

**Study on the Spatial Structure of Large Scale
Retail Stores Based on Space Syntax:
Case Study in Wuhan**

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Study on the Spatial Structure of Large Scale Retail Stores Based on Space Syntax: Case Study in Wuhan

by

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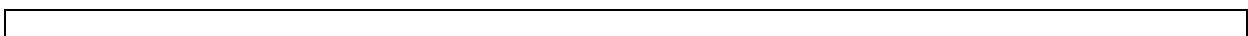
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Abstract

Large-scale retail stores are closely related to the daily life of citizens and constitute the core of the urban commercial space. In contemporary China, the urban retail is developing fast, however, the theoretical basis and technical approach for formulating the urban spatial planning which involve the retail space doesn't keep up the pace correspondingly. In China's urban planning practice, urban retail facilities are planned roughly based on various levels of service radius and the never changed per capita indicators. Lacking of valid methods for more accurate spatial allocation has been an obstacle in urban planning.

Scientific methods on spatial research and systematic evaluation of retail inner developing mechanism will be greatly helpful to retail spatial development. This research aims to analyse the spatial pattern of large-scale stores based on space syntax theory and to explore the correlativity between variations in syntax accessibility and the spatial pattern of large-scale stores.

The followings are the main conclusions of the research:

- (1) This research develops a framework of spatial topology analysis based on the space syntax theory, which including following innovations: the trail to break the traditional long axial line network; the trail to analyse the bus route network; By taking both the syntax accessibility of road and bus network into consideration, gives the scopes of urban syntax centres of city level, local level and sub local level respectively.
- (2) In the analysis of the retail distribution pattern, the city level, local level and sub local level urban retail centres are proposed respectively according to the spatial distributions of the quantity and scale of the retail stores. The spatial distribution pattern of each retail format is also discussed.
- (3) The correlativity analysis found that, there are spatial correlations between the retail locations and the urban space syntax centres. The space syntax is a useful tool to explain the allocation logic of urban retail space and it is more reasonable to apply the partitioned transportation network instead of the traditional long axial line network.

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1. Introduction

1.1. Background

1.1.1. Urban function and urban spatial development in contemporary China

As the rapid economic development and accelerating urbanization, Chinese cities have been changing accordingly not only in number and size of the city but in urban functions and space.

Urban function could be closely allied with the urban economic makeup. Since the People's Republic of China was founded in 1949, the key word of Chinese economic construction has been transferred from massive industrialization and planned economy, to the restructuring of the state-owned enterprises, inflowing foreign direct investment, and encouraging the development of private companies as the result of the market economic policy. During this economic restructure and fast developing urbanization process, Chinese municipal governments have devoted the endeavours to cultivate the service-based economy to replace the original industrial-based economy by encouraging the development of tertiary industry, especially the modern service industry, which may provide more new sources of economic growth and adapt to the new international division of labour.

Urban function change results in urban spatial restructure, which can be mainly manifest in two aspects in China. On one hand, the secondary industry sector is transferred outside the major cities, to new urban areas or growth centres. On the other hand, increasing commercial activities agglomerate in city center and diffuse to the sub-urban districts and the city fringe along the urban developing axis. In the latter case many commercial land-uses have emerged within urban area and become the core of urban revitalization and development.

1.1.2. Retail and retail spatial planning in China

According the definition of U.S. Department of Commerce, retail activity consists of the final activities and steps needed to place merchandise made elsewhere into the hands of the consumer or to provide services to the consumer. The retail sector is a large part of the tertiary industry and constitutes a significant part of city functions related to the flow of customers, goods, finance and information. Due to the intensified transformation of consumer's demand, the retail places become the most fast-changing spaces in China's urban area. Normally, whether the retail space can be successfully shaped is one of the key factors to city's vitality and prosperity.

1.1.2.1. Transformation of retail formats and scale

With the process of economic internationalization, retail is becoming a global industry. Many of the world prominent retailers already put their development strategy on international, especially open the new market in developing country. Under this international transfers, retail formats is often the key to gain competitive position in host country (Goldman, 2001). The transfers of retail formats have to

keep in step with the increasing living standard and the diverse consuming demands of local conditions.

Accompany by the economic restructure and the accession to WTO, China domestic market gradually growing to a buyer market. This condition intensifies foreign and local retailer's competition. Accordingly, China's retail formats diversified quickly from simplex category of grocery store in the 1950's to 17 categories at present, contains supermarket, hypermarket, shopping center, specialty store, exclusive shop, home center, etc. (Table 1).

Table 1: Classification of retail formats in China

Classification of retail formats		Basic qualification
Store-based retail		
1	Traditional Grocery Store	Independently operate; Mainly sell foodstuff; located within residential area, service radiuses are about 0.3km.
2	Convenience Store	Mainly sell foodstuff and daily necessities. Located within residential area or by the main public facilities; service radiuses less than 5 min. walk.
3	Discount Store	300-500 m ² ; service radiuses are about 2km.
4	Supermarket	<600 m ² ; service radiuses are about 2km.
5	Hypermarket	> 6000 m ² ; service radiuses more than 2km.
6	Warehouse Club	> 6000 m ² .
7	Department Store	6000 m ² -20000 m ² .
8	Speciality Store	Office Supply; Toy Stores; Home Appliance; Drug Store; Apparel Shop, etc.
9	Exclusive shop	
10	Home Center	> 6000 m ² .
11	Shopping Center/Shopping Mall	Community Shopping Center (< 50,000 m ²); Regional Shopping Center (< 100,000 m ²); Super-regional Shopping Center (>100,000 m ²); Factory Outlets Center.
Non-store Selling		
1. Television Shopping; 2. Mail Order; 3.Shop on Network; 4. Vending Machine; 5. Tele-Shopping		

1.1.2.2. China's urban planning and urban retail networks planning

The emergence of new retail formats in China's cities has mutual interactions with urban space. On the one hand, the locations of the diverse retail places are determined by common or specific environmental conditions. On the other, such retailing hot-spots may attract activity flows and result in reorganization of surrounding land uses in a certain spatial-temporal radius.

(1) China's urban planning system

The China's urban planning system contains five levels from macro to micro: urban master plan, immediate plan, district plan, regulatory plan and detailed plan. In general, the main content of urban planning in each level states the urban function, size, spatial distribution and development direction of projected areas in recent or in the long-term.

With the in depth understanding of the self-organized urban system, the global trend of urban planning is from "top-down" to "bottom-up". On the contrary to the top-down plan, the bottom-up plan start at detailing the very first level elements of the city system based on the principal that the whole is grander than gathered subsystems(Zhang, 2006). This concept is being widely accepted in China as well. With such concept, it is necessary for urban planning professionals evaluate the diverse forces (For example demand and supply), which will promote or impede urban change, from the market before formulating the plan in order to balance the competition of various urban functions on urban space. However, it's never an easy job, especially to relate every disaggregated subsystem (including physical space and non-physical space) of the complex and dynamic city system. Therefore, developing proper methodologies to realize the bottom-up way of thinking in urban planning practice has become the hot issue.

(2) Urban spatial planning of retail spaces

In China, urban spatial planning of urban retail spaces mainly projects the development of retail land use in size and distribution. Regarding the different levels of service radius, the retail land use planning embedded in different levels of urban planning respectively. All along, the retail space plan has generally been formulated based on the empirical per capita indicators and lack of scientific verification with regard to an understanding of spatial relationships that may influence consumer behaviour and thereby retail performance.

Compare to retail development and formats' evolution, the retail spatial planning and management in urban planning field are not adjusted in pace. In many cases, urban planning, which without properly analyse and forecast the variational market demand and supply directly results in unsuccessful spatial arrangement and failures of steering the development of retail space toward a beneficial pattern.

The latest version of China's national land use classification standard was initiated at 1990. In that standard, urban major retail places belong to C21 and C26 respectively (table 2), and the small-scale retail places that served for neighbourhood belong to residential category generally.

Table 2: Commercial land use classification in China

Codes		Classification		Remark
C (Commercial and public facilities)	C1	Political office		
	C2	Commercial and financial		
		C21	Commercial	Retail
		C22	Financing and insurance	Bank, credit cooperative, trust and investment corporation, stock exchange, insurance company, etc.
		C23	Trade and advice	Trading company, consultative agency, etc.
		C24	Service	Restaurant, hair-dressing and beauty, garage, repair service, ticket office, etc.
		C25	Hotel	Hotel, hostel, resort, etc.
		C26	Market	Farm produce, small commodity, industry goods market, market complexes, etc.
	C3		Cultural and recreational facility	
	C4		Sport facility	
	C5		Hospital	
	C6		Educational and science research	
	C7		Cultural relics and historical sites	
	C9		Other public facility	Religious facilities, Social welfare, etc.

1.1.3. Definition of large-scale retail store

Large-scale retail stores constitute the core of the urban commercial center. In this research, the urban large-scale retail store refers to stores of any retail formats with the business area more than 3000 m².

1.2. Research problem statement

Large-scale retail stores are closely related to the daily life of citizens and constitute the core of the urban commercial space. In contemporary China, the urban retail is developing fast, however, the theoretical basis and technical approach for formulating the urban spatial planning which involve the retail space does not keep pace. In China's urban planning practice, urban retail facilities are planned roughly based on various levels of service radius and the never changed per capita indicators. Lacking of valid methods for more accurate spatial allocation may results in failure or poor performance of retail centres and therefore of urban planning. From 1996 on, many newly planned retail locations could not develop as it was expected and some of them began to bankrupt in large and middle cities all over the China, including Wuhan. Though the whole environment of national economy contributed to this situation more or less, the basic reason was that investors of those large scale retail stores selected the location blindly without thinking much of the market investigation and the territorial analysis (Cheng, 2004). Therefore, to explore the correlation between urban retail layouts of various formats and urban spatial structure have becoming an urgent issue for more valid urban spatial planning.

There are many urban land use studies mainly dealing with the relationship between spatial structure and commercial activity embodied in the concept of accessibility. The term accessibility has been considered as the mediating factor for determining the activities occurred in locations and the demand for travel, which measures the cost or distance from a location to other activities or opportunities such as working, shopping, etc. (Iacono, 2008). However, many of these practices shows obstacles, which mainly remained in twofold: First, the commercial activities are highly complex networks, despite the different social environment, there are variety demands for different actors, thus it is difficult to identify the every relevant aspect for measuring the accessibility; Second, it is hard to capture and quantitatively map the human subjective cognition and common behaviour in the actual urban space. To solve these problems, a new perspective that is more resistant to the outer influence as well as can reflects the economic force to instead the trial of cover the all to express the accessibility is needed. Then, the topological relations of the road network, as a relatively stable physical quality intrinsically embraces social attributes and represents the topological accessibility from one place to any other, might be a proper research object.

This research tries to depart from the concept of Space Syntax and disaggregates the urban space to a finite set of small-scale vista spaces that are interconnected and can be perceived by human to explore to what extent the space syntax accessibility of the urban road network impacts the layout of retail activities.

Research hypotheses:

The development and emergence of the large-scale retail spaces is correlated to locations that are relatively well connected via the road network.

1.3. Research objectives

Main objective:

The main objective of this thesis is to analyse the spatial pattern of large-scale stores based on space syntax theory and to discuss the correlation between variations in space syntax accessibility and the spatial pattern of large-scale stores.

Sub objectives:

1. To analyse the structure of the urban road and bus route network;
2. To analyse the characteristics and pattern of large-scale retail stores;
3. To determine if the spatial pattern of urban retail stores can be explained by variations in space syntax accessibility of urban transportation network;

1.4. Research questions

In order to achieve the research objectives, the questions shown in the table below will be addressed.

Table 3: Research Objectives and Research Questions:

	Research objectives	Research questions	Research methods
1	To analyse the structure of the urban road network and bus route network;	1a How to properly derive the axial lines of the road and bus routes network	literature review and Space syntax analysis;
		1b What does the syntax accessibility pattern of Wuhan? And where are the space syntax centres?	Space syntax analysis;
2	To analyse the characteristics and pattern of large-scale retail stores;	2a How many large-scale retail stores in Wuhan? And what are the formats of them?	Maps overlap; literature review; statistical analysis
		2b What is the distribution pattern of these large scale retail stores? And where are the urban retail centres?	Maps overlap; statistical analysis

3	To determine if the spatial pattern of urban retail stores can be explained by variations in connectivity of the road network and bus route network;	3a To what extent the space syntax accessibility of the urban transportation network impacts the spatial pattern of urban retail stores?	Maps overlap; Statistical analysis SPSS; literature review
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1.5. Conceptual framework

This research tries to looking at the spatial development of large-scale retail spaces employs the concept of Connectivity. Urban land-use location pattern and the road net work that connect the locations are two major components of the urban spatial pattern.

In modern Chinese city, most of urban changes are triggered by economical activity, and mutually impacts on the transportation network construction and land use evolution. Thus, to achieve the research objectives that to examine the spatial pattern of large-scale retail spaces within a city, this research start with drawing on the economical Bid-rent model as basic theory to describing the trade off between the connectivity of road network and urban retail places distribution in space.

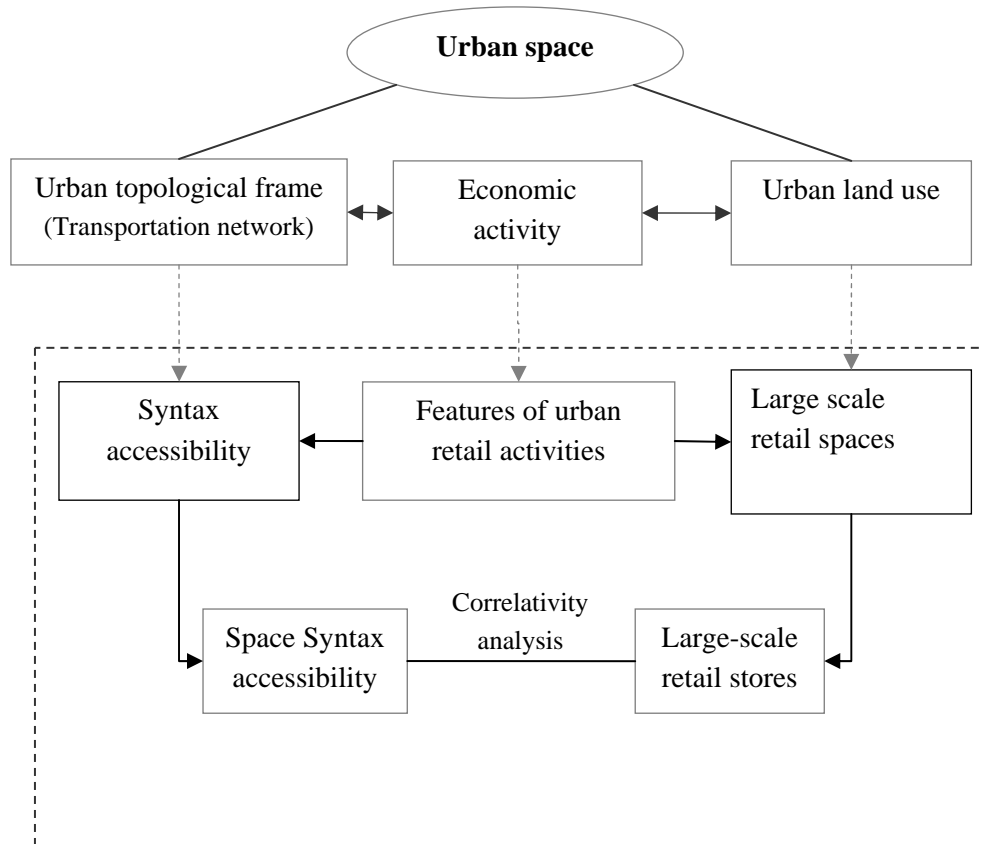


Figure 1: Conceptual framework

1.6. Research design

The whole research process can be demonstrated as the workflow following:

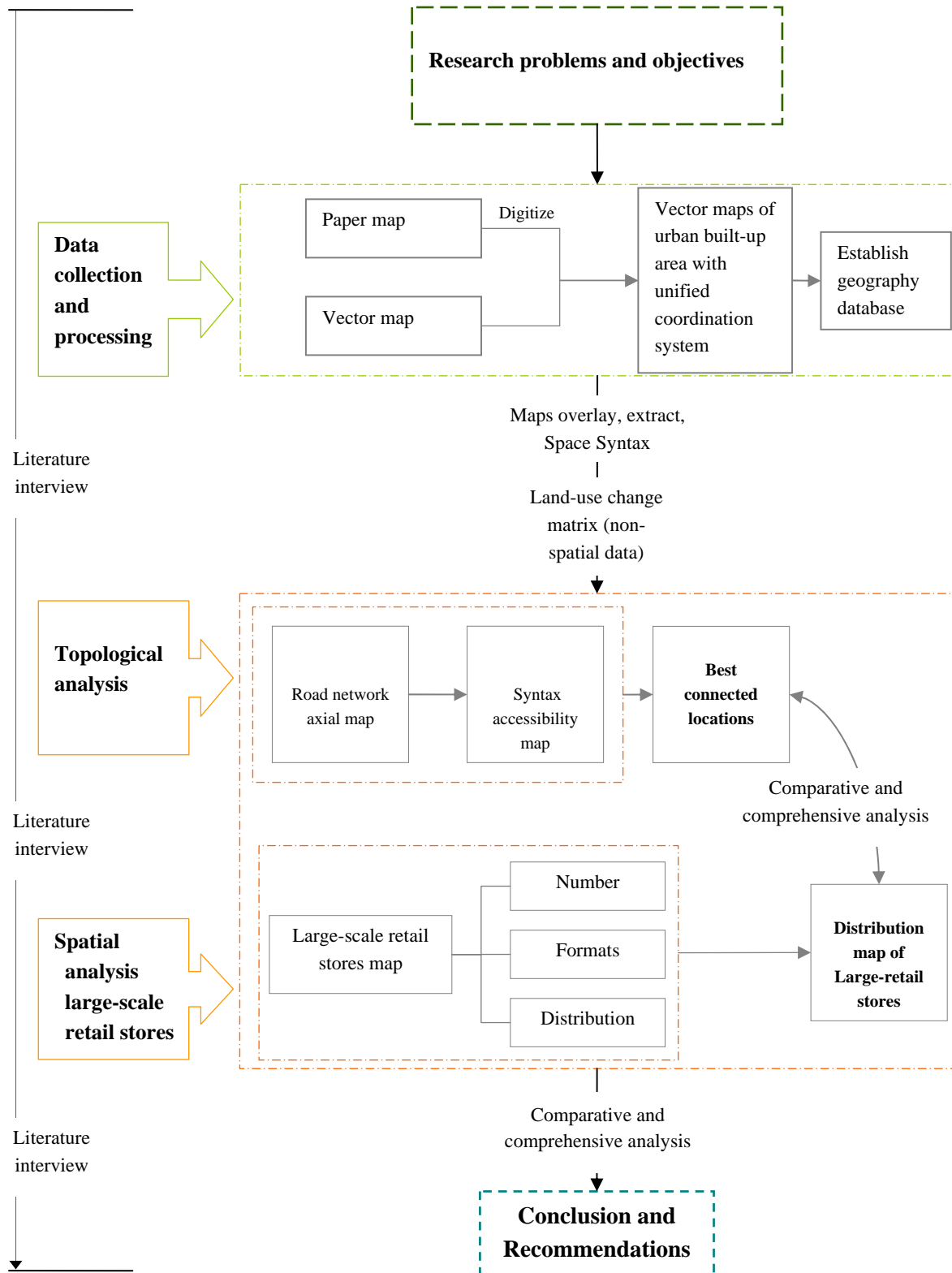


Figure 2: The research framework

This research is to exploring the spatial development of large-scale retail spaces through topological analysis. In order to achieve the research objective, five steps are needed to be carried out as following:

Step 1: Literature review;

In the first step, by literature review related theories and terms will be defined. These theories mainly involve two fields: urban spatial planning and commercial geography. In addition, the notions of China's retail formats, and large-scale retail spaces, urban topological structure are needed to be defined

Step 2: Data collection and processing;

In this step, the main tasks are unifying the different formats maps and establishing a geographic database.

Step 3: Urban topological structure analysis

The urban spatial topology structure will be studied though using the space syntax methods. In the space syntax analysis, the complex urban spatial system will be represented as simplified axial map of road topology network; Integration will be the most apparent parameter for urban spatial pattern analysis. This step will show where the best connected locations are, which indicate the principal centres of development.

Step 4: Spatial development of large-scale retail spaces;

This step mainly examines the spatial development of large-scale retail places regarding the different formats.

Step 5: Conclusion and drawing recommendations for revising the master plan

The analysis of step 3 and 4 will tell the integration value of urban topological structure; where the large-scale retail places clustered the most and the correlated impacted factors which could give references to configure the land-use for the new master plan. Also, it will give clues that to what extent the space syntax accessibility of urban transport network impact on the spatial development of large-scale retail spaces.

1.7. Structure of this thesis

This thesis is structured into eight chapters as following:

Chapter 1: Introduction

This chapter states the present development of urban space and retail sector in China, the definition of Large-scale retail shopping centre, the research problem, research objectives and the research framework.

Chapter 2: Theories about Economic Geography and Urban Topology

This chapter gives a theories review about Economic Geography and Urban Topology which relative to this research topic.

Chapter 3: Background of Study Area

This chapter presents some background of Wuhan.

Chapter 4: Methodology and Data Collection

A methodology for this research will be developed in this chapter, including the methods for topological analysis based on space syntax, distribution analysis of large-scale retail stores and correlativity analysis between the syntax accessibility and the spatial pattern of the large-scale retail stores.

Chapter 5: Syntax Accessibility of the Road and Bus Route Network

This chapter adjust some technical principles in space syntax analysis regarding the characteristics of urban retail for this research and sums up the syntax accessibility pattern of Wuhan through analysing the space syntax accessibility of the road and bus route network.

Chapter 6: Pattern of Large-Scale Retail Stores

This chapter analyse the spatial pattern of the Large-scale retail stores in Wuhan

Chapter 7: Correlativity Between Syntax Accessibility and Retail Pattern

This chapter analyse the correlativity between the syntax accessibility of the urban transport network and spatial pattern of the large-scale retail stores based on the results of Chapter 5 and Chapter 6.

Chapter 8: Conclusion and Recommendation

This chapter presents the conclusions derived from the results and findings of this research and provide some recommendations for supporting the urban spatial planning and urban retail planning in the future.

