A study on the Evolution of Morphological Vitality of Ancient City along the Silk Road Based on Space Syntax—Taking Zhangye as an example

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Abstract: Zhangye is one of the Chinese historical and cultural cities announced by the State Council in 1986. It is not only the historical junction of the “Ancient Juyan Road” and the “Ancient Silk Road”, but also an important economic and cultural town and the key position of introduction of Buddhist culture into China. On the basis of morphological evolution, this paper analyzes the changes of the space structure of Zhangye ancient city and its status and function as a core in the overall urban space structure through space syntax. At the same time, this paper discusses the public space, road network structure and space elements of Zhangye historical area. Especially the internal connection between traditional architecture, landscape, commerce, etc. On this basis, the specific strategies for promoting the vitality and attractiveness of the historical space of Zhangye are proposed, which provides a research foundation for the protection and sustainable development of the historical city in the future.

1. Introduction
A Historical and cultural city a kind of social space, which has the characteristics of "collective cognition" and is an important crystallization of the evolution of human society. After thousands of years of development, it not only retains traces of history in the early stage of construction, but also reflects the social and cultural characteristics of contemporary urbanization. The historical form of a city is influenced by the natural environment and social life, as well as the changes of internal and external conditions. The protection of historic ancient cities has become an effective way to retain the cultural memory of a city.

In June 2014, the Silk Road was successfully applied as a World Heritage Site. Excavating the potential value and deep connotation of the historical heritage city along the Silk Road culture is conducive to the integration of China's “One Belt and One Road initiative” Silk Road culture, economy, tourism and the sustainable development of historical city protection and renewal. It is not only the historical junction of the “Juyan Ancient Road” and the “Ancient Silk Road”, but also an important node of economic and cultural towns and Buddhist cultures introduced to China, which retains a large number of historic traditional buildings. The development of the western region and the implementation of the urban development strategy along the “one Belt and one Road initiative” led to the new development opportunities in Zhangye City. At present, Zhangye center of historical area space development faced with the city space structure imbalance, the traditional public space is gradually replaced by the modern urban commercial space and lack of the historical area of historical and cultural connotation, so the dynamic evolution of historic Zhangye city form, has become a Zhangye historical urban renewal and...
protection, and urban social and economic development must face the important issue. This paper analyzes the evolution process of Zhangye historical area of Evolution of morphological vitality from the perspective of quantitative and qualitative, explores the influencing factors behind it and proposes corresponding strategies to promote the protection and renewal of Zhangye historical area history and culture, and give suggestions for Zhangye's sustainable development.

2. Overview and Evolution of Zhangye Historical Area

2.1. Overview of Zhangye city

Zhangye, located in the middle of Hexi Corridor in Gansu Province, which is the second batch of famous historical and cultural cities in China. According to archaeologists, our ancestors lived here more than 4000 years ago. It has been more than 2100 years since the Western Han Dynasty established its regime. From the place of Yong Zhou in the pre-Qin period to the military fortress in the Han Song period, from the provincial capitals of Gansu Province and Shanxi Province in the yuan, Ming and Qing Dynasties to the Autonomous Prefecture of Gansu Province in the Qing Dynasty, Zhangye experienced a complex historical evolution (Figure 1). The scope of the historical area of Zhangye studied in this paper refers to the historical core protection scope (the city range before 1949) in the Zhangye Historical and Cultural City Protection Plan (2018-2035), and the area enclosed by the East, West, South and North Ring Road (area 4.84 Km²).

![Figure 1. Zhangye historical evolution of the scope of the jurisdiction map.](image)

2.2. The Evolution of the Historical Form of Zhangye historical area

According to the records of Ganzhou Fuzhi, the present historical area of Zhangye was built in the early years of the Great Day (about 605 AD). During the Ming and Qing Dynasties, the buildings in the historical area were distributed in an orderly manner, with religious buildings mostly, followed by government buildings and residential houses. As the defensive building in the center of the historical area, Zhenyuan Building can overlook the entire historical area and control the sights of the four streets of the east, south, west and north, forming the landscape intention of the majestic style of the frontier; As a high-rise building, the Sui and Tang wooden pagodas can overlook the surrounding situations of the great Buddhist temple, Shanxi guild hall building group and Hsi Lai temple building group. Zhenyuan building and Sui and Tang wooden pagodas set the pattern of the historical area at the upper limit of the vertical direction; the North-South street as the traditional central axis in the historical area limits the pattern of the historical area at the horizontal direction.

