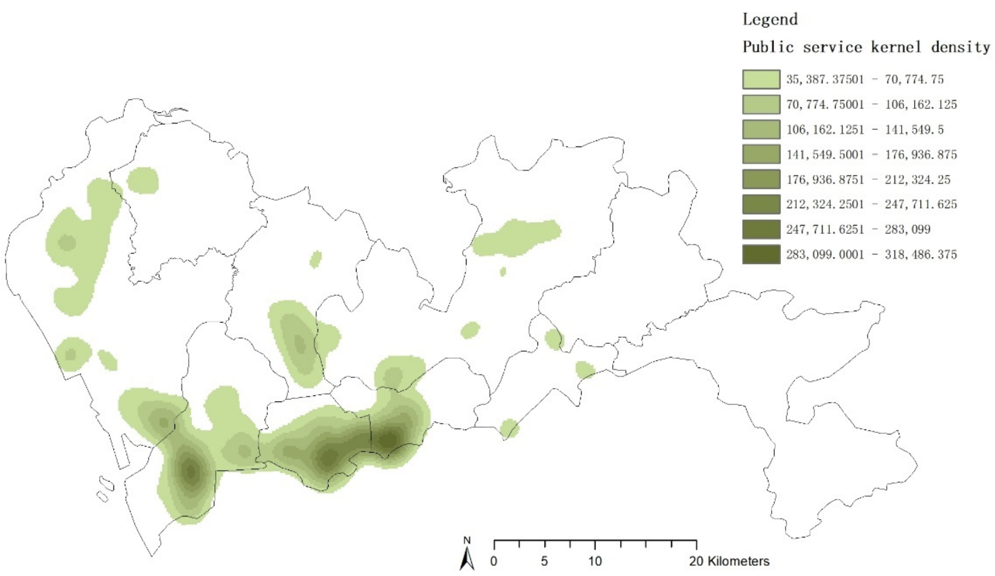

Figure 5-15. KDE analysis of public service facilities.

In addition, the third largest number of sports and leisure facilities are more evenly distributed. Except for the central district of Luohu, which has the highest density of facilities, the other administrative districts have a more balanced development of sports facilities coverage and density (Figure 5-16). The effect of national fitness is remarkable.

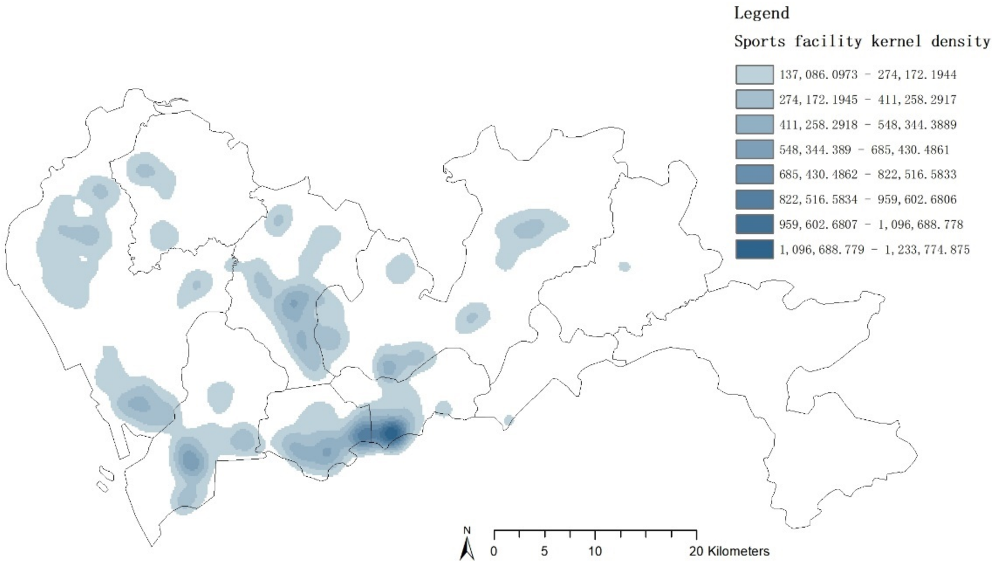

Figure 5-16. KDE analysis of sports and leisure facilities.

5.1.3 Special built environment factors

Shenzhen urban villages can also be regarded as a built environment. Shenzhen urban villages are urbanized areas located outside the central city of Shenzhen, in which a large number of migrant workers from all over the country live [19,20]. The existence and development of Shenzhen urban villages is an important historical and cultural background in the urbanization process of Shenzhen, and their existence and development reflect the course and characteristics of Shenzhen's urban development. In Shenzhen's urban villages, many people with different backgrounds live, work and study here, forming a unique urban village culture. The existence of Shenzhen urban villages provides low-cost living space for migrant workers and meets their needs for living in Shenzhen, while contributing to the economic development of Shenzhen [21]. However, with the continuous development of Shenzhen city, the existence of urban villages has also brought some problems, such as environmental pollution and security problems. Therefore, the Shenzhen government is also actively promoting the transformation and upgrading of urban villages to meet the development needs of the city.

Therefore, this paper proposes to study the impact of urban villages on urban vitality from an urban perspective, as a special built environment, at the neighborhood scale. I included the urban village indicator as one of the independent variables. Kernel density estimation (KDE) was used to map the distance between geographical location and urban villages. This approach reflected the spatial clustering of analysis targets [22]. In this study, I obtained the urban village point data from Amap and analyzed the distance from urban village (DUV) data for each cell by KDE.

The Shenzhen urban village data points used in this paper contain a total of 2460 village point information. It contains information such as name, address, latitude and longitude (Figure 5-17).

FID	Shape *	name	address	adname	pname	cityname	tel	type	lon	lat
0	Point	大望村	新平大道	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名|商务住宅;住宅区;	114.166879	22.605837
1	Point	向西村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.120581	22.545319
2	Point	莲塘	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.163914	22.56566
3	Point	田心村	宝岗路168号	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名|商务住宅;住宅区;	114.107941	22.56964
4	Point	文锦渡	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.121416	22.543252
5	Point	水贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.120551	22.574605
6	Point	独树	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.119228	22.578856
7	Point	附城	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.126491	22.546465
8	Point	新桥	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.139595	22.545333
9	Point	新湖	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.11269	22.537565
10	Point	田贝村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.117926	22.566036
11	Point	湖贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.124101	22.548709
12	Point	大坪	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.173061	22.60471
13	Point	向东	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.122191	22.544335
14	Point	大径	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.165677	22.597162
15	Point	长岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.178967	22.557747
16	Point	怡景花园	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.13374	22.55855
17	Point	梅岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.19433	22.59695
18	Point	坳下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.164257	22.569826
19	Point	西岭下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.152446	22.555729
20	Point	旧围	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.103784	22.547619
21	Point	茅径	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.096736	22.57801
22	Point	上田贝	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.116879	22.567156
23	Point	洪岭	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.102547	22.5572
24	Point	田心村牌坊	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.107816	22.569765
25	Point	上下坪	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.080508	22.596159
26	Point	新田村	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.172211	22.604678
27	Point	新屋下	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.110126	22.59191
28	Point	大望耕作口	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.162838	22.606643
29	Point	禾塘岗	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.182597	22.597222
30	Point	落马石	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.176395	22.613309
31	Point	马水凤	罗湖区	罗湖区	广东省	深圳市	[]	地名地址信息;普通地名;村庄级地名	114.192335	22.589193

Figure 5-17. Shenzhen urban village data content.

Among them, Longgang District has the largest number of urban villages, with 797 urban villages, Baoan District 428, Futian District 116, Guangming District 138, Longhua District 298, Luohu

District 171, Pingshan District 239, Nanshan District 203, and Yantian District 70 urban villages (Table 5-4).

Administrative region	Number of Urban Villages
Baoan District	428
Futian District	116
Guangming District	138
Longgang District	797
Longhua District	298
Luohu District	171
Nanshan District	203
Pingshan District	239
Yantian District	70

Table 5-4. Number of urban villages in each district of Shenzhen.

I conducted a nuclear density analysis of urban villages to analyze the clustering of urban villages (Figure 5-18, 5-19). As shown in the figure, the urban villages are gathered to the highest extent in Luohu Railway Station Area, Longhua Central Area, Longgang Central Area, and Baoan Shajing Area. It can be found that urban villages are widely distributed in Shenzhen and have a great impact on the built environment and economic and social development of the city.

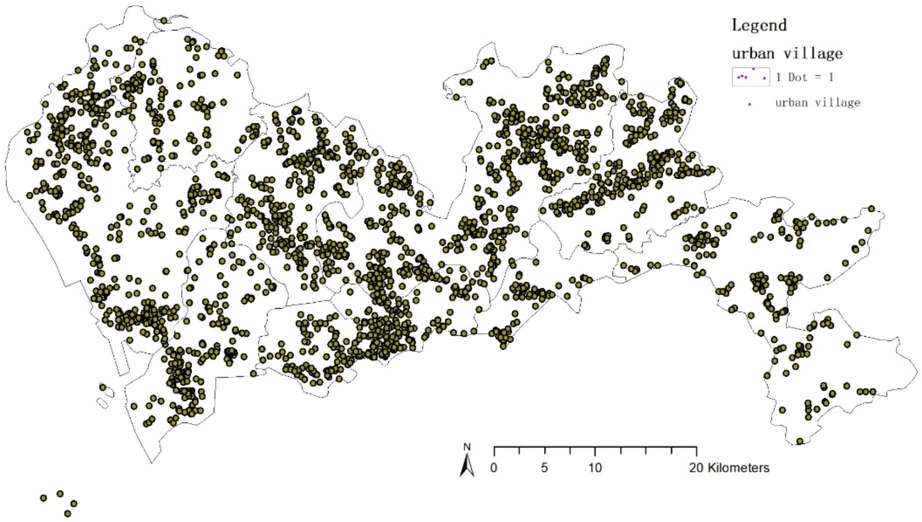

Figure 5-18. Shenzhen urban village distribution.

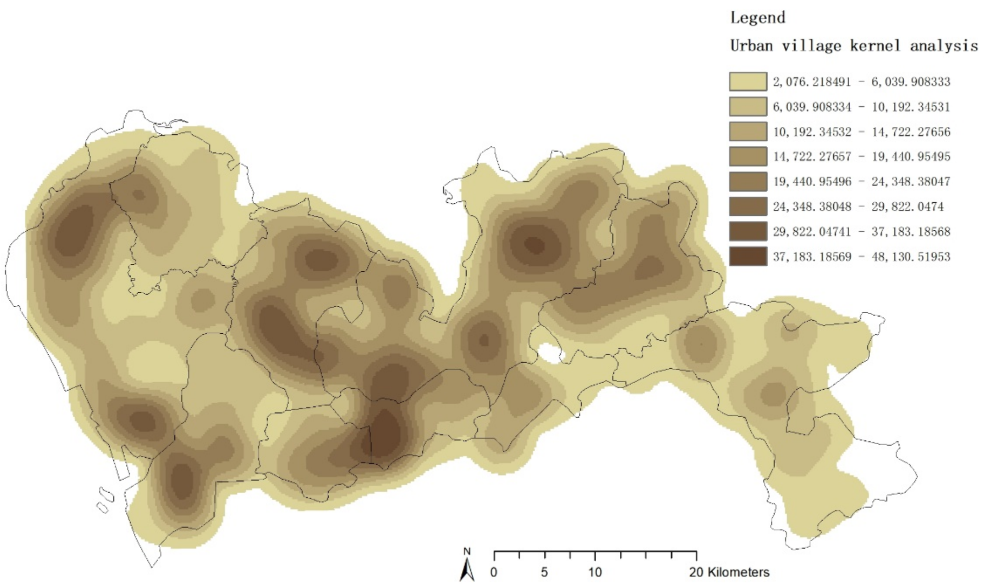

Figure 5-19. KDE analysis of urban villages in Shenzhen.

5.1.4 Summary of Built Environment Indicators

The data of the indicators in the above three morphological dimensions were compiled, and the data were analyzed spatially and processed by ArcGIS platform, and the data of 12 built environment indicators were detailed as follows (Table 5-5).

Component	Variables	Description	Mean	Std.	Max	Min
Urban form	Road network density (RND)	The total length of roads in the space unit divided by the area of the unit	1541.97	1785.70	15,639.50	0.00
	Transportation facilities density (TFD)	The total number of transportation facilities in a unit divided by the area of the unit	4.65	9.14	118.00	0.00
	Building density (BuD)	The total area of building footprints in a unit divided by the area of the unit	363,834.56	607,483.34	5,834,529.17	0.00
Urban village	Distance from urban villages (DUV)	The straight-line distance from the centroid of the space unit to the nearest urban village	0.11	0.13	0.75	0.00

POI	Food facilities density (FoD)	The total number of food facilities in a unit divided by the area of the unit	14.64	34.49	415.00	0.00
	Shopping facilities density (ShD)	The total number of shopping facilities in a unit divided by the area of the unit	19.75	47.97	1112.00	0.00
	Public service facilities density (PuSD)	The total number of public service facilities in a unit divided by the area of the unit	10.07	21.14	236.00	0.00
	Recreation & Entertainment density (REnD)	The total number of recreation & entertainment facilities in a unit divided by the area of the unit	0.83	2.34	72.00	0.00
	Residential facilities density (ReD)	The total number of residential facilities in a unit divided by the area of the unit	3.59	6.99	164.00	0.00
	Medical facilities density (MeD)	The total number of medical facilities in a unit divided by the area of the unit	2.49	5.98	62.00	0.00
	Outdoor and recreation density (ORD)	The total number of POIs in the outdoor and recreation category divided by the area of the unit	0.47	2.01	74.00	0.00

	Sports and leisure density (SLD)	The total number of sports and leisure in a unit divided by the area of the unit	0.89	2.16	29.00	0.00

Table 5-5. Description of indicators for built environment.

5.2 Analysis of factors influencing comprehensive urban vitality based on multiple linear regression model

5.2.1 Modeling Approach

This paper uses a linear regression method to analyze the effects of various factors in the built environment on the vitality of new cities [23]. The comprehensive urban vitality value obtained in the third sheet is used as the dependent variable, and the 12 factors of the built environment in the three levels in Chapter 4 are the independent variables. The data were prepared for analysis by cleaning, missing value filling, and outlier handling operations. Regression analysis was used to explore the effects of the factors on the vitality of the new towns. Different methods such as linear regression and multiple regression were tried. Specifically, regression coefficients and standard errors were calculated for each independent variable on the dependent variable, as well as the correlation between them. These results can help us to understand the degree and direction of the influence of each factor on the vitality of the new city. Finally, a statistical significance test is required to determine the reliability of the regression results. This can be done by calculating the standard errors, t-values, and P-values of the regression coefficients. If the p-value is less than the significance level (usually 0.05), the regression coefficient can be considered significant, meaning that the independent variable has a significant effect on the dependent variable.

5.2.1.1 Ordinary Least Squares Model

Ordinary least squares regression model (OLS) is the most popular technology to study the relationship between urban vitality and urban morphology. It explains the connection between the dependent and independent variables [3,24,25]. Multiple linear regression models were used to help explore the relationships between incompatible parameters [25]. The dependent variable in this paper was the composite vitality value determined through economic, social, and cultural vitality, while the built environment indicators were the independent variables. The formula is as follows:

$$y = \beta_0 + \sum_{j=1}^{m} \beta_j x_j + \varepsilon$$

where y is the dependent variable, x_j is the *jth* independent variable, β_j denotes the corresponding estimated coefficient, and ε is the residual.

However, the relationship between geographic variables usually varies with location, which affects the accuracy of regression models. The spatial dynamics of the interaction between spatial variables cannot be explained by the OLS model since it ignores the spatial influence of variables [26].