2. Theories about Economic Georaphy and Urban Topology

This research of studying the spatial structure of large-scale urban retail stores within the city is closely related to the theories and researches on two scientific domains: commercial geography and urban topology.

2.1. Theories about economic geography

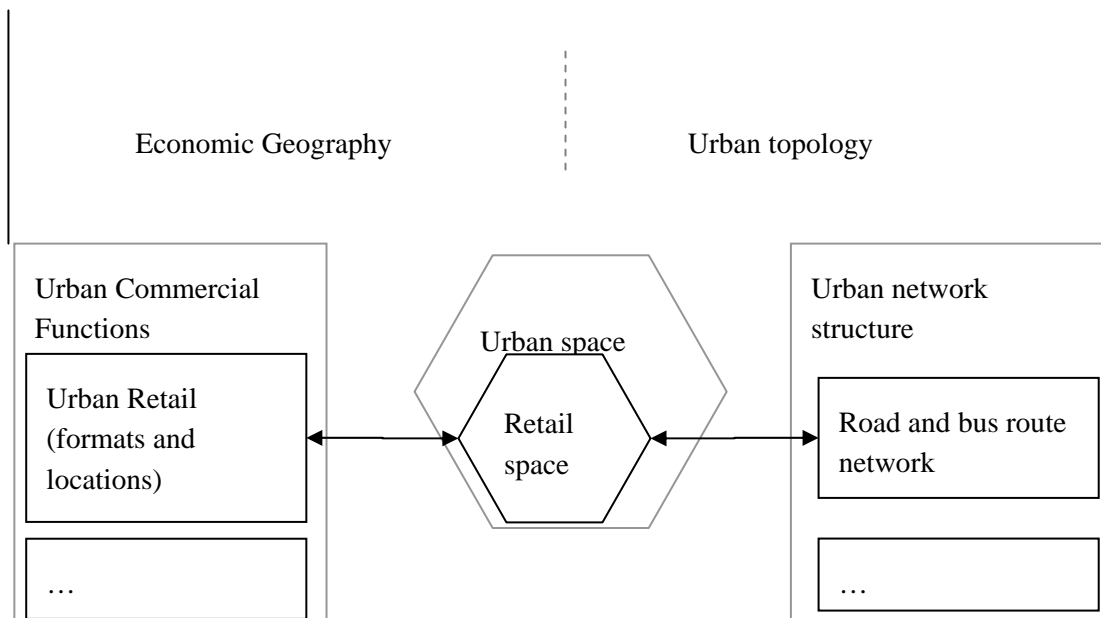


Figure 3: Two relative research domains

Economic geography is the study that concerned the locations, distribution of the economic activities in space in order to understand the mechanism of the economic spatial development.

2.1.1. Central place theory

Central place theory is an economic geography theory of regional scale, formulated by the German geographer Walter Christaller in 1933. The theory suggests that the number, size and distribution of cities, as central places, are organized by invisible laws, and form an orderly hexagonal hierarchical pattern. The German economist August Losch is considered as another founder of the central place theory. Compare to the research of Christaller, Losch find hexagonal pattern as the optimized pattern through mathematical calculations and it in-depth prove Christaller's experience-based work. Though central place theory established earlier than the self-organization theory, it is also well acknowledged as classical depiction of self-organized evolution in spatial system today (Zhang, 2006).

Some important ideas of the central place theory, though it is a study at a regional level, also may related to the hierarchy and location of retail settlements in space at city level. The first is the starting point of human purchase habit and the service threshold of concept, are essential to study the locations of the retail in urban areas. The second is range which is the maximum distance a consumer will travel to purchase a good. According to these, in China's urban planning practice, urban retail facilities are planned based on various levels of service radius and the per capita indicators. But the central place theory is a description of a retail spatial self-organization rather than to explain (Liu, 2001).

2.1.2. Bid-rent theory

Much of the land use theory is based on the Alonso's bid rent theory, which is a geographical economic theory that explains why demand for land, and land spatial patterns vary across the urban area (Pacione, 2005). There are 3 elements in bid-rent theory: rent, distance from CBD and land users, the relationships in between are described through bid-rent curve (Figure 4).

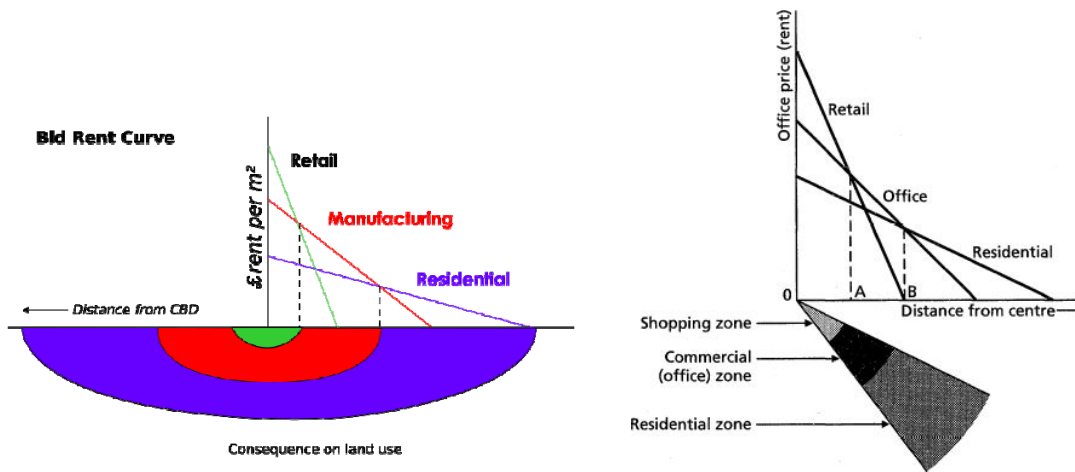


Figure 4: Bid Rent Curve (left)

Figure 5: land use allocation in relation to bid-rents (right)

The key issue of the rent-bid theory is the rents. In this concept, different urban activities have different affordable domain of the rents and each location has particular rents. Since the competitive allocation of locations, the higher rents imply the lower aggregate transport costs (Rhind, 1980). The Figure 5 of land use allocation in relation to bid-rents shows that the rents reflect variation on accessibility and directly determine the spatial allocation of different urban land use, the retail sector among which requires maximum accessibility. However, the assumption of the rents equals transport accessibility in this model does not hold true in practice. Besides the traffic factors, the present land conditions, nature environments and the proximities to other existing public facilities such as schools, hospitals, etc. are also impact factors influencing the rents that should not be ignored. So this research will directly use the inner topological connectivity of the urban transportation network itself instead of the urban rent surface to reflect the transport accessibility to explore the correlations between the accessibility and the urban retail centres.

2.2. Urban topology and space syntax

2.2.1. Urban topology

Urban spatial topology has been the traditional method for urban spatial structure analysis. (Zhu, 2006) the main technological characteristics are as flowing:

- Urban spatial structure is simplified as the geometry networks constituted by the features of points, lines, blocks, and arcs. The links among them represents the urban spatial relations.
- Urban topological analysis is a rational method based on the technological integration of computer and modern spatial information, it objectively reveals the of urban structure change in the process of urban evolution.

2.2.2. Urban space legibility and imageability

The concept of urban space legibility and imageability was proposed by Kevin Lynch with the perspective of human behaviour and psychology. He thought the characteristics of the good city form is the place legibility, with which the citizen's who live there may easily understand the layout of the place (Lynch, 2001). Lynch has many findings about the relationships between people's activities and their perceptions to the diverse urban space. In his surveys and interviews, Lynch found that people would like to move following their perception of the urban space and there are consistencies in people's imaginary trips, such as most people would like to go through the vivid area of the city and people often loose their way at the place where contains weak boundaries, isolations and so on. Lynch defined 5 main elements of an imaginable city: paths, edges, district, node and landmark. He thought place legibility and imageability are important basis of urban spatial planning (Lynch, 2001).

2.2.3. Space syntax

The idea of space syntax is based on urban topology and is related to the ideas of Lynch. It is originally conceived by Bill Hillier, Julienne Hanson and colleagues at The Bartlett, University College London in the late 1970s. Reverse to those approaches that try to define the city in the output of spatialised processes, Space syntax makes the physical city the primary object of attention, and examines it's morphology to detect the imprint of economic and social processes (Hillier, 2007). This technique explains the structuring logic of urban space assuming there is an intelligible structure to built space as it is perceived and explored by users moving through space (Peponis, 2007), and proposes a common framework that comprised by simplified axial map of road network lines to represents the morphology for describing how spatial environments enable or impede users' behaviours. Space syntax is implicit in the urban self-organization mechanism of urban spatial development and is becoming a new paradigm of the urban spatial studies.

2.3. Theoretical framework for this research

The city can be studied objectively or subjectively with the perspectives of the city as a physical city or cognitive city. The urban space exits as a complex whole of physical features and social features. Urban development is also the processes of urban economic activities in constant interaction with the physical space. Therefore it is meaningful for this research to set a theoretical framework that can

combine the two aspects together. This research involves the theories of urban topology and economic geography. The theoretical framework of this research is proposed as following:

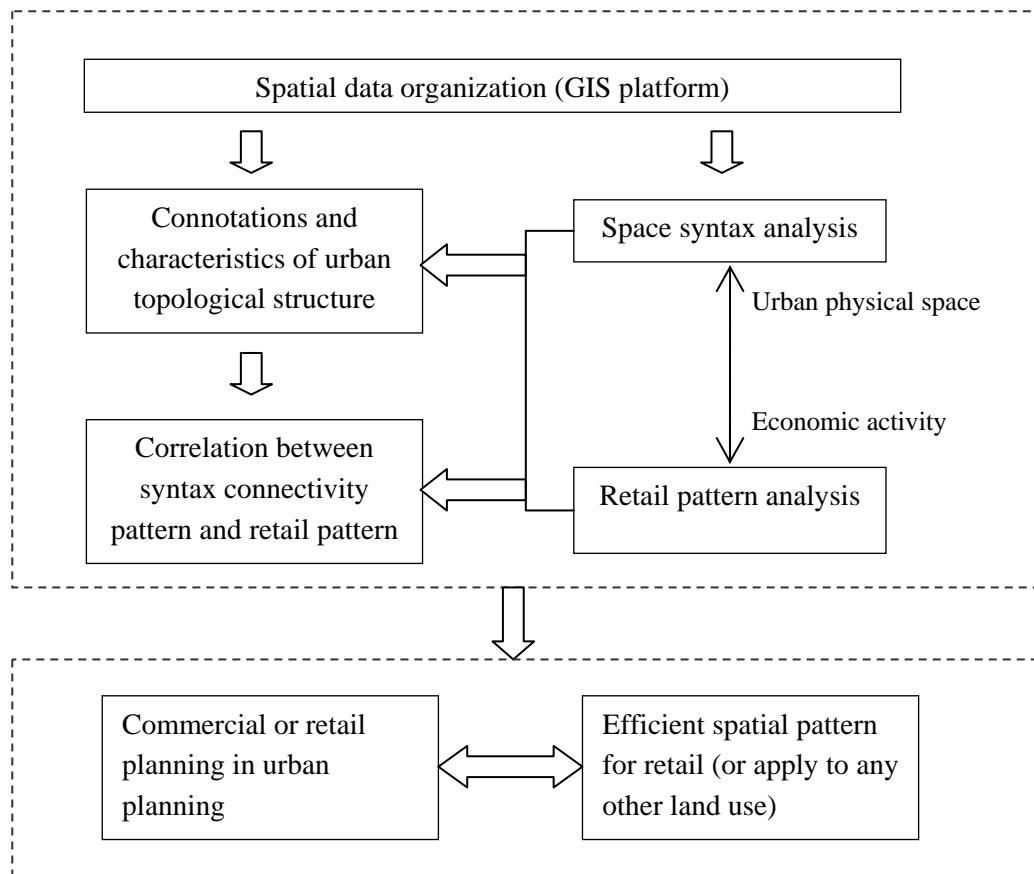


Figure 6: Theoretical framework for this research

3. Methodology and Data Collection

This chapter described the methodology used in this research, including three parts: topological analysis using space syntax; analyzing the pattern of urban large-scale retail shopping centres and analyzing the correlativity between the transport network connectivity and the retail distribution pattern. This chapter will also introduce the data used in this research and their sources.

3.1. Topological analysis using Space Syntax

It is common to apply urban topology to analyse the urban structure through exploring the structural relationship between the points, lines and blocks that derived from the urban space. With similar principal, Space Syntax is one of computational technologies of urban topology. In space syntax, the urban space is extracted as axial network comprised by axial lines and Junctions based on the road network. Through calculation, each axial space will be valued out the syntax parameters which imply the diversity of syntax accessibility in urban space.

3.1.1. Syntax elements and urban spatial features

(1) Syntax axial line:

The road is primary spatial element of the city. The structure of the road network is a fundamental determinant of urban movement patterns, so the road contains both spatial and social attributes. Space syntax takes the linear space along the road as major research object and the syntax axial lines are created based on the urban road network.

(2) Syntax node:

The syntax node including the natural road junctions and the turning points of the road

(3) Syntax Network:

The syntax topological network constitutes the least number of longest axial lines, the nodes, and the syntax attributes of each axial space.

(4) Syntax center:

The Center in syntax topological space refers to the axis with the highest value of syntax integration. To some extent, such axial center correspond the actual urban space more realistically and effectively. The question to be examined is whether the functional economic centres are related to the syntax based central locations.

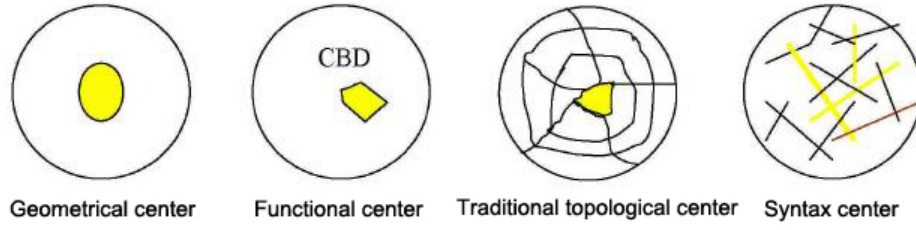


Figure 7: Different presentations of urban spatial center

3.1.2. Parameters and formulas

In space syntax analysis, the topological space that constituted by syntax axis is the study object, and its inner topological relations are reflected by the parameters of the axis. These parameters include Connectivity, Depth and Integration (Global Integration and Local Integration).

Connectivity: The Connectivity is defined as the number of axial lines that are directly linked to the given axial line.

Depth: the number of lines distance from the given number of step to that axial line

$$\sum_{s=1}^m s \times N_s \begin{cases} \text{connectivity} & \text{iff } s=1 \\ \text{local depth} & \text{iff } s=3 \\ \text{global depth} & \text{iff } s=m \end{cases}$$

S: the shortest distance (steps) from a given axial line to another

Integration: The Integration value is measure for relational asymmetry which represents the accessibility and penetrability of the certain road space. Considering different depth, the Integration constitutes Local Integration and Global Integration.

The formulas of Integration are calculated as followings:

$$I_{(i)} = \frac{1}{RRA_{(i)}} = \frac{n \left[\log_2 \left(\frac{n+2}{3} - 1 \right) + 1 \right]}{(n-1)|MD-1|}$$

$$MD = \frac{\sum_{s=1}^m s \times N_s}{n-1}$$

$I_{(i)}$: Integration value of the given axial line within i steps

Connectivity: when $i=1$ the integration value is called Connectivity;

Local Integration: when $i=3$ the integration value is called Local Integration;

Global Integration: when $i=m$ the integration value is called Global integration.

n : the total number of axial lines within i steps;

According to Space Syntax theory, the relationship means that the bigger the integration value the more integrated the axial line is. Depending on the depth used, the integration value is matched as Local Integration and Global Integration. For each axial line, the Local Integration considers both immediate and non-immediate neighbourhoods up to a few steps (normally three steps) away, which is matched the local depth. Depends on the global depth, Global integration considers both immediate and non-immediate neighbourhoods up to all steps away. In corresponding urban transportation network, the Local Integration and Global Integration reflect the differences on the accessibility of roads in different spatial scale. By using the Integration graph representation, space syntax analysis could provide a configurable description map of an urban spatial pattern and relative connectivity across space(Jiang, 2002). So this research will apply these parameters of Integration to analyse the accessibility pattern of the urban road and bus rout network.

3.1.3. Process of Space Syntax analysis

The space syntax analysis can be implemented through following steps:

1. Create a reasonable principal for deriving axial lines from the road and bus route network considering the spatial validity (axial length) of a single syntax value in this research;
2. Draw axial line in ArcGIS based on this principal and the present road map;
3. Using Axwman 4.0 extension to calculate the space syntax values and generate the syntax accessibility maps;
4. Interpret the space syntax values of the axial lines and explore the structural pattern of the urban road network.
5. Discuss the application of space syntax for this research and give a conclusion of this part of research.

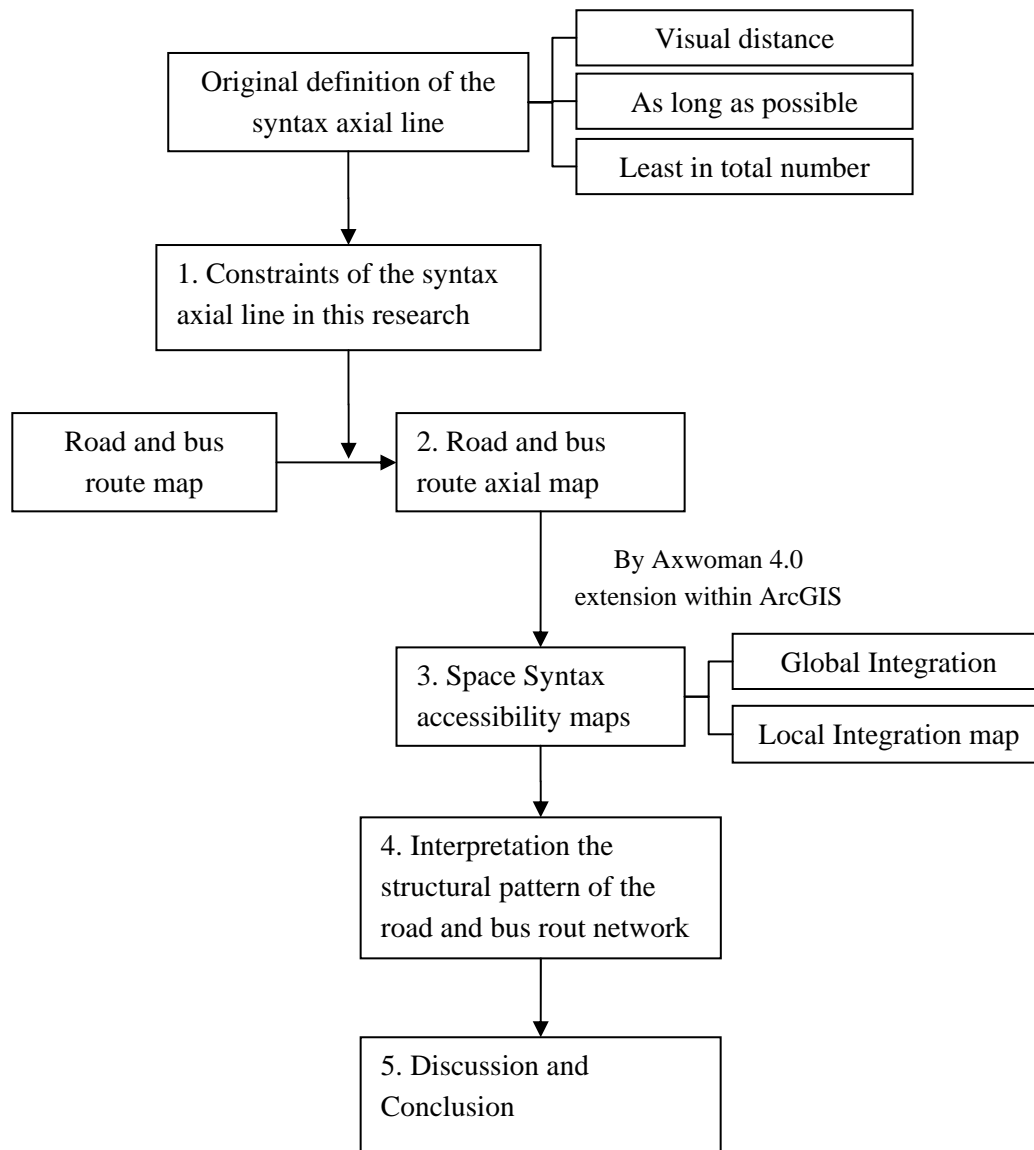


Figure 8: The framework of Space Syntax analysis

3.2. Procedure of analyzing pattern of large-scale retail stores

The urban retail pattern analysis can be implemented through following steps:

1. Collect the data of the large scale retail stores, including their non-spatial properties and spatial locations.
2. Create geo-database for the retail stores in ArcGIS, and input the basic attributes to each features.
3. According the distribution map describe the distribution pattern of large scale retail stores.

The whole procedure is summarised as following.

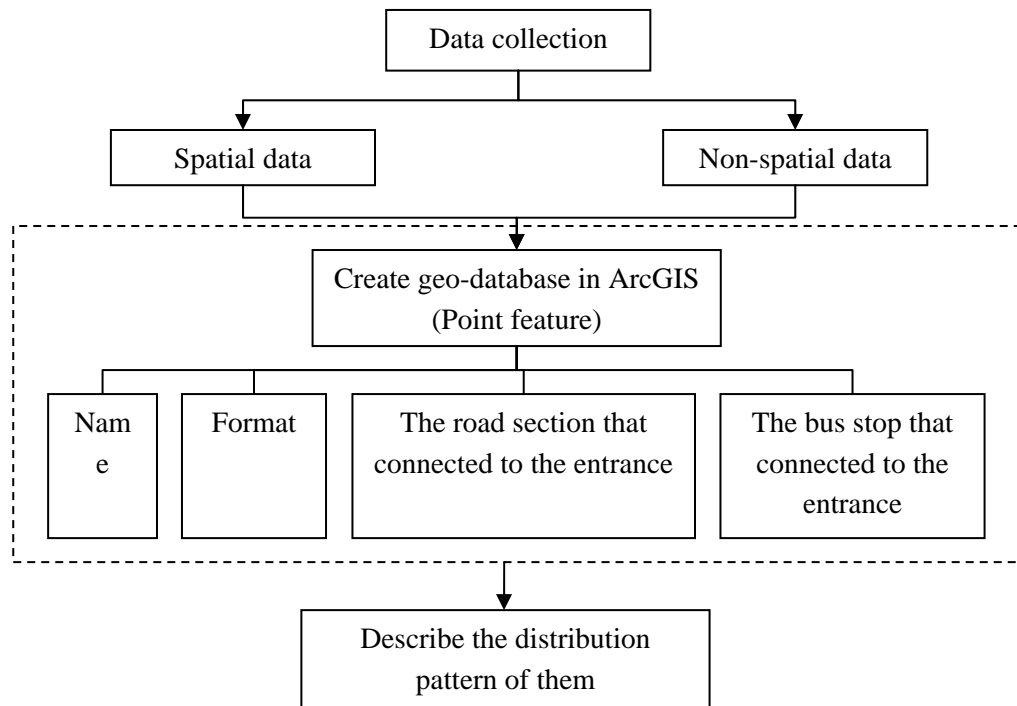


Figure 9: The framework of analyzing pattern of large-scale retail stores

3.3. Procedure of analyzing the correlativity between syntax accessibility and retail distribution pattern

Combine the results of space syntax and retail pattern analysis to study the correlations between syntax accessibility and retail distribution. The whole procedure is summarised as following.