In the early days of the founding of the People's Republic of China, the historical area of Zhangye basically continued the pattern of the historical area from the late Qing Dynasty to the Republic of China. As the center of the historical area, Zhenyuan Building takes the historical area wall of the Ming and Qing Dynasties as the urban boundary, and takes the four streets of the east, west, south and north as the axis. The road divides the historical area into nine square areas of different sizes in the form of a grid. In the early days of reform and opening up in 1978, the economic development of Zhangye City increased rapidly, and modern commercial buildings continued to emerge, and the central position gradually strengthened. Due to the influence of factors such as policies and economy, the layout of the road network and the layout of public spaces in the city have gradually improved. At present, the
historical area is mainly composed of residential, commercial and other facilities, and combined with the original traditional public space to form a larger urban core area (Figure 2, Figure 3).

3. Research methods - the application and construction of space syntax

In the 1970s, Professor Hillier (1996) first proposed the concept of “spatial syntax” based on the syntactic concept of A.N Chomsky. As a syntactic structure, space implies social logic and is closely related to environmental behavior and movement patterns. It is believed that there will be a potential spatial organization system in both the external space and the internal space of the building, and this organization system will change with the change of human activities, and then this organization system constitutes the theoretical framework of the relationship between human and the space in which they are located[1]. The basis of this theory is spatial syntax. The calculation rule is to convert the physical space form of urban form, architecture and even landscape into mathematical model to calculate and deduce the calculation logic, so that researchers can accurately observe and explain the spatial characteristics, human behavior and social logic and judgment. In recent years, with the rapid pace of historical city protection and renewal, more and more attention has been paid to the research of historical city. Through the continuous integration of new theories and mathematical models, urban morphology model has been established. Therefore, spatial syntax has been gradually applied to the research of urban spatial morphology.

From the perspective of morphology, the road grid is the basic framework of urban spatial form, and its overall structure determines the urban layout and spatial structure. In the process of path structure analysis, one path is a linear unit, which maintains continuity with other paths through intersections. In syntactic expression, the axis method, as an effective method for analyzing urban road networks, can clearly show the important roads and regional spatial structures in the study area. The axis method, as an analysis of the urban spatial structure, represents the movement path of human perception and behavior. Linear streets can be an important link between matter and cognition, or between matter and behavior in the axis approach [2].

In syntactic parsing, the degree of integration and intelligibility is an important means of urban spatial structure measurement analysis. It is simplified by the topology between spaces as an axis graph model or a line segment model (Figure. 4). The degree of integration of historical ancient cities is to determine the distribution and distribution of populations in the study area. The level of comprehensibility is an important indicator of urban memory, which studies the relevance of the region to its background. These variable values have important reference value for the study of the characteristics of public space in traditional historical cities. The mathematical logic is as follows:

(1) **Integration:** The degree of integration I_i indicates the distribution and accessibility of the unit space in the overall system; Its mathematical formula is:
\[ R_{Ai} = \frac{2(MD_i - 1)}{n - 2}, \quad I_i = RRA_i = \frac{n \log_2 \left( \frac{n + 2}{3} - 1 \right) + 1}{(n - 1)(MD_i - 1)} \]  

(1)

MD is the average depth value, n is the summary point, RA_i is the global integration degree, and I_i is the local integration degree.

2) **Intelligibility:** Represents the interrelationship between local and global connectivity features. If the local scope is a space with high internal connectivity values and high overall integration, the spatial system is clear and easy to understand. The lower intelligibility shows that it is difficult for pedestrians to perceive the spatial characteristics of the entire block system through the local features of the block; Its mathematical formula is:

\[ R^2 = \frac{\sum (C_i - \bar{C})(I_i - \bar{I})^2}{\sum (C_i - \bar{C})^2 \sum (I_i - \bar{I})^2} \]  

(2)

C is the connection value of all cell spaces, I is the global integration degree of all cell spaces.

