# Research on the Street Vitality of Wenchuan County Based on Space Syntax

Hai Xiao*, Hongtao Zhang, Mingjie Li, Lili Zhang, Guifu Yang
* Corresponding author's e-mail: 41228@sicau.edu.cn, 2319747453@qq.com,
1796053246@qq.com, 2273386642@qq.com, 2507272118@qq.com

College of Architecture and Urban-Rural Planning, Sichuan Agricultural University,
Dujiangyan, China

**Abstract**—The post-earthquake restoration and reconstruction had an important impact on the development of various ethnic groups in Wenchuan County and the spatial layout of the county. In order to explore the spatial pattern of the population distribution in Wenchuan County, this study is based on location service data and field surveys, using a series of quantitative indicators of the spatial syntax model to measure the relationship between space and population activities. The main research results are as follows: (1) There is a difference between the theoretical population distribution and the actual situation in the Wenchuan county area: theoretically, the population should decrease with the decrease of spatial accessibility, but in reality, the opposite phenomenon occurs due to the influence of the city's regional functions. (2) The vitality of the streets in Wenchuan County shows temporal and spatial regularity: commercial land in the afternoon, square land in the evening, and residential land in the evening show a concentration of people. (3) The types of land used in Wenchuan County, such as square land, cultural land, educational land, and commercial land, have a greater impact on the vitality of streets. Location-based service data and field surveys promote the gradual improvement of the theoretical and technical system for the study of the spatial pattern of urban population distribution, and thus play a more scientific guiding role in the realization of a comprehensive and coordinated sustainable development of the city.

**Keywords-** Spatial Syntax; LBS Data; Street Sitality; Wenchuan County; Integration; Big Data

## 1    Introduction

As the main frame of a city, the street connects the functional areas of the city and is an indispensable place for residents' lives [1]. With the improvement of living standards, how to improve the vitality of streets has become an important topic in shaping a vibrant and livable city [2].

Population agglomeration is a comprehensive indicator that can display population distribution. It can not only effectively reflect the spatial structure of the main functional zoning, but also be an important prerequisite for the optimization of its layout. Therefore, it is necessary to explore the vitality of streets through the degree of population concentration.

The application of ArcGIS software and Baidu heat map based on Location-based Service (LBS) data provides new tools for urban spatial analysis. The combination of the two is not

only an application of traditional theories, but also can give full play to the real-time and accuracy of big data to make up for the lagging and large errors of spatial syntax analysis technology [3]. The in-depth analysis of space structure and the precise analysis of social logic in space syntax theory can open up new ideas for the exploration of man-land relationship.

Wenchuan County is a multi-ethnic area where Tibetans, Qiangs and Hans live together with distinctive spatial distribution patterns and ethnic distribution characteristics.

This study uses ArcGIS software to analyze the characteristics of population agglomeration in different regions and time periods in Wenchuan County, and uses a spatial syntax model to analyze the road connection value and spatial integration value of Wenchuan County; compare the analysis results of the spatial syntax model with the characteristics of Wenchuan population aggregation to filter out areas where the theoretical and actual population distributions are quite different; through field research and questionnaire surveys, analyze the driving causes of regional population agglomeration. Based on the above analysis, explore the distribution and change patterns of crowd activities and ethnic settlements and their influencing factors.

## 2    Research methods

### 2.1 Spatial syntax model

The specific function of a space is limited by its connection with the surrounding space. This research explores the connection relationship between spaces to identify the spatial units with the highest spatial accessibility and the strongest spatial pivotal effect, and provide differentiated construction opinions for the space.

The spatial syntax model energizes spatial vitality, and can explain the spatial characteristics of population activities through a series of measurable indicators [4]. Commonly used space syntax indicators generally include Connectivity Value、Total Depth、Mean Depth Value、Relativized Asymmetry、Relativized RA and Integration Value.

The connection value refers to the number of nodes directly connected to a node in the system. The connection value of a certain space is positively correlated with the connection degree of the surrounding space, the influence on the surrounding space, and the space permeability. The global topological depth refers to starting from the central element, summing the number of topological steps in all situations, and assigning the final value to the central element, which is the global topological depth of this central element [5]. The average depth value refers to the ratio of the global topological depth of an element to the total number of elements in the system. It reflects the average number of topological steps from an element to other elements. The formula is:

$$\text{Mean Depth}(a_1) = \frac{\text{Total Depth}(a_1)}{n\text{-}1} \tag{1}$$

$a_1$ is an element in the system, n is the total number of elements in the system.