5.2.1.2 Global Moran's I

I calculated the Moran's I to understand the spatial patterns of urban dynamism. Moran's I is a critical research indicator for studying dependence between variables [6]. Moran's I typically have a value between −1.0 and 1.0, with greater absolute values de-noting stronger spatial autocorrelation. The local relationship between the vitality and built environment was defined using the local indicator of spatial association (LISA) under various spatial and urban built environment conditions [27].

5.2.1.3 Spatial Lag Multiple Regression Model

The urban form elements were spatially inter-related because urban planning had the characteristics of spatial continuity. For example, roads and communities were connected in adjacent space units. Therefore, the spatial element studied may have been affected by its adjacent elements. The ordinary least squares (OLS) model based on independent assumptions has limited ability to analyze this type of data. However, spatial lag multiple regression model (SLM) can weaken the deviation of autocorrelation, thus reducing the mutual interference of adjacent units [6]. The formula is as follows:

$$Y = \beta_0 + \rho WY + \sum_i \beta_i X_i + \varepsilon$$

where Y denotes the dependent variable, X_i represents the explanatory variable i, β_0 is the intercept, β_i is the estimated coefficient of the explanatory variable, W is the spatial weight matrix, with ρ as the spatial autoregressive coefficient, and ε is the error term. In this paper, the dependent variable was the urban vitality and the explanatory variable was the factors of the built environment.

5.2.2 Independent variable multicollinearity diagnosis

Spatial autocorrelation refers to geographic things distributed in different spatial locations, and there is a statistical correlation between the values of one of their attributes, and usually the closer two observations are to each other, the greater the correlation. Specifically, it can be divided into spatial positive correlation and spatial negative correlation. Positive correlation indicates that the change of an attribute value of a unit has the same trend as its neighboring spatial units, while negative correlation is the opposite trend.

When the number of independent variables in a regression model is large, these independent variables may be correlated with each other. A classical assumption of multiple linear regression models is that there cannot be a linear relationship between the independent variables of the regression model, and if this assumption is violated, it is said that there is multicollinearity in the regression model. Multicollinearity will have serious consequences for the least squares method, causing confusion in the regression results. Tolerance (tol) and variance inflation factor (VIF) are generally used in statistics to identify co-linearity, and they are reciprocal. It is usually considered that serious multicollinearity exists when the Tol value is less than 0.1, or the VIF value is greater than 10; the VIF value is generally required to be less than 5.

The correlation between all independent variables is further investigated. When the stronger the multiple correlation of an independent variable with other independent variables, the more it should be removed from the model; the stronger the correlation of an independent variable with the dependent variable, the more it should be introduced into the model. Based on the results of correlation coefficient analysis between all variables. As shown in Figure (5-20, 5-21), the correlation coefficient of food (FoD) is extremely high, reaching 0.9, and when the correlation coefficient between the independent variables exceeds 0.8 it should be removed directly. Further analysis of the correlation between the two and the dependent variable. Shopping (ShD), public services (PuSD) and health care (MeD) had strong positive correlations (correlation coefficient $r>0.8$) and were all excluded from the model.

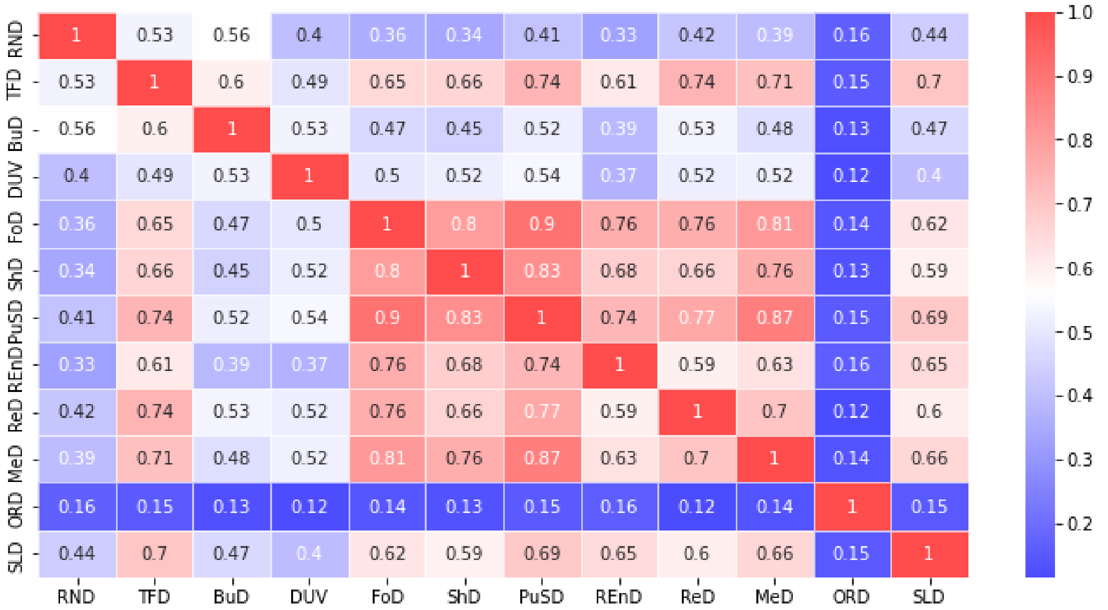

Figure 5-20. Correlation matrix of dependent variable.

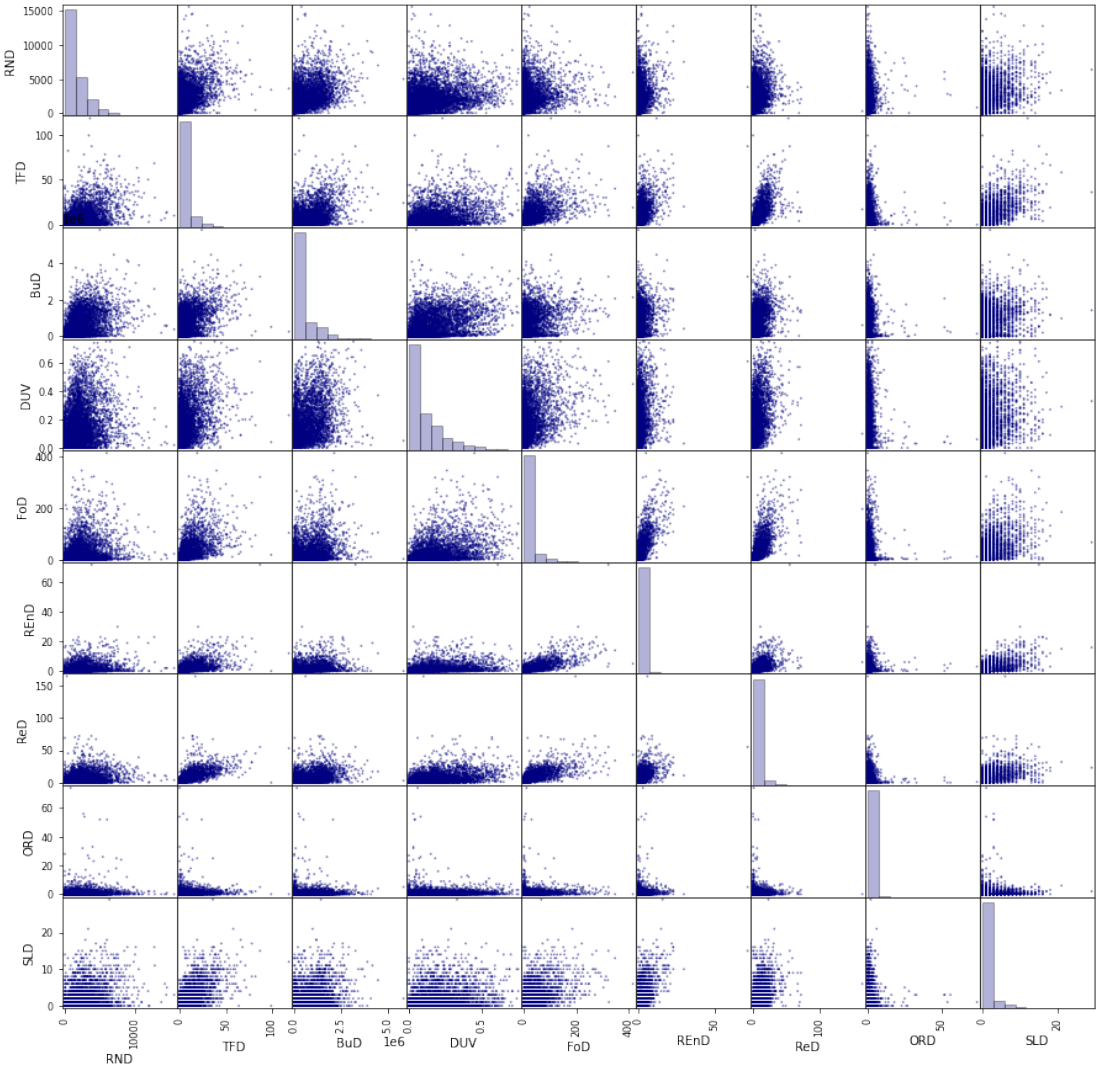

Figure 5-21. Correlation matrix of dependent variable.

Therefore, only the indicator of shopping facilities (ShD) was selected for modeling, which reduces the problem of multicollinearity. Three aspects of other urban built environment factors were modeled and their relationships with urban vitality were analyzed, including roads, transportation facilities and floor space in terms of form, proximity to urban villages in terms of urban village factors, and dining facilities, recreational facilities, housing, outdoor attractions and sports and health in terms of function. The relevant results are listed in Table 4.

Variable	Coefficient	Std. Error	t-Statistic	Probability	Model Diagnosis

CONSTANT	−74.0718	18.525	−3.9985	0.0000	
RND	0.0595	0.0091	6.5149	0.0000	
TFD	36.4748	2.5703	14.1909	0.0000	$R^2 = 0.3340$
BuD	0.0001	0.0000	3.8882	0.0001	Adjusted $R^2 = 0.3333$
DUV	−887.301	126.55	−7.0115	0.0000	LogL = −72,861.6
ShD	4.1320	0.4255	9.7103	0.0000	AIC = 145,743
REnD	195.617	8.2414	23.736	0.0000	F = 477.683
ReD	−45.6359	2.9904	−15.2609	0.0000	$p = 0$
ORD	−2.2176	6.4593	−0.3433	0.7312	
SLD	81.0221	9.0196	8.9829	0.0000	

Table 5-6. Description of indicators for built environment.

Table 4. Result of OLS model.

5.2.3 Model results testing

After normalizing the variables and verifying the multicollinearity of the independent variables, a multiple linear regression analysis was conducted between the new city vitality and the factors influencing the urban built environment, and the model results were tested and analyzed using the goodness-of-fit test, F-test, partial correlation coefficient analysis, and t-test, as follows.

The goodness-of-fit test and F-test were conducted from the perspective of the model as a whole.

The goodness-of-fit of the model is measured by the multiple coefficients of determination R^2, which indicates the proportion of the total variance of the dependent variable y that is explained by multiple independent variables, and the value of R^2 ranges from 0 to 1, with the closer to 1 indicating the stronger linear correlation between the dependent variable and the independent variable. The F-test reflects the significance of the overall regression relationship between the dependent variable y and the k independent variables, and is also called the overall significance test. The test passes when the F value is greater than the critical value of the F statistic.

The existence of a significant linear relationship between all explanatory variables (independent variables) jointly and the explanatory variable (dependent variable) does not mean that each independent variable has a significant effect on the dependent variable separately. The bias correlation coefficient is the degree of direct influence of each independent variable on the dependent variable, net of the indirect influence of other variables. t-test is based on the t-value to test whether the independent variable corresponding to the regression coefficient has a significant influence on the dependent variable. t-test assumes that the regression coefficient of the independent variable is zero at some significance level, i.e., the independent and dependent variables are not correlated. Given the significance level and the sample size, the critical value can be determined, and when the t-value is greater than the critical value, the original hypothesis is rejected. The corresponding P-value indicates the sum of the probabilities of having the sample or more extreme results than the sample when the original hypothesis is true. a smaller P-value indicates a better model significance.

5.2.3.1 Least squares regression model test

Table (5-7) displays the findings of a linear regression analysis with road network density (RND), transportation facilities (TFD), building density (BuD), distance from urban villages (DUV), shopping facilities (ShD), recreation and entertainment (REnD), residential (ReD), outdoor and recreation (ORD), and sports and leisure (SLD) as the independent variables and urban vitality as the dependent variable. The model R^2 value of 0.334 implies that RND, TFD, BuD, DUV, ShD, REnD, ReD, ORD, and SLD can explain 33.4% of the variation in urban vitality. The regression model passed the F-test ($F = 477.683$, $p < 0.05$). P-values for the significance analysis of the eight explanatory variables of RND, TFD, BuD, DUV, ShD, REnD, ReD, and SLD on urban vitality were all less than 0.05, indicating that the indicators in three dimensions of urban form, urban village, and urban function had a significant impact on vitality. The regression coefficients of DUV and ReD were negative, indicating a negative effect of the variables on urban vitality, while RND, TFD, BuD, ShD, REnD, and SLD showed a significant positive effect on urban vitality. The ORD variable appeared non-significant ($p = 0.7312$) and was excluded.

5.2.3.2 Spatial lag regression model test

The model was then optimized and further spatial regression models were used to lessen the influence of spatial autocorrelation [6]. The SLM model was selected because both the Robust LM (lag) and Robust LM (error) tests were significant; the Robust LM (lag) values were higher. This was determined via Lagrange multiplier tests for LM lag, LM error, Robust LM lag, and Robust LM error. Therefore, the SLM regression analysis was carried out with the dependent variable and urban vitality after excluding ORD. The results are shown in Table 5, where the model R^2 value increased from 0.334 in Table 5 to 0.445, indicating a significant optimization of the SLM model compared to the OLS model. Seven variables—RND, TFD, DUV, ShD, REnD, ReD, and SLD—had a significant impact on vitality ($p < 0.05$), while building density had no significant effect on urban vitality ($p = 0.6098$). It is worth noting that road network density, transportation facilities, shopping facilities, recreation and entertainment, and sports and leisure facilities significantly increased urban vitality.

Variable	Coefficient	Std. Error	t-Statistic	Probability	Model Diagnosis
CONSTANT	−29.6145	16.9158	−1.7507	0.0800	
RND	0.0214	0.0083	2.5625	0.0104	R^2 = 0.4451
TFD	14.7271	2.3713	6.2107	0.0000	LogL = −72,260.6
BuD	0.0000	0.0000	0.5104	0.6098	AIC = 144,541
DUV	−834.246	115.517	−7.2218	0.0000	p = 0
ShD	4.7488	0.3890	12.2079	0.0000	
REnD	161.501	7.5144	21.4922	0.0000	
ReD	−38.382	2.7266	−14.0767	0.0000	
SLD	70.5386	8.2414	8.5591	0.0000	

Table 5-7. Result of SLM model.

5.2.4 Analysis of model results

Based on the above experimental results, the influence relationship between built environment elements and urban vitality is summarized.

The explanatory power of the SLM model for the OLS model increased from 33.4% to 44.5%, which is a significant improvement. Among them, road network density, transportation facilities, urban villages, recreation, residential facilities and sports and leisure facilities have significant effects on urban vitality. Among them, urban villages and residential facilities have a negative effect on urban vitality, while the remaining five indicators have a significant positive effect on urban vitality, i.e., the larger their values are, the higher the urban vitality value is. The results of the urban village factor indicate that the further away from the urban village, the higher the vitality. In other words, renewing or even demolishing and rebuilding urban villages can help to increase vitality. At the transportation level, increasing the density of road network and transportation facilities, and strengthening the transportation links between Shenzhen districts can enhance urban vitality. The POI results show that the higher the density of various functional elements, the more people can be motivated to go out to their destinations, and the greater the urban vitality. Increasing the density of various facilities can help to improve the vitality.