Figure 4. Schematic diagram of spatial syntax axis generation.

4. Research on the evolution of space morphology of Zhangye historical area based on space syntax

For the historical area of Zhangye, first of all, through the analysis of the overall and local integration degree of the historical area of Zhangye in different periods, it analyzes the aggregation state of the historical area and the level of the aggregation of the core area; secondly, through the value of the comprehensibility parameter, it judges the high and low changes of the spatial form of the historical area of Zhangye in history. Therefore, this paper will analyze the historical area of Zhangye from two research methods of integration and comprehensibility, and explore the internal topological relationship of the evolution of historical city form.

4.1. Analysis of the integration degree of Zhangye historical area

The internal organizational relationship of traditional Chinese cities is composed of its road network and core space. The road is the basic framework of urban spatial form. The relationship of path configuration determines the urban spatial layout and spatial structure. Therefore, the analysis of urban internal structural form is transformed into the topological analysis of road network structure [3]. This paper analyzes the integration degree of the road network of Zhangye historical area in Ming and Qing Dynasty, the early period of the founding of the people's Republic of China (1949), the early period of reform and opening up (1978) and 2019.

Through the comparative analysis of the global integration degree of Zhangye historical area (Figure. 5, Table 1), it is found that the layout of Zhangye historical area in the Ming and Qing Dynasties was simple, and the historical area road network expanded less. The city is the main living and working area of residents. In the historical area, the town is far from the intersection and the east and west streets and the north and south streets are the most integrated and relatively concentrated, and the other branches are less integrated. In the early days of the founding of the people's Republic of China, the city basically continued the pattern before the founding of the people's Republic of China. The east-west and North-South streets in the historical area had the highest degree of integration, which were the two main axes of the city. Zhangye section of 312 and 227 national highways is the main road for the city's external
connection, which strengthens the connection between the spatial organizations inside and outside the
city. In 1955, Lanzhou Xinjiang Railway was opened to traffic, which provided convenient
transportation for the development of urban economy. Industry and mining began to distribute freely
along both sides of the road. Zhanghuo highway has become the main road section of the city's external
economy. Compared with the city’s integration degree, its industrial area has a higher color temperature,
and the urban spatial model has expanded from the inward agglomeration to the outward circle. From
1978 to 2004, the integration degree of roads in the historical area increased significantly, and the
integration degree of industrial areas in Binhe New District, the south side of railway station and the
northwest side of the historical area increased significantly compared with the early days of the people's
Republic of China, but it has a strong dependence on the historical area as a whole. The urban spatial
form expands from the inside out to form a multi-center spatial distribution with the historical area
as the core, the industrial area as the production core and the zhanghuo highway as the connecting axis.
From 2004 to 2019, under the sustainable development of urban ecology, the integration of Binhe New
District, wetland new urban area and Southern District increased significantly, while the integration of
the historical area area decreased. The integration of Southern District was the highest, and the spatial
structure of the city was in a multi-core form.

Figure 5. Zhangye global integration analysis.

Table 1. Analysis of integration degree of Zhangye.

| Parameter value | Ming and Qing Dynasties | 1949 | 1978 | 2019 |
|-----------------|-------------------------|------|------|------|
| Global integration | 1.85488 | 1.4782 | 1.12631 | 1.6952 |

In general, the value of the global integration of Zhangye historical area varies from high to low to
high, showing a wavy line. The increase in urban roads has been complicated and complicated, and
cities have gradually evolved from single nuclear to multi-nuclear. The streets where the initial free-
growth distribution continued to improve with the development of the city and the systematic road
network structure gradually tended to open the grid system. Although the global integration degree of
the city has steadily increased year by year, the position of integration has gradually shifted outward
from the historical area, the aggregation of the historical area is gradually weakening, and the
functionality is gradually replaced.