The relative asymmetry value and the actual relative asymmetry value mean that in a system, the topological depth between an element and other elements is affected by the symmetry of the system, the connection relationship between the elements, and the total number of

elements. The significance is to eliminate the influence of the first two on the global topological depth of the element, and the formula is as follows:

$$\text{Relativized Asymmetry}(d_1) = \frac{\text{Mean Depth}(d_1)\text{-}1}{\frac{n}{2}\text{-}1} \tag{2}$$

$d_1$ is an element in the system, and n is the total number of elements in the system.

The spatial relationship examines the relationship between the central space and all other spaces in the system. In this study, in order to more rigorously reflect the calculation principle of removing the central element, the above formula is appropriately adjusted as follows:

$$\text{Relativized Asymmetry}(d_1) = \frac{\text{Mean Depth}(d_1)}{\frac{n\text{-}1}{2}} \tag{3}$$

Since the influence of the central element has been eliminated during the calculation of the average depth value, no secondary elimination is performed during the calculation of the above formula; the total number of system elements n in the denominator of the above formula is taken after the influence of the central element is eliminated, and then the value of the total number of remaining elements Half participate in the calculation, effectively eliminating the influence of system asymmetry on the calculation results.

$$\text{RA of Diamond} = \frac{n\left\{\log_2(\frac{n}{3})\text{-}1\right\}+1}{\frac{(n\text{-}1)(n+1)}{2}} \tag{4}$$

n is the total number of elements in the system.

$$\text{Relativized RA}(d_1) = \frac{\text{RA}(d_1)}{\text{RA of Diamond}} \tag{5}$$

$d_1$ is an element in the system.

The degree of integration is obtained by processing a series of process formulas such as average depth value, relative asymmetry value and actual relative asymmetry value. Since the global depth value is inversely related to the level of accessibility, for ease of understanding, the following formula (6) is defined, so that the higher the global depth value, the smaller the integration value, and the lower the global depth value, the greater the integration value. In this way, the numerical change of the degree of integration is consistent with the concept and direction of accessibility, that is, a space with a high degree of integration has high accessibility. The formula is as follows:

$$\text{Integration}(d_1) = \frac{1}{\text{RRA}(d_1)} \tag{6}$$

$d_1$ is an element in the system.

According to the reconstruction of the existing spatial pattern after the earthquake in Wenchuan County, this paper selects the connection value, the average depth value, and the integration value as the characteristic numerical indicators of its spatial structure.

## 2.2 LBS data

This study uses mobile phone signaling data to study the characteristics of the spatial and temporal distribution of Wenchuan County residents and their migration patterns. Mobile

phone signaling data is a type of LBS (Location-based Service) data. LBS uses base stations to receive signals to reflect the location information of users of electronic devices and provide dynamic data on the temporal and spatial scale of the population. Through the analysis of population vitality changes, the interaction relationship from vitality points to lines to planes can be explored. The population changes in the main streets, the buildings and places on both sides of the street in order to explore the reasons for the vitality of the streets and the street area.

## 3    Research on the Vitality of Streets in Wenchuan County

### 3.1 Overview of the research area

This study takes Wenchuan County as the research area, which is located in the northwest of the Sichuan Basin. Due to the influence of geographical factors, the belt-shaped space of Wenchuan has been further divided, forming the characteristics of clear functional division and regular ethnic distribution.

According to the geographical spatial pattern, this study divides the Wenchuan county area into three areas A, B, and C as shown in the figure. The settlements of ethnic minority residents are mainly distributed in Area C, while the Han people mainly live in Areas A and B.

### 3.2 Data acquisition and processing

This research first presents the acquired geographic coordinate information of the residents in space through ArcGIS software, and deletes the data outside the scope of the research. Then use the nuclear density analysis tool to analyze the population location data with 500 meters as the buffer radius, and visualize it to obtain a heat map (Figure 6).