The degree of influence of each influencing factor on urban vitality can be analyzed according to the partial correlation coefficients of independent variables in the regression models. In both models, the bias correlation coefficient of distance from urban villages is the largest, so urban villages have the most significant negative effect on the enhancement of urban vitality. While leisure and recreational facilities are the largest correlation coefficients among the positive influencing factors, indicating that increasing the density of leisure and recreational facilities has the best effect on the enhancement of urban vitality. Besides, from the classification point of view, the traffic aspect has an average effect on the improvement of urban vitality. And from the functional perspective, the impact of various types of POI facilities on vitality is unevenly distributed.

In both experiments, there is no correlation between outdoor facilities and urban vitality. It indicates that the use of outdoor facilities can already meet the needs of people. Building density in the OLS model also shows a significant effect on urban vitality, but the effect is almost invisible. In the SLM model, the effect of building density on vitality is not significant. Because people's demand for space is not related to building density, they only need to provide spatial places and will not pay attention to the specific morphological characteristics of buildings and the information of floor area ratio, so there is no correlation between building density and urban vitality, and the model is excluded.

5.3 Analysis of factors influencing comprehensive urban vitality based on a geographically weighted regression model

5.3.1 Model construction

GWR (Geographically Weighted Regression) is a geographic data processing technique that can solve the problem of non-smoothness of spatial data and improve the prediction effect of the model [28]. Its core idea is to assign different weights according to spatial geographic location and incorporate spatial autocorrelation factors into the regression model. The spatial regression model introduces spatial autocorrelation on the basis of the general linear regression model, and deeply explores and utilizes the spatial information of the data. However, the parameters of the spatial regression model do not vary with spatial location, so in essence the spatial regression model is a global model, and the parameters in the model are the same for all study areas. In fact, due to spatial heterogeneity, the quantitative relationships between the independent and dependent variables on different spatial regions may be different. Geographically weighted regression (GWR) is essentially a locally weighted least squares method, where the weight is a function of the distance between the geospatial location of the point i to be estimated and the geospatial location of the other observations j. The regression coefficient β of GWR is no longer a global uniform single value, but varies with the change of spatial location of the model parameters. These parameter values estimated at each spatial location describe how the parameters vary with the spatial location under study and are used to explore the spatial heterogeneity of the spatial data [26].

Firstly, using the findings of the multiple linear regression model, seven factors related to urban vitality, namely road network density, transportation facilities, urban villages, recreation, residential facilities and sports and leisure facilities, and commercial facilities, were selected as independent variables, and the overall urban vitality value was used as the dependent variable for model construction and analysis. Determine the weight matrix. Then, by setting the bandwidth (or kernel function), the space is divided into several local areas, and regression equations are built for each area separately. Based on the input data, the GWR model is run to obtain results such as regression coefficients and goodness-of-fit.

Geographically weighted regression (GWR) was used to estimate spatial heterogeneity using the factors strongly linked with urban dynamism in the SLM; the findings are reported in Table (5-8). An AIC of 141,859 and average adjusted R^2 of 0.5899 indicate a high level of explanatory power. Compared to OLS and SLM, it displays a better model fit. The range of standardized residuals is [−18.14, 28.72], with approximately 95% at [−2, 2], indicating a good overall performance for GWR. The local R^2 values ranged between 0.30 and 0.90, indicating that the GWR model effectively fit the data (Figure 5-22, 5-23).

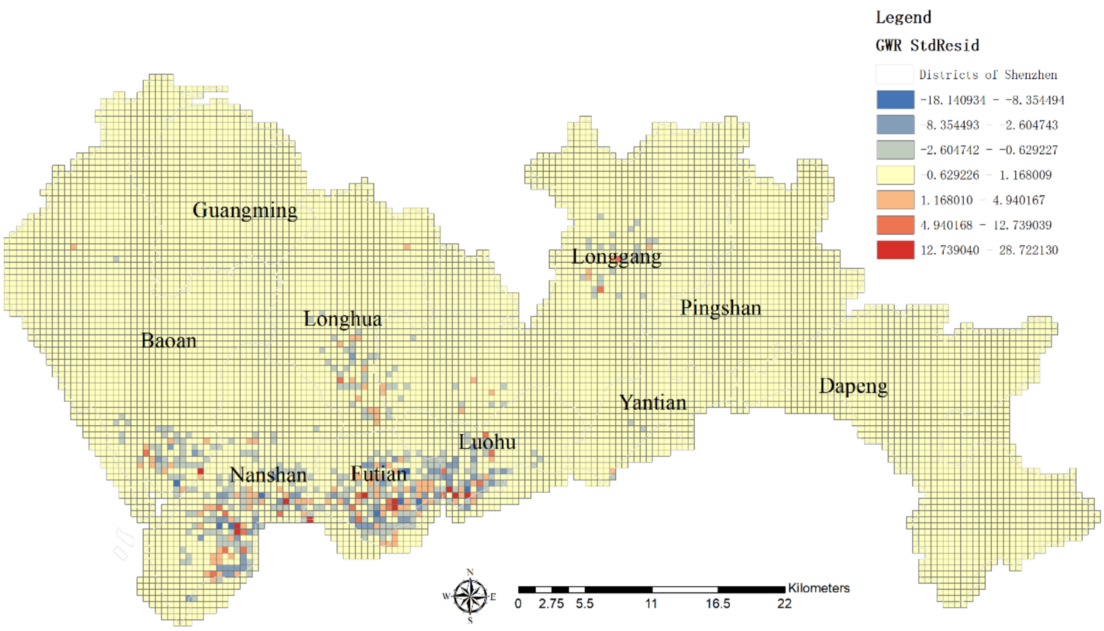

Figure 5-22. Standardized residuals distribution of GWR model.

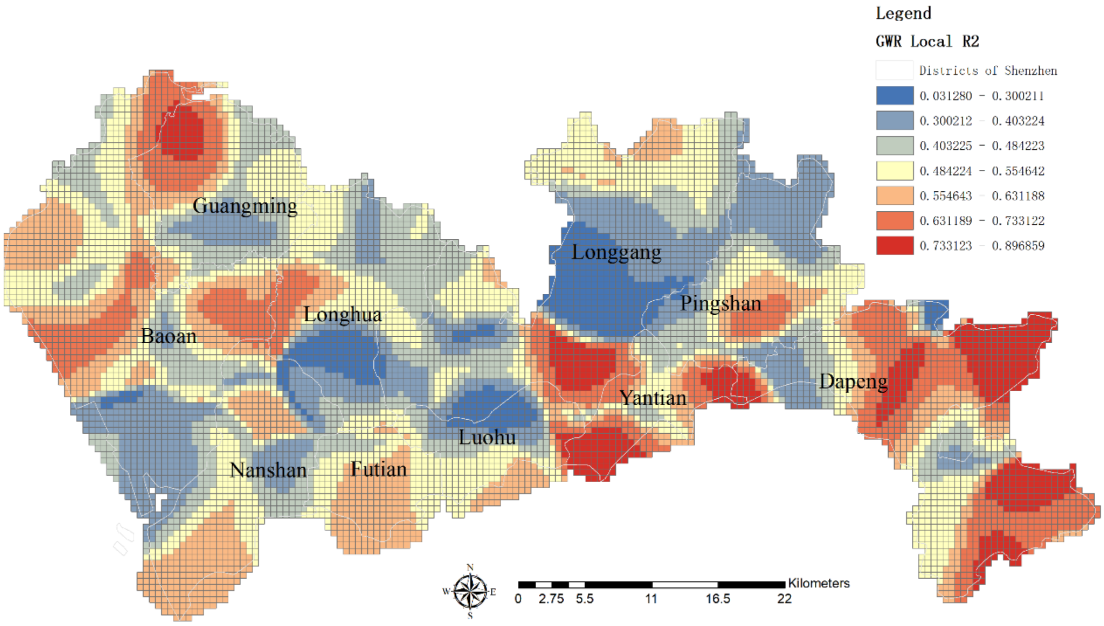

Figure 5-23. R^2 distribution of GWR model.

As shown in Table (5-8), the adjusted R^2 of the spatial-temporal geographically weighted regression model is 0.5899, indicating that the spatial-temporal geographically weighted regression model can explain more than 59% of the changes in the comprehensive vitality of cities, which has a significant advantage over multiple linear regression. The statistical results show that, unlike the constant coefficient of a certain indicator within the same multiple linear regression model, the coefficient of each indicator in the regression model obtained by spatial-temporal geographic weighting regression will change accordingly as the spatial-temporal coordinates of the sample change, so that the relationship and changes of each indicator on the comprehensive vitality of the city can be explained from a more refined scale.

Variable	Mean	Std	Min	Max	Model Diagnosis
RND	0.0203	0.0568	−0.0950	0.3329	R^2 = 0.6146
TFD	8.3607	17.8053	−80.6268	98.4331	Adjusted R^2 = 0.5899
DUV	−130.8055	921.8018	−4939.5691	1369.5485	LogL = −72,260.6
ShD	4.6223	8.4785	−3.6611	43.3419	AIC = 141,859
REnD	68.1365	138.6568	−189.3592	824.1901	
ReD	−15.8130	49.0429	−269.1397	97.4530	
SLD	34.8054	64.5109	−81.1455	479.9015	

Table 5-8. Result of GWR model.

5.3.2 Model results testing

The GWR model can be solved on the basis of the bandwidth preference. The interpretation of GWR model results needs to focus on two aspects: model diagnostic information and visual analysis of the results; GWR model diagnostic information mainly includes: residual sum ofsquares (RSS), which reflects the prediction accuracy of the model; R^2 or its adjusted version (Adjusted R^2), which reflects the goodness-of-fit (GoF) of the model; AICc, which integrates the GoF and model complexity of the GWR model results; and AICc, which reflects the GoF and model complexity of the GWR model results. -The AICc: a combination of GoF and model complexity reflecting the GWR model results. In general, the diagnostic statistics of the GWR model can be compared cross-sectionally with the results of the corresponding general linear regression analysis to see whether and to what extent the GWR model reflects significant improvement. Note that the AICc value is a relative statistic for a specific modeling process, i.e., the corresponding AICc value is comparable for the same set of data and the same dependent variable. When the AICc value varies by more than 3, the model results can be considered significantly different from each other.

5.3.3 Spatial and temporal distribution characteristics of regression coefficients and analysis of results

In order to better show the explanation of the change of the influence relationship of the indicators on the spatial dimension on the comprehensive urban vitality, the spatial distribution of the regression coefficients of each spatial unit is visualized and compared. In order to more intuitively study the influence relationship of each indicator on the comprehensive vitality of the city, the 0 value of the coefficient is adjusted as the cold and warm color dividing line, with the warm color indicating the area where the coefficient is positive and the cold color indicating the area where the coefficient is negative. The darker areas in the warm color region indicate that the urban comprehensive vitality is more sensitive to the change of a certain index, and the growth of urban comprehensive vitality is more obvious with the change of this index, which indicates that it is easier to achieve the effect of creating urban comprehensive vitality by increasing this index in this part of the city.

5.3.3.1 Spatial heterogeneity in the influence of urban form elements on vitality

Dense road networks (RND) are vital in promoting urban vitality; the small-scale neighborhoods formed by dense road networks are prone to promote human interaction on the streets [29]. This is consistent with previous research findings [30]. The possible reason for this is that as cities develop, roads not only function as commuting zones, but the U-shaped spaces of the streets are also increasingly converted into open spaces where people can rest and stay, increasing the vitality of the streets. This trend is aligned with China’s urban upper planning, which calls for the return of roads to pedestrians and promotes cities with small blocks and dense road networks. The impact of transportation facilities (TFD) suggests that more transportation facilities, such as subways and bus stops, can improve accessibility and promote urban vitality. This feature is more evident in Futian and Luohu districts.

(1) Road network density

Road network density has a positive effect on urban vitality. The GWR results show that there is a spatial and temporal variation in the effect of road network density on urban vitality (Figure 5-24). In Luohu and Futian districts, increasing road network density helps to improve urban vitality. However, in Longgang central area, Baoan central and Nanshan coastal area, road network density has the opposite effect on urban vitality. It indicates that with the growth of the overall city scale, spatial scale and multipolar morphological leap, the correlation between road network density, an indicator of traffic factor describing the accessibility, and urban vitality tends to increase, showing the joint development of road network density and urban vitality resolution ability. The ability of road network density to analyze urban vitality is relatively higher in the central city and lower in the peripheral sub-cities. The characteristics of circles are obvious.

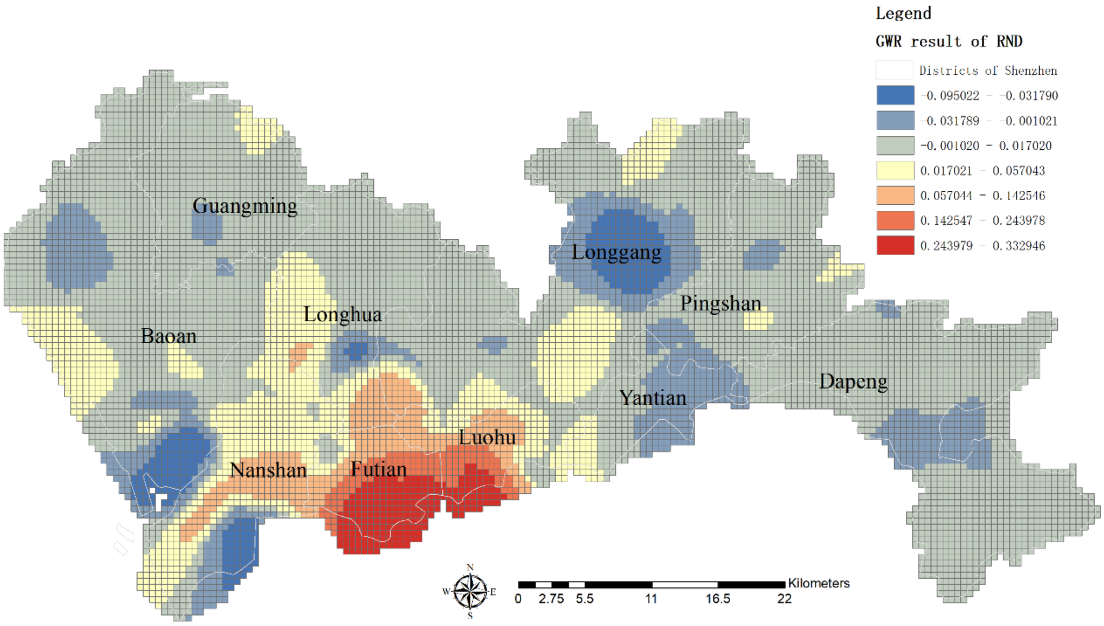

Figure 5-24. Spatial distribution of GWR model regression coefficients for road network density (RND)

(2) Density of transportation facilities

Urban vitality increases with the increase of traffic facility density, showing a positive correlation. In the spatial variation of the absolute value of the regression coefficient, it decreases from the central urban area to the peripheral urban areas, with the highest values appearing in Luohu District, Futian District and Nanshan District, and the lowest values in Baoan, Guangming and Longhua Districts, indicating that the impact of traffic facility density on the central urban area is much greater than that on the peripheral urban areas (Figure 5-25). This indicates that the population density is higher in the central urban areas and the traffic demand is greater. In the central urban areas, people usually need faster ways to travel to meet their work and life needs. Therefore, high-density transportation facilities, such as subways, light rail and buses, can better meet people's travel needs and alleviate urban traffic congestion. In contrast, peripheral urban areas have relatively fewer transportation facilities and lower population densities, and thus have relatively lower transportation demand. In addition, because peripheral urban areas typically have greater land and housing prices, it may be more difficult and economically uneconomical to build high-density transportation facilities. Therefore, although peripheral urban areas also require good transportation facilities, they may have less impact than central urban areas.