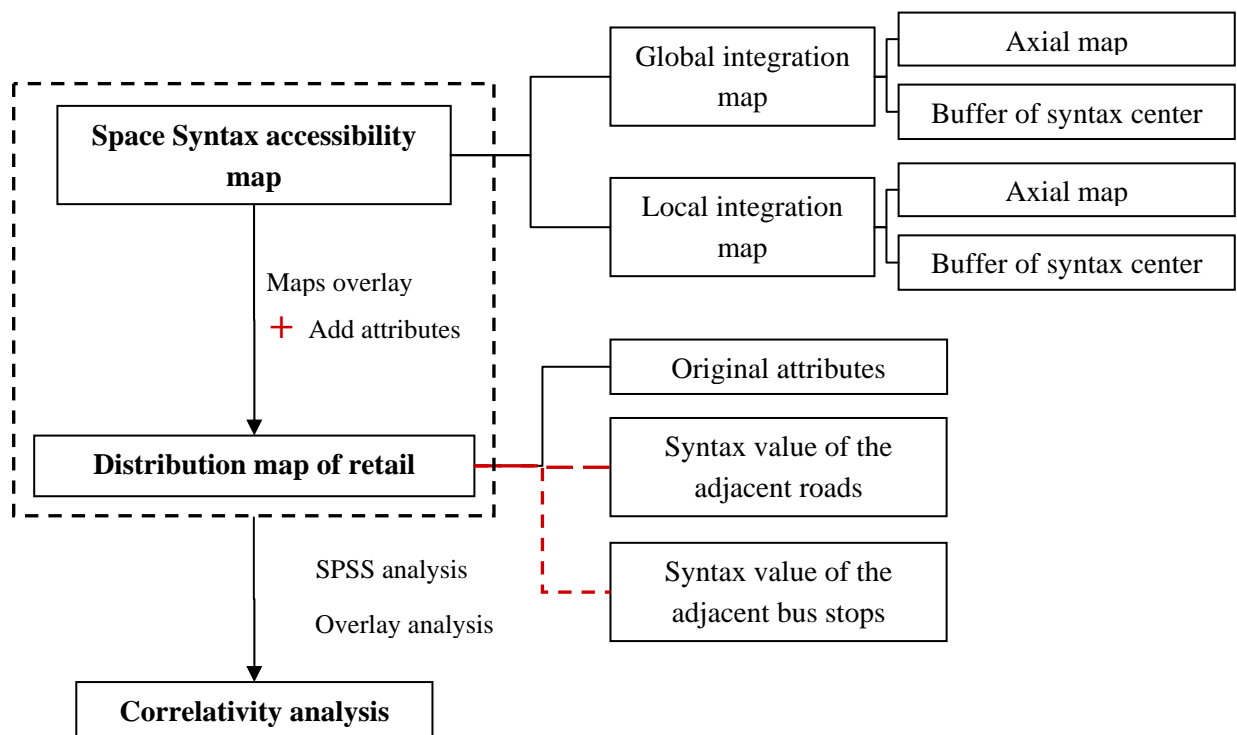


Figure 10: The framework of correlation analysis

3.4. Data source and collection

All the data expected includes road map, present land-use maps, social and economic data, etc. Some maps may need to be digitized. Statistic analysis is needed to deal with the non-spatial data.

Table 4: The data list

Data	Source
1. Wuhan traffic map (paper map, 2008)	Wuhan University library
2. Administrative district border (paper map, 2008)	Wuhan University library
3. Road line (.shp)	Dr. Huang Zhengdong
4. Bus line in the main city area (.shp)	Dr. Huang Zhengdong
5. Bus stop in the main city area(.shp)	Dr. Huang Zhengdong
6. Wuhan urban planning in history	Wuhan University library
7. Statistics Bulletin of Economic and Social Development of Wuhan and some major provincial cities in central and western China (2002 and 2007)	Wuhan statistic bureau
8. Wuhan transportation annual report (2008)	Wuhan transportation planning institution
9. Information of large-scale retail store	Wuhan commercial bureau

4. Background of study area

This chapter introduces the case study area, giving a brief background introduction about the urban transport and retail sector development in Wuhan.

4.1. A profile of study area

4.1.1. Location of Wuhan

The study area of this research is urban built up area of Wuhan city. Wuhan is the capital city of Hubei province (Figure 11b), located in the central part of China (Figure 11a).

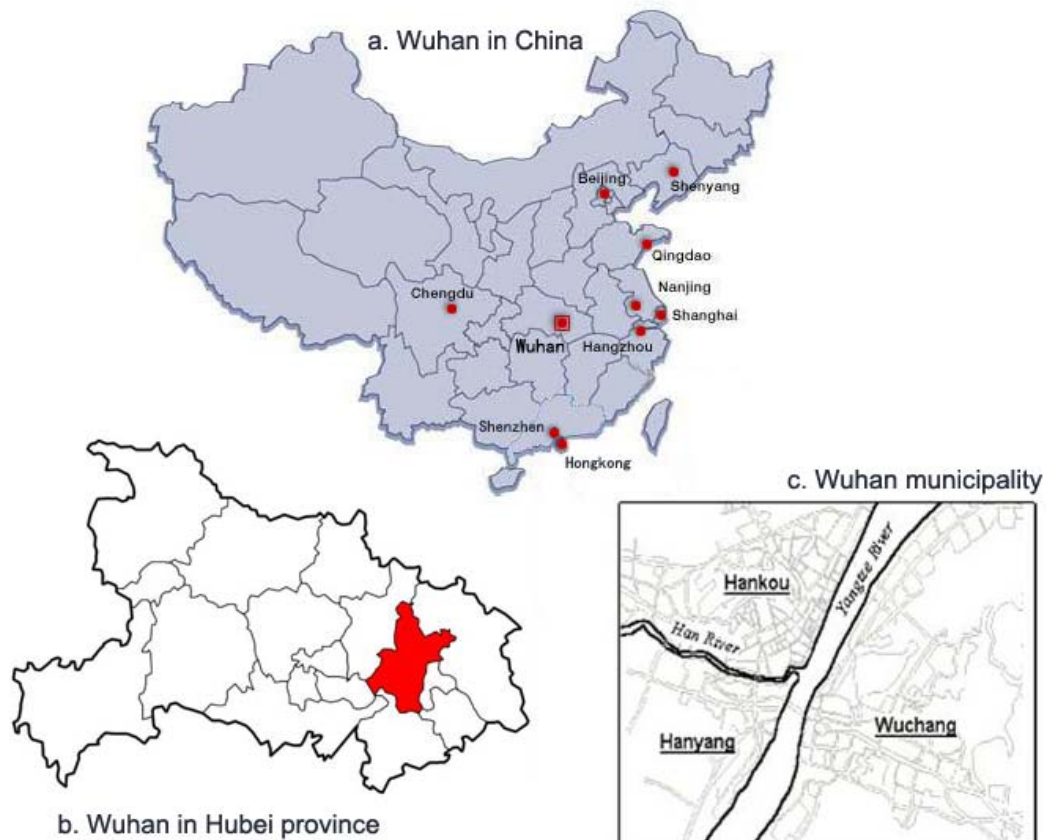
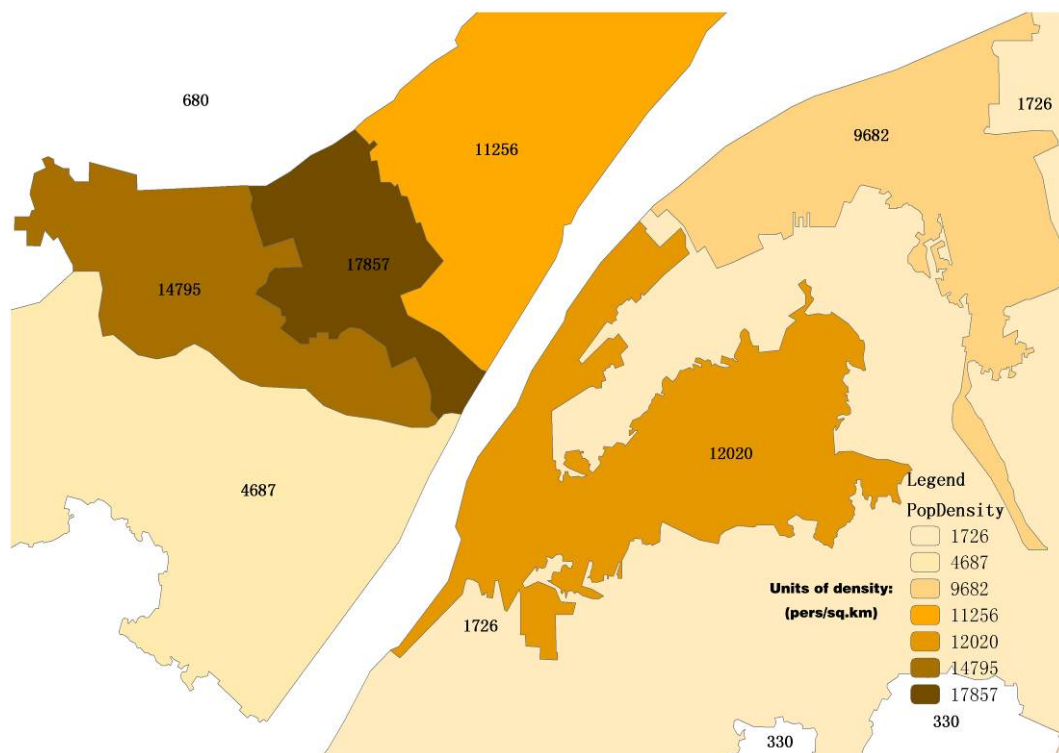


Figure 11: Location of Wuhan

4.1.2. Urban scale and density of population

According to the statistics of 2007, Wuhan has the urban land of 450.77 KM². The seven central districts covered 353.83 KM². At the end of 2007, the total household register population approaches 8.28 million, of which, 5.27 million are urban residents.

The density of population in urban area is very high. The value of four downtown districts of Jianghan, Jiangnan, Qiaokou and Wuchang have already exceeds ten thousands person per square kilometre.



Density of population in Wuhan

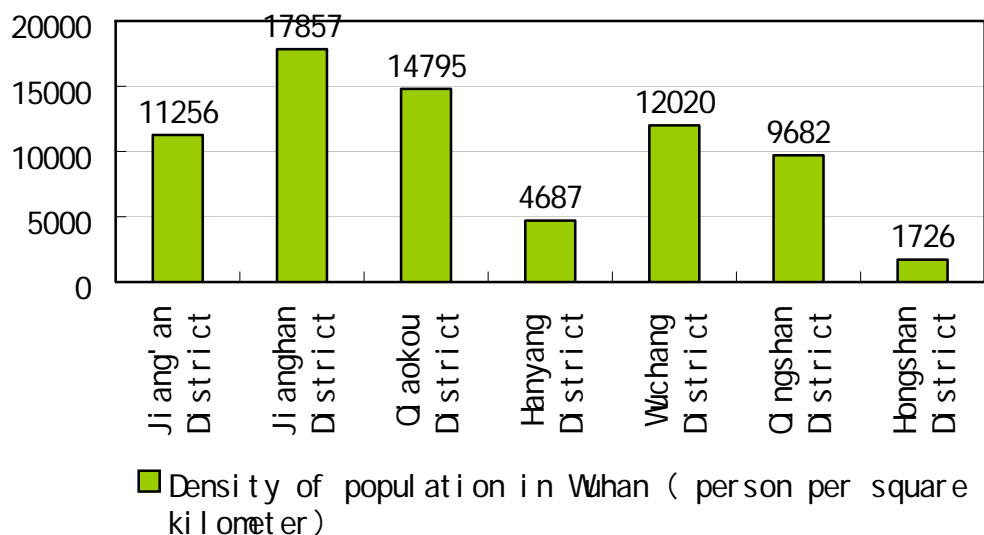


Figure 12: Density of population in Wuhan (according to the statistics of the fifth national census in November 2000. unit: person per square kilometre)

4.1.3. Urban economic development and the urban retail sector

Wuhan has been under the process of urbanization and industrial upgrading. In 2002, the primary, secondary and tertiary industries are accounted for 6.3 percent, 44.1 percent and 49.6 percent, respectively. This proportion has been optimized to 4.1:45.8: 50.1 by 2007. At present, both urban

policy and social demand encourage the priority to the tertiary industry for the modern urban development.

The retail trade of Wuhan has always been in the forefront in the nation. Over the last decade, Wuhan retail trade is maintaining steady increase, showed strong competitiveness and vitality among the major cities in the country. In 2007, the total retail sales of social consumer goods in Wuhan are 151.83 billion Yuan, up 17.4%, ranked 7 at 19 sub-provincial level cities in China, next to Shanghai (384.8 billion yuan), Beijing (3800 million), Guangzhou (259.5 billion Yuan), Shenzhen (191.503 billion Yuan) and Chongqing (1661.23 million), Tianjin (160374 million Yuan). The comparing statistics of some provincial capital cities in central and western China is showed as the following table.

Table 5: Comparing statistics of the provincial capital cities in the central and western China

	Changsha	Xian	Chengdu	Zhengzhou	Nanchang	Wuhan	
	2002	2002	2002	2002	2002	2002	2007
1 Total population (million)	6.01	9.98	10.44	6.97	4.49	7.68	8.29
Urban population(million)	1.96	5.1	4.52	3.22	1.96	4.59	5.27
2 GDP(billion Yuan)	72.8	73.3	149	82.8	48.5	134.7	313.5
Rank in major cities	22	21	8	20	25	9	–
3 GDP per capita(Yuan)	12443	10620	14665	12335	11129	17882	37811
Rank in major cities	21	29	18	23	27	15	–
4 Retail sales of consumer goods(billion Yuan)	34.4	36.5	62.7	38.6	16	68.5	151.8
Rank in major cities	22	19	7	16	29	6	7

4.2. Characteristics of urban transportation in Wuhan

In Wuhan, the bus, ferry, light rail, taxis, private car and bicycle are common means of transportation. According to the Wuhan transportation annual report of 2007, the vehicles possessing capacity in Wuhan is 760,000, the number of private cars is 246,000. Some available government information from the official website of Wuhan municipal construction committee demonstrates that 62.5 percent of total residential traffics are non-motorized transportation and 40.5 percent of the total traffics are walking. On the aspect of public transportation, bus is the most frequently used transport means. In 2007, passenger transportation volume of bus reached 1.39 billion person times, which accounted for 70% percent of all public transport journeys (Figure 13). The remainder means of public transport are taxi, light bus and light weight track.

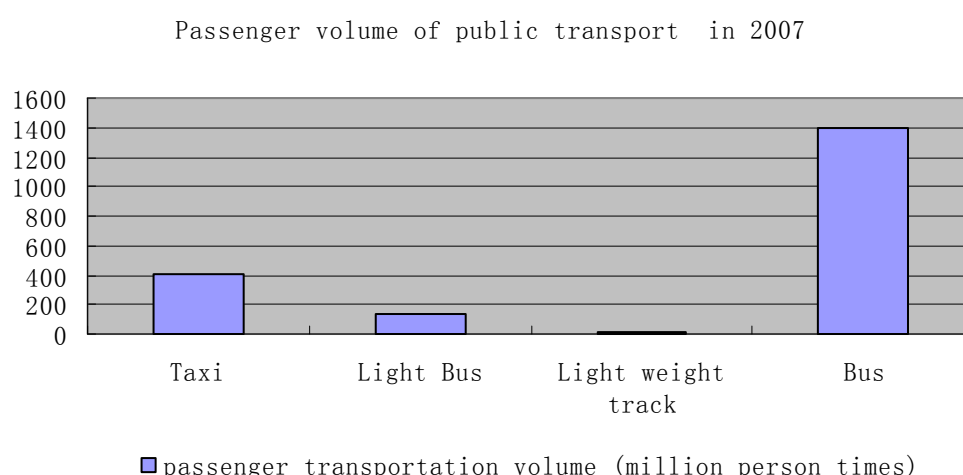


Figure 13: Passengers transported by public traffic vehicles in 2007 (Unit: million person times)
Source: Wuhan transportation annual report of 2007 (by Wuhan transportation planning institution)

From this it appears that, in present status, the non-motorized transport and Bus take significant part of residential daily traffics in Wuhan.

The research by Kongtao (Kong, 2001) suggested that, the mode of transportation is relevant to the density of the population. He summarized the status of 20 cities in the U.S., when density of population exceeds 4800/KM² the public transport account for about 30% of total urban transport; when density at 7000/ KM² both private car and public transport carries 42.3% of total transport respectively ; when density reaches 8115/ KM² the proportion of public transport will exceed 50%. In other words, the higher population density there is the less private car transportation and the more public transportation. In combination with the status development of Wuhan, the private car ownership keeps increasing in recent years but is still way below the American levels. The population density also raises year by year, most citizens living densely in multi storied or high-rise apartment building, and in consequence, the requirement of commercial and service facilities of local level are high in quantity and density. In addition, the municipal policies for sustainable city are encouraging the development of public and non-motorized transportation. So in the future, the non-motorized and public transport in Wuhan will remain the mainstream and the most promising part of the urban transportation. As a consequence, in this research I would examine retail store locations in relation to both e road network as well as the bus network system.

5. Syntax accessibility of the road and bus route network

In this chapter, the research flowchart in section 4.1 will be applied. In general, two main sections are included in this chapter: data procession and outputs interpretation. In accordance with the calculation results propose the city syntax centre, the local syntax centres and the sub local syntax centres of Wuhan.

5.1. Data procession

The process of data procession contains 3 parts: formulating the principles for deriving the axial line of the road and bus route network; creating axial map following the principles and calculating syntax accessibility.

5.1.1. Principles for deriving the axial line of road net work

In general, there is no any formal or automatic way deriving the axial map (Jiang, 2002). In Hillier's initial definition, "the axial map constitutes the least number of longest axial lines" (Hillier, 1984). However, in practice, there are a lot of obstacles in applying this principle. Firstly, it is very difficult to insure the axial line is exactly the longest in visual distance. That's because deriving axial line is a manual work, different operator may have different judgement. Then next, it would be quite difficult to insure there are the least number of axial lines. Furthermore, without standards of practice, it is almost impossible to check the precision for every axial line, especially in the study of large urban area.

At very first, I try to create an axial map based on the original definition and neglected all the potential inaccuracy mentioned above. After the axial map of the road network is derived, the statistics of those axial lines display that there is a large interval between the maximum and minimum lengths of the axial line (Figure 14, in this frequency graph, the x-axis is the axial length and the y-axis is the total number of the axial lines at a certain length). Compared to many western cities, Wuhan has much larger spatial scale. One straight road may continue a long distance. As the result, the maximum length in this axial network is approximates to 13 kilometres long. By calculated the space syntax value based on such axial map, two syntax accessibility maps are obtained: Global Integration map (Figure 15) and Local Integration map (Figure 16). To some extent, such outputs may valuable for some macro and strategically studies of the whole urban structure, but not for this research. From these two maps, each axial line, no matter the spatial distance, was assigned one unique set of syntax accessibility property which is illogical in reality. Many axial lines were too long to be a clustering unit for urban retail locations, so these results are not ideal to support my later research about retail locations which selves are relatively micro-scale space.

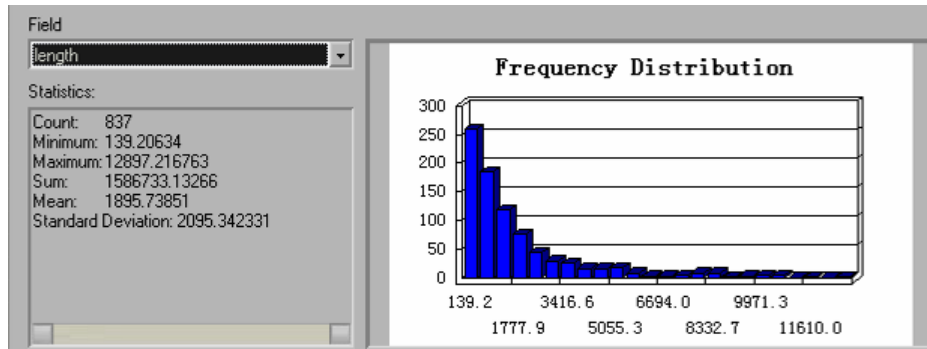


Figure 14: The frequency distribution of the axial length

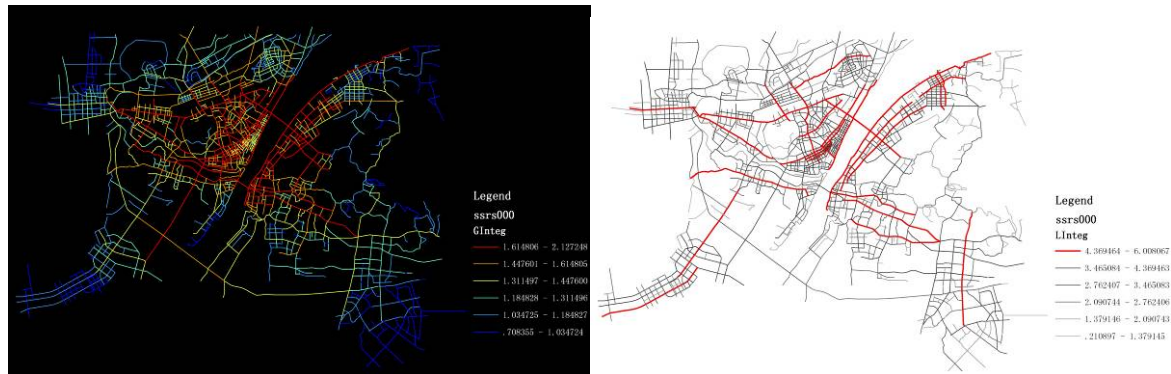


Figure 15: Global integration map of traditional syntax axial network (left)

Figure 16: Local integration map of traditional syntax axial network (right)

Given all that, it is necessary for this research to Figure out the following question beforehand that how to properly partition one road into several axial lines to formulate more logical constraints for deriving the axial line.