In this study, the convex map of Wenchuan County was imported into the DepthMapX platform, the spatial connection relationship was manually set, and the DepthMapX and Axwoman were used for spatial analysis.
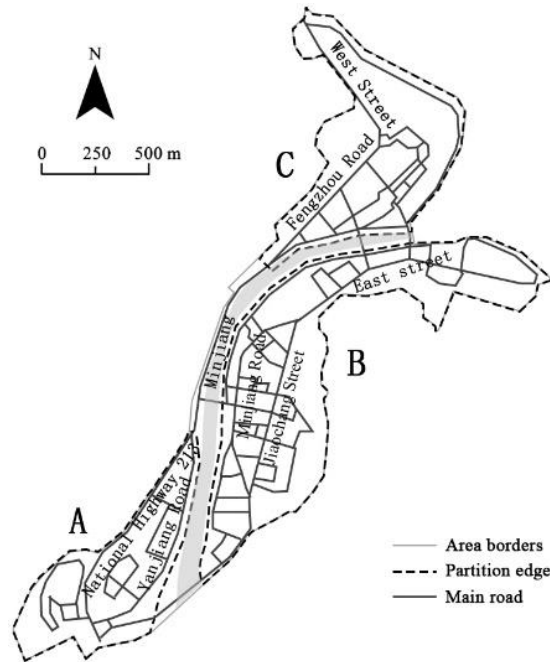
**Fig.1** Area division map

### 3.3 Results and discussion

Spatial syntax analysis. This study analyzes the spatial connection value and average depth value of the study area and visualizes it, as shown in Figure 2 and Figure 3.It can be seen from Figure 3 that Jiaochang Street, the middle section of Minjiang Road and the upper section of Minjiang Road have the lowest average depth values, indicating that these streets have the best accessibility. They mainly undertake commercial and trade functions. The residential areas, People's Hospital of Wenchuan, and the government institutions are located on the 213 National Highway, East Street, Fengzhou Road and other places with lower accessibility. Meanwhile, the road density in areas where ethnic minorities live is generally lower than in areas where Han people live, and the connection value of roads is also the same.It can be seen by analyzing Figure 4, the spatial integration value of the county is between 0.10 and 0.40. The numerical change of the spatial integration reflects the ability of the space itself to attract arriving traffic, and provides a reference for studying the activity of the space itself. In this study, the areas with spatial integration values of 0.01-0.19, 0.20-0.31, and 0.32-0.40 were classified as low integration regions, medium integration regions and high integration regions, respectively. Through the comparative analysis of Figures 4 and 5, it can be seen that among the belt-shaped areas of Wenchuan County, the central area with the highest spatial integration is mostly distributed with educational land; while there are more residential lands in area A and the northern part of area C where the spatial integration is low. The main economic and cultural activities of Wenchuan County are mostly concentrated in Area B. Such a layout has led to the characteristics of the flow of educated people in Wenchuan County to and divergence from the center. This feature of migration also fits with the characteristics of the
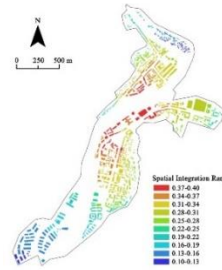
development of Wenchuan County from the center to the ends after the reconstruction of the 512 earthquake, as well as the characteristics of the times of developing education and economy first, and then recreation and leisure.
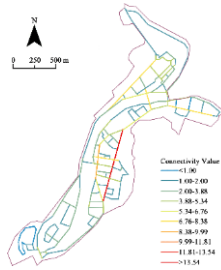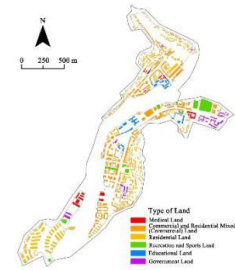


**Fig.2** Connection value map
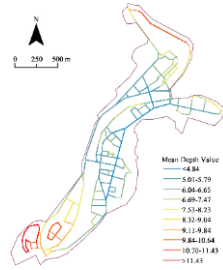
**Fig.3** Average depth value map

**Fig.4** Integration map

**Fig.5** Land use function zoning map

LBS data analysis. According to Figure 6, the population distribution of Wenchuan County has mainly formed 8 agglomeration areas. Comparing the heat map with the road network, and analyzing from the spatial dimension, the activity space of Wenchuan County presents obvious characteristics of a belt-like layout along the road. Analyzing the spatial distribution characteristics of residents' activities from the time dimension, the migration has regularity and effectively enhances the vitality of streets.
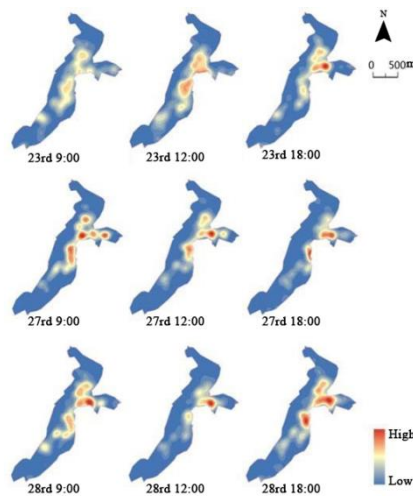