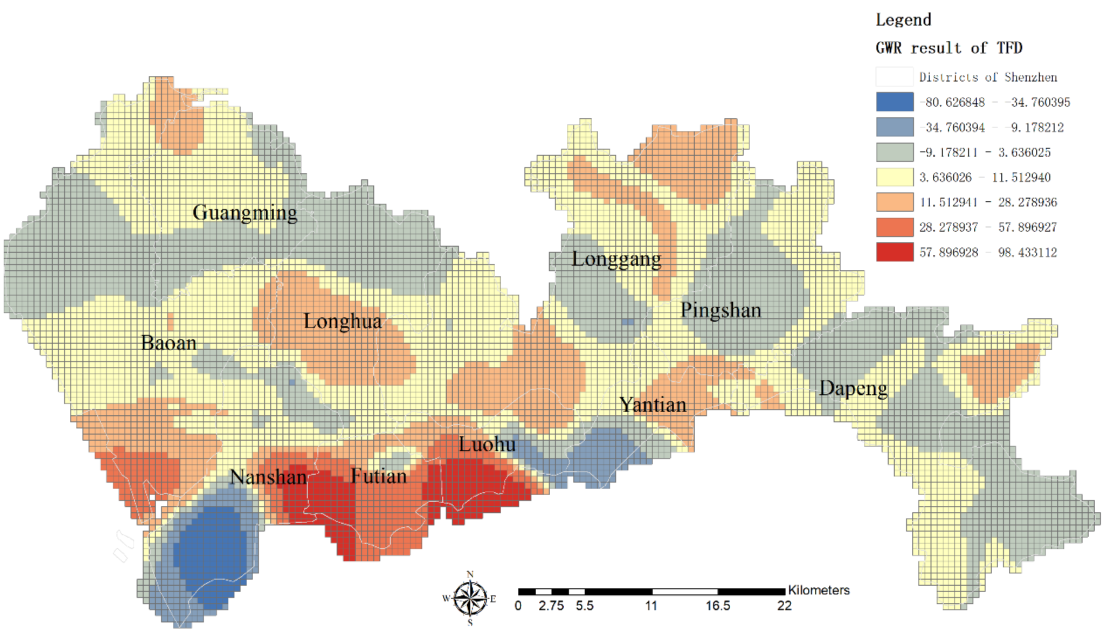

Figure 5-25. Spatial distribution of GWR model regression coefficients for transportation facility density (TFD).

5.3.3.2 Spatial heterogeneity in the influence of urban functional elements on vitality

The functional built environment indicators ShD, REnD, and SLD contribute significantly to the vitality of urban areas. The density of shopping facilities, leisure and recreation facilities, and sports and health facilities have a significant positive effect on urban vitality. This can be explained by the reality that individuals can more easily access these functional destinations to meet their daily needs, which aligned with the results of earlier research [31]. According to Figure 8, the increase in facilities in the central area of Shenzhen can result in a significant increase in urban vitality. A negative association between residential density and urban vitality is also shown in this study. Due to the mismatch between population and urban space, urban vitality is weaker in certain single-function residential areas [6]. This trend may occur because people expect more diverse and convenient services, such as shopping, transportation, leisure, and other facilities, to enrich their daily activities.

(1) Shopping facilities

Shopping facilities have a positive impact on urban vitality. The areas where shopping facilities have the greatest impact on vitality are in the Nanshan District and the Dapeng Jiaochangwei tourist attraction. And there is a decreasing circle effect to the north. However, in the northern urban areas, the impact of commercial facilities on urban vitality is smaller (Figure 5-26).

The increase in the overall density of commercial facilities in Nanshan Futian will promote the increase of urban vitality. The increased density of commercial facilities can bring more business opportunities and employment opportunities, which in turn attracts more people to the area. As the population grows, the economic vitality of the area will also increase. Also, more commercial facilities mean more business activity and consumer spending, which helps promote the growth and development of the local economy. With the economic development and urbanization of Shenzhen, the commercial facilities in Nanshan Futian area have also developed rapidly. The increased density of overall commercial facilities not only provides residents with more places and choices for consumption, but also injects new vitality into the economic development of the city.

When the density of commercial facilities increases, people can choose from a variety of shopping and entertainment options, thus increasing the choice of social interaction and recreational activities. This also helps to promote vitality and interaction in the local community. At the same time, more commercial facilities also mean more businesses and competition, which helps promote a thriving and diverse local market. However, increased density of commercial facilities may also have some negative impacts, such as traffic congestion, environmental pollution and urban planning issues. Therefore, when planning the layout and development of commercial facilities, these negative impacts need to be taken into account and measures taken to mitigate them accordingly.

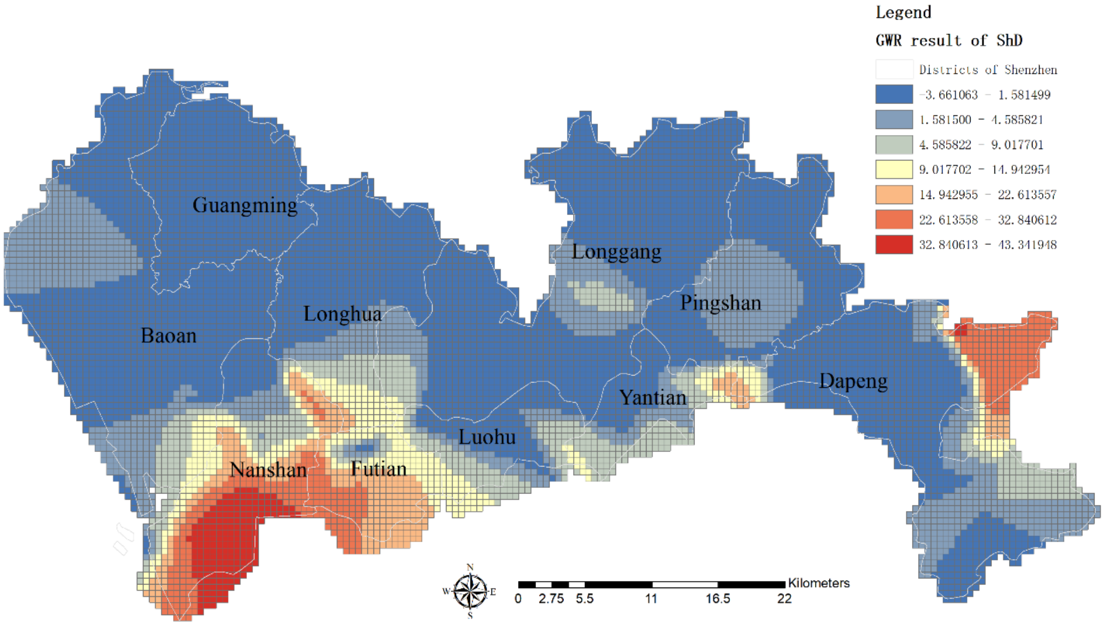

Figure 5-26. Spatial distribution of GWR model regression coefficients for shopping facilities density (ShD).

(2) Recreation and leisure facilities

The regression coefficients of leisure and recreation facilities on urban vitality are mostly positive (Figure 5-27), which have positive effects on urban vitality. The spatial distribution of the regression coefficients decreases from Futian District to the periphery, with the maximum value appearing in Futian Central District and the minimum value appearing in Longhua North Station Area. This indicates that leisure and recreation facilities have a greater impact on Futian District and the adjacent Luohu District and part of Nanshan District, and a smaller impact on the peripheral urban areas. This is due to the fact that most of the leisure and entertainment facilities are located in commercial properties, and the city center is relatively rich and dense with a wide variety of entertainment venues, such as concerts, talk shows, and theaters. In the outer northern urban areas, on the other hand, there is a relative lack of recreational facilities, so recreational facilities have less influence on the vitality of the outer urban areas.

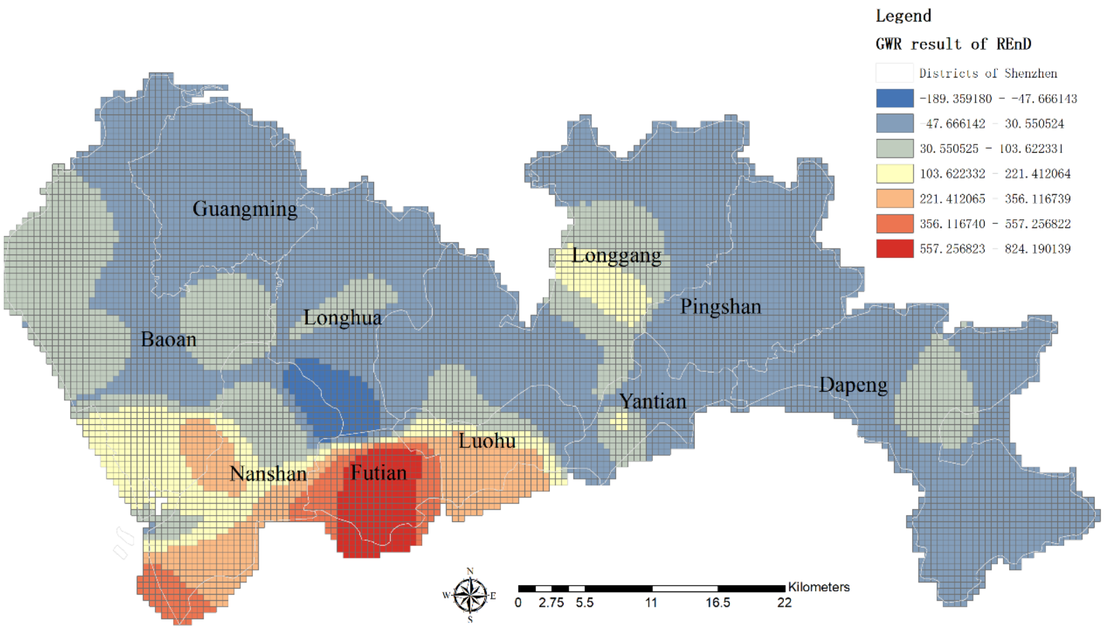

Figure 5-27. Spatial distribution of GWR model regression coefficients for recreation and entertainment density (REnD).

(3) Sports and leisure facilities

The spatial differentiation of sports and leisure facilities for urban vitality is relatively different from others. There were no north-south or east-west distribution characteristics in the circle, but higher regression coefficients were observed in Luohu, Futian, Nanshan, Longhua, and Longgang. Presents a multi-center structure. In these regions, sports facilities have the greatest promoting effect on urban vitality, and the impact of a more uniform distribution of sports facilities on vitality is not significantly different in spatial distribution (Figure 5-28). In addition, in the coastal areas of Guangming, Dapeng, and Futian, sports and leisure facilities have a negative impact on urban vitality. These places have obvious natural ecological characteristics and are not suitable for the development of sports facilities.

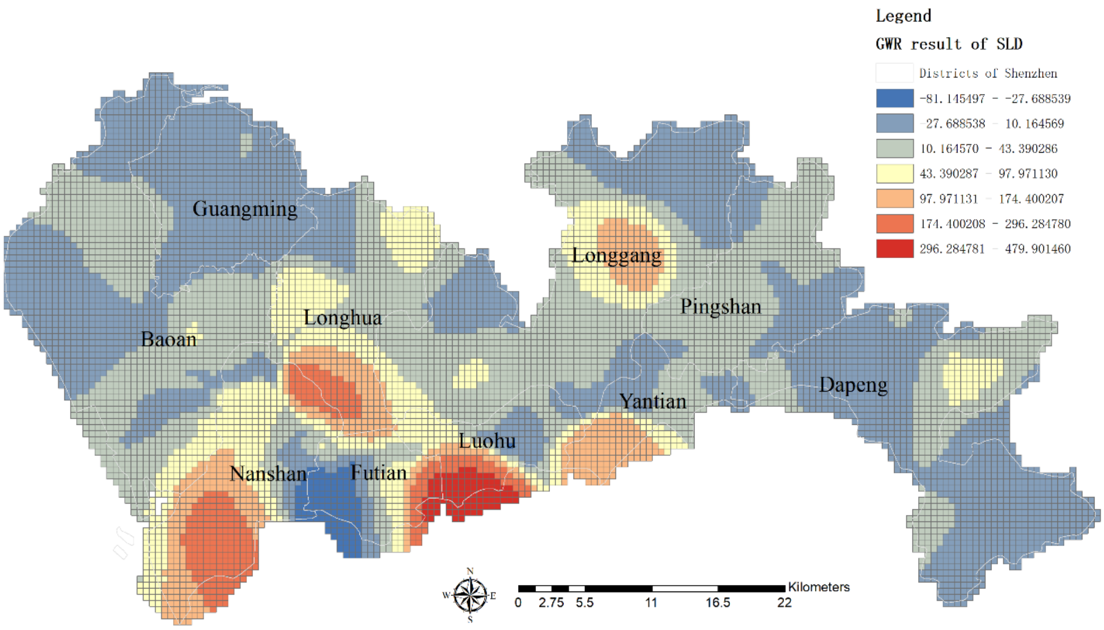

Figure 5-28. Spatial distribution of GWR model regression coefficients for sports and leisure density (SLD).

(4) Residential facilities

In this study, it was found that residential areas have a negative impact on urban vitality. This indicates that housing has suppressed the development of urban vitality. Unlike other functional indicators, residential facilities exhibit opposite spatial differentiation characteristics for urban vitality. In the central urban area, the regression coefficient of residential facility density in Luohu and Nanshan districts is negative, which has a reverse effect on urban vitality (Figure 5-29). In terms of regression coefficient distribution, the negative value in the central urban area has changed to a positive value in most units of the northern peripheral space. The increase in residential density in urban fringe areas will promote urban vitality. Firstly, as the residential density in urban fringe areas increases, the scale of population flow into cities will also correspondingly expand, resulting in more consumption and market demand. Secondly, the development of urban fringe areas can also drive the economic development of surrounding areas, forming a virtuous cycle. In addition, the development of urban fringe areas can also alleviate urban traffic pressure, environmental pollution and other issues, and improve the sustainable development level of the city. Therefore, appropriately increasing the residential density of urban fringe areas is an effective way to promote urban vitality.

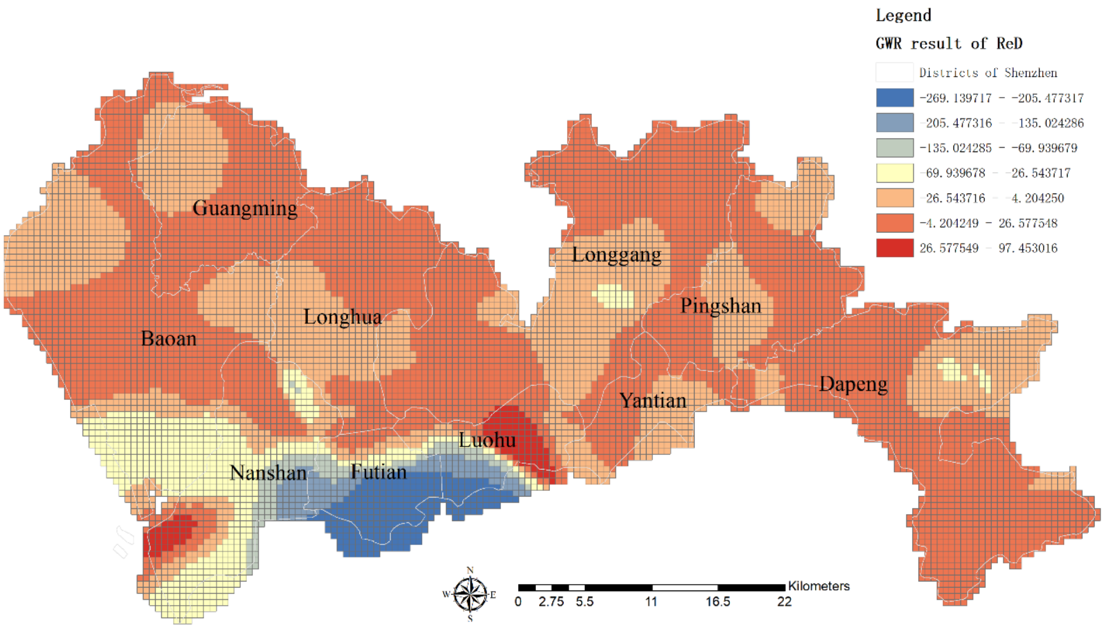

Figure 5-29. Spatial distribution of GWR model regression coefficients for residential facility density (ReD).