4.2. Syntactic Analysis of Historical Forms of Historical Area Based on Intelligibility
In syntactic analysis, the degree of comprehensibility can be used to discriminate the level of
identifiability of the surveyed elements, and the analysis of intelligibility is usually explained by linear
regression equations with global and local integration values (R=3). For the historical historical area, the urban form of different periods is taken as the base, and the degree of contrast under its historical evolution is analyzed to explore its causal relationship. As the historical area pattern of the Ming and Qing Dynasties was continued, the road network was improved and the identifiability of the historical area was improved. The historical area was the most understandable in 1949. From 1978 to 2019, the development model of the city gradually went outward. The core of the group outside the historical area had a certain impact, which led to the gradual reduction of the intelligibility of the historical area and the decrease of the recognizability of the historical area. In the syntactic measure analysis (Figure. 6, Table 2), the historical historical area (red) in the Ming and Qing Dynasties, the early period of the founding of the country (blue), and the 1978 period (purple), above the regression line of the 2019 period (black), the slope gradually decreased. It shows that the intelligibility of the historical area of Zhangye has gradually decreased gradually over time. The higher the intelligibility of the historical area (the higher the slope of the regression line), the higher the frequency of human social activity in the historical area, the functionality of the space in the old city are also more likely to be identified. In other words, since the Ming and Qing Dynasties, the historical historical area has maintained a certain degree of comprehensibility, which is the political, economic and cultural center of Zhangye City. Compared with other periods in 2019, the understanding value of 0.5800 is relatively low (when R2 is greater than 0.5, it has a certain degree of identification). The external expansion of the city and the construction of Binhe new area and other multi-center clusters have a certain impact on the development of the urban spatial structure, but the inertia thinking of people's life and consumption makes the historical area of Zhangye still have a high degree of identification. This has provided a positive role in the renewal and transformation of historical urban areas.

Figure.6 Historical area Intelligibility analysis.

Table.2 An analysis of the intelligibility of the historical area.

| Time            | Average global integration | Average local integration (R=3) | Intelligibility |
|-----------------|----------------------------|---------------------------------|-----------------|
| Ming and Qing Dynasty | 1.8548                    | 1.9043                          | 0.9889          |
| 1949            | 2.0756                     | 2.1306                          | 0.9954          |
| 1978            | 2.0678                     | 2.2161                          | 0.9812          |
| 2019            | 1.4183                     | 1.9928                          | 0.5800          |
5. Analysis of the dynamic characteristics of the spatial nodes of Zhangye historical area based on the spatial syntax

As the carrier of people's life, human activities are the direct source of creating urban space vitality [4]. The vitality of a space depends on two aspects: the strength of node spatial aggregation and the level of recognizability. With strong aggregation, the flow of people is large, and the vitality of space is increased. Similarly, the identifiability of space nodes is strong, the attraction of space is strong, and the vitality of space is increased. In this paper, the spatial syntax is used to analyze the changes of integration and comprehensibility between the spatial nodes and the road section in each period of Zhangye historical area to judge the vitality of the node space. Considering the impact on the public space and urban development of Zhangye historical area and the data on the degree of road axis integration, the spatial nodes of the historical area are classified into three categories: traditional public space nodes, commercial space nodes and landscape space nodes.

Traditional public space (Figure 7) is an important public space node in Zhangye historical area, and it is arranged along the streets with the highest degree of integration, such as Taoist temple, temple, government office, hall and other traditional public spaces. On the basis of the integration degree, it is found that the integration degree of traditional public space in four time stages is analyzed. During the Ming and Qing Dynasties, the religious space nodes scattered between the east-west street and the Democratic east-west road had disappeared, such as three God’s Temple and Guanyu Temple. Due to the relatively concentrated and open space, the integration of Big Buddha Temple and Muta Temple on both sides of the county street has become the core of the traditional public space of the historical area. Moral Anno, Minqin Hall, Gao Longbing House, Hsi Lai Temple, these four traditional public spaces, due to the lack of space around the road, the accessibility is relatively small, the integration is relatively small. In other words, the change of urban road network structure affects the accessibility of traditional public space nodes, such as: eastern warehouse with the optimization of road network structure, the integration of spatial nodes increases, the spatial vitality becomes higher; and the traditional public space The openness of the nodes and their relative concentration, such as the combination of Big Buddha Temple and Muta Temple and the Plaza, also correspondingly improve the integration and vitality of the space nodes.