To come back to the theme, this research is mainly to explore the correlations between the syntax accessibility and large-scale retail locations. To use some conceptions in the Central Place theory for reference, the scale of each syntax axial unit in the axial network should taking account the human purchase habits and retail features as well. In detail, the long roads should be partitioned into several segments of fine scale that can be cognized by customers as a continuous space within walkable distance. Refer to some social studies, the average walking pace in Chinese cities is around 5-6 kilometres per hour (400-500 meters per 5 minutes). In general, 5 to 10 minutes' walking is an appropriate distance for most people. On another hand, regarding the market demand, each syntax axial unit should have a valid length that suitable for large-scale retail stores gathering as well. According to some information on the internet, many famous commercial streets in China and abroad are approximately 300-1000 meters long (table 6). Many of the traditional commercial streets, which formed through naturally clustering process, are no longer than 600 meters. By contrast, the modern commercial walking streets are a bit longer, but the valid commercial lengths for retail centres clustering are normally no more than 1 kilometre. In many cases of commercial street design, including those cases in international metropolis, one kilometre can be considered as a limited threshold length to avoid overrun the market demand and lose the vitality).

Table 6: Some famous commercial streets and their length in China and abroad

Country	City	Street	Total length (Meters)	Golden section for retail	Golden length (Meters)
China	Beijing	Dazhalan	275	whole street	275
		Xidan	880	South junction-Xidan shopping center	550
		Wangfujing walking street	810	south junction-Bamiancao junction	600
	Wuhan	Jiangnanlu walking street	1210	Wuhanguan-Zhongshandadao	890
	Shanghai	Nanjinglu walking street	1033	Xizangzhonglu-Henanzhonglu	1033
Japan	Tokyo	Ginza	600	whole street	600
U.S	NewYork	Wall Street	500	whole street	500

Constraints for deriving the axial line in this research:

- Continual vista by pedestrians' perspective.

For example: If the vista is cut by bend or a big junction which wider than or at least equal to the width of the road then I partition the road.

- Less length differences among the road segments. The road segments should not longer than ten minutes walking by normal walk pace, that's around one kilometre, most of the axial lines should be 200-600 metres based on actual status.

For example: if the road segment between the natural junctions still longer than 1000 meters, I evenly partition it according its actual length into a certain number of pieces of 300-600 metres.

Based on the constraints above, a new axial map is derived from the road network. Its length frequency distribution graph is as the following figure. In this frequency graph, the x-axis is axial length and the y-axis is the total number of the axial lines at a certain length.

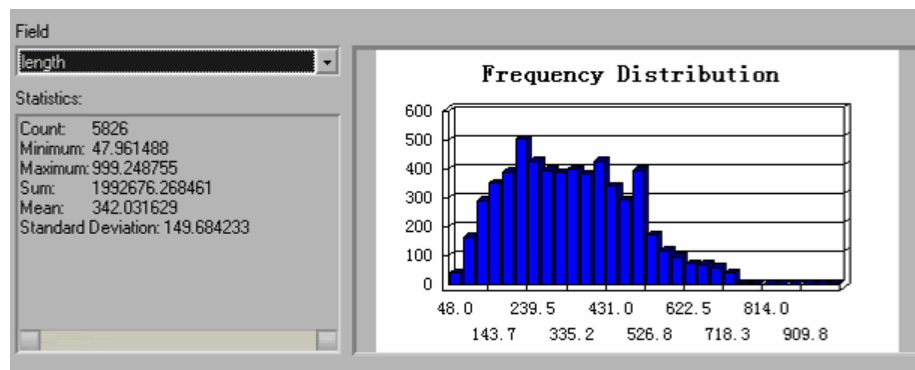


Figure 17: The frequency distribution of the axial length after adjustment

5.1.2. Principles for deriving the axial line of bus route network

5.1.2.1. Data of bus route network

The bus system takes significant part in urban public transportation.

The bus route data contains bus routes and bus stops. In common ArcGIS based bus transportation model, the bus route can be represented by single-line symbol referenced to the road segments (Figure 18) or by the directional-line symbol based on the actual bus routes with directions (Figure 19). In many actual cases in Wuhan, a bus route may have two different or partly different routes on its go and return directions (Figure 20). These cases may cause different bus availabilities of a certain location or of the two opposite directions on a same road segment. In other word, the direction is an important aspect that may influence the accessibility of a location by bus. Therefore, I apply the directional bus route as research object in my research.



Figure 18: Virtual bus routes

Figure 19: Actual bus routes with directions

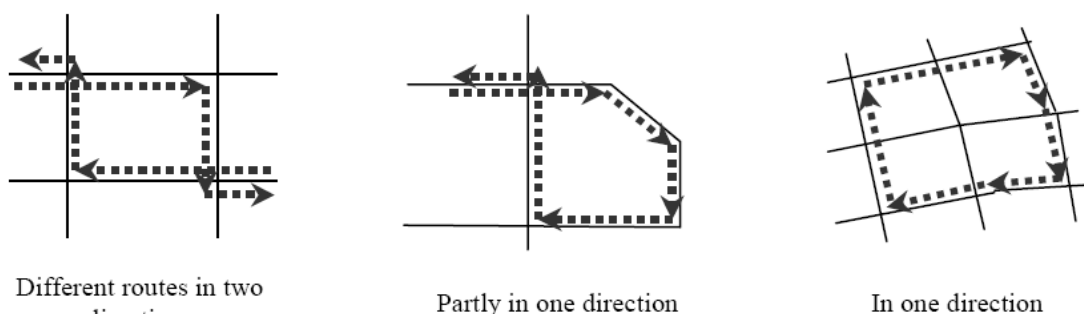


Figure 20: Cases of bus lines with different routes

Due to the availability of the data, the bus route network applied in this research is limited in the core city area of Wuhan. As Figure 21 shows, five districts of Jiangnan, Jiangnan, Qiaokou, Hanyang and Wuchang have full data. Two districts of Qingshan and Hongshan have deficient data. Three districts of Dongxihu, Zhuankou and Jiangxia have no data of bus route network.

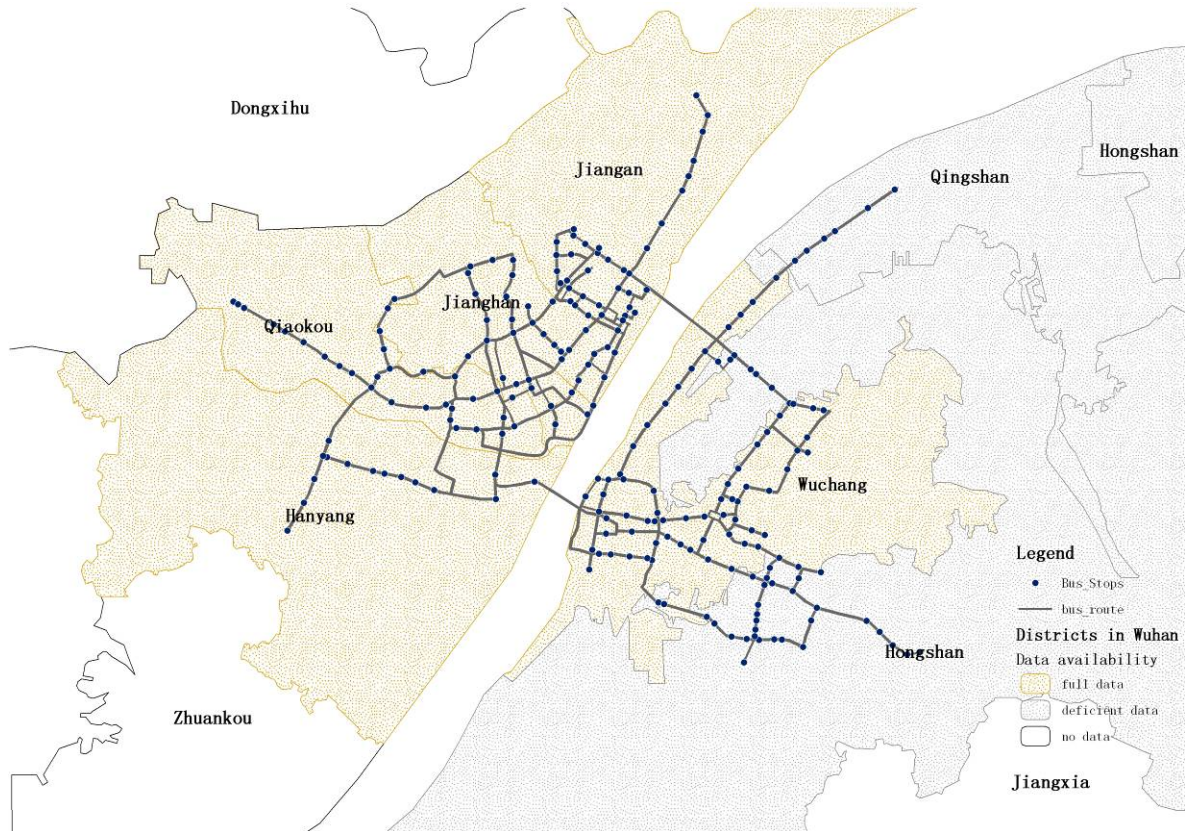


Figure 21: Bus route data applied in this research

5.1.2.2. Principles for derive the axial line of bus route network:

The section between two directly linked stops is the axial unit. Due to the available data, the bus network used in my research contains 683 route sections and 232 bus stops in total. Average length of the bus route section is 1030 meters (Figure 23). Those sections cross the Han and the Yangtze River are longer in length, of which the section with maximum length of 5908 meters crosses the second bridge.

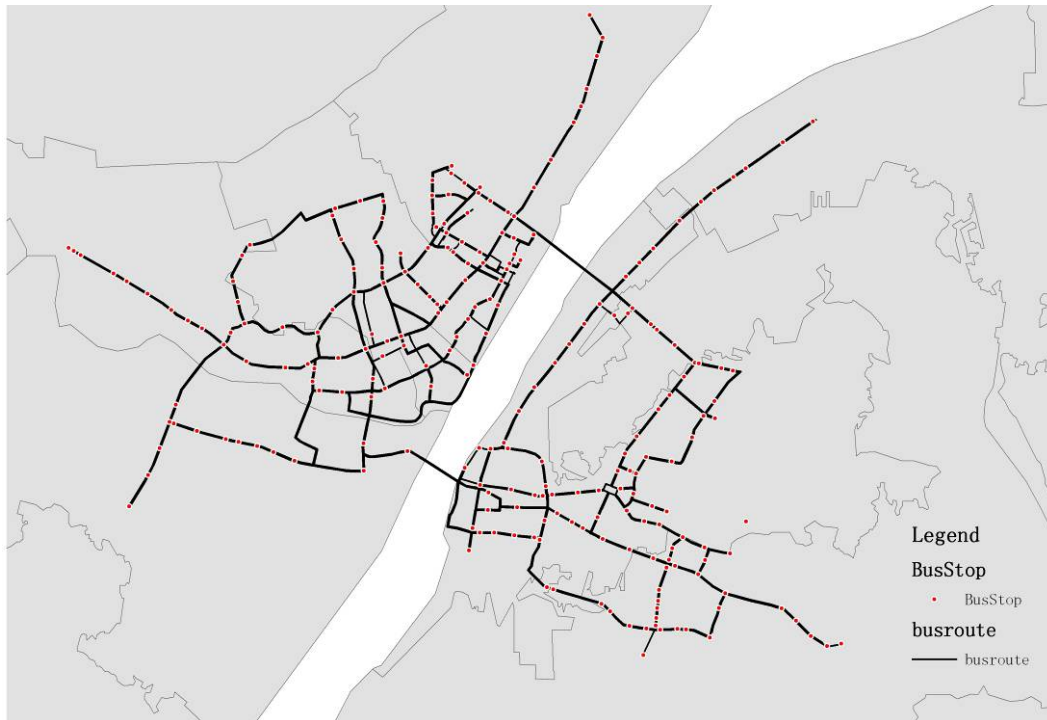


Figure 22: Bus route and bus stop

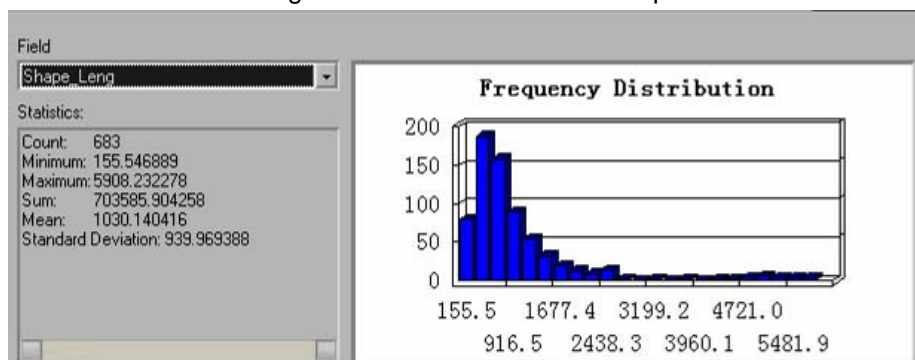


Figure 23 the frequency distribution of the distance between two directly connected stops

5.2. Interpret the different outputs of space syntax analysis

5.2.1. Syntax accessibility maps of the road network

(1) Global integration maps of the road network:

The Global integration value of one specific axial line reflects the route complexity from it to all others in the road network. The higher value represents higher syntax accessibility in global scale. The global integration graph is gained by calculating the parameters in Axwman 4.0. The result value from low to high are showed from blue to red and classified by the method of quantile.

As the result of different road networks were applied, two Global Integration maps of Figure 24 and Figure 25 look different. The Figure 25 contains one more ferry line. In Figure 24, the top class of road axial lines located in old Wuchang, and the areas down the bridge in Hanyang and the areas along the Han River in Hankou. In Figure 25, the top class road segments are centred in old Wuchang, the areas down the bridge in Hanyang and the areas along the Yangtze River in Hankou. In experience, the

map with ferry line accords better with the citizens' cognition of Wuhan. I talk to some people who live in old Wuchang and they say that before the year 2000, especially before the second bridge was constructed, ferry had been major mean of public transport which links the two sides of the Yangtze River. At that time, many bus routes don't cross the river but end at the ferry. Ferry stops had been significant transfer nodes for both people and goods. Although present ferry line may not as crowded as past it should not be neglect in the urban transportation network. Then, all analysis in this research will apply the road network with the ferry line.

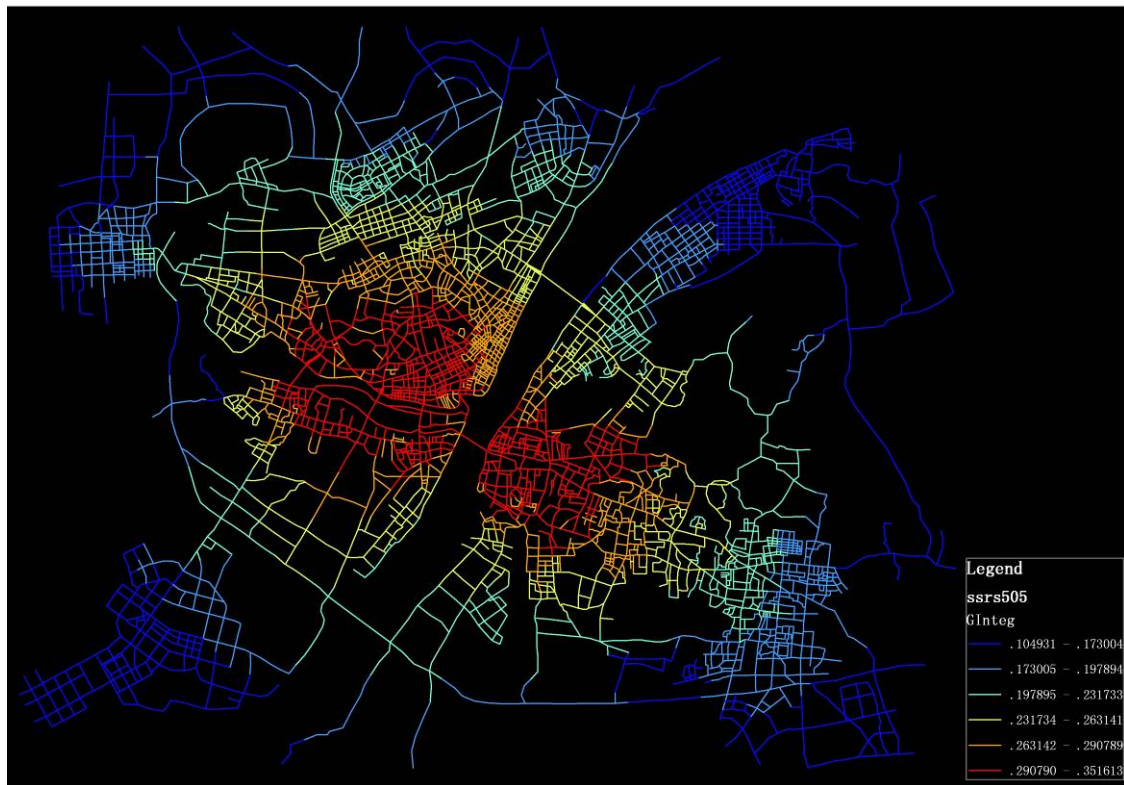


Figure 24 Global integration map of the road network

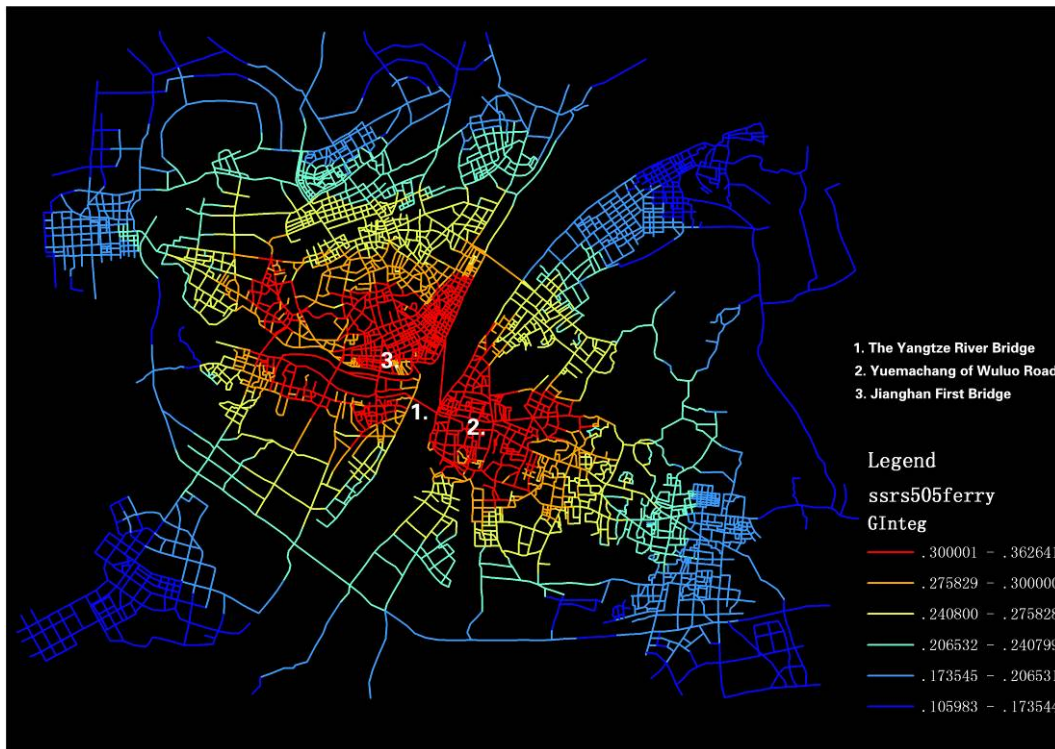


Figure 25: Global integration map of the road network with major ferry line.

In Wuhan, the road segment which has the maximum global integration value is the Yangtze River Bridge. The Yuemachang section of Wuluo Road is close behind. The best area is concentrated to the junction of the Han River and Yangtze River, showed as red colour in Figure 16.

In town of Wuchang, the best roads are Wuluo Road from Yuemachang to Fujiapo and Minzhu Road of Simenkou section. The best area located within the extent that north to the Sha Lake, south to the Xiongchu Road, west to the Yangtze River, east to the Zhongnan Road and Luoshi Road.

In town of Hanyang, the best roads are Yingwu Road from Jiangnan First Bridge to Zhongjiachun and Qintai road. The best area located along the Han River

In town of Hankou, the best roads are Wuhanguan, Jiangnan Road and Jiangnan First Bridge. The best area covers the old town center of Hankou along the Yangtze River, north to the Zhongshan Park.

(2) Local integration map of road network

According the definitions of the axial line, the higher local integration value reflects the better connected locations in local scale (within three steps). Regarding the principles for deriving the axial lines in my research, such local scale could be reached by slow mode of transportation (i.e. walking or bicycle).

By calculation, the local integration values of each road section are obtained. From high to low, these values can be classified into six classes by natural break method. In quantity, the top two classes, which value higher than 2.78, take sixteen percent of road sections among total, of which three percent among total road sections have the values higher than 3.14. For better visualization the local centres and the decreasing trends of accessibility, the first two classes are represented as red and pink colour

respectively (Figure 26). Through observation on the result map, these road sections are scattered evenly to all the local neighbourhoods, to a great extent, can reflect the space syntax centres of local sphere.