5.3.3.3 Spatial heterogeneity in the influence of special BE elements on vitality

In addition, the study reveals a negative correlation between urban villages and urban vitality. It demonstrates that the closer a place is to the urban village, the more dynamic it will become. The reason for this trend is likely that urban villages usually have a poor living environment, high building and population density, and fewer supporting facilities. As a result, urban villages rarely become urban destinations and hardly generate urban dynamism. On this basis, GWR has expanded to explain the characteristics of spatial differentiation. The urban central area composed of Luohu, Nanshan, Futian, and Bao'an has lower vitality as it is closer to the urban village. On the contrary, in periphery districts such as Bao'an, Longhua, Guangming, and Longgang, villages often have a positive impact on urban vitality (Figure 5-30). Urban villages are significantly clustered and denser in these areas, providing possible spaces and places for various activities of urban development. Urban villages, as unique urban spaces, evoke a sense of identity related to place, which in turn enhances urban memory. Residential areas have a similarly negative impact on vitality in central districts; however, they have a positive effect on vitality in periphery districts (Figure 5-30).

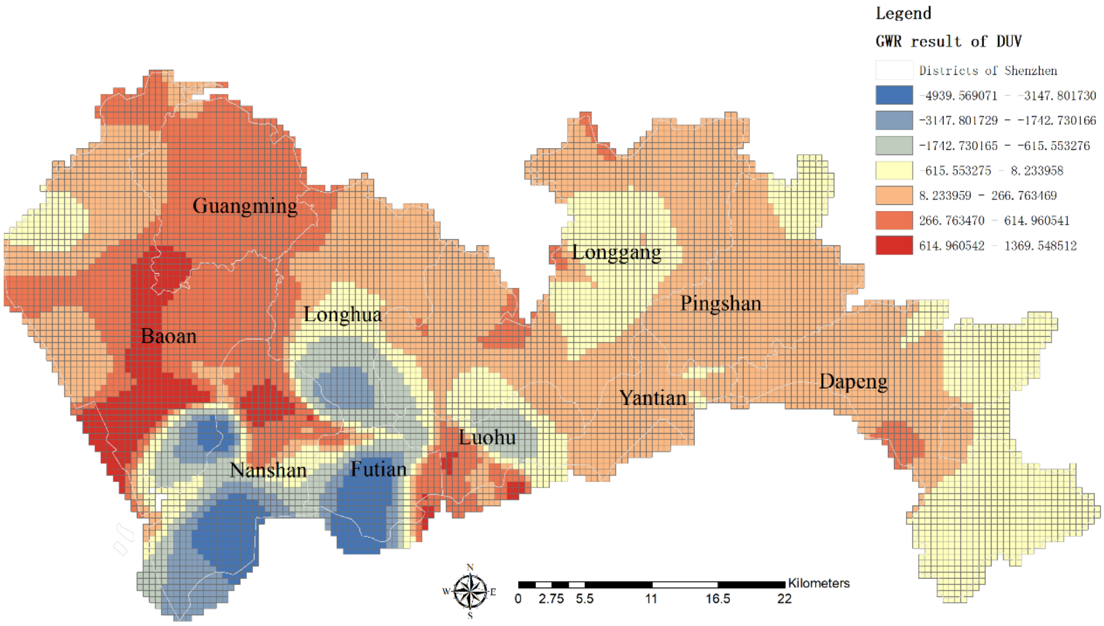

Figure 5-30. Spatial distribution of GWR model regression coefficients for distance from urban villages (DUV).

5.4 Summary

This chapter constructs an indicator system for the influencing factors of urban comprehensive vitality based on the urban built environment. The indicator system includes three primary indicators, namely form factors, functional factors, and special built environment, as well as 12 secondary indicators. Different indicator quantification methods are designed based on the definitions of each indicator. By constructing multiple linear regression models and geographic weighted regression models between urban comprehensive vitality and various explanatory variables, and comparing the explanatory degrees of different models for changes in urban comprehensive vitality, a better geographic weighted regression model was selected to explain the impact of various variables on urban comprehensive vitality.

Detailed analysis was conducted on the spatial distribution of selected urban architectural environmental variables. In terms of Urban morphology, the road network density of the whole region is relatively high, with an average road network density of 9.7 km/km^2, which is higher than the planned road network density target of 8 km/km^2 in China. Compared to the northern region, the road density in the southern central area is higher; Compared with other central areas and significantly different from other regions, the transportation facility density in Luohu Central Area is relatively high; In terms of building density distribution, the central urban area is slightly higher than other urban areas, and the overall distribution is relatively stable. In terms of urban villages, various indicators reflect the dispersion of spatial layout of urban villages in various regions of Shenzhen. In terms of urban functions, in terms of POI, the high-density units of FoD, ShD, PuSD, and MeD are evenly distributed in various regional centers of Shenzhen, presenting a multi-center layout structure; The overall density of REnD, SLD, and ORD is relatively low and dispersed; The density of the western and northern regions of ReD is slightly higher than that of the central and southern regions.

5.5 Sustainable development planning strategies based on urban vitality

5.5.1 Overall planning strategy

Through the study of the influence of urban built environment elements on the comprehensive urban vitality, urban vitality creation strategies can be proposed from different perspectives to alleviate the problem of uneven spatial distribution of comprehensive urban vitality to a certain extent, promote the balanced, comprehensive and sustainable development of the city as a whole and build a better urban living environment [32,33]. Based on this study, the following overall planning strategies can be proposed for the Shenzhen city as a whole:

(1) From the perspective of urban villages, urban planning should focus on people-oriented and residents' needs. In the large number of old communities and urban villages that exist in the central part of the city, the proportion of public services and public activity places should be appropriately increased, and commercial facilities, recreational facilities, and sports and leisure facilities should be appropriately increased. It is encouraged to improve the efficiency of space utilization and enhance the quality of life of residents by means of urban village renovation or overall relocation, while in the peripheral urban areas, urban villages need to be properly maintained and preserved.

(2) From the perspective of urban form, the construction of road traffic system should pay attention to the spatial differences. For the sub-city areas far from the city center, it is more economical to increase the density of roads and improve the bus system than to increase the density of subway stations.

(3) From the perspective of urban functions, it is generally believed that the mix of functions and the density of various facilities have a facilitating effect on urban vitality, but it is found that there is spatial variability in the influence of each index for the central city of Shenzhen, so the arrangement of different functions needs to take into account the specific regional conditions.

5.5.2 Partition planning strategy

The results of the spatial differentiation show clear boundaries between the highly developed urban centers and the less developed non-urban centers. The dynamism of the highly developed urban centers (Baoan, Luohu, Futian, and Nanshan) is dampened by the urban villages and residential areas, while the flourishing of other formal and functional elements of the built environment has a positive impact. The six underdeveloped non-central urban areas, however, have the opposite effect. Therefore, urban planners should avoid strategies of major demolition in urban regeneration construction in non-core areas, instead encouraging strategies that are more likely to stimulate urban vitality. This finding contributes to the achievement of more sustainable urban development goals [34,35].

5.5.2.1 Response strategies for central urban areas

The central urban area includes Luohu District, Futian District and Nanshan District.

Luohu District is located in the central part of the Shenzhen Special Economic Zone and is an early commercial center of Shenzhen. The district was established on January 4, 1990, and the district people's government was established on September 21 of the same year. The district government is located in Huangbei Street. The district has a total area of 78.36 square kilometers, and its administrative area is connected to Yantian District in the east, to Futian District in the west and Hongling Road in the west, to Shenzhen River in the south and Hong Kong in the south, and to Longgang District and Baoan District in the north. The industrial planning of Luohu District focuses on the development of commerce, logistics, tourism, cultural and creative industries. In recent years, Luohu District is also actively developing digital economy and cross-border e-commerce industry. From the results of the Luohu Vitality Divergence, more transportation facilities, such as subways and bus stations, can improve accessibility and promote urban vitality. The density of transportation facilities in the central area of Luohu is high, and increasing the density of the road network can help improve urban vitality. Appropriate increases in commercial facilities and recreational activities likewise have a positive impact on the vitality of most of Luohu. Sports and leisure facilities have the greatest impact on Luohu vitality, especially in Shenzhen Railway Station and the International Consumer Center, where there is a greater demand for sports and leisure facilities. The density of residential facilities in Luohu has a negative regression coefficient for most units, indicating that the residential areas of Luohu have an inverse effect on urban vitality. Urban villages also exhibit a similar negative effect.

Futian District, as the center of Shenzhen's geographical location, is positioned as the administrative, cultural, financial, business and international communication center of Shenzhen, the core area of the headquarters economy and the modern service industry cluster, focusing on the "three new engines" of the Shenzhen-Hong Kong Science and Technology Innovation Cooperation Zone in the Loop, the new financial center of Xiangmi Lake and the vibrant circle around the central park, to build a central innovation zone with international influence and The central innovation district, central business district and central vitality district with international influence and radiation. Increasing the density of road network can help improve the urban vitality of Futian District. The impact of the density of transportation facilities is also much greater in Futian than in the peripheral urban areas, showing a positive impact. The increase in the density of overall commercial facilities in Futian will promote the increase of urban vitality. Leisure and recreation facilities have the greatest impact on the vitality of Luo Futian District, with high values covering almost the entire area of Futian. In the coastal area of Futian, most of the units' sports and recreation facilities have a negative impact on urban vitality. In addition, residential functions and urban villages also show a more concentrated negative correlation, in contrast to the peripheral zones.

Nanshan District, the western part of the Shenzhen Special Economic Zone, is positioned as a cluster of science and technology industry innovation, higher education and headquarters economy, focusing on promoting the construction of Qianhai Shenzhen-Hong Kong Modern Service Industry Cooperation Zone, Xili Lake International Science and Education City, Shekou International Ocean City, Xili High-speed Railway New City and Shenzhen Bay Super Headquarters Base, and building the central intellectual district of Nanshan and a world-class innovative coastal central city. In terms of vitality performance, the increase of road network density in Nanshan Central District is conducive to vitality, while in coastal areas, the opposite effect of road network density is observed. The impact of traffic facility density also varies in Nanshan District, with negative impact in Shekou and Houhai area and positive impact in Xili area of OCT, indicating a greater demand for traffic facilities in the north and east of Nanshan. The increase in the overall density of commercial facilities, entertainment and leisure facilities and sports and leisure facilities in Nanshan District not only provides residents with more places and choices for consumption and activities, but also injects new vitality into the economic development of the city, which is more obvious in the south. The density of residential facilities in Nanshan District has little impact on vitality, and the impact of urban villages on vitality shows negative values.

Therefore, the following planning strategies are proposed for the urban center area:

(1) Increasing the density of the road network. Improve the rail transit system, increase the number of rail transit stations under the permitted conditions, and improve the capacity of the subway. Improve the rail transit system, increase the number of rail transit stations where possible, and increase the capacity of the subway.

(2) Appropriately increase the density of commercial facilities, leisure facilities, and sports and leisure facilities, improve the number of regional functional types, and increase the functional mix of the region.

(3) Control the development of residential volume and free up more public space and facilities for public activities. Encourage the transformation of urban villages, improve the image of old and dilapidated urban villages, and carry out appropriate vacations and alterations.

5.5.2.2 Peripheral urban area coping strategies

In terms of spatial-temporal divergence results, non-urban centers show similar influence relationships.

Bao'an and Longgang districts have developed rapidly in recent years and quickly leaped to become peripheral urban centers. Bao'an District is positioned as the western center of Shenzhen city and international aviation hub. Bao'an District is the western center of Shenzhen city and international aviation hub, focusing on the development of digital economy, exhibition economy, marine economy, airside economy, cultural tourism economy and high-end manufacturing. Baoan District is the manufacturing base of Shenzhen, with many famous electronic manufacturing enterprises such as Huawei and Foxconn. Baoan District's industrial planning focuses on the development of advanced manufacturing, intelligent manufacturing, aerospace and new materials industries. Longgang District is the eastern center of Shenzhen city, the center of international cooperation in higher education, and the center of international cultural and sports activities and exchanges. Focus on promoting the construction of Dayun Shenzhen-Hong Kong International Science and Education City, Banxuegang Science and Technology City, Eastern High-speed Railway New City, International Low-carbon City, Baolong Science and Technology City and other areas, the formation of "a core, two cores and multiple pivot points" development pattern, to create a national demonstration area for the integration of industries and cities in Longgang and the global electronic information industry highlands. Longgang District is the industrial town of Shenzhen, with many industrial parks and production bases. The industrial planning of Longgang District focuses on the development of manufacturing, logistics and warehousing, electronic information and other industries. In recent years, Longgang District is also actively developing modern agriculture and tourism.

In addition, each district in Shenzhen has its own new positioning. Longhua District is an integrated service center in central Shenzhen, a digital economy pioneer area, a future city pilot area, a wisdom governance demonstration area, an important transportation hub, a highland for emerging industries and a new city for fashion industries. Pingshan District is the eastern center of Shenzhen city, comprehensive transportation hub, high-tech industry and advanced manufacturing innovation cluster, and biomedical technology industry city. Guangming District is the northern center of Shenzhen, a science and technology innovation center, an important transportation hub, a pioneering area for scientific research economy, a high-tech industry and an advanced manufacturing cluster. Dapeng New District is a coastal tourism service center, marine science and technology and education base, and a pioneer area for the development of precision medicine and rehabilitation medicine.

According to the regression coefficient space of each district, the following planning strategies are proposed for the peripheral areas of the city:

(1) Road network density has a positive impact on urban vitality in most units around the city, therefore, it is recommended to increase the road network density. The density of transportation facilities has a more obvious impact on vitality. Improving the rail transit system, adding more rail transit stations and increasing the subway carrying capacity can increase the urban vitality in the periphery.

(2) In the urban periphery, commercial facilities have less influence on vitality, and most of the units show negative effects. In Dapeng east coast more field tail area, Longhua center, Longgang center and Baoan Shajing area to increase commercial facilities can increase urban vitality, other areas should try to control the density of commercial facilities.

(3) Baoan, Longhua, Longgang and Pingshan can increase the density of sports facilities to increase urban vitality. However, Guangming and Dapeng are not suitable for sports and leisure facilities due to the geographical environment, and the impact is negative.

(4) The surrounding urban areas are not suitable for the layout of leisure and recreational facilities, which has a suppressive effect on vitality.

(5) For the peripheral urban areas, residential density has a positive impact on vitality, and the planning of peripheral residential can be appropriately increased.

(6) Preserving urban villages, especially in Baoan District, urban villages help the most to improve urban vitality. Therefore, for urban villages in the periphery of the city, they should be carefully updated and demolished, and new old roads should be developed.

5.5.3 Impact Analysis of Urban Villages

The results of the spatial differentiation show clear boundaries between the highly developed urban centers and the less developed non-urban centers. The dynamism of the highly developed urban centers (Baoan, Luohu, Futian, and Nanshan) is dampened by the urban villages and residential areas, while the flourishing of other formal and functional elements of the built environment has a positive impact. The six underdeveloped non-central urban areas, however, have the opposite effect. Therefore, urban planners should avoid strategies of major demolition in urban regeneration construction in non-core areas, instead encouraging strategies that are more likely to stimulate urban vitality. This finding contributes to the achievement of more sustainable urban development goals.