Figure 7 Analysis on the vitality of traditional public space in Zhangye historical area.

The commercial space (Figure. 8) is characterized by the vitality of modern cities, and its degree of aggregation affects the spatial pattern of urban space. From the analysis of Zhang Jian's integration degree in three periods, it is seen that East-West Street, North-South Street and County Street continued to maintain a high degree of integration from 1949 to 2019. The corresponding space nodes are Ming and Qing Commercial Street, Jincheng Street, and Sogou Fashion Plaza. The business activities of Ma Shenmiaow Street are more active. Since 1978, due to the construction of residential communities, commercial vitality and integration have been reduced. However, some commercial buildings and shopping centers in the South Street area have been established one after another, and new urban vitality points have emerged, which has led to an increase in the integration level from Zhenyuan Building to the southern end of South Street. The historical development of Zhangye’’s historical district is basically
consistent with the situation of spatial integration analysis, that is, the higher the degree of integration, the stronger the commercial vigor.

The natural landscape space is dominated by landscapes, natural landscape nodes, landscape parks, and historical area gates (Figure 9), which also affects the development of the city to a certain extent. Since 1949, due to the development of the city, there have been fewer landscape nodes in the historical area. The natural reed ponds of this period have been replaced by buildings such as residential commercial buildings. At present, only the landscape nodes such as Ganquan Park, Ganquan pond, Chenjia Garden and Chang Shamen Site Park are reserved. Through comparative analysis, it is found that the landscape nodes affect the integration degree of the street to a certain extent. For example, the integration degree of Chenjia Garden Lane is increasing year by year. At the same time, the large-scale landscape nodes are often combined with the clustered commercial space to improve the vitality of the space nodes. For example, the combination of Ganquan Park and Ming and Qing Street has improved the concentration of Ganquan Park.

Figure 8 Analysis on the Vitality of Commercial Space in Zhangye historical area.

Figure 9 Analysis of landscape space vitality of Zhangye historical area.

From the numerical point of view (Table 3, Figure 10), the intelligibility of each spatial node is basically close to 1, and the invisibility of the landscape space node is only 0.7926 in 1978. This indicates that the space layout of the landscape nodes of the historical area is lowly identifiable. After 1978, due to the concept of sustainable ecological development, the government has greatly improved the landscape greening in the historical area, and the understanding degree has increased the identifiability of the landscape nodes. Comparing the traditional public space with the commercial space, it is found that the global integration and intelligibility between the two are very close, and only the local integration degree (R=3) of the traditional public space fluctuates greatly. This shows that the spatial distribution of the traditional public space in the historical area after 1978 is centrally dispersed and has a multi-centered character. The recognizability of space has a certain limiting effect on the formation of node space. The quantitative analysis of space syntax reveals that the identifiability of spatial nodes that cannot be obtained by traditional analytical methods is potentially attractive to other spaces.
Table 3. Historical area Intelligibility analysis chart.

| Space node name   | Time | Global integration | Local integration (R=3) | Intelligibility |
|-------------------|------|--------------------|-------------------------|-----------------|
| Ming and Qing Dynasty | 1949 | 1.9432             | 1.9742                  | 0.9949          |
| Traditional public space | 1949 | 2.4737             | 2.5178                  | 0.9933          |
|                    | 1978 | 3.4342             | 3.6335                  | 0.9193          |
|                    | 2019 | 2.2509             | 2.4210                  | 0.9783          |
|                    | 1949 | 2.6979             | 2.7655                  | 0.9954          |
| Commercial space   | 1978 | 2.8594             | 3.3366                  | 0.9561          |
|                    | 2019 | 2.3692             | 2.5834                  | 0.9895          |
|                    | 1949 | 2.4754             | 2.5136                  | 0.9954          |
| Landscape space    | 1978 | 2.4786             | 2.6174                  | 0.7926          |
|                    | 2019 | 2.2716             | 2.5047                  | 0.9701          |

Figure 10 Analysis of the intelligibility of spatial nodes in Zhangye historical area.

