Z E S Z Y T Y N A U K O W E P O L I T E C H N I K I P O Z N A Ń S K I E J
Nr 14 Architektura, Urbanistyka, Architektura Wnętrz 2023
DOI: 10.21008/j.2658-2619.2023.14.12

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RESEARCH ON THE CONSERVATION AND RENEWAL OF THE TRADITIONAL SETTLEMENTS OF DIQIANG ETHNIC GROUP IN WESTERN SICHUAN BASED ON A QUANTITATIVE FORM ANALYSIS

Focusing on the traditional settlements of Diqiang Ethnic Group in Western Sichuan, the present study analyzes the settlement forms quantitatively from three aspects: boundary pattern, plane structure, and vertical space, aiming to form a data interval describing the characteristics of the mountain settlements and presenting them in three-dimensional space. This data interval can be transformed into parameters that can be evaluated and used and can help to retain the characteristics of the settlement forms, to pin down the unchanging factors in the evolution of the settlements, to promote the conservation of the settlement forms and to explore the construction strategies consistent with the characteristics of the settlements in the process of conservation and renewal.

Keywords: quantitative form indicators, boundary pattern, plane structure, vertical space, conservation and renewal strategies

1. REVIEW OF THE STUDIES ON TRADITIONAL SETTLEMENTS OF DIQIANG IN WESTERN SICHUAN

Most scholars have studied the forms of the traditional settlements qualitatively by means of induction and classification from the anthropological and sociological perspectives. With the introduction of new methods such as GIS and space syntax, researchers in the eastern region of China has gradually turned to the mathematical analyses and quantitative researches on the forms of the traditional settlements,

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expecting to update the research methods on the basis of theoretical experience [Wang 2013] studied the boundary pattern of traditional settlements such as Xidi and Hongcun in the east, and concluded three characteristics of the settlement boundaries: complexity, ambiguity and boundary effect [Wang 2009] converted the space composition of traditional settlements into mathematical models, which also put forward the index representing the space structure of the settlement with a multidimensional matrix diagram by looking for the relevant geometric quantitative relationship from the configuration diagram of the settlements [Mao 2019] confirmed the fractal isomorphic idea that the traditional settlements conformed to the topography and echoed the similarity and fusion of the landform in terms of their direction, form and scale based on the Box Dimension method [Yang 2015] obtained the data of the graphic characteristics of the traditional settlement boundary through the analysis of the shape index of the rural settlements in Qiongbei area, thus summarizing the graphic characteristics of the traditional settlement boundary and the factors influencing them. In particular [Yang 2015] analyzed the influences of important nodes on the settlement forms by the shape index of settlements and the demi-dimensionality of settlement space [Zhou 2019] established a quantitative index system representing the formal characteristics of the settlements three-dimensionally according to the plane space, the vertical space and the architectural chaos of the mountain settlements, so as to comprehensively describe the overall characteristics of mountain settlement forms and to form a scientific method to describe the forms of the settlements either two or three-dimensionally with quantitative indicators.

The Diqiang ethnic group in western Sichuan includes Tibetan, Qiang, Yi and other major ethnic minorities distributed in the high-altitude areas of Sichuan. In the process of development and evolution of the traditional settlement form in this area, the settlement forms tend to be stable in the process of continuous adaptation and transformation to the environment. Compared with the plains, the mountain settlements in the Diqiang region of western Sichuan rely on a more complex and diverse topography and hydrological environment, giving birth to a three-dimensional settlement space model and a multi-ethnic culture. Such settlements without standard planning show diversity and vitality. Studying the plane structure of traditional settlements quantitatively is conducive to accurately identifying the cultural features of the settlement space forms, analyzing the different types and space laws of settlement forms, and providing scientific support for the conservation of the regional cultures and cultural heritage, so as to pass down the local cultures, preserve the historical forms, and protect the connection between material space and cultural landscape.

2. QUANTITATIVE ANALYSIS OF THE ETHNIC SETTLEMENT FORMS IN WESTERN SICHUAN

Combined with six batches of traditional Chinese villages in western Sichuan, the present study finds the important indicators that affect the settlement forms, and presents a quantitative analysis of the boundary pattern, the plane structure and the vertical space of the settlements. The research framework are summarized and presented in Table 1.