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CHAPTER 6

An Empirical Study of Urban Village Renewal Based on Vitality Revival - Nantou Ancient City as an Example

6.1 Introduction to Nantou Ancient City

Nantou Ancient City, also known as Xin'an Old City, is located 8 meters north of Nantou Flyover in Nansan District, Shenzhen (next to Shennan Avenue), covering an area of about 70,000 square meters, and is currently the largest historical and cultural heritage tourist attraction in Shenzhen, with a long history of more than 1730 years (Figure 7-1). Nantou Ancient City is located on the east coast of the Pearl River estuary, and was the administrative center of the coastal area of Lingnan, a sea defense fortress, a distribution center for maritime traffic and foreign trade, and the historical source of Shenzhen, Hong Kong and Macao. The ancient and majestic Nantou Old Town is a valuable remnant of ancient Lingnan culture, which has experienced and recorded the history of Shenzhen and Nantou area. With a long history and several changes, Nantou Old Town has become the political, economic, trade and cultural center of Nanshan District, Shenzhen [1].

Fig.7-1. Nantou Ancient City Top View (source: https://www.baidu.com).

6.2 Historical development of the ancient city of Nantou

Nantou Ancient City is the most concentrated area of cultural relic's protection units in the SAR. It has irreplaceable historical and cultural values on major issues such as Hong Kong's territorial sovereignty and cultural origin. To a large extent, the history of Shenzhen city's development is the common source of development in Shenzhen and Hong Kong. With the advancement of Shenzhen's urban renewal, more and more urban villages will face demolition, reconstruction or renovation. Nantou Ancient City is a city-level cultural relic's protection unit, which has maintained a high level of integrity in the urban renewal process with its long-standing development and historical preservation of buildings. The historical features of Nantou Ancient City are mostly non-continuously distributed islands, fragmented surviving historical buildings or architectural communities, and it seems more accurate to define them as "fragmented historical locations". The core area of the site (about 10 hectares) is the typical village in the city.

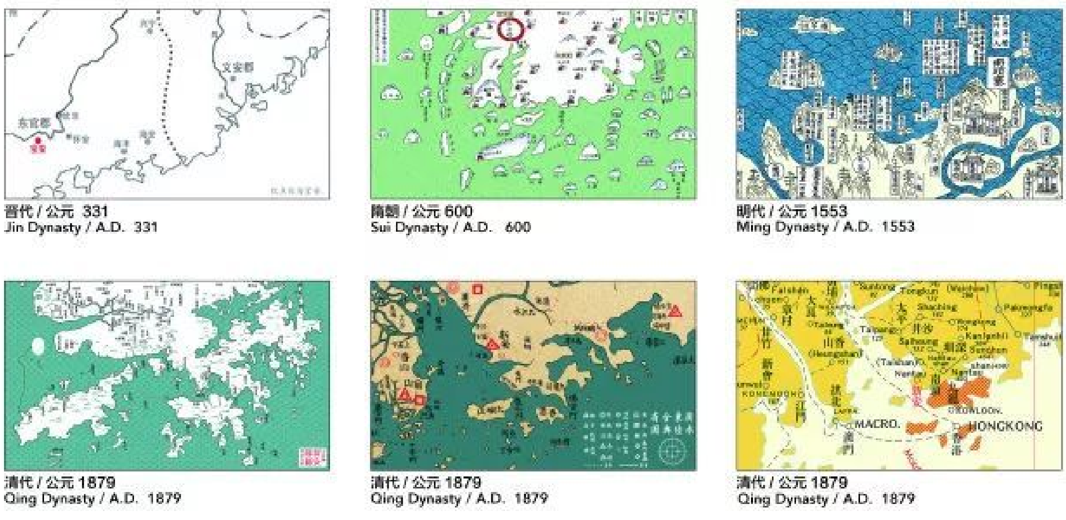

Figure 7-2. Historical Map of Nantou Ancient City.

According to the “Xin'an County Records”, the existing Nantou Ancient City was built in 1394, the 27th year of the Ming dynasty's Hongwu era, and was originally the city of the Dongguan Imperial Guard (see "Chronology" for its historical changes). The ancient city of Nantou is irregularly rectangular in shape, resting on a mountain and facing the sea, surrounded by the original ditch, with the longest wall area of 680 meters from east to west and the widest of 500 meters from north to south [2]. The northern wall is still a section of varying heights and intermittent ruins, the northern gate and western gate of the northern wall were destroyed, the eastern gate exists but has been changed to a stone structure, only the southern gate is well preserved. Nantou ancient city six vertical and one horizontal road network and the natural terrain of the perfect combination of the county street, Xianning Street, Yong Ying Street, Juxiu Street, and Yang Street, Yingen Street, Wutong Street, Pailou Street, New Street and other 9 streets, so the villagers commonly called Nantou ancient city "nine streets". The existing streets are actually Zhongshan East Street, West Street, South Street, Chaoyang Street, Xingming Street, Chunjing Street, Wutong Street, Culture Street and other 8, the area is about 0-3 square kilometers, inhabited by more than 15,000 people, is the most densely populated, the liveliest area within the jurisdiction of the present Nantou City Community Committee [2]. It is proved that when the Ming government restored the county in Nantou in 1573 and named it "Xin'an", it was found that "Dongguan County" had been located in Nantou as early as the Eastern Jin Dynasty, and "Xin'an County Magazine" also recorded that it was in the area of "Dongguan County". The "Xin'an County Magazine" also records that it was built on the site of the "Dongguan County".

Except for a small number of cultural preservation buildings in the ancient city, most of the buildings are the remains of various historical periods after the founding of New China and the reform and opening up. These architectural relics (such as the popular brushed stones in the 70s and 80s and the mosaics in the early 90s) and contemporary buildings continue to grow on their own and coexist in the ancient city [3]. Strongly supported by the innovation of Shenzhen's urban renewal policy, the ancient city of Nantou has undergone two important renewal and transformation nodes. The first is the 2017 Shenzhen-Hong Kong Urban Biennale, where the exhibition is placed in public spaces and historical buildings in the ancient city. However, at the end of the exhibition, the popularity of the ancient city was reduced, and there was no real renewal of the ancient city. In August 2020, the demonstration section of the ancient city of Nantou, which was transformed by the "Butterfly Transformation Rebirth Plan", was officially opened, giving the ancient city another chance to rejuvenate.

6.3 Mechanisms of the influence of two urban events on the renewal of the ancient city of Nantou

6.3.1 2017 Nantou Ancient City Shenzhen-Hong Kong Urban Biennale

The 2017 "Biennale" follows the general principle of "in situ conservation, activation and reorganization", and the theme is "city symbiosis". The exhibition organizing committee explored the "harmonious but different" urban model in the alleys and residential buildings of the ancient city of Nantou, making people rethink the relationship between the city, public space and the countryside. The main exhibition venue of the Twin Cities Biennale is held in the ancient village of Nantou, which is undoubtedly the biggest highlight and has attracted enough attention. The exhibition model with the city as the exhibition venue and the multidimensional space of the village as the basis for creation has aroused people's attention to the urban village. If the thousand-year cultural history is the most unique in the world, then it is a unique part of Nantou's development. The development direction of the ancient city of Nantou is positioned to have cultural vitality, flexible development, and enhance the influence of regional brands. This is undoubtedly accurate and unique. The slogan of the exhibition also reflects this, that the "city center" of the special zone is returning to "urban origin" in the new era (Figure 7-3).

Figure 7-3. Aerial view of Nantou ancient city (left); Nantou Ancient City 2017 Biennale Public Space (right) (source: https://www.archdaily.cn).

6.3.1.1 The Activation Method of the “Shenzhen-Hong Kong Bi-city Biennale” in the Super City Shenzhen City Village:

The main exhibition venue of the Twin Cities Biennale was held in the village of Nantou Ancient City, which is undoubtedly the biggest highlight and attracted enough attention. The exhibition mode of “City is the exhibition venue”, with the multidimensional space in the village as the base of creation, evokes people's attention to the village in the city. If we say that the history of the millennial culture is the most unique in the world, it is the unique part of Nantou’s development. The development direction of Nantou Ancient City is positioned to have cultural vitality, flexible development and enhance the influence of regional brands, which is undoubtedly accurate and unique. This is also reflected in the slogan of the exhibition, the “city center” of the SAR is returning to the “city origin” in the new era.

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(1) Reshape Public Space Order

Taking advantage opportunity of the Biennale, re-opening the north-south spatial axis has the symbolic meaning of the ancient city rejuvenation and the practical value of the space frame (Figure 7-4). First step is to identify spaces with important significance and cultural capacity, such as parks attached to the gates and Guandi Temple, urban streets and sidewalks, basketball courts, iron houses, and factory buildings. Then plan the space structure of the exhibition area with the cross-shaped axis. Reintegrate into a highly consistent narrative main line for space reconstruction and exhibition, and attempt to reconstruct the public open space system that is scarce in the ancient city through the above design.

Figure 7-4. Nantou Concept Space Axis Survey (source: https://www.archdaily.cn)

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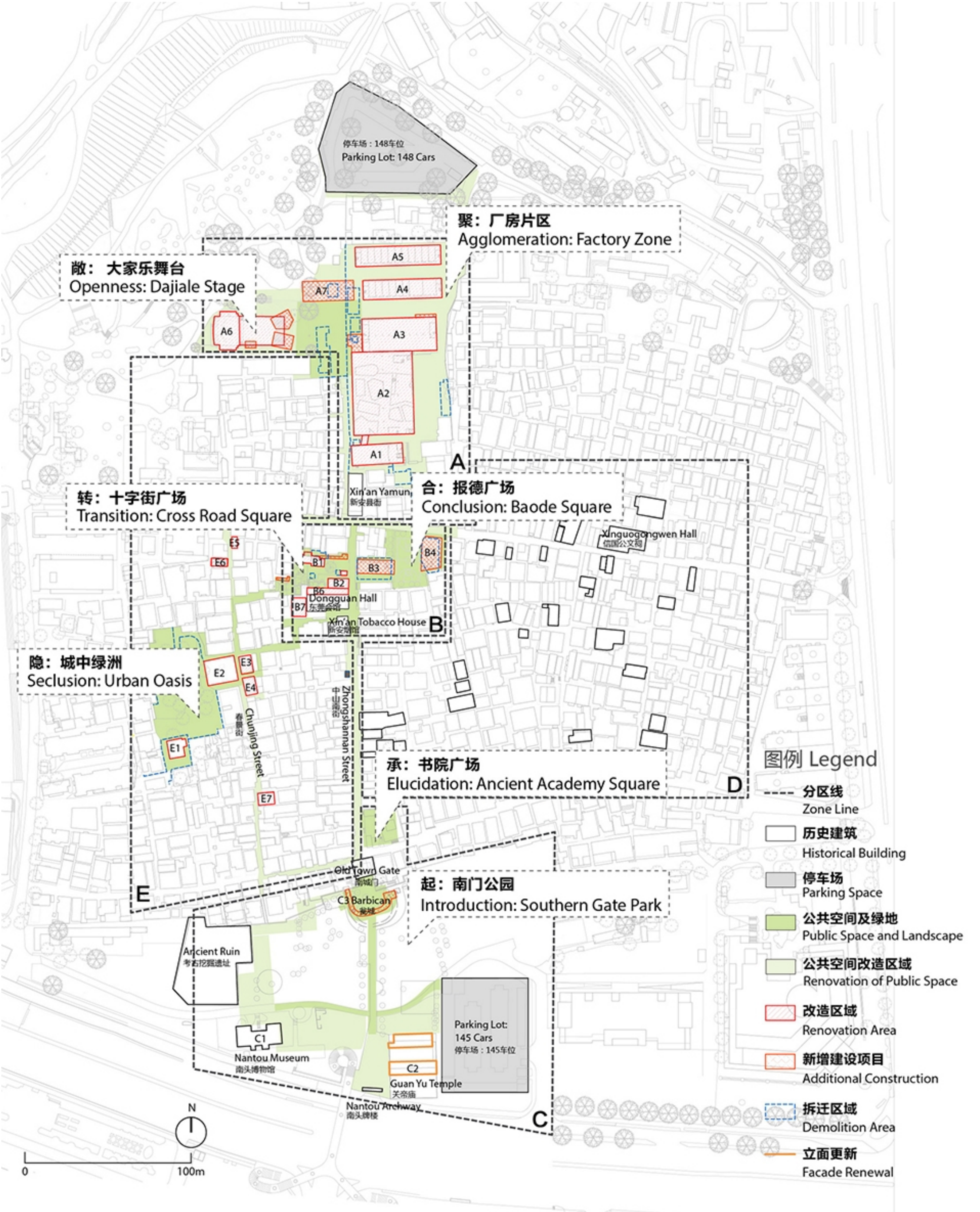

Figure 7-5. Nantou renewal zoning planning (source: https://www.archdaily.cn).

(2) Activate Space Vigor with Point and Surface

In accordance with the requirements of the "Biennale", the renovation and upgrading of the factory building of Nantou Ancient City will focus on the transformation and upgrading of public buildings such as power distribution rooms and pump houses to enhance the public landscape. For example, in the remodeling of the ancient city center "Beauty Square", organizing committee agreed to rebuild two temporary commercial tin houses on the side of the square as a community public event space. The two new building roofs evolved into viewing steps, slowly descending to the side of the court, trying to grow with the surrounding buildings with subtle differences. Together with the numerous windows, balconies and roofs of the surrounding residential buildings, it creates a three-dimensional urban theater. People sit and enjoy the vivid, lively urban drama that greatly enhances the comfort and environmental satisfaction of the residents (Figure 7-6).

Figure 7-6. Public Space Renewal (source: https://www.archdaily.cn).

(3) The Perfect Interpretation of the Beauty of Art and Symbiosis

Well-known architects, designers, photographers and artists gathered here to upgrade the five dimensions of industry, culture, commerce, environment and residence step-by-step in a strategic way. Creative design, distinctive business and many other elements make it a design town. More than 230 exhibitors from 25 countries around the world work in the full design field, covering architecture, installation, imaging, painting, modeling, literature, photography, and performance art. The purpose is to explore and reflect on China's urban development model in the context of globalization, and depict the vision of the future city.

More than 200 academic and public events were held throughout the three-month period. Attracting the whole country even worldwide by means of forums, performances, workshops, etc., the three-month "Biennale" replaced the structure of the new city with the new industry, and opened the "Iceberg" of the ancient city to interpret the symbiotic art and symbiotic beauty of the village.

(4) Infusion of Cultural Identity and Sense of Belonging

During the exhibition, through cultural guidance, media publicity, and participation of local residents, the urban exhibitions attracted diverse groups of people of different ages, educational backgrounds and different professional fields, in the meantime, it promoted the attention of the residents in the city and increased public interest in the environment, culture, and art. After the exhibition, the community could organize the cultural institutions that have already entered the city to build a cultural platform to accelerate the cultural and industrial upgrading of the ancient city, and update and develop independently.

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Figure 7-8. Public Space Renewal (source: https://www.archdaily.cn).

6.3.2 2020 Nantou Ancient City "Butterfly Rebirth Plan"

The ancient city of Nantou, once the "first county in eastern Guangdong", carries the region's history of more than 1,700 years. At this point in time, it has become the best place for people to look back to the past, look to the future, and find the root culture and identity. This is not an urban village reconstruction that started out of thin air but is based on the accumulation of multiple versions of the reconstruction plan and the government's efforts over the past ten years. From the controversial large-scale demolition, to the discussion of building Lingnan ancient town, to the use of "design + history and culture" to create a cultural and creative town, repeated discussions and plans have made the activation and renewal of the ancient city of Nantou more and more clear (Figure 7-9).

Figure 7-9. Street Space Reconstruction of Nantou Ancient City.

The reform ideas are based on people. From an economic point of view, the ancient city of Nantou lacks future-oriented core industries and needs to introduce appropriate industrial activation; from a cultural point of view, it is necessary to highlight the historical culture of the ancient city and present the historical and cultural differences between Shenzhen and Hong Kong and Macao. From a social point of view, it is necessary to adjust the population structure of the ancient city and introduce young people who can bring positive effects to the ancient city and bring a new concept and long-term concept to the area. Positive effect. The transformation path and thinking ultimately point to how to attract a group of creative workers to work and settle in the ancient city and provide space for their development [3].