According to the actual investigation, it can be found that the spatial characteristics reflected by the historical area syntax parameters are consistent with the actual situation. The integration degree and intelligibility of the node space affect the parameters of the surrounding space. However, the modern traditional historical city update weakens the identifiability of the node space itself, considering only the connection function or other relatively single functions [5]. If the node space is designed reasonably, the degree of recognizability is increased, and it has certain control ability and guiding role in the actual space development, which has positive effects for traditional urban renewal.

6. Research on the Protection and Sustainable Development of Zhangye historical area

Based on the topological analysis and Research on the different periods of spatial form characteristics of the historical area of Zhangye, this paper demonstrates the change process of spatial form in the transition from “traditional” to “contemporary” in the historical area of Zhangye. In the process of urbanization of the famous historical and cultural city of Zhangye, the modern cultural space is put into the traditional space, which presents the problems of vitality of spatial form and change of spatial cultural characteristics. This paper puts forward several viewpoints on the syntactic measurement of the spatial morphology of ancient cities.
6.1. Optimize the road network structure of the historical area and increase accessibility.  
For the road network structure, the biggest difference between the traditional city and the modern city is the street function design and the road network structure planning. From the perspective of road network connection, in addition to the traditional axis of North-South street, east-west street, democratic East-West Road, youth east-west road and County Government Street, most of the other historical streets are End Road, which has a low degree of integration and discrimination. The cut-off road will limit the direction of progress, while the connectivity road increases the optional of the road, which significantly improves the accessibility and cognition of urban spatial nodes. Therefore, on the basis of retaining the traditional pattern of the road network, the communication and connection of some broken roads in the historical area can improve the accessibility around the site, optimize the hierarchical relationship between the road network branch and the main road, and increase the accessibility between the spatial nodes and people in the historical area street.

6.2. Increase the diversity of the traditional space nodes in the historical area and increase the degree of recognition of the historical area.  
Through syntactic analysis and graphic interpretation, the public space of zhangye historical area presents a multi-center distribution connected by paths. In addition, the way of life and spiritual pursuit of change in the original space node transpose function, resulting in a loss of historic blocks to zhangye city control, the traditional public space and commercial space in the city, the historical area of internal nodes space accessibility is homogenizing, some historical street roadway clustering gradually weakened, such as the temple lane, warehouse gate street, etc. Therefore, under certain conditions, we need to redefine the historical street and lane resources to increase the recognition degree. In the traditional public space node, by highlighting its cultural characteristics, integrating relevant resources, promoting the diversification of functions, and enhancing its status and role in the urban space system structure, we need to show a stronger cohesion effect.

6.3. Explore the historical and cultural connotation of the potential historical area, and enhance the attraction of the traditional public space of the historical area.  
As the historical intersection of “Juayn ancient road” and "ancient silk road", zhangye has accumulated a large amount of natural and cultural heritage in the process of long-term historical development. On the one hand, local residents can strengthen their awareness of traditional culture protection through policy guidance; on the other hand, urban silk road cultural form can be integrated into modern life through digging into the historical and cultural connotation of the historical area, especially the combination of material and non-material culture. Through the historical and cultural experience, increase the vitality and attraction of traditional public space. For example, there are still a lot of historical and cultural allusions happened in wenmiao alley during the Ming and Qing dynasties. Therefore, we can promote the spread of traditional culture through street plays, tea house story-telling and other forms. While paying attention to the fabric relationship of the historical area, it is helpful to avoid one-sided and single emphasis on material space elements or historical and cultural elements, which is of positive significance to the sustainable renewal, overall protection and development of the historical area of zhangye of the silk road culture.

7. Summary  
Zhangye is one of China's famous historical and cultural cities. Protecting its material and intangible cultural heritage is an inescapable historical responsibility of the contemporary people. As an important city along the cultural section of the silk road in Gansu, the morphological evolution of Zhangege historic city is the result of the interaction of multiple factors. This paper combines quantitative and qualitative methods. Through the analysis of the evolution of the space structure of Zhangye historical area and the dynamic changes of important space nodes. On the basis of continuing the development morphological of the historical area, the paper proposes strategies for optimizing the road network, improving the
traditional space integration degree, and excavating the cultural connotation of the historical area in order to promote the development of Zhangye historical area tourism economy and culture.

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