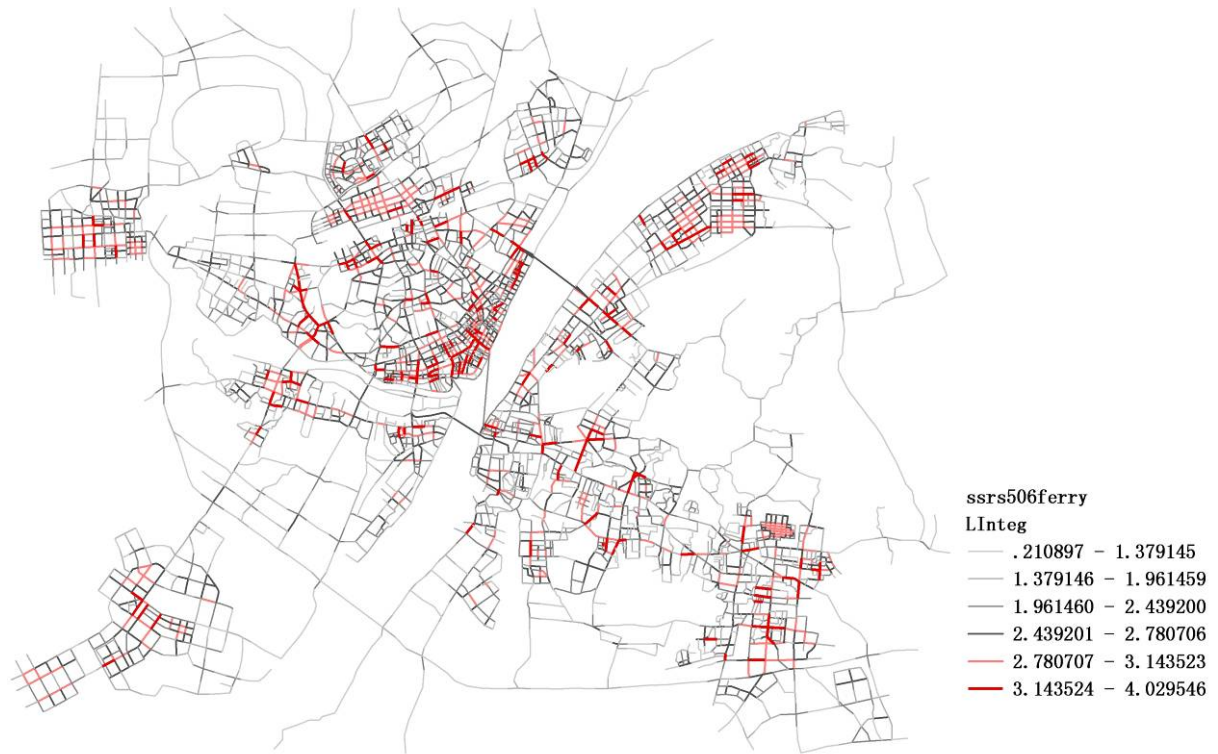


Figure 26: Local integration map of the road network

5.2.2. Syntax accessibility maps of the bus route network

The bus route network is a bit different from the road network, different bus lines connected by the bus stops, the locations of the bus stops are much meaningful than the spaces along the bus line. So after calculated the syntax accessibility of the bus line network I assign the syntax value of the bus line sections to each stops linked. For the cases that one stop may linked to several bus line sections, I assign the highest value to the stop.

5.2.2.1. Global integration maps of the bus route network:

The global integration value of the bus routes from low to high are showed from blue to red and are classified as 6 levels by the method of quantile (Figure 27).

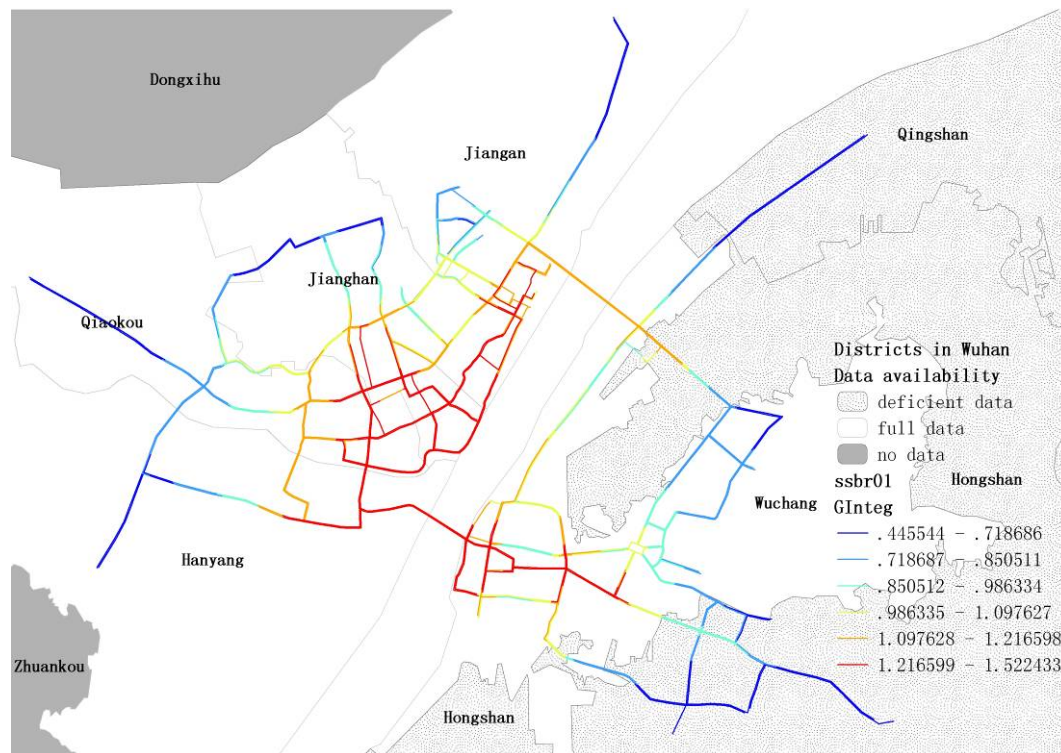


Figure 27: Global integration graph

As based on the space syntax calculation, the best connected section of bus routes in Wuhan is from the bus stop of Jiangnan Road to the stop of Guqintai. The second place is from the stop of Guqintai to the stop of Liji Road. The third is the section from the stop of Guqintai to the stop of Wusheng Road. All these tree sections via a stop of Guqintai and cross the Han River by Jiangnan First Bridge in common. In Wuchang, the best sections of global accessibility are those via the Wuluo Road and connect the end of the Yangtze River Bridge. In Han yang, the best sections are those connect the end of the Yangtze River Bridge and those connect the end of the Jiangnan First Bridge. In Hankou, the best sections are those connect the Jiangnan First Bridge and Jiangnan Road.

Through assigning the global integration value to the bus stops, the variations of stops' accessibility are obtained. As indicated in following figure, the graduated symbol represents the value from low to high. The higher value expresses the higher accessibility of the locations by bus.

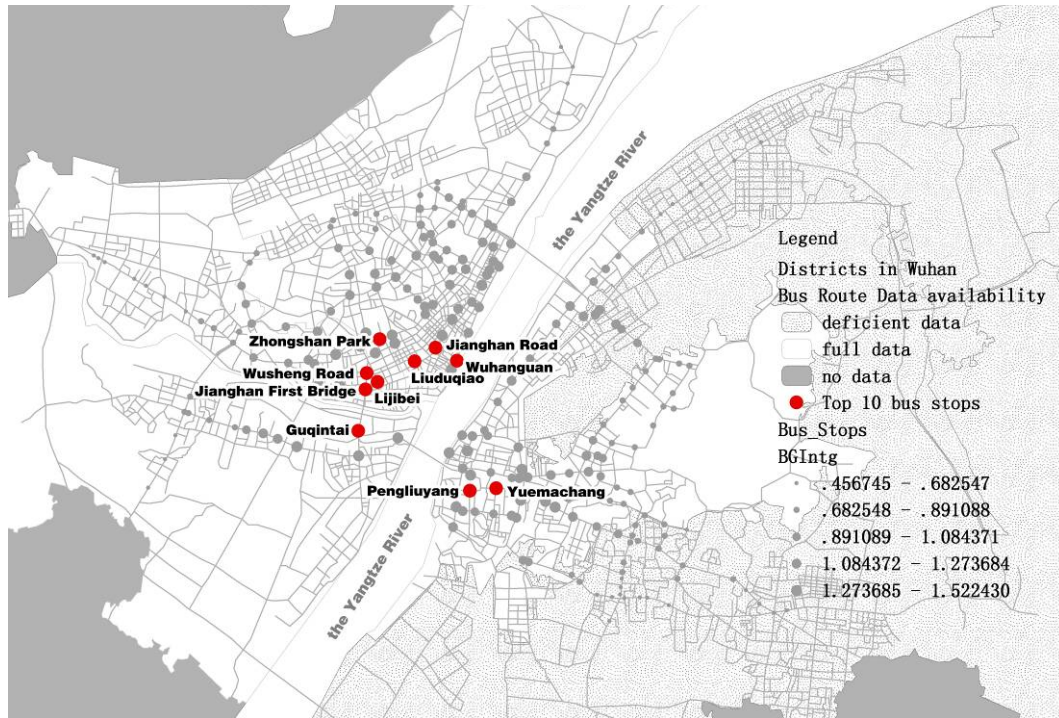


Figure 28: assign the global integration value to the bus stops

The statistics on the space syntax attribute table illustrate that the top ten best connected bus stops in Wuhan are Jiangnan Road, Guqintai and Lijibei Road, Wusheng Road, Yuemachang, Liuduqiao, Jiangnan First Bridge, Wuhanguan, Pengliuyang Road and Zhongshan Park (Table 7).

Relating the spatial distribution, 7 out of these 10 stops located in Hankou, 2 in Wuchang, 1 in Hanyang. In Hankou, the stops of Jiangnan Road and Wuhanguan are the two entrance of the Jiangnan Road commercial pedestrian street; the stops of Wusheng Road, Jiangnan First Bridge and Lijibei are gathered at the junction of Wusheng Road and Zhongshan Road, there are the entrances of the wholesale centre of Wuhan; the stop of Zhongshan Park connects the Public Park, Wuhan Exhibition hall and several large-scale shopping stores. In Hanyang, the stop of Guqintai located between the ends of Yangtze River Bridge and Jiangnan First Bridge. In Wuchang, the stops of Yuemachang and Pengliuyang are the starting point of the Yangtze River Bridge. These 3 stops are considered as the most important transit hub linking tree towns of Wuhan.

Table 7: Top ten bus stop of global integration

Rank	Stop Name	Global Integration
1	Jiangnan Road	1.52243
2	Guqintai	1.52243
3	Lijibei Road	1.52045
4	Wusheng Road	1.51847
5	Yuemachang	1.48799
6	Liuduqiao	1.45961
7	Jiangnan First Bridge	1.44471
8	Wuhanguan	1.438036
9	Pengliuyang Road	1.42054
10	Zhongshan Park	1.41537

5.2.2.2. Local integration maps of the bus route network:

The local integration value of the bus routes from low to high are shown as graduated red and are classified as 6 levels by the method of equal intervals (Figure 29). In Wuchang, Wuluo Road, Zhongshan Road, Xudong Road and Zhongnan Road have good local accessibility by bus. In Hankou, the Zhongshan Avenue, Jiefang Avenue and Yanjiang Avenue, which are parallel to the Yangtze River, have good local accessibility by bus. In Hanyang, the sections that connect the stop of Guqintai which link the two bridges have good local accessibility.

Compared to the global integration graph, the best locally accessed locations are dispersed. Through assign the local integration value to the bus stops, the variations on accessibility of the stops are mapped. As indicated in Figure 30, the graduated symbol represents the value from low to high. The higher value expresses the higher local accessibility of the locations by bus.

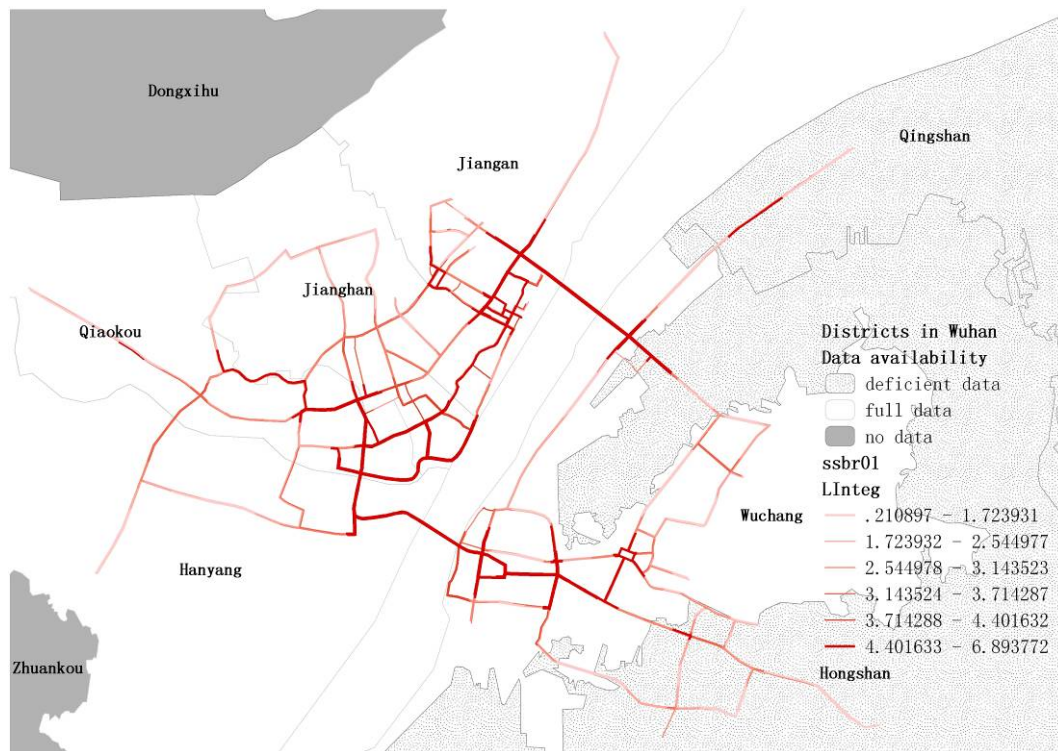


Figure 29: Local integration graph of bus routes in Wuhan

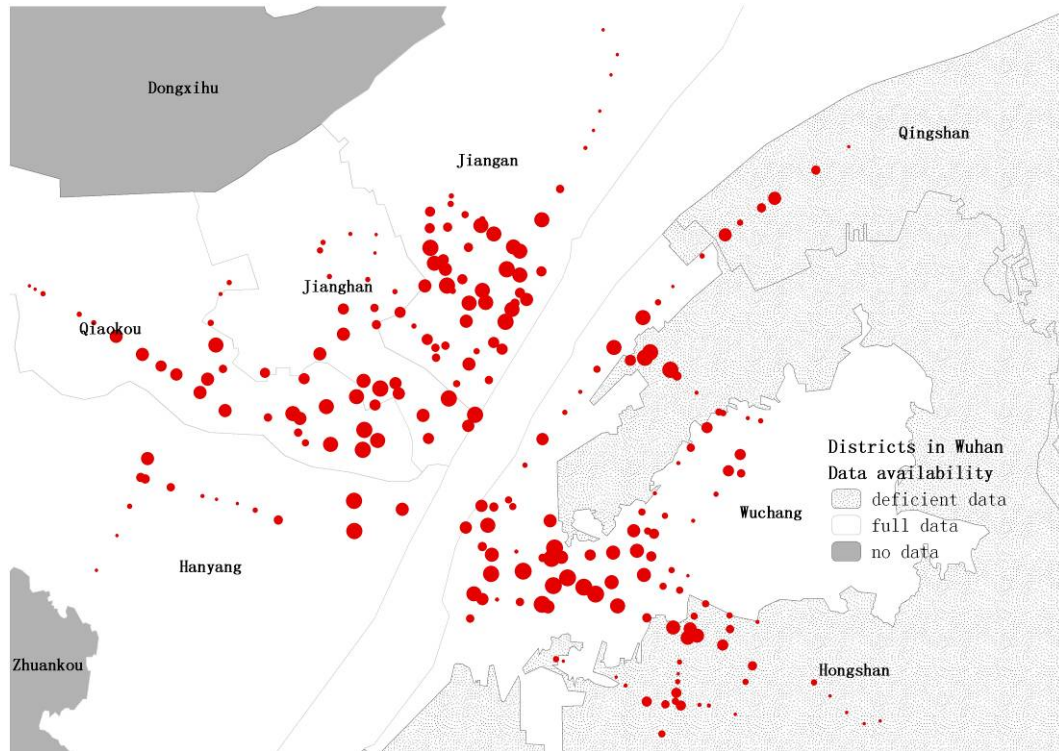


Figure 30: Assign the local integration value to the bus stops

5.3. Conclusion and discussion

This Chapter analyses the syntax accessibility pattern of transportation networks by applying the space syntax, including following innovations: the trail to break the traditional long axial line network; the trail to analyse the bus route network; By taking both the syntax accessibility of road and bus network into consideration, gives the scopes of urban syntax centres of three levels.

(1) On city level:

Wuhan is divided into three parts by the Yangtze River and the Han River. On global scale, the areas where proximate to the Yangtze River Bridge, Jiangnan First Bridge, and the ferry have high syntax accessibility. The peak global integration value of the road network occurs at the Yangtze River Bridge, which indicates that the Yangtze River Bridge is the topological axial center of Wuhan. The peak areas in Wuchang are Simenkou and the sections along the Wuluo Road from Yuemachang to Fujiapo; The peak areas in Hanyang are Yingwu Road from Jiangnan First Bridge to Qintai Road and to Zhongjiachun; In Hankou, the peak areas located at Wuhanguan and Jiangnan First Bridge.

The highest global integration of bus routes in Wuhan is occurring at the section from Jiangnan Road to Guqintai. In city scale, the top ten best connected bus stops are Jiangnan Road, Guqintai, Lijibei Road, Wusheng Road, Yuemachang, Liuduqiao, Jiangnan First Bridge, Wuhanguan, Pengliuyang Road and Zhongshan Park. Regarding the global accessibility of the road network, the locations of these top 10 bus stops also locate at the roads which are the peak areas of the global integration.

● City syntax centres:

Wuhan as a metropolitan has a very large urban built-up area. Seven central districts covered 353.83 KM². To the citizens, long distance travels such as inter district traffic and crossing the river have to rely on the motor vehicles in particular the public transport. Therefore, in my research, to determine the city syntax centre has to consider together with the accessibility of bus stops.

On city level, the locations where have best global accessibility of both road and bus networks are considered as the city syntax center.

Based on the locations of the top 10 bus stops, five city syntax centres can be recognized as the city syntax centres (Table 8 and Figure 31).

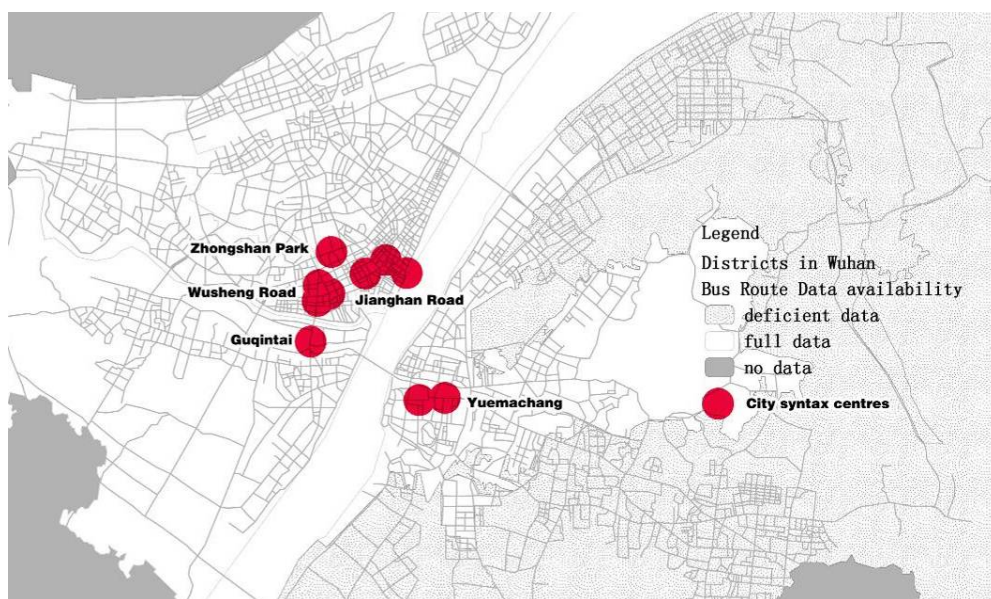


Figure 31: City syntax centres of Wuhan.

Table 8: City syntax centres of Wuhan

	City syntax centres	Present status
Town of Wuchang	Yuemachang	the end of the Yangtze River Bridge; the She Hill (public park, nature mountain); the historical interests (Yellow Crane Tower and Museum of Wuchang Uprising); the bus transit hub
Town of Hankou	Wusheng Road (Jiangnan First Bridge- Wusheng Road- Liji Road)	Several shopping stores and traditional wholesale centre.
	Jiangnan Road (Wuhanguan- Jiangnan Road- Liuduqiao)	Commercial pedestrian street, Wuhan Ferry
	Zhongshan Park	Public Park, Wuhan exhibition hall, Shopping stores
Town of Hanyang	Guqintai	The end of the Yangtze River Bridge and Jiangnan First Bridge; the Gui Hill (public park, nature mountain); the Yue Lake; the bus transit hub

(2) On local level:

The local integration graph visualizes the variations of local accessibility of the road sections. Local center scattered in the city and given more specific spatial positions. In large and densely populated urban area, just as Wuhan, the local centres also carry lot of traffic and could potentially attract local level commercial and service activities. In local syntax map of the road network, the road sections which value higher than 2.78 (top 1/6) are considered as easy accessed.

In Wuchang, Wuluo Road, Zhongshan Road, Xudong Road and Zhongnan Road have good local accessibility by bus. Most bus stops located along the Wuluo Road have relative high local integration value. In Hankou, the Zhongshan Avenue, Jiefang Avenue and Yanjiang Avenue, which are parallel to the Yangtze River, have good local accessibility by bus. In Hanyang, the sections that connect the stop of Guqintai which link the two bridges have good local accessibility. The bus route data in Qingshan District and Hongshan District where far from the city center is incomplete, it doesn't affect the result value in core city.

● Local syntax centres:

The local syntax centres refers to the locations where have good accessibility of both road and bus stops on local level. By overlay the two local space syntax maps of road network and bus stops, the local syntax centres are obtained as following Figure. It is worth noting that, the areas of Zhongshan Park, Jiangnan Road and Wusheng Road, which are the city syntax centres, are also local syntax centres. On both city and local scale, these areas have very good connectivity. Other detail of the local syntax centres are summarized in the Table below.