The comprehensive consideration of the transformation path laid the foundation for the success of another round of renewal of the urban village. First, make up for the shortcomings of the infrastructure in the villages in the city, upgrade the outdated infrastructure, such as the buried reconstruction of the municipal pipeline network, and eliminate hidden safety hazards, so that the infrastructure can meet people's basic needs for housing and quality of life; secondly, it is Upgrade the public service facilities inside and outside the ancient city. Renovate the street paving, lighting system, repair and maintain historical culture and old buildings in the villages in the city, add community service centers, toilets, markets and other service facilities to protect the lives of residents.

The focus of this renovation is on the public space. From the results of on-site interviews and questionnaire surveys, it can also be found that the most people have chosen to promote public space as the most important requirement for urban renewal (Figure 7-10). The ancient city of Nantou is one of the few urban villages in Shenzhen that has a large area of green space resources. However, the crowded space of the village in the city makes the owners and tenants occupy the public space as much as possible, which greatly reduces the comfort of residents and visitors. In order to improve this situation, first of all, the original Nanchengmen Park and Academy Plaza in the ancient city were renovated and upgraded, and landscape greening such as pocket parks was added. The site has been organized and renovated, and infrastructure has been added to make it a comfortable and cozy living area. Emphasis is placed on creating the scene force of the ancient city, and the transformation of the interface of the ancient city is mainly concentrated on the cross axis formed by the north-south street and the east-west street. Under the premise of respecting the authenticity of history and the accumulation of times, taking into account the architectural performance and visual beauty, the architectural style is controlled and graded by stages to create a Lingnan historical district that continues the street life memory, deeply explores the historical and cultural connotation, and forms a reflection The "spectrum" of Shenzhen's 40-year history of reform and opening up. The main street style is based on the Lingnan architectural style and incorporates contemporary aesthetic decorative elements. By controlling the selection and application ratio of new and old materials and new and old elements, the transformation from the street skin to the depth of the street-facing buildings creates a simple coordination of the ground floor and vivid colors on the upper floor. The fragrant ancient city style and cultural scene blending ancient and modern.

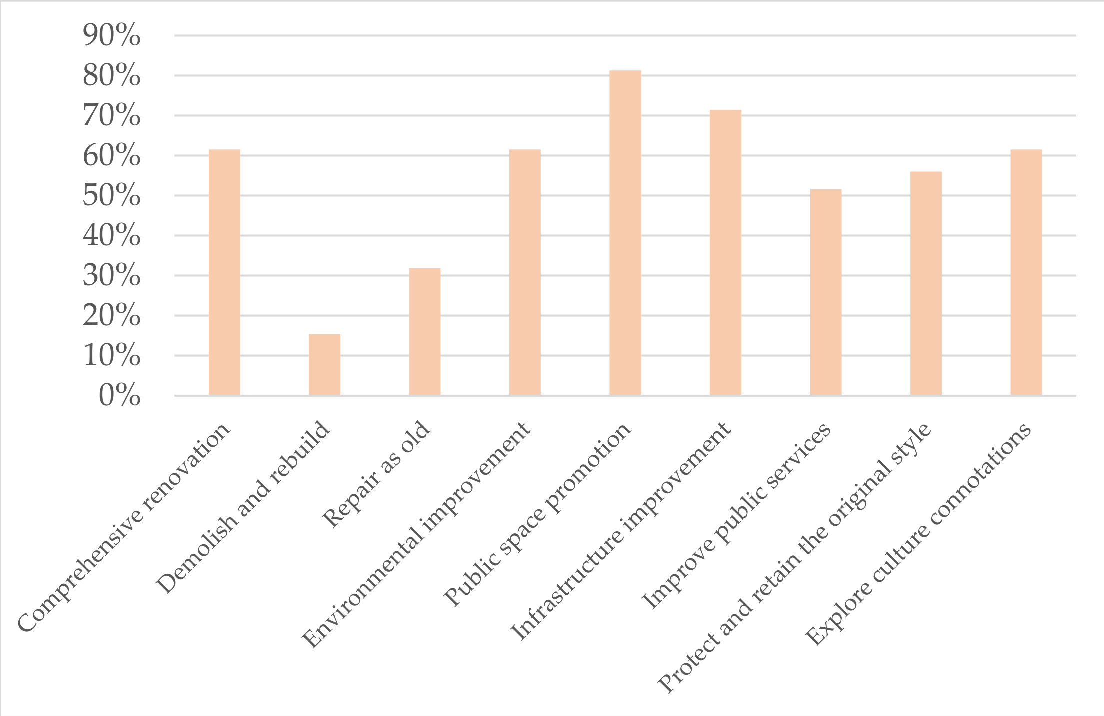

Figure 7-10. Survey of willingness to renew and transform the village in the city.

In addition, the success of this transformation lies in the precise positioning and upgrading of the industry, the transformation of old factories and some buildings in the ancient city, and the creation of nearly 20,000 square meters of creative office space. Guide the entry of cultural, art and creative design industries, provide joint office space and industry incubation platform for creative institutions, and effectively gather all kinds of creative talents and institutions to gather in Nantou. The industrial agglomeration effect will drive the transformation and upgrading of internal industries, and can effectively promote the upgrading of the original business, space and population structure in the ancient city, stimulate the cultural vitality of the ancient city, and realize the revival of the community.

Figure 7-11. The original and new appearance of the renovated building

Figure 7-12. The main road after renewal.

Finally, provide and transform as many high-quality living spaces as possible. Most of the rental houses in the ancient city have a poor living environment. On the basis of retaining the large frame of the original peasant house, the structure is reinforced, the interior and exterior are renovated, the property management system is introduced, the apartment configuration is upgraded, and the modern ideal residence combining functionality and aesthetics is transformed. The environment provides high-quality rental space and integrated community services for new residents.

Figure 7-13. Decoration Constructed: Nantou Twin Shop-Houses by 11 Architecture (source: https://www.archdaily.cn).

6.4 Reconstruction of the Spatial Value of Villages in the City

The village in the city is like a "sponge" that can accommodate the population of the city and is an important part of the city. Take Shenzhen as an example. There are more than 240 urban villages in Shenzhen, with a construction area of 200 million square meters. The urban villages are less than 5% of Shenzhen's area, but they accommodate more than 11 million residents. Cities and villages, foreign cultures and local traditions, development and backwardness, inheritance and disappearance, urban villages are a complex contradiction. Whether it is artistic creation or urban construction, it is a hot spot in the public eye. For a long time, urban villages have been regarded as the “cancer” of urban development. When it comes to urban villages, most of them are waiting for demolition. With the development of society, the value of urban villages has gradually been seen. It is sought to reduce the damage to the original culture of urban villages as much as possible in the context of transformation and renewal, making the city more tolerant and promoting the healthy development of the city [4]. Urban villages have begun to transform from temporary settlements into potential innovation incubators and may also become another "hybrid beauty."

Urban symbiosis is a popular interdisciplinary concept. It is an urban model that calls for diversity, tolerance and vitality on the premise of respecting human nature and history. It is a symbiosis of different levels of urban culture, society and space. Cities and villages, history and reality, chaos and order, have reached heterogeneous coexistence under the mode of symbiosis. Under this symbiosis perspective, I need to explore how to use the humanistic value of urban villages to realize mutual benefit and mutual benefit between urban villages and the economy and society.

The transformation of the urban village in Shenzhen was based on a comprehensive overthrow of reconstruction and comprehensive remediation. Based on the particularity and cultural value of Nantou Ancient City, the large-scale demolition and construction of new buildings is not suitable, and the comprehensive refinement is more inclined to the upgrading of physical space, and it is difficult to promote the cultural rejuvenation of the ancient city and empower the future development. Therefore, it is necessary to iterate the urban renewal model. In the early stages of the transformation, the city culture was activated through top-down planning and guidance and government investment. Ancient city will attract social resources into the community, and then self-renewal of the community based on residents will naturally happen.

6.5 Urban renewal Strategy

6.5.1 Spatial Strategy

The urban village is an important living carrier for foreign immigrants, and this special urban space has also given birth to a variety of lifestyles. Many daily behaviors are inevitably attached to a special physical space environment and influenced by the state of the environment at the same time, and with the accumulation of time, these behaviors gradually evolve into a fixed pattern (i.e., lifestyle or habit). This can be explained by Bourdieu's "field-habitus" theory, in which the objective "field" of the urban village is able to breed different kinds of the "habitus" is inseparable from its fine mesh-like texture and unique street space.

Although Shenzhen's urban villages are completely surrounded by the surrounding urban space, the scale of roads, streets and building bases is relatively small in both old and new villages, and later buildings are raised, but the spatial texture of flat streets and alleys does not change. (Figure 6-20) Such small-scale streets and alleys are suitable for walking, interconnected and well-connected, increasing the frequency of people's interactions, maintaining harmonious relationships, and strengthening the interactive stickiness of people and space. (Figure 6-19) According to Yang-Gaier, the frequency of people's outdoor activities is closely related to the external physical environment, and a suitable spatial environment can better undertake necessary activities and trigger more spontaneous and social activities. Therefore, the streets and alleys in urban villages give birth to daily leisure activities such as playing chess, cards, and children playing, and nurture social and cultural activities such as gossip and rituals, as well as accommodating economic activities such as night markets and The economic activities such as night markets and mobile vendors are also included. The street space in urban villages is full of health and vitality, and it contributes to the diversity of the urban landscape and the evolution of the integration of multiple cultures.

In this regard, Jane Jacobs has a similar view. She believes that for an area to be vibrant with diversity it should have four conditions: 1) two or more functions in the area; 2) the streets must be short and have a sufficient number of intersections; 3) there are different buildings that can meet the needs of both low- and high-rent tenants; and 4) there is a sufficiently dense population. Jacobs' ideas have influenced generations of planners, but her views have also been controversial, one reason being that the ideas she articulated have not been scientifically proven [5]. But Marco De Nadai and colleagues from the University of Trento have invented a means of collecting urban data that can be used to test the relationship between Jacobs' conditions and urban vitality. Using a new generation of urban databases, social media and cell phones, they compiled data from six Italian cities, including Rome and Florence, that corroborate Jacobs' argument, so that these conditions make cities more diverse and are scientifically valid [6,7].

6.5.2 Cultural Strategies

6.5.2.1 Tapping cultural heritage resources in urban villages

Shenzhen put forward the strategy of cultural city in 2004, after which a lot of cultural construction was carried out, holding various cultural exhibitions such as cultural fair and biennale, inviting international masters to design a large number of public cultural buildings, such as Shenzhen Concert Hall, library, contemporary art museum, etc. Shenzhen also has the reputation of "design capital" and "city of library". City of Library" reputation. Shenzhen has made great achievements in cultural industry, cultural architecture and public cultural undertakings, however, the work on the excavation, protection and development of historical culture in Shenzhen still needs to be strengthened, which is one of the important reasons why Shenzhen has not taken off the "cultural desert" hat for many years.

The thickness and richness of Shenzhen's local cultural heritage cannot be compared with those of

Beijing, Xi'an and Guangzhou, but Shenzhen also has a history that can be traced back more than a thousand years and has its own cultural characteristics and strengths. Therefore, I should go beyond the original conventional criteria and values of historical and cultural heritage recognition, and put Shenzhen's historical and cultural conservation into a comprehensive consideration of its own special development trajectory. The European cultural heritage recognition emphasizes the combination of "human memory" and the adjustment of the "overall" scope according to the preservation status of different heritage to obtain the heritage elements [8]. The identification of Shenzhen's historical and cultural heritage should not compete with other cities in terms of time, but should recognize that Shenzhen is to preserve its own "urban memory". The cultural heritage that needs to be protected is diverse, and whether it can be included in the national protection system is not entirely proof of the value of the heritage. The characteristics of cultural heritage specific to Shenzhen should be determined in the conservation process, "not by considering too much its age or historical value, but by focusing on whether it has far-reaching implications for society.

6.5.2.2 Maintaining the diversity of cultural subjects

The vitality of a place comes from diversity, and when the social ecology is very rich, charm will naturally appear. Therefore, there can't be only one kind of people in the region, even if they are high quality people, only high-quality people are as unattractive as only low-quality people. The current blossoming of the historical district into a commercial street development activity, the early can still be generally recognized, such as Beijing's Nanluoguxiang, Chengdu's Kuanzhai Alley, Fuzhou's Sanfang Qi Xiang and so on. However, with the brutal entry of tourism, the phenomenon of "a thousand streets with one side" and "a thousand streets with one industry" was gradually created - red lanterns, antique plaques, coffee shops, ceramic stores, etc. (Figure 6-24). (Figure 6-24) The main reason is the top-down development, resulting in the convergence of business subjects, resulting in the gentrification of commercial streets, thus missing the possibility of daily diversity. The law of the world that can form culture is diversity, but space is not the only factor that plays a role. Interpreted from the perspective of spatial culturality, physical space and cultural values are a symbolic relationship, and the characteristics of space cannot be static, but are more profoundly influenced by the cultural groups behind it.

6.5.3 Operation Strategy

6.5.3.1 Update policy system flexibility development

The famous Nobel laureate in economics and institutional economist North once said, "An institution is a set of rules, a premiere order, and a moral and ethical code of conduct that has been developed to constrain the behavior of individuals in pursuit of the welfare or utility maximizing interests of the subject". Institutions go through a process from formulation to implementation, and once formed, they generate inertia, leading to a certain "path dependence. Therefore, at the initial stage of system design, the flexibility of the system itself should be taken into account. Insufficient flexibility will easily lead to excessive rigidity in the later implementation, which will lead to various derivative problems.

Since the establishment of Shenzhen Special Administrative Region, economic development has achieved world-renowned achievements, a very important reason is the "special" Shenzhen in the system. At the beginning of Shenzhen's construction, there were no vested interest groups on a large scale, and there were no institutional restrictions in the original area (Bao'an County). Shenzhen's development model is to set development goals, by all parties to explore the construction of their own forces, without too much institutional constraints, in practice to find a development path. This relatively free development model has created the image of Shenzhen today as an "innovative" and "bold" city. However, because of the low historical burden and low cost of institutional transformation in Shenzhen, some policies and systems related to urban villages in the development process are not well thought out, often because the policies are too rigid and lead to a series of practical obstacles in the implementation.

From the current policy regulations, we can see that the Shenzhen government has a series of specific target requirements for urban village regeneration, and the policy-making department certainly has its own considerations for the formulation of these requirements, but it needs to be further explored whether the relevant regulations can be tested by time and provide a long-term beneficial promotion for urban village regeneration [4,9]. Therefore, it is suggested that the policies related to urban village renewal should be formulated flexibly:

First, it is suggested that no specific area requirement should be set for demolition and redevelopment. The minimum area requirement for demolition and redevelopment is in fact an encouragement or a requirement to carry out urban village demolition and redevelopment on a large scale, while small-scale demolition and redevelopment is already prohibited by law. In addition, the Technical Provisions on Urban Renewal Unit Preparation (2016) stipulate that the territorial scope of the former rural collective economic organizations in Futian, Luohu, Nanshan and Yantian districts should, in principle, be designated as urban renewal units in the scope of the whole village, while the territorial scope of the former rural collective economic organizations in other districts are encouraged to be designated as urban renewal units in the scope of the whole village.

6.5.3.2 Enriching the main participants of renewal

Tenants are the absolute subjects of life in urban villages, and the group most affected by renewal is the tenants living in urban villages. Tenants' right to participate in renewal is neglected and will accumulate social problems over time, so it is necessary to establish tenants' right to participate in renewal. Article 21 of Japan's Urban Redevelopment Law stipulates that real estate tenants can become the main body of urban renewal implementation by joining the renewal association, and have the right to express their opinions on the design of the plan and related resolutions [10]. The key point in the implementation of urban renewal in Japan is to integrate first and implement later, which means that the project will be suspended or delayed if consensus is not reached among all parties, and this measure ensures the status of all participants. Therefore, it is recommended that the government should give tenants' groups the right to participate in the renewal planning from the beginning of the development of the renewal plan, and establish the main position of tenants' participation.