Table 1. The important indicators that affect the settlement forms, and presents a quantitative analysis of the boundary pattern, the plane structure and the vertical space of the settlements

Description Factor	Explanation	Quantifying Index	Definition	Significance
Plane Boundary	The area enclosed by the boundary of the outermost building of the settlement. Due to the different topography, river distribution, religious belief, etc., the settlement boundary shows irregularity, the space layouts of the settlements are at random and are determined by the geographical conditions.	Aspect ratio	The aspect ratio λ is an indicator to determine the narrowness of the settlement boundary pattern, showing the development direction of the settlement master control pattern: λ=L/W (L is the length of the settlement boundary presented in an enclosed figure, W is the width of the boundary outer rectangle).	Through a quantitative analysis of the boundary, the type of a particular settlement can be determined and its shape characteristics can be quickly evaluated. Based on this, three types of settlement forms are quantitatively determined: linear, radial, and clustered.
		Two-dimensional shape index	When the area is the same, the degree of boundary tortuousness is judged according to the ratio of the perimeter. $S = P/p\_0 = P/(1.5\lambda - \sqrt{\lambda} + 1.5)\sqrt{(\lambda/\pi A)}$ (P is the actual perimeter of the boundary under a certain field of view; P0 is the perimeter of the ellipse under the same area and the same aspect ratio in the same field of view; S is the shape index under this field of view)	The boundary complexity of the settlement is judged and measured by this index, which reflects the degree of the complexity of the boundary and that of the integration of the settlement with the surrounding environment. The smaller the index is, the less complex and rough the boundary is; the larger the index is, the more complex and more tortuous the boundary is.

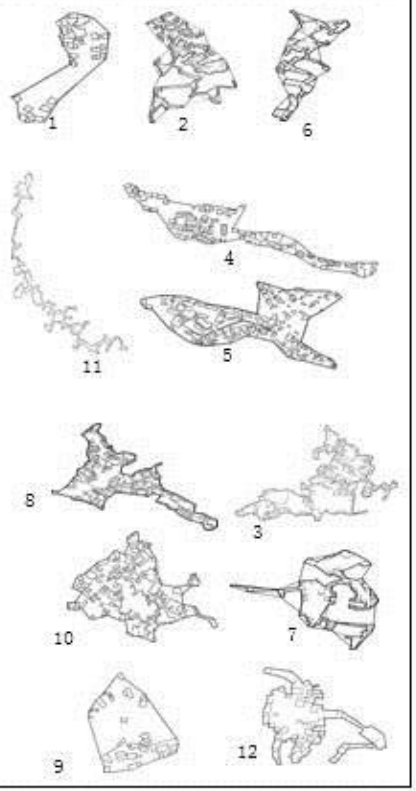
Table 1 – continue

Description Factor	Explanation	Quantifying Index	Definition	Significance
Plane Structure	This includes roads, nodes, areas, boundaries, signs, and so on. It describes that the settlement construction takes the initial site selection as the occurrence point, and connects the various blocks of the settlement construction with the street space as the channel axis, reflecting the development direction and mode of the settlement.	Building density	Reflecting the density of buildings in a certain area. The closer the buildings are to each other, the greater the density in the area, and the closer the correlation between the building units.	Describe the degree of congestion inside the settlement and the continuity and structural characteristics of the settlement space, the greater the building density, the stronger the sense of space and continuity.
		Box dimension	$d = \lim_{x \to 0}[\log N(x) / \log\left(\frac{1}{\varepsilon}\right)]$ *ε is the length of a single square, N (ε) is the number of small squares covered by the graph, and d is the fractional dimension value; N(ε) and 1/ε the number required to cover a line segment per unit length N (ε) = 1/ε, the number required to cover a square with a unit side length N (ε) = (1/ε) 2, the number required to cover a unit of side cube N(ε) = (1/ε)*	The fractional dimensional values reflect the degree of irregularity and self-similarity of the building filling capacity and space complexity to the bottom of the settlement map. It is used to determine the degree of complexity of the building pattern spot.
Vertical Space	The quantitative expression of the topography of the settlement base site determines and limits the development scale and the trend of the mountain settlement. It is the important reasons for the formation of the settlement patterns and the characteristics of production and lifestyle	Surface roughness	The mean of all slopes in the zone after positive secing calculation is a function of slope; The geological significance is that it can express the difference between the real area of the surface and the vertical projection area; T = 1/cos(slope* П/180) = sec (slope* П/180) in which T is the surface roughness, slope represents the calculated slope value, and sec is the sec function.	An indicator that reflects the fluctuations of the earth's surface
		Relief amplitude	The difference between the maximum elevation and the minimum elevation in the area; R = Hmax-Hmin formula, where R is the undulating degree of the terrain, Hmax is the maximum elevation in the region, and Hmin is the minimum elevation value in the region	A quantitative indicator that describes the formal characteristics of the topography.