Because of the incomplete data of bus line, the local syntax centre in Qingshan District and Hongshan District are missing.

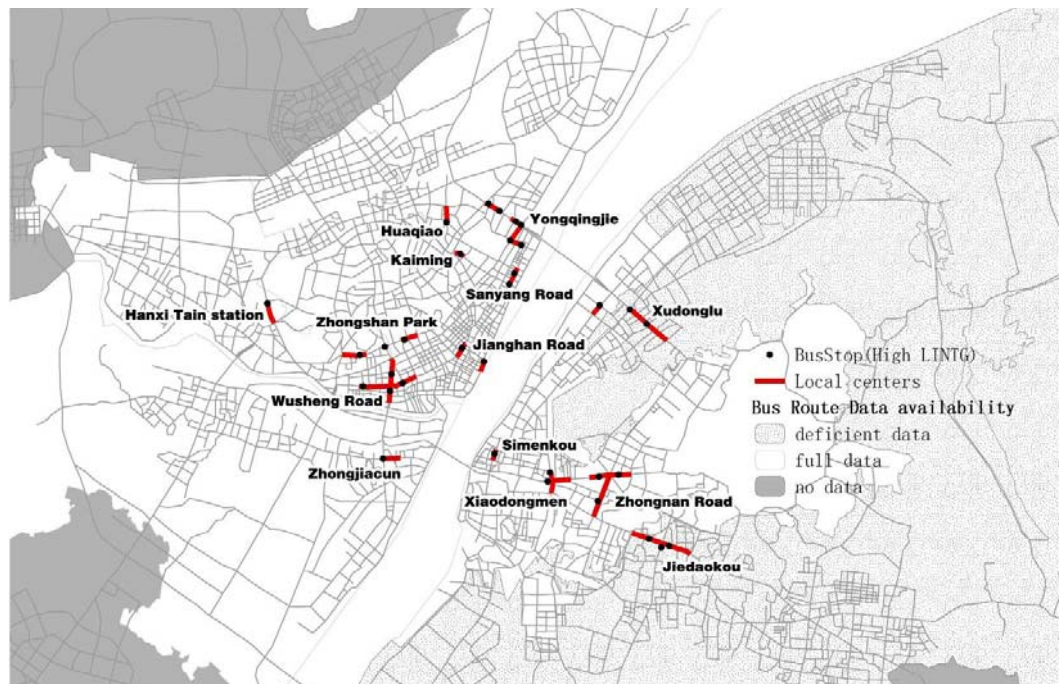


Figure 32: Local syntax centres in Wuhan

Table 9: Local syntax centres of Wuhan

	Local syntax centres	Present status
Town of Wuchang	Zhongnan Road	Commercial cluster
	Xiaodongmen	Commercial cluster of decoration and building materials
	Xudong Road	Commercial cluster; Second Bridge
	Hongshan Square	Hongshan GYM; Open square; Political office; Commercial cluster of telecommunication products
	Jiedaokou-Guangbutun	Commercial cluster of digital products; Universities
	Simenkou	Traditional commercial cluster
	Xujiapeng	New residential (Factories before); Political office; commercial; Second Bridge Park
Town of Hankou	Wusheng Road (Jiangnan First Bridge-Wusheng Road- Liji Road)	Commercial cluster and traditional wholesale centre
	Jiangnan Road (Wuhanguan-Jiangnan Road- Liuduqiao)	Commercial pedestrian street, Wuhan Ferry
	Sanyang Road	Political office;
	Zhongshan Park - Hangkong Road-Tongji Hospital	Commercial cluster; Exhibition centre; Public park
	Yongqingjie- Huangpu Road	Construction site: planning as traditional commercial streets and political office
	Kaiming Road (Aomen Road- Jianshe Avenue)	Hospital; Political office; Commercial
	Huaqiaoqicun (Huangxiaohe Road)	Residential; Commercial; Office building
	Hanxi Train Station	Commercial cluster (decoration and building materials)
Town of Hanyang	Zhongjiacun	Commercial center of Hanyang

● Sub-local syntax centres:

The sub-local syntax centres are those locations have optimum local accessibility of road (do not consider the availability of bus service). In sub-local scales, they are easy accessed by slow transport means. In this case study of Wuhan, the sub local syntax centres are the road segments which local integration value higher than 2.78 (the first 1/6 of total amount). The distribution map of the sub-local syntax centres is showed as following.

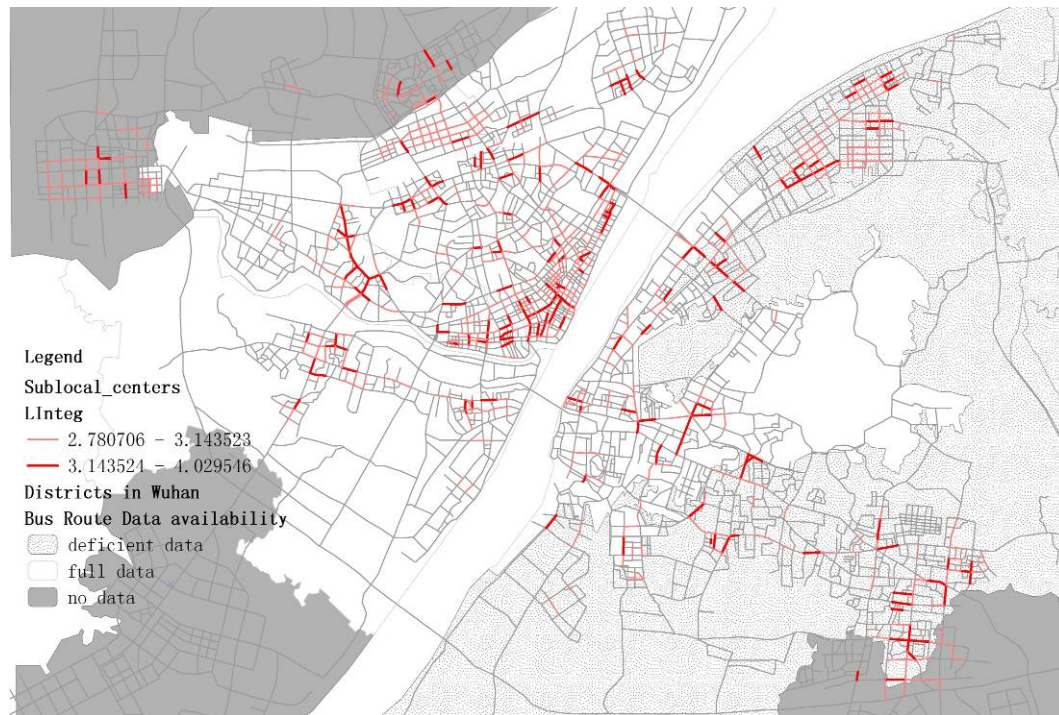


Figure 33: Sub local syntax centres in Wuhan

6. Pattern of Large-scale Retail Stores

In this chapter, the research flowchart in section 4.2 will be applied. Two main sections are included in this chapter: establishing the database of large scale retail stores and describe the distribution pattern of them.

6.1. Establish the database of large scale retail stores

The approach to developing the database of large scale retail stores consisting of 3 steps as the following:

- (1) According to the National Standards on the Classification of Retail Business Modalities, the large scale retail stores in Wuhan consist of 5 formats: department store, shopping center/ mall, hypermarket, warehouse club, home center and specialty store. The large scale specialty stores mainly involve book store, home appliance and cyber center. For my research, I firstly make a full list of large retailers of each format in Wuhan, and then find the full list of their subsidiary large scale stores from their official website.

Showed as table below, there are 142 large scale retail stores in total amount, including 10 department stores, 26 shopping centres, 37 hypermarkets, 20 warehouse clubs, 10 book stores, 18 home appliance stores, 18 home centres and 3 cyber centres.

Table 10: Large scale retail stores in Wuhan

Company	Department Store	Shopping Center/Mall	Hypermarket	Warehouse Club	Book Store	Home Appliance	Home Center	Cyber Center	Total
New World		6							6
Grand Ocean		2							2
Hanshang		3							3
Zhongshang		3	6						9
Wushang	1	3	12						16
Xinyijia			3						3
Carrefour			5						5
Wal-mart			2						2
Trust-mart			2						2
Beijing Hualian			2						2
Lotus			3						3
Zhongbai				17					17
Metro				2					2
Guomei						6			6
Gongmao						7			7
SuNing						5			5
OuYaDa							3		3

Jinmakaixuan							3		3
Haomeijia							2		2
B&Q							1		1
Hubei Xinhua					6				5
Others	7	11	2	1	4		9	3	37
Total	8	28	37	20	10	18	18	3	142

- (2) Establishing the distribution map of large-scale stores in ArcGIS, consulted the paper map (Wuhan, 2008) and the 3D virtual reality map of Wuhan (Figure 34) for detail location information (map address: www.3dwh.net, by Hubei Daily Media Group, 2007).

In distribution map, the point features represent the retail stores. For testing the accuracy of the retail spot, I also went to check 90 of the large scale stores by bus in the field, and confirmed that all the locations and the road segments surrounding which obtained from the 3D map are 100% correct.

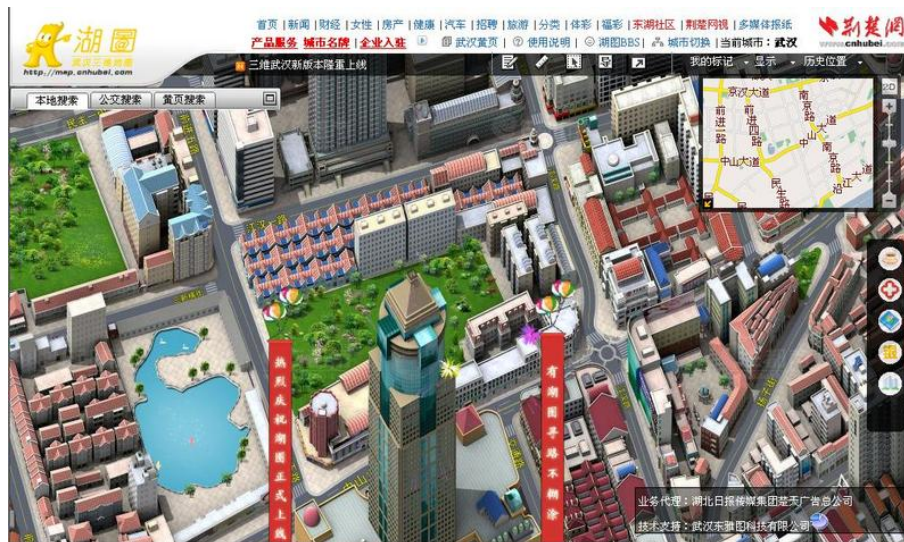


Figure 34: Wuhan 3D map (www.3dwh.net)

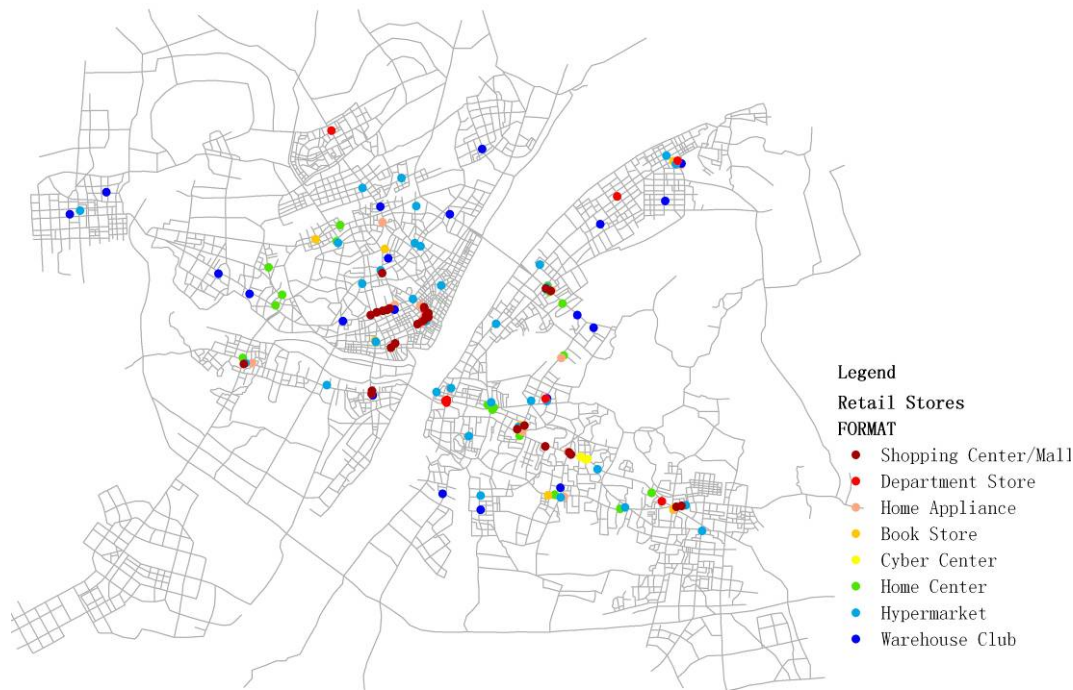


Figure 35: Distribution map of large scale retail stores in Wuhan

(3) Add attributes to the point features

As showed in the figure below, the basic attributes firstly added to the retail stores including Name, Format, Road ID (The road section that connected to the entrance), and Bus stop ID (The bus stop that connected to the entrance)

FID	Shape *	ID	NAME	FORMAT	ROADID	bus_ID
133	Point	0	ZhongBai	Warehouse Club	37	84
113	Point	0	ZhongShangPingJia	Hypermarket	49	0
112	Point	0	ZhongShangPingJia	Hypermarket	81	122
119	Point	0	ZhongBai	Warehouse Club	191	0
122	Point	0	JinMaKaiXuan	Home Center	309	201
117	Point	0	XinYiJia	Hypermarket	314	48
6	Point	0	ZhongBai	Warehouse Club	322	0 0
115	Point	0	XinYiJia	Hypermarket	333	160
59	Point	0	LuGuang	Department Store	358	148 0
57	Point	0	ZhongShangPingJia	Hypermarket	360	195 0
91	Point	0	GongMao	Home Appliance	360	195 0
80	Point	0	Carrefour	Hypermarket	371	69 0

Figure 36: Attribute table of retail stores in ArcGIS

6.2. Distribution pattern of large scale retail stores

6.2.1. Distribution pattern of different retail formats

(1) Shopping center/mall

The shopping center/mall is a modern retail format in Wuhan, which comes from developed western country. In recent years many large shopping center settled in Wuhan, as well as many department stores has gradually upgraded to a shopping centre. Different from many sparsely populated Western cities, Wuhan shopping centres are highly centralized in urban downtown areas or local centre. There are 28 shopping centres in total, 16 of which concentrated in the downtown of Hankou; 9 stores in Wuchang and 3 in Hanyang.

On city level, the biggest cluster of shopping centre is the area from Jiangnan Road (8 stores) to Jiefang Avenue (5 stores). On local level, Zhongjiacun, Zhongnan Road, Jiedaokou, Xudong Road and Luxiang are retail clusters where respectively concentrated more than two shopping centres. These clusters also combined with multiple formats of large-scale stores.



Figure 37: Distribution map of shopping centre/mall

Figure 38: Distribution map of department store

(2) Department store

Department store is one of the traditional retail formats in Wuhan, which is smaller than shopping center on scale. These stores located within the large and old residential communities, including Changqinghuayuan, Honggangcheng, Jiansheerlu, Shuiguohu, Simenkou and Luxiang.

(3) Hypermarket and warehouse club

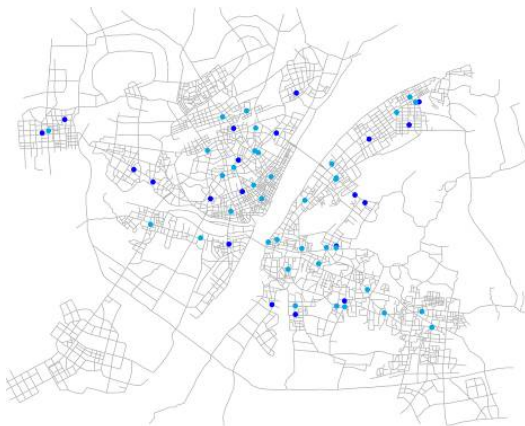


Figure 39: Distribution map of hypermarket and warehouse club

The hypermarket and warehouse club mainly sale foods, dresses, groceries and other household needs, which have large demand in the market. There are 37 hypermarkets and 20 warehouse clubs in total. They evenly dispersed in the urban layout. They might be adjacent to other formats of stores, but keep a distance from each other of the same kind.

(4) Home appliance

Home appliances stores are always located in the busy commercial area and proximate to large-scale shopping centres or hypermarkets, they rarely exist independently



Figure 40: Distribution map of home appliance stores (left)

Figure 41: Distribution map of home centres (right)

(5) Home centre

The large scale home centres are proximate to the intercity or inter district traffic corridors. In Wuhan, the traditional home building material clusters are Xiaodongmen and Hanxi, which located close to the Wuchang railway station and Hanxi retail way station respectively. In addition, the Hankou railway station, Xudong Road and Xiongchu Avenue are also gathered many modern home centres.

(6) Cyber center

The only cluster of cyber center in Wuhan located in Wuchang Guangbutun, where within the cluster of universities and the Science and Technology Zone of Wuhan. Guangbutun is one of the busy sections of Wuluo Road, adjacent to the commercial center of Wuchang.

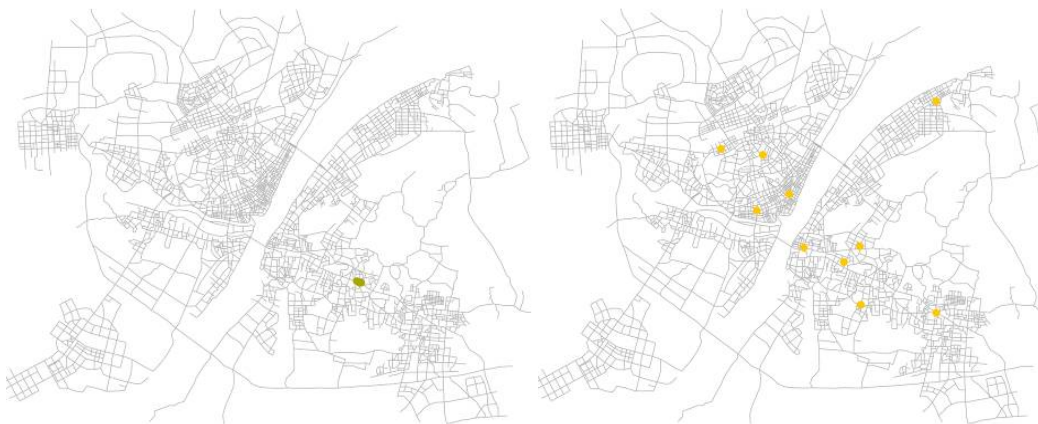


Figure 42: Distribution map of cyber centres (left)

Figure 43: Distribution map of book stores (right)

(7) Book store

Similar with the home appliance store, the large scale book stores always locate within the city or local center, and adjacent to the shopping centres or hypermarkets.

6.2.2. Distribution of retail clusters

Table 11: Retail clusters of Wuhan

	Retail clusters	Formats of the retail cluster	Quantity
Wuchang (60 out of 79 stores in these retail clusters)	● Zhongnan Road (Hongshan Square- Zhongnan Road- Dingziqiao)	2 shopping centres; 2 home appliance stores; 1 book store; 3 hypermarkets; 1 home centre	9
	● Jiedaokou (Jiedaokou- Guangbutun)	3 shopping centres; 3 cyber centres; 1 home appliance stores; 1 hypermarkets;	8
	● Xudong Road (Youyi Avenue- Xudongcun)	2 shopping centres; 2 home appliance stores; 2 hypermarkets; 3 home centres	9
	● Luxiang Square	1 department store; 2 shopping centres; 2 home appliance stores; 1 book store; 1 hypermarket;	7
	● Simenkou	3 department stores; 1 home appliance; 1 book store; 2 hypermarkets;	7
	● Xiongchu Avenue (Chubancheng- Youlicun)	2 home appliance stores; 1 book store; 2 hypermarkets; 1 home centre; 1 warehouse club	7
	● Badajia	1 department store; 1 home appliance; 1 book store; 2 hypermarkets; 1 warehouse club	6
	● Xiaodongmen	3 home centres; 1 hypermarket	4
	● Shuiguohu	1 warehouse club; 1 hypermarket; 1 book store; 1 department store	4
Hankou (26 out of 55 stores in these retail clusters)	● Jiangnan Road (Zhongshan Avenue- Jiangnan Road)	8 shopping centre; 2 home appliance stores; 1 book store; 2 hypermarkets	13;
	● Zhongshan Park - Hangkong Road	5 Shopping centres; 2 home appliance stores; 1 warehouse club	8
	● Wusheng Road (Jiangnan First Bridge- Wusheng Road- Liji Road)	2 Shopping centres; 1 home centre; 1 book store; 1 hypermarkets	5
Hanyang	● Zhongjiacun	2 Shopping centres; 1 warehouse club; 1 hypermarkets	4
	● Wangjiawan	1 Shopping centres; 1 home centre; 1 home appliance stores; 1 hypermarkets	4

The retail clusters refers to the place that comprise at least 2 retail formats and continually concentrated more than 3 large-scale retail stores. Based on the distribution map of retail stores, the retail clusters in Wuhan are summarized as the table above.

The distribution of retail clusters in Wuchang is multi-centred. There are 9 retail clusters, of which The Zhongnan Road and the Jiedaokou are adjoin to each other and concentrated 17 large-scale stores of 6 retail formats. They together formed the core of Wuchang retail centre. Xudong Road, Luxiang Square, Xiongchu Avenue, Simenkou, Badajia and Shuiguohu are 6 local retail centres, which respectively gathered 4-9 stores of at least 4 retail formats. Xiaodongmen is the specialty cluster for home centres.

The distribution of retail clusters in Hankou is poly-centred. There are 3 retail clusters in Hankou gathered 26 large scale stores. All the 3 clusters located in the downtown of Hankou, one adjacent to another. More than half of the city's large scale shopping centres settled within these areas. They together formed the city retail centre. It is likely because of such large retail cluster producing "black hole" effect, there are no other large retail clusters in main urban area. In the districts out side the city retail centre, there simply scattered hypermarket, warehouse club or specialty stores in pair or separately

Compared to Wuchang and Hankou, Hanyang is developing on a smaller scale. There are 2 local retail clusters in Hanyang, Zhongjiacun and Wangjiawan.