In the process of urban village regeneration, the active and effective participation of all parties is mobilized, and a good communication and collaboration platform is built. Establishing a system of game, communication and collaboration among local governments, development entities, property owners, tenants, expert teams and community planners can better promote a multi-dimensional value balance in the decision-making and implementation of urban village regeneration projects.

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CHAPTER 7

Discussion and Conclusion

7.1 Research findings

One of the main goals of sustainable urban growth is to promote vitality, especially in the context of the gradual abandonment of rugged urbanization and increasing demand for quality urban space. As one of the first metropolises to undergo urbanization in China, the logic and phenotype behind Shenzhen's urban development is worth studying. This study uses a multi-source urban dataset to give strong knowledge of urban vitality and analyses the results through an urban built environment dataset to validate the scientific validity of urban big data in perceiving urban space.

By merging economic, social, and cultural data, this research, using Shenzhen as a sample, re-evaluates the spatial patterning of urban vitality and its affecting elements and creates a comprehensive urban vitality indicator. A system is proposed by integrating urban built environment factors. The system consists of three dimensions (urban form, urban village, and urban function) including 12 indicators. The model and variables were progressively screened and, finally, a spatial lag model was used to explain the effects of built environment elements on vigor globally. The GWR model was then extended to analyze the factors influencing the spatial differentiation of vitality. The findings show that:

(1) Dense Road networks, rich and diversified transportation facilities, dense commercial facilities, recreational facilities, and sports and leisure facilities are beneficial elements that promote urban liveliness. However, urban villages and residential compound have negative effects on urban liveliness, while building density has a minimal impact on a city's vitality.

(2) The built environment has a spatially heterogeneous impact on vitality. Thus, urban design strategies should be designed to maximize resource use for sustainable development in various places.

(3) The current urban form presents inhibiting influences between urban villages and vitality. The problem of urban villages deserves attention in terms of urban planning and design and there is an urgent need for scientific regeneration and development methods in both localized optimization and overall improvement.

(4) Using social events as a cultural catalyst for urban renewal helps to discover the positive significance of spatial value reconstruction of "urban villages" in urban development.

As a conclusion, it is proposed that highly developed urban centers and underdeveloped urban peripheries should have different strategies for enhancing vitality in urban regeneration. A crude deconstruction of an urban village or an unplanned construction of a commercial facility will equally harm the heritage of the place and diminish its urban vitality. This paper focuses on environmental and sustainable development issues in society and has both academic and practical implications for sustainable urban development and planning. The findings give a better understanding of the current dynamics of China’s cities and identify and develop urban design strategies to optimize the allocation of resources for sustainable development in different regions. These insights can function as principles globally to support future urban planners, policymakers, and researchers interested in promoting sustainable urban development through vitality-based urban regeneration.

7.2 Research limitations and prospects

7.2.1 Limitations

This paper adopts a research instrument combining qualitative research and quantitative analysis, macro and micro multi-scale analysis, and theoretical analysis and application verification, and uses multi-source heterogeneous big data as the data source to explore the role of urban villages in urban vitality, and to explore the development direction of urban villages and the influence mechanism of urban vitality. In the process of the study, there are some problems and shortcomings. First of all, big data itself cannot fully explain the formation and changes of urban vitality. Urban vitality is a complex concept that involves many aspects such as economy, society and culture. Although big data can provide a large amount of information and data, how to integrate this information and extract valuable insights from them still requires in-depth research and analysis. Second, there are some limitations to the application of big data. For example, big data analysis requires sufficient amount of data and high-quality data sources, while in reality, data collection and integration are not perfect in many cities.

Secondly, urban villages are difficult to collect data because of the difficulty of data collection: the population in urban villages is highly mobile, and it is difficult to obtain information. Also, the social problems in urban villages are complex, and multiple factors need to be considered before accurate conclusions can be drawn. For the specific study of urban villages, research methods are limited, mainly using questionnaires and field visits as well as case studies, but these methods are difficult to understand the social, economic, and cultural characteristics of urban villages in a comprehensive way. The existence of urban villages is closely related to urban planning and construction, so it is necessary for the government, scholars, and all parties in society to work together to develop effective policies to solve the problems of urban villages.

7.2.2 Prospects

As urbanization continues to advance, the problem of urban villages will become more and more prominent. In the future, the research on urban villages and urban vitality will be more in-depth and extensive. First, strengthen data collection and analysis: with the development of technology, the methods of data collection and analysis will become more advanced and efficient. Future research will pay more attention to data collection and analysis in order to better understand the social, economic, and cultural characteristics of urban villages. Second, explore new research methods: In addition to questionnaires and field visits, future research may also adopt more new research methods, such as network analysis and big data mining, in order to better understand the characteristics and problems of urban villages. Finally, strengthening policy formulation and implementation: future research will focus more on the effects of policy formulation and implementation in order to better solve the problems of urban villages. The government, scholars and social parties should work together to develop more effective policies to solve the problems of urban villages.

7.3 Conclusion

7.3.1 Research Novelty: Reconstruct Definition of Urban Vitality and Establish Examine Model

There is not a single definition for urban vitality as groups from different social backgrounds have different understandings of this concept. The data sources of urban big data are rich and diverse and widely available for various economic social fields and sectors. With rich types and large quantities, big data can reflect the phenomena and problems in urban development in a more scientific way. By using urban big data in economic, social, and cultural aspects to describe urban vitality, it is found that the urban vitality in Shenzhen is distributed in multi-centered clusters. The central districts, such as Luohu, Futian, and Nanshan, have higher urban vitality indices; the vitality performance is also better in the central areas of some periphery districts, such as Bao'an, Longhua and Longgang, while the non-central areas of northern and eastern parts of Shenzhen show lower vitality areas, with an uneven distribution of urban vitality and a polycentric structure. This trend occurs because of the uneven development process of Shenzhen's urban districts. On this basis, a system of factors influencing urban vitality in Shenzhen is constructed from three aspects: form, function, and atypical urban space. In order to understand the influencing factors of the regional differentiation of vitality in Shenzhen, the link between significant influencing factors and vitality is investigated using a geographically weighted regression (GWR) model.

7.3.2 Contribution: Finding of Positive and Negative Factor to Urban Vitality

The study obtained significant results for seven urban built environment factors (RND, TFD, DUV, ShD, REnD, ReD, and SLD) in three dimensions (urban form, urban village, and urban function). At the global level, Shenzhen’s urban vitality is strongly influenced by the accessible distance to urban villages (DUV) and the density of recreational facilities (REnD). A denser road network, public transportation stops, commercial facilities, entertainment/sports facilities, and leisure facilities attract more people. Resulting social activities can create more economic, social, and cultural vitality. On the other hand, distance to urban villages (DUV) and residential facilities density (ReD) shows a dampening effect on vitality.

Dense road networks (RND) are vital in promoting urban vitality; the small-scale neighborhoods formed by dense road networks are prone to promote human interaction on the streets [1]. This is consistent with previous research findings [2]. The possible reason for this is that as cities develop, roads not only function as commuting zones, but the U-shaped spaces of the streets are also increasingly converted into open spaces where people can rest and stay, increasing the vitality of the streets. This trend is aligned with China’s urban upper planning, which calls for the return of roads to pedestrians and promotes cities with small blocks and dense road networks. The impact of transportation facilities (TFD) suggests that more transportation facilities, such as subways and bus stops, can improve accessibility and promote urban vitality. This feature is more evident in Futian and Luohu districts.

The functional built environment indicators ShD, REnD, and SLD contribute significantly to the vitality of urban areas. The density of shopping facilities, leisure and recreation facilities, and sports and health facilities have a significant positive effect on urban vitality. This can be explained by the reality that individuals can more easily access these functional destinations to meet their daily needs, which aligned with the results of earlier research [3]. The increase in facilities in the central area of Shenzhen can result in a significant increase in urban vitality. A negative association between residential density and urban vitality is also shown in this study. Due to the mismatch between population and urban space, urban vitality is weaker in certain single-function residential areas [4]. This trend may occur because people expect more diverse and convenient services, such as shopping, transportation, leisure, and other facilities, to enrich their daily activities.

In addition, the study reveals a negative correlation between urban villages and urban vitality. It demonstrates that the closer a place is to the urban village, the more dynamic it will become. The reason for this trend is likely that urban villages usually have a poor living environment, high building and population density, and fewer supporting facilities. As a result, urban villages rarely become urban destinations and hardly generate urban dynamism. On this basis, GWR has expanded to explain the characteristics of spatial differentiation. The urban central area composed of Luohu, Nanshan, Futian, and Bao'an has lower vitality as it is closer to the urban village. On the contrary, in periphery districts such as Bao'an, Longhua, Guangming, and Longgang, villages often have a positive impact on urban vitality. Urban villages are significantly clustered and denser in these areas, providing possible spaces and places for various activities of urban development. Urban villages, as unique urban spaces, evoke a sense of identity related to place, which in turn enhances urban memory. Residential areas have a similarly negative impact on vitality in central districts; however, they have a positive effect on vitality in periphery districts.

7.3.3 Significance: Diverse Strategies to Develop Built Environment for Central Districts and Periphery Districts

The results of the spatial differentiation show clear boundaries between the highly developed urban centers and the less developed non-urban centers. The dynamism of the highly developed urban centers (Baoan, Luohu, Futian, and Nanshan) is dampened by the urban villages and residential areas, while the flourishing of other formal and functional elements of the built environment has a positive impact. The six underdeveloped non-central urban areas, however, have the opposite effect. Therefore, urban planners should avoid strategies of major demolition in urban regeneration construction in non-core areas, instead encouraging strategies that are more likely to stimulate urban vitality. This finding contributes to the achievement of more sustainable urban development goals.

Highly developed urban centers have a high level of vitality, which is depicted by the findings of some studies on the vitality of other cities [5]. For example, the study found that the high vitality areas in the main city of Xining are concentrated near shopping centers, pedestrian streets, rivers, and schools [6]. Due to their geographic advantages, metropolitan centers have more diverse urban design and regeneration policies when it comes to social, environmental, and economic variables. As an example, the city government of Kayseri proposes that in urban regeneration, a design quality standard approach should be developed according to the specific locational situation of the project, contributing to the revitalization of the city [7]. The case of Cairo proves the key role of changes in functional neighborhood on the perceived impact of people. Diverse activities stitch up the gaps between different urban forms [8], which explains the higher distribution of vitality in the city center.

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Appendix

Steps for Obtaining Data from Dianping:

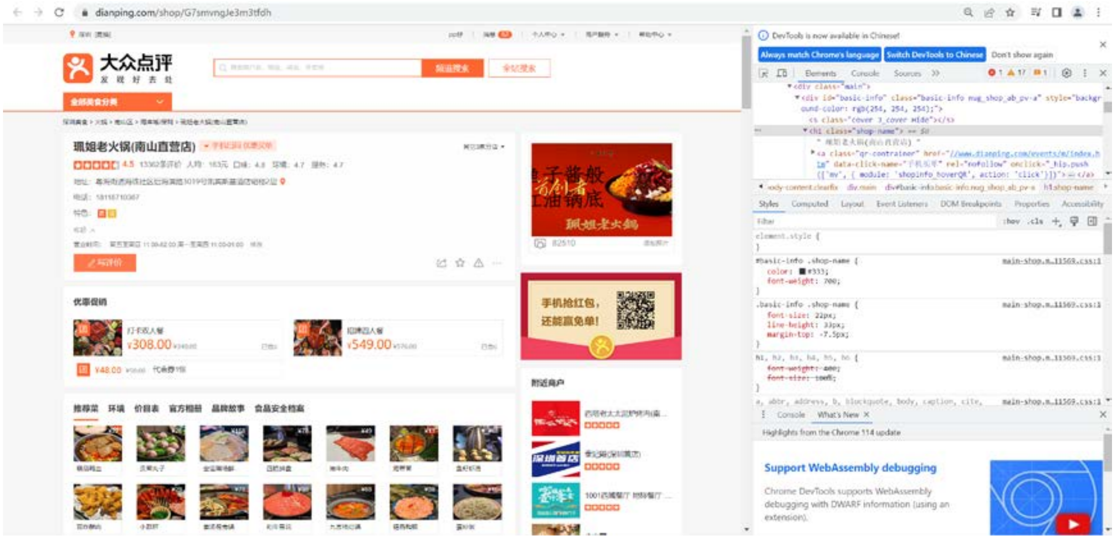

Figure 8-1. Dianping website page

1. Install the required libraries

Before starting, install some necessary libraries, including requests, Beautiful Soup, and lXML.

//pip install requests

//pip install BeautifulSoup4

//pip install lxml

2.Send a request and obtain webpage content

Use the requests library to send requests and obtain content from the public review webpage. Provide the appropriate URL and parameters.

```
import requests

url = "https://www.dianping.com/search?keyword=restaurant&page=1&sort=default"
response = requests.get(url)
content = response.content
```

3. Parsing web page content

Use Beautiful Soup and lXML libraries to parse web page content. Firstly, I need to pass the HTML content to the Beautiful Soup object, and then use the various methods it provides to parse the data.

```
from bs4 import BeautifulSoup

soup = BeautifulSoup(content, 'lxml')
```

4.Extract data

Use the selector method provided by Beautiful Soup, such as find_ All () and find () to extract the data. The following is an example code to extract the name and rating of each restaurant in the restaurant list:

```
results = soup.find_all('div', {'class': 'dp-item'})

for result in results:
    title = result.find('a', {'class': 'dp-item-title'}).text
    rating = result.find('span', {'class': 'dp-item-rating dp-item-rating-num'}).text
    print("Title: ", title)
    print("Rating: ", rating)
```

5.Process Next Page Link

Process the next page link in the webpage to obtain more page data.

```
next_page = soup.find('a', {'class': 'dp-pagination-next'})
if next_page:
    url = next_page['href']
    response = requests.get(url)
    content = response.content
    # 重复步骤3-4来解析下一页的数据
```

The following is the complete code for obtaining review data using Python:

```python
import requests
import parsel

url = 'https://www.dianping.com/search/keyword/344/0_%E7%81%AB%E9%94%85/p2'
headers = {
    'Cookie': 'fspop=test; cy=344; cye=changsha; _lxsdk_cuid=181f2b8ceedc8-00c68dfc700ble-c4c7526-384000-181f2b8ceedc8; _lxsdk=181f2b
    'Host': 'www.dianping.com',
    'Referer': 'https://www.dianping.com/search/keyword/344/0_%E7%81%AB%E9%94%85',
    'User-Agent': 'Mozilla/5.0 (Windows NT 10.0; WOW64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/101.0.0.0 Safari/537.36',
}

response = requests.get(url=url, headers=headers)
selector = parsel.Selector(response.text)
href = selector.css('.shop-list ul li .pic a::attr(href)').getall()
print(href)
for index in href:
    html_data = requests.get(url=index, headers=headers).text
    selector_1 = parsel.Selector(html_data)
    title = selector_1.css('.shop-name::text').get()  # 店名
    count = selector_1.css('#reviewCount::text').get()  # 评论
    Price = selector_1.css('#avgPriceTitle::text').get()  # 人均消费
    item_list = selector_1.css('#comment_score .item::text').getall()  # 评价
    taste = item_list[0].split(': ')[-1]  # 口味评分
    environment = item_list[1].split(': ')[-1]  # 环境评分
    service = item_list[-1].split(': ')[-1]  # 服务评分
    address = selector_1.css('#address::text').get()  # 地址
    tel = selector_1.css('.tel ::text').getall()[-1]  # 电话
    dit = {
        '店名': title,
        '评论': count,
        '人均消费': Price,
        '口味': taste,
        '环境': environment,
        '服务': service,
        '地址': address,
        '电话': tel,
        '详情页': index,
    }
    print(dit)
```

Figure 8-2. Python code to obtain data from Dianping websites