**Fig.6** Population distribution heat map

Comprehensive comparative analysis. Since the population agglomeration area obtained by theoretical analysis is only based on the geographical distribution pattern of the space itself, the population distribution obtained by it can reflect the true situation only when the attractiveness of all spatial units is the same. By comprehensively comparing the theoretical population agglomeration area derived from the spatial syntax with the actual population agglomeration area obtained by LBS data, this study obtained the areas where the theoretical

analysis and the actual situation are different, which provides scientific options for the next field investigation to explore the reasons for the differences. In order to facilitate the targeted proposal of countermeasures and suggestions, the study further divided the three areas into three categories. Among them, areas with high population concentration and good spatial accessibility are high-density population areas. Areas with low population concentration and low spatial accessibility are low-density population areas, which mainly include area A and the northern part of area C. It is worth noting that the method of dividing each area into high and low-density population areas here is a method of categorizing the theoretical and actual population distributions of different areas, rather than a quantitative result.

**Tab.1** Comprehensive comparative analysis of population agglomeration areas

| Spatial syntactic analysis | LBS data analysis | Partition | Match or not |
|---|---|---|---|
| — | Cultural Square | Area B | No |
| — | Wenchuan Museum | Area B | No |
| Vegetable market | Vegetable market | Area B | Yes |
| Guozhuang Square | Guozhuang Square | Area B | Yes |
| — | Weizhou Normal School | Area B | No |
| — | Wenchuan Stadium | Area B | No |
| Wenchuan Lantian Primary School | Wenchuan Lantian Primary School | Area C | Yes |
| Weizhou Normal School Affiliated Primary School | Weizhou Normal School Affiliated Primary School | Area C | Yes |
| Wenchuan Modern Tianfu Hospital | Wenchuan Modern Tianfu Hospital | Area C | Yes |

Field result verification. In this field survey, a total of 435 questionnaires were distributed, of which 416 were valid questionnaires, with an effective rate of 95.63%.The results of field investigation and data processing were verified, and the following conclusions were drawn: Wenchuan County has a small population and there are certain regularities in population activities. The narrow and long space of Wenchuan County and the division of units have resulted in the simplification of the road structure, and further restricted the main service functions carried by each area and the ability to attract people. The long and narrow development pattern has brought inconvenience to the exchanges among various regions. Although some areas do not perform well in terms of spatial accessibility, they all promote commercial trade and cultural exchanges between various ethnic groups on both sides of the Minjiang River due to their significant service functions.

## 4  Conclusions and countermeasures

This study explores the characteristics and laws of Wenchuan County's regional population distribution from both theoretical and practical aspects, and draws the following conclusion: Theoretically, Wenchuan County's population agglomeration area mainly includes the five areas of the vegetable market, Guozhuang Square, Wenchuan Lantian Primary School, Weizhou Normal School Affiliated Primary School and Wenchuan Modern Tianfu Hospital.

According to LBS data analysis, the actual population agglomeration areas of Wenchuan County mainly include Cultural Square, Wenchuan Museum, the vegetable market, Guozhuang Square, Weizhou Normal School, Wenchuan Gymnasium, Wenchuan Lantian Primary School, Weizhou Normal School Affiliated Primary School and Wenchuan Modern Tianfu Hospital, there are differences in population agglomeration areas in theory and in practice.

For high-density population areas, it is necessary to sort out the main functions of production and life services and realize the optimized development of population centers. The medium-density population distribution area should sort out its main service functions, accurately locate the customer group, and form a new urban population sub-center. The low-density population distribution area should strengthen its block connection with the main population center. The newly built area after the earthquake needs to be connected with a highly accessible road network to further explore the vitality of the area.

In multi-ethnic areas such as Wenchuan, where the space is relatively closed due to topographical factors, it is necessary to improve accessibility for public spaces where various ethnic minorities hold activities. Meanwhile, the deployment of cultural and leisure facilities in these areas can effectively enhance the public vitality within these areas and promote cultural exchanges among residents of various ethnic groups.

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