6.3. Conclusion and discussion

Highly concentrated large scale retail stores of multiple formats forms the retail clusters. In this case study of Wuhan the shopping centres or department stores are the main body, surrounding by home appliance stores, hypermarkets, book stores, etc. According to the size and spatial locations, these retail clusters can be classified as city retail centre and local retail centre. The retail cluster that composed of the stores of single format can be recognized as specialty retail centre. Scattered large scale stores, mostly hypermarkets or ware house club, can be considered as sub local retail centres.

By analysing the present spatial distribution of the large scale retail stores, the hierarchy of retail centres are obtained (Figure 44).

(1) City retail centre

The city retail centre is the most concentrated retail area in the city, the service area of which covers the whole city.

In this case study, the city retail centre located in the downtown of Hankou, comprise Wusheng Road retail cluster, Jiangnan Road retail cluster and Zhongshan Park retail cluster, which is the busiest area in Wuhan. There are 26 large scale retail stores together. More than half shopping centres among total settled within these area. Wusheng Road and Jiangnan Road was the traditional commercial centre of Wuhan in history, due to the easy accessibility by both land transport and water transport. In addition to the retail function, there also a traditional whole sale center in Wusheng Road Cluster.

(2) Local retail centres

The local retail centres refers to the retail clusters which constitutes more than three large scale retail stores.

There are 9 local retail centres in Wuhan, 7 in Wuchang, 2 in Hanyang:

In Wuchang, the local retail centres are Zhongnan Road- Jiedaokou, Xudong Road, Luxiang Square, Xiongchu Avenue, Simenkou, Badajia and Shuiguohu. Zhongnan Road-Jiedaokou is the largest one; Simenkou is the oldest one located in old inner Wuchang; Xudong and Luxiang are newly developed, large, modern and popular. Badajia and Shuiguohu are sophisticated commercial centres of large community.

In Hanyang, the local retail centres are Zhongjiacun and Wangjiawan. At present, Zhongjiacun is upgrading to a more modern and complex retail centre of Hanyang.

(3) Sub local retail centres

All the dispersed large scale retail stores out side the city or local retail clusters are considered as sub local retail centres. Most of them are hypermarkets or warehouse club. They located within the high density or large scale residential communities and keep a certain distance to each other.

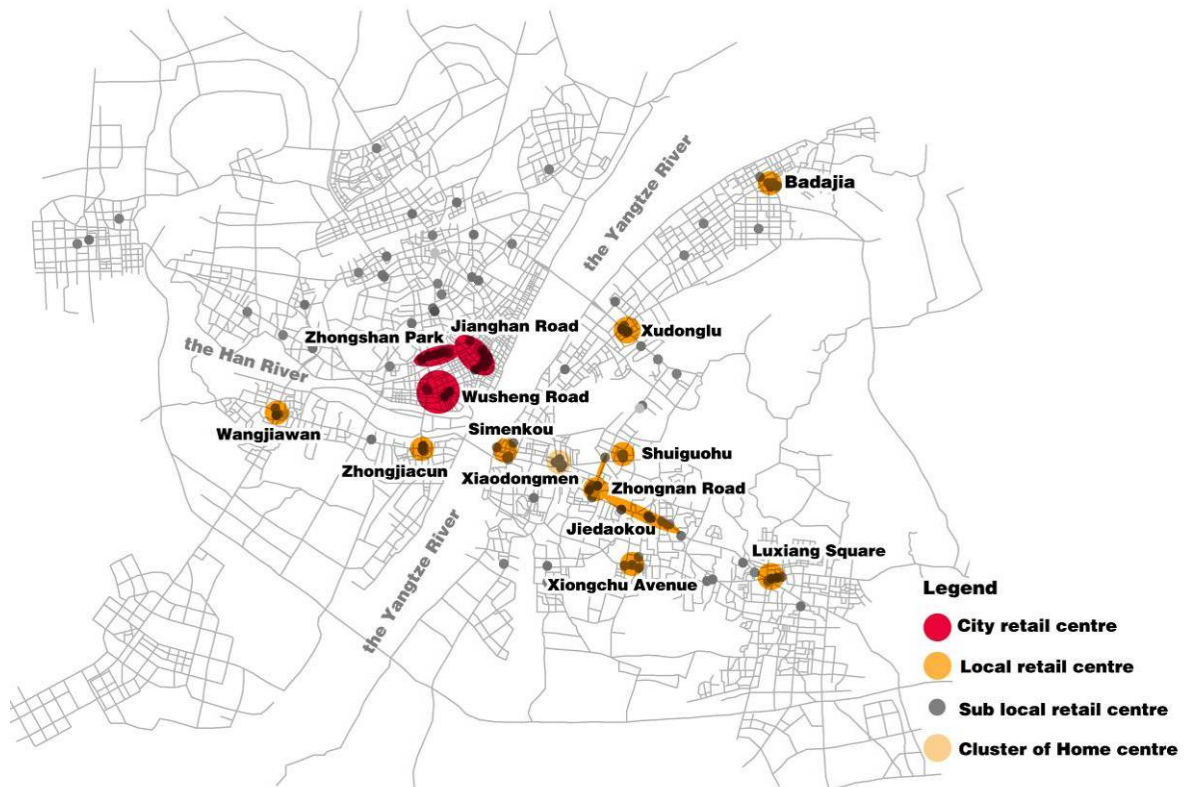


Figure 44: Retail centres in Wuhan

7. Correlation between syntax accessibility and retail pattern

The Chapter 5 and Chapter 6 give the urban space syntax pattern and urban retail pattern of China. Based on these results, this chapter analyse the correlativity between the syntax accessibility of the urban transport network and distribution pattern of the large-scale retail stores. The research flowchart in section 4.3 will be applied.

Urban physical space and urban functions are mutual influenced. The formation and the development of the urban retail space spring from the social behaviour pattern, in particular the economic activities. It is said that three most important decisions which contributory to the success are “Location, Location, and Location”. That is, to seize the optimum accessed locations for people and goods in the space competition. The road network is exactly the spatial carrier of variety social activity flows. Therefore, analysing the correlativity between syntax accessibility and retail pattern can help to understand the intrinsic structural relationship of the retail spatial development and it may helps based on one certain aspect to presume the other in the future urban planning or retail spatial planning.

7.1. City syntax centre and city retail centre

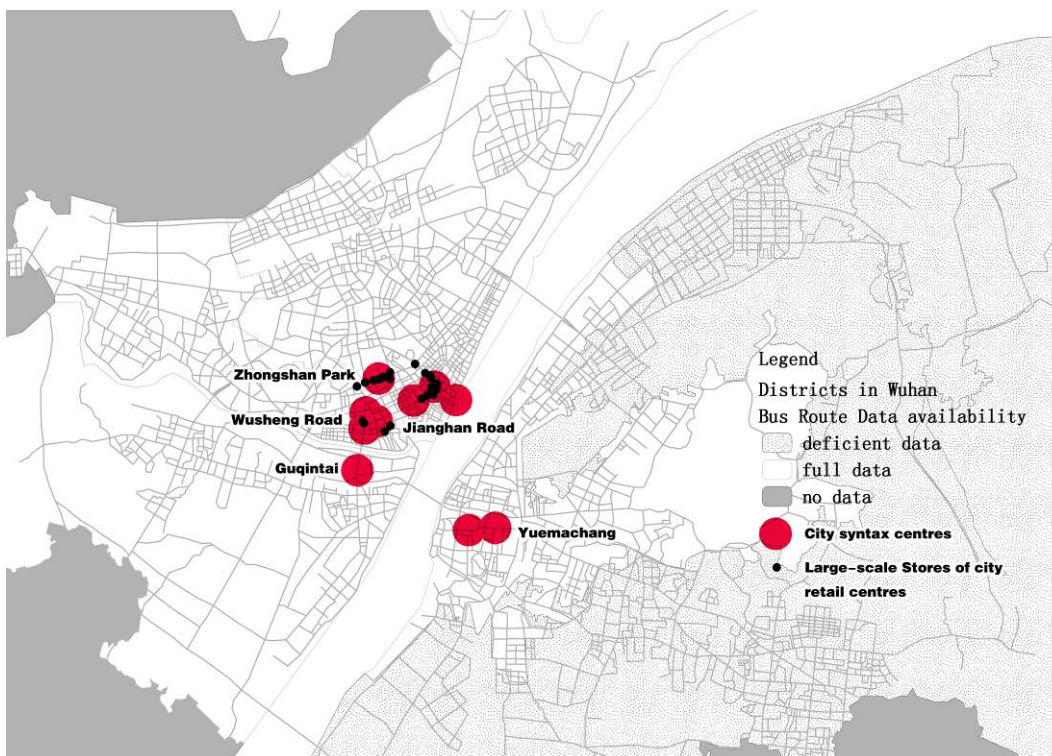


Figure 45: City syntax centres and the city retail centre

The city syntax centres are highlighted as showed in the Figure above. 7 out of the top 10 best connected locations on global scale are concentrated in downtown area of Hankou, which is

favourable for rounding up scale of economy. By overlay the maps of city syntax centre and city retail centre, we can see that, the city retail centre is exactly corresponding with this area. The Jiangnan Road and the Wusheng Road retail clusters are both traditional city commercial centre and the peak area of Global integration.

Guqintai and Yuemachang are also the city syntax centre, as well as the bus transit hub which connected three parts of Wuhan. However, no retail clusters there. The reason may have two aspects: First, the nature constrains of these locations affect the appeal for retailers. Both the two ends of the Yangtze River Bridge located at the foot of hills. In addition, the Guqintai located at lake side and the Yuemachang located within a reservation area for historical interest. By nature and policies constrains, these locations have lower construction density, lower road network density and lower local accessibility (lower local integration value) as well. The huge traffic flows are carried by the dimensional express road, which limits the free walk of the pedestrians. Second, there is a restricted demand for the city level retail centres. The city retail centre in Hankou already have 26 large-scale retail stores, 16 out of them are large scale shopping centres. For city like Wuhan, such supply capacity is already sufficient to meet market demands. Within a certain distance, it won't have strong demands for another city level retail centre.

7.2. Local syntax centre and local retail centre

Wuhan is well known as the “city of lakes”. Showed as the table below, most of the lakes locate in Wuchang and Hanyang. By the facts of the nature features, the urban build up areas in Wuchang and Hanyang are parted by the lakes. The overlaid distribution map of the local syntax centres and the retail centres displays this poly-centred spatial pattern, especially in Wuchang and Hanyang.

Table 12: Water areas in inner city of Wuhan

	Hankou	Hanyang	Wuchang	Total
Water areas (KM²)	1.5608	16.9064	156.8855	175.3527
Proportion	0.89%	9.64%	89.47%	100.00%

Showed as the Figure below, the distributions of local syntax centres and local retail centres are accurately corresponding to each other in the city layout. In downtown of Wuhan, all the local retail centres directly located at the road sections which have both high local integration value of road and bus network.

In Hankou, three retail clusters gathered in Jiangnan Road, Wusheng Road and Zhongshan Park which are both the city and local syntax centres. Affected by their gravity, there is no other independent retail clusters in a certain distance. Although not all the local syntax centres have retail clusters, they are always the attractions of the retail spots or the potential commercial streets.

Because of the incomplete data of bus line, the local syntax centre in Qingshan District and Hongshan District are missing. Nevertheless, all the retail clusters in these areas already satisfy two necessary conditions at least, which are high road local integration value and existing bus stops.

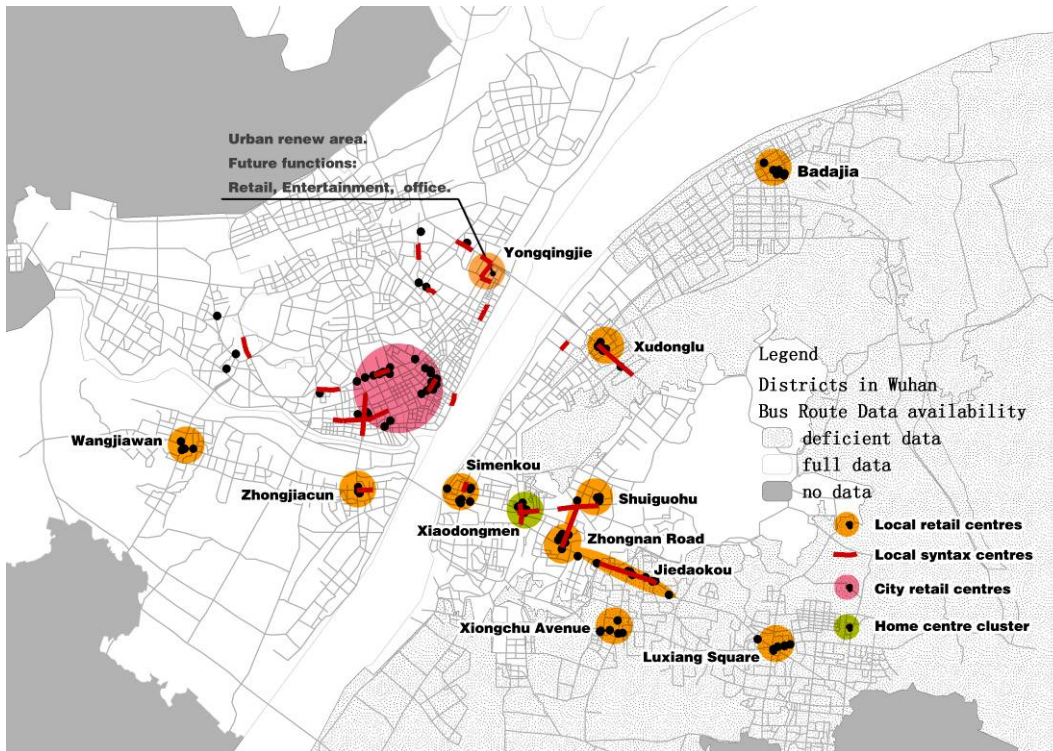


Figure 46: Local syntax centres and the local retail centres

7.3. Sublocal syntax centre and large scale retail stores

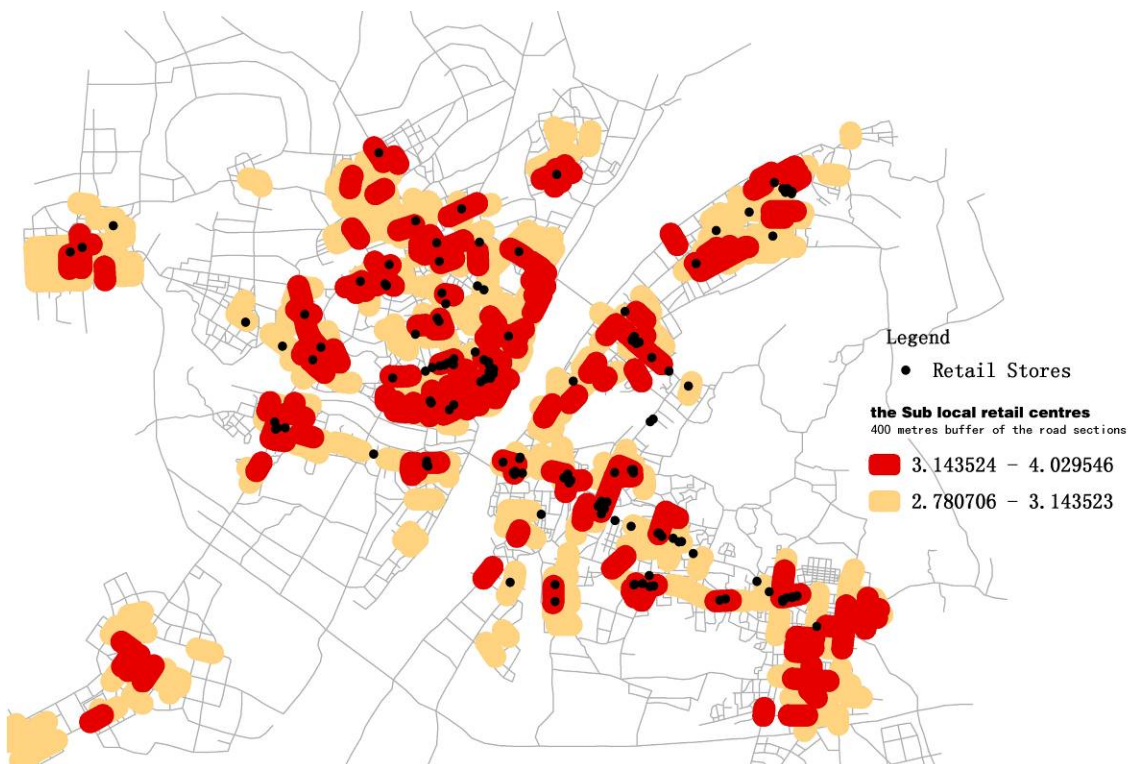


Figure 47: Large scale retail stores and sub local retail centres

Through overlaying the distribution map of the retail stores and the sub local syntax centres, it is found that, almost all the large scale retail stores are directly located within the sub local syntax centres(depicted above). For the statistical analysis, I join the space syntax attributes of the axial segment which directly pass the stores and the best one which within the 400 meters radius (within 5 minutes walking) of the stores to the attribute table of retail centres accordingly. If the store directly faces more than one road segment I take the line segment with highest syntax value.

The Figure 48 is the scatter map of syntax accessibility of all the road sections; the Figure 49 is the scatter map of syntax accessibility of the retail locations; the Figure 50 is the scatter map of syntax accessibility of the retail buffers. Comparing these three graphs, the mean local integration value of all the road segments is 2.098 while the mean value of the large scale retail stores is 3.170 and the mean value of the retail buffers is 3.370. Almost all the retail stores directly located at or very close to the road sections which have high local integration value. In other words, the high road local integration is one of the essential requirements for the large scale retail locations. The global integrations of the stores distributed evenly in the whole range.

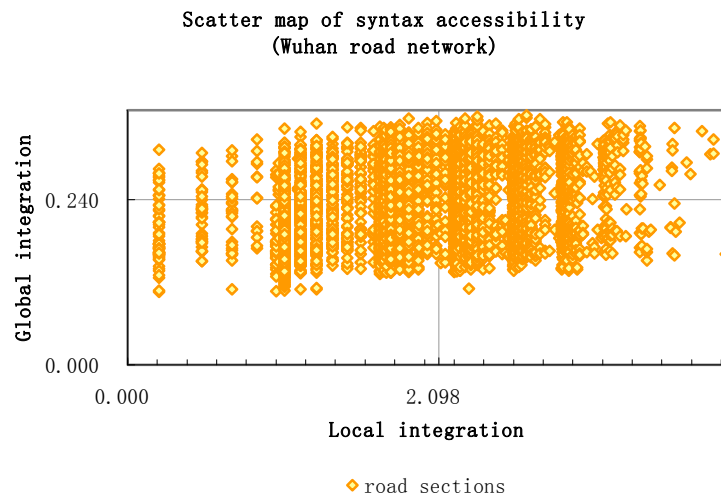


Figure 48: Scatter map of syntax accessibility (Road network)
0.24 is the mean global integration value, 2.098 is the mean local integration value

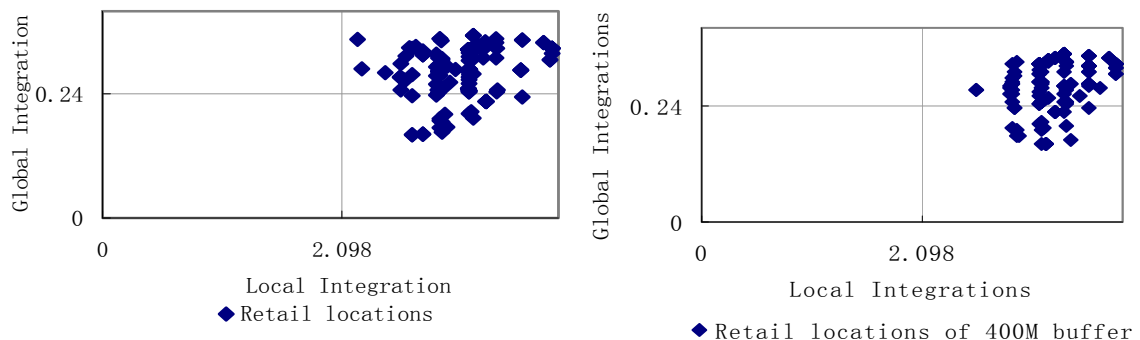


Figure 49: Syntax accessibility of the retail locations (left)

Figure 50: Syntax accessibility of the retail locations (right)

The average space syntax value of the retail locations indicates that there are no big differences between different retail formats. All the retail formats requires relative high local accessibility. The locations of the shopping centre are the best. The shopping centre as the main body of the city or local retail centres, both the average local and global integration value of them are the highest. Accordingly, Warehouse club, hypermarket and the department store, usually as the main body of the separated local or sub local retail centres, have lower average global integration, (Table 13, Figure 51 - Figure 57).

Table 13: Average syntax accessibilities of different retail formats

Retail formats	Average Local Integration Value	Average Global Integration Value
Cyber Center	2.95	0.28
Warehouse Club	2.97	0.26
Hypermarket	3.10	0.28
Department Store	3.11	0.27
Book Store	3.17	0.29
Home Appliance	3.24	0.28
Home Centre	3.30	0.29
Shopping Center/Mall	3.31	0.31

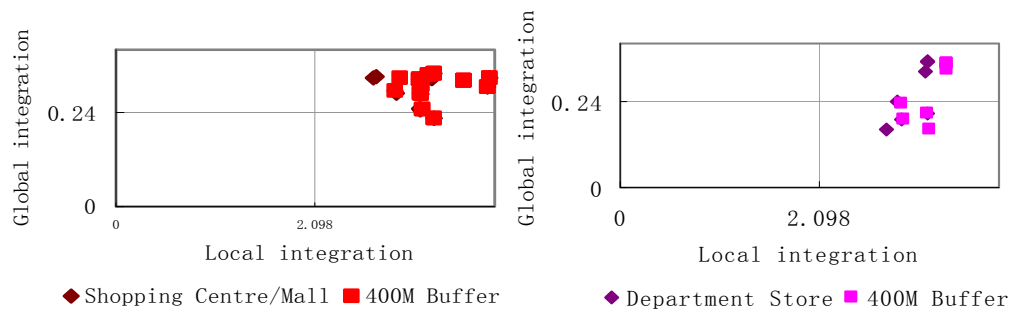


Figure 51: Syntax accessibility of retail locations--- shopping centre/mall

Figure 52: Syntax accessibility of retail locations--- department store

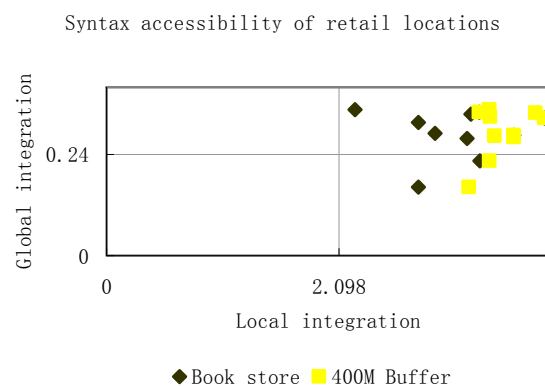
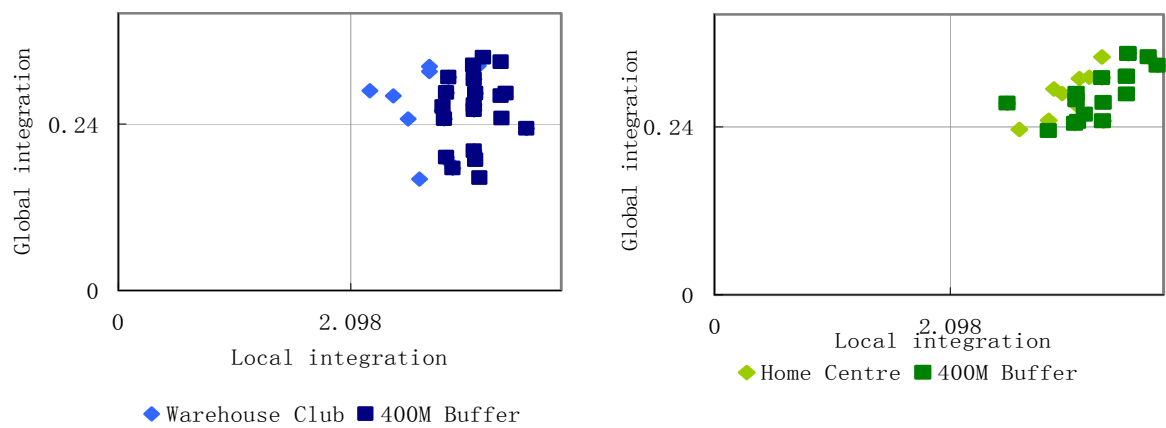
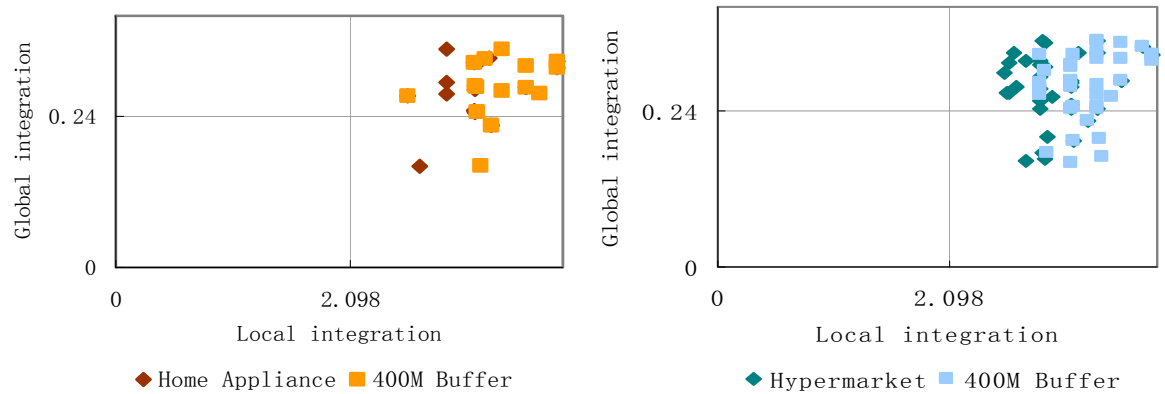


Figure 53: Syntax accessibility of retail locations--- book store



7.4. The Syntax centre of traditional axial network and the retail centres

All the space syntax analysis of the sections above is based on the partitioned road network. Then, this section will analyse the syntax accessibility of the traditional axial network and compare the results and the accessibility pattern of the partitioned road network and the urban retail pattern.

(1) Global syntax centres and the retail centres

In the Figure below, the red lines are the peak global integration values of the partitioned road network. The results, as researched in previous sections, are well accordance with the downtown area and the city retail centre. The yellow lines represent the peak global integration values of the traditional road network. The results of global syntax centre are not located within the very downtown area. The best road is the Second Yangtze River Bridge, following by the Fazhan Avenue, Linjiang Avenue, Youyi Avenue, Heping Avenue, Jiefang Avenue and Jiangnan River Bridge. The characteristics of all these roads are long, straight and less junctions. Although the traditional space syntax has been successfully applied to many urban GIS studies in western countries and suggests that the global integration centre of the traditional road network has high relations with the city commercial centre. However, it is not proved in this case study of Wuhan. The reasons may include flowing aspects:

- Wuhan is a poly centric city, constrained by the nature features. In such urban morphology, the inter district long lines which directly connect the different parts of the city, in particular when the two sides have similar development scale, may have the best global integration value.
- Wuhan has a large city scale. The urban development exists great differences among varied spatial locations. In urban area, many inter district roads are longer than 10 kilometres. However, many roads in downtown are shorter than 500 metres. To some extent, it is illogical to compare the syntax accessibility of them. And the result may not well display the real spatial difference.



Figure 58: Global syntax centres and the retail centres

(2) Local syntax centres and the retail centres

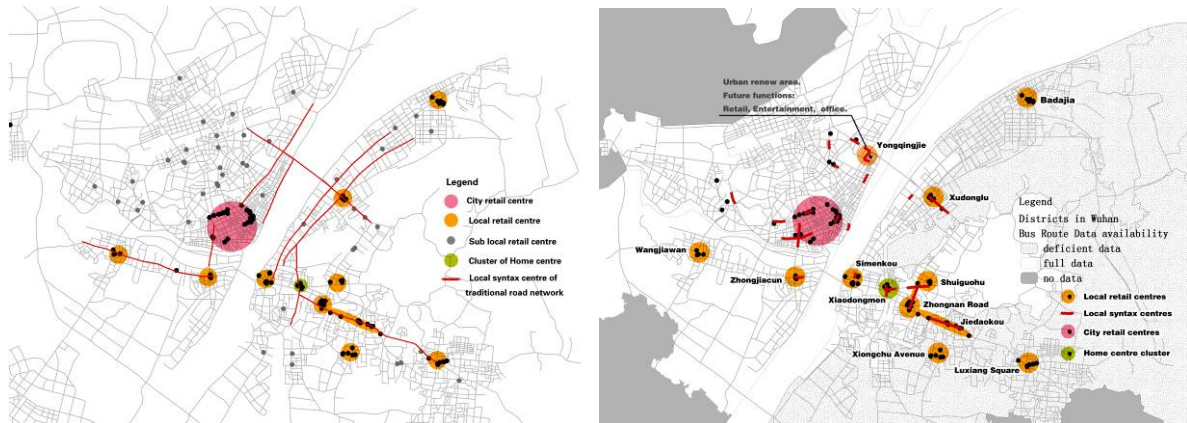


Figure 59: Local syntax centres and the retail centres- traditional road network (left)

Figure 60: Local syntax centres and the retail centres- partitioned road network (right)

The local syntax centres of the traditional road network are showed as the Figure 59. All these centres are urban main roads. Along them located the local retail centres of Xudong, Zhongnan Road, Jiedaokou, Luxiang, Xiaodongmen, Zhongjiacun and Wangjiawan. It is not convinced that, there are no local syntax centres in the old town of Wuchang and Hankou. The Figure 60 is the result map of partitioned road network. This map represents the local centre more precisely with the scale of the humanity. These syntax centres accurately accordance to the retail locations.

(3) Sub local syntax centres and the retail stores

The sub local syntax centres of the traditional road network are showed in Figure 61. Relates the reality, almost all the city trunk roads are highlighted as the sub local syntax centres. These roads are significant in local transportations. Most large scale retail stores locate along or adjacent to these roads. To a certain extant, it proves that there is a correlation between the sub local syntax centres and the retail activities. However, such long linear sub syntax centres beyond the scale of humanity still have difference with the perceptive centres of residents, which are not the same as the descriptions in the space syntax theory.

The Figure 62 and the Figure 63 shows the different syntax centres of traditional road network and the partitioned road network. The latter composed of short lines. Most locations are exactly the community and retail centres. It proves that, it is reasonable to partition the road network into the scale of humanity.

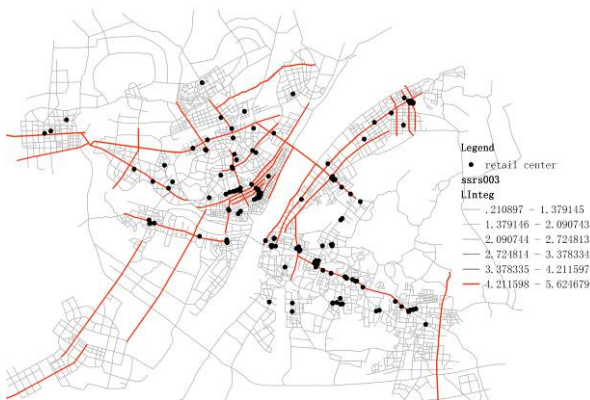


Figure 61: Sub local syntax centres and the retail centres- traditional road network

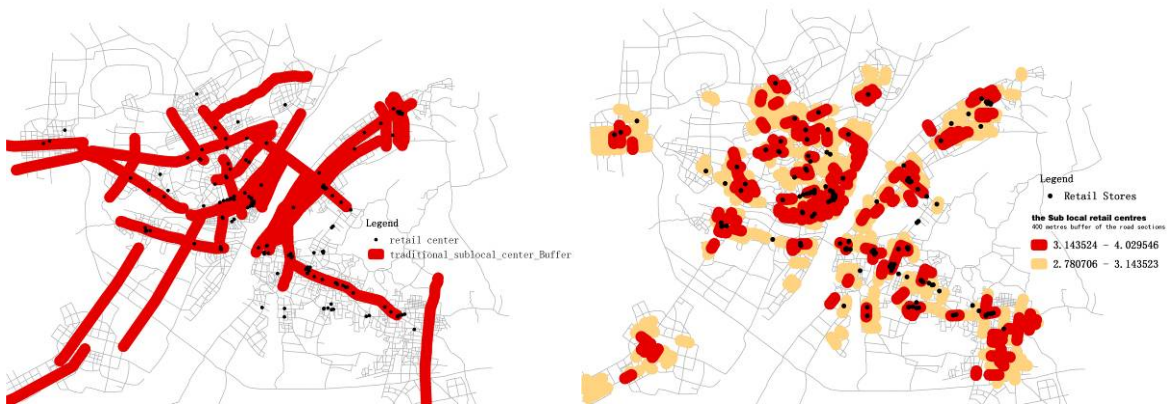


Figure 62: Buffer of sub local syntax centres and the retail centres- traditional road network

Figure 63: Buffer of sub local syntax centres and the retail centres- partitioned road network

7.5. Conclusion and discussion

Through the correlation analysis, it is further verified that there are inter correlations between the space syntax accessibility and retail locations:

- (1) The city retail centre is spatially corresponding with the city syntax centre;
- (2) The local retail centres are spatially corresponding with the local syntax centre.
- (3) The sub local retail centres are spatially corresponding with the sub local syntax centres. The relative high sub local syntax accessibility is one of the primary conditions to be a retail location.
- (4) There still some well connected locations do not have large scale retail stores or other commercial activities. In this case study of Wuhan the main reasons may closely relate to three causes: Firstly, the constructions might be constrained by the nature and policy conditions. Secondly, the existing supply already satisfies the demand at a certain scale. Thirdly, it might be the new developing areas many facilities have not developed yet. But once all the conditions are ripe, these locations could be investment opportunity locations.

In reality, both the retail locations and the bus stop locations can be easily altered for adapting the market demand, all these spatial accordance reflect the self organized process of mutual influence and adjustment between the two.

In addition, the short axial line based space syntax model is showed superior in the spatial analysis and representation of the urban structure, especially for the polycentric large Chinese city such as Wuhan.

8. Conclusion and Recommendation

This chapter presents the conclusions derived from the results and findings of this research and provide some recommendations for supporting the urban spatial planning and urban retail planning in the future.

8.1. Main conclusions

This research develops a framework of spatial topology analysis based on the space syntax theory, which including following innovations: the trail to break the traditional long axial line network; the trail to analyse the bus route network; By taking both the syntax accessibility of road and bus network into consideration, gives the scopes of urban syntax centres of city level, local level and sub local level respectively.

In the analysis of the retail distribution pattern, the city level, local level and sub local level urban retail centres are proposed respectively according to the spatial distributions of the quantity and scale of the retail stores. The spatial distribution pattern of each retail format is also discussed.

The correlation analysis found that, there are spatial correlations between the retail locations and the urban space syntax centres. The space syntax is a useful tool to explain the allocation logic of urban retail space and it is more reasonable to apply the partitioned transportation network instead of the traditional long axial line network.

8.1.1. The urban space syntax accessibility pattern

8.1.1.1. Formulate a principle for deriving the short axial line:

(1) Road network

According to the statistics of the golden length of some famous commercial street, it is found that most valid lengths of the commercial street are no longer than 1000 KM. In addition, Wuhan is a large city, and there are large differences in spatial development. However, many urban roads are very long, of which the longest one is approximates to 13 kilometres. Many axial lines were too long to be a clustering unit for urban retail locations, and illogical to be assigned one single accessibility property. So the long axial line network is not ideal to support my later research about retail locations which selves are relatively micro-scale space. For solving this problem to adapt to my research objectives, I formulate a principle for deriving the short axial line as following:

The constraints for deriving the axial line in this research:

- Continual vista by pedestrians' perspective.

For example: If the vista is cut by bend or a big junction which wider than or at least equal to the width of the road then I partition the road.

- Less length differences among the road segments. The road segments should not longer than ten minutes walking by normal walk pace, that's around one kilometre, most of the axial lines should be 200-600 metres based on actual status.

For example: if the road segment between the natural junctions still longer than 1000 meters, I evenly partition it according its actual length into a certain number of pieces of 300-600 metres.

(2) Bus route network:

It is the very first trail to analyse the bus route network by space syntax.

Different from the road network, the each bus line has definite directions, orientation and destination, and the bus stops are the spatial substance of the bus route network. According to this features of the bus line, I consider the section between two directly linked stops as the axial unit. For deriving the axial lines, I break the routes at each actual bus stop. After the space syntax calculation, I assigned the syntax parameters of the axial segments to their corresponding bus stops.

8.1.1.2. Syntax accessibility pattern of urban

By space syntax analysis, the syntax accessibility patterns of the road and bus network are obtained respectively. Taking the two together into consideration, this research gives the scopes of urban syntax centres of city level, local level and sub local level respectively.

(1) City syntax centre

On city level, the locations where have best global accessibility of both road and bus networks are considered as the city syntax center. In the case study of Wuhan, five city syntax centres can be recognized as the city syntax centres. They are Wusheng Road, Jiangnan Road, Zhongshan Park in Hankou and the two ends of the Yangtze River Bridge: Guqintai in Hanyang and Yuemachang in Wuchang.

(2) Local syntax centre

The local syntax centres refers to the locations where have good syntax accessibility of both road and bus stops on local level. By overlay the two result maps, the local syntax centres are obtained. In Wuchang the local syntax centres are Zhongnan Road, Xiaodongmen, Xudong Road, Hongshan Square, Jiedaokou-Guangbutun and Simenkou. In Hankou the local syntax centres are Xujiapeng, Wusheng Road (Jiangnan First Bridge-Wusheng Road- Liji Road, Jiangnan Road (Wuhanguan-Jiangnan Road- Liuduqiao), Sanyang Road, Zhongshan Park - Hangkong Road- Tongji Hospital, Yongqingjie- Huangpu Road, Kaiming Road (Aomen Road- Jianshe Avenue), Huaqiaoyicun (Huangxiaohe Road) and Hanxi Train Station. In Hanyang the local syntax centre is Zhongjiacun. These results well represent the polycentric develop pattern of Wuhan.

In addition, it is worth noting that, the areas of Zhongshan Park, Jiangnan Road and Wusheng Road, which are the city syntax centres, are also local syntax centres. On both city and local scale, these areas have very good connectivity.

(3) Sub local syntax centre

The sub-local syntax centres are those locations have optimum local accessibility of road (do not consider the availability of bus service). In sub-local scales, they are easy accessed by slow transport means. In this case study of Wuhan, the sub local syntax centres are the road segments which local integration value higher than 2.78 (the first 1/6 of total amount).

8.1.2. The urban retail pattern

8.1.2.1. Distribution pattern of the stores considering the retail formats

In the case study of Wuhan, the shopping centres are highly centralized in urban downtown areas or local centre, which is different from many sparsely populated Western cities. There are 28 shopping centres in total, 16 of which concentrated in the downtown of Hankou; 9 stores in Wuchang and 3 in Hanyang. The department stores located within the large and old residential communities, including Changqinghuayuan, Honggangcheng, Jiansheerlu, Shuiguohu, Simenkou and Luxiang. The hypermarket and warehouse club evenly dispersed in the urban layout. They might be adjacent to other formats of stores, but keep a distance from each other of the same kind. The large scale home centres are proximate to the intercity or inter district traffic corridors. In Wuhan, the traditional home building material clusters are Xiaodongmen and Hanxi, which located close to the Wuchang railway station and Hanxi retail way station respectively. The only cluster of cyber center in Wuhan located in Wuchang Guangbutun, where within the cluster of universities and the Science and Technology Zone of Wuhan. The home appliance store and the large scale book stores always locate within the city or local center, and adjacent to the shopping centres or hypermarkets.

8.1.2.2. The urban retail centres

By statistically analysing the spatial distributions of the quantity and scale of the large scale retail stores, the hierarch of the urban retail centres is generalized as following.

(1) City retail centre:

The city retail centre is the most concentrated retail area in the city, the service area of which covers the whole city.

In this case study, the city retail centre located in the downtown of Hankou, comprise Wusheng Road retail cluster, Jiangnan Road retail cluster and Zhongshan Park retail cluster, which is the busiest area in Wuhan. There are 26 large scale retail stores together. More than half shopping centres among total settled within these area.

(2) Local retail centre:

The local retail centres refers to the retail clusters which constitutes more than three large scale retail stores.

There are 9 local retail centres in this case study of Wuhan. 7 of which in Wuchang and 2 in Hanyang:

In Wuchang, the local retail centres are Zhongnan Road- Jiedaokou, Xudong Road, Luxiang Square, Xiongchu Avenue, Simenkou, Badajia and Shuiguohu. In Hanyang, the local retail centres are Zhongjiacun and Wangjiawan.

(3) Sub local retail centre

All the dispersed large scale retail stores out side the city or local retail clusters are considered as sub local retail centres. Most of them in Wuhan are hypermarkets or warehouse club. They located within the centre area of high density or large scale residential communities and keep a certain distance from one to each other.

8.1.3. Correlation between syntax accessibility and retail pattern

8.1.3.1. There are correlations between the city retail pattern and syntax accessibility pattern

The specific sites of the large scale retail stores and their commercial circles are determined by retailers based upon their respective business plans and market investigations. Both the locations of the retail stores and the bus stops can be easily altered. The relation between the retail spatial distribution and the inherent topological property of the urban transportation network performs a self-organized linkage of the urban development.

It is found through the comparative analysis, although the distribution patterns are various form different retail formats, all the large scale retail stores requires high space syntax accessibility. The urban syntax centres and urban retail centres at all levels in Wuhan are well matched in the city layout.

- The city retail centre located at the city syntax centre, where well connected by both roads and bus routes on global scale.
- In inner city, the local retail centre located at the local syntax centre, where well connected by both roads and bus routes on local scale. In urban border districts, the local retail centres are well connected by road network and there are bus services available.
- Large scale retail stores located at the sub local syntax centre where may not have bus service but well connected by roads on local scale. In other word, the relative high sub local syntax accessibility is one of the primary conditions to be a retail location.

8.1.3.2. Is it more meaningful to apply the short axial line representation?

Although the long axial line based representation of space syntax has been well applied to many urban studies. There are still disadvantages exposed in this research. In Wuhan, there are many long axial lines in the road network. They are too long to be assigned one unique syntax property in reality, which is against to the representation of the spatial differences. Also, they are too long to be a clustering unit for retail locations. By comparison, the outputs of the partitioned road network give more precise representation. Each syntax axial unit have a valid length that suitable for large-scale retail stores gathering and accord with the scale of humanity. As showed in the result maps, it is more cognitively meaningful to apply the short axial line representation.

8.2. Recommendations

This research provides contributions as follows:

- The partitioned axial map gives more precise representations of the urban syntax accessibility pattern and more accordance to the cognizable scale of humanity. The principle for deriving the partitioned axial line can be well used in the space syntax analysis of the large and polycentric cities.
- Taking account the bus routes in space syntax analysis is also helps to give more precise depictions of the urban syntax accessibility pattern.
- The Analysis of the correlativity between syntax accessibility and retail pattern is help to understand the intrinsic structural relationship of the retail spatial development. The results of this research will benefit to the implementation of the bottom up planning. It helps based on one certain aspect to presume the other in the future urban planning or retail spatial planning. For the further urban development in the future, those locations where are the sub local syntax centres can be considered as potential sites of retail land uses, where are the local syntax centres can be considered as the potential sites to become local level retail centres. In new town planning, the locations where are the city syntax centre can be considered as potential site as city retail centre. In the cases of urban renew, it is also may consider to give the priority to the urban syntax centres for development. And vice versa, through improving the syntax accessibility of a certain location may attracts the settlement of the large scale retail stores or promote the vitality of the existing retail centres.

Recommendations to further research:

- Many more type of public transport network can be considered into space syntax analysis to assist assessing the urban syntax accessibility pattern.
- The correlativity between syntax accessibility and the spatial pattern of other land uses can be further studied to support the future urban planning.
- The process of deriving the axial line has to be manually and it is very time consuming. The space syntax analysis tool still need to be further developed.

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