Based on this framework, the settlement forms were quantitatively studied from closed plane figure enclosed by the boundary, the spot relationship of plane figure and fluctuation degree of vertical space in the mathematical sense. Numerical results and settlement plane pattern that could describe the characteristics of settlement forms were obtained (Table 2).

Table 2. Describtion of the characteristics of settlement forms

No.	Name of settlement	Aspect ratio	Two-dimen-sional shape index	Buil-ding density	Box-counting dimen-sion	Degree of relief	Roughness of surface	Traditional settlement plane figure
1	Changde Village	4.20	3.05	0.25	1.14	1.7220	1.0546	
2	Dabie Village	2.13	3.19	0.29	1.48	2.3435	1.0703	
3	Ganbao Tibetan Village	1.55	2.67	0.35	1.57	1.2314	1.0215	
4	Jiazu Village	3.98	2.45	0.34	1.27	1.4451	1.0337	
5	Luobo Village	1.89	2.74	0.43	1.51	1.0204	1.0121	
6	Qiwan Village	2.58	2.62	0.35	1.33	1.1749	1.0157	
7	Ranliu Village	1.17	2.86	0.24	1.21	0.6536	1.0057	
8	Sergu Tibetan Village	1.77	2.65	0.31	1.46	2.0492	1.0429	
9	Siwa Village	1.34	2.35	0.33	1.17	1.3890	1.0330	
10	Taoping Qiang Village	1.27	1.90	0.47	1.61	1.2188	1.0146	
11	Zhuwo Village	2.80	3.18	0.40	1.41	1.0869	1.0153	
12	Zhuokeji Tibetan Vill	1.49	1.98	0.40	1.50	0.7740	1.0073	



Through space interpretation of mathematical parameters in the field of architecture, which is obtained in the quantitative discussion of settlement forms, the comprehensive research and analysis of settlement space forms is completed. It can be seen that plane boundary and vertical space are factors reflecting the landscape pattern of traditional settlements and the degree of compatibility with nature. Building density and box dimension are important indicators to reflect the influences of settlement space texture and public buildings inside the settlement on internal space forms. As can be seen from the table, the description objects of external forms of settlements – plane boundary and vertical space, show great complexity. The median value of their limit aspect ratio is 1.5. If the value is larger, the settlement is clustered; if smaller, it is linear. The larger the two-dimensional shape index is, the higher the complexity and tortuousness of boundary figure are. In the analysis of space forms inside the settlement, the greater the building density is, the more space the buildings occupy. The larger the fractal box dimension is, the more chaotic the layout of architectural plane spots is and the higher the complexity of the inner space of settlement is. Through the probability distribution of building density obtained by calculation of settlement density and the normal distribution, the distribution characteristics of regional settlement buildings and the dispersion degree of settlement center can be understood.

3. THE CONSERVATION AND RENEWAL OF DIQIANG SETTLEMENTS IN WESTERN SICHUAN BASED ON A QUANTITATIVE FORM ANALYSIS

Some data indexes obtained by quantitative analysis of settlement forms are applied in the conservation and renewal of settlements, such as division of the existing traditional settlement plane type, control of conservation scope, street and lane scale, and control of density, space forms and space boundary of updated and new buildings. This can effectively ensure that the key characteristics of settlement forms are maintained in the conservation, development and construction, and that the style authenticity is achieved in the process of evolution and renewal. The application strategies of this working framework are shown in Table 1.

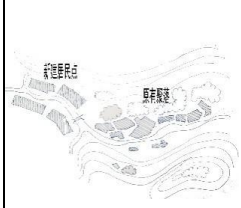
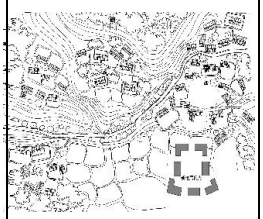
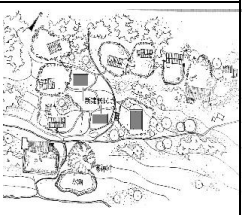
3.1. Analysis and space development strategies based on settlement form types

In the study of settlement boundary pattern the basic space form of closed plane figure formed by settlement boundary and the tortuousness and complexity of boundary are defined by aspect ratio of outer rectangle λ and two-dimensional

shape index, which reflect the characteristic existence of settlement boundary. The forms of Diqiang settlements in western Sichuan are complex and diverse, which are greatly influenced by landscape relationship and the change of cultural and folk customs, thus presenting different space shapes. Through quantitative analysis of aspect ratio of settlement boundary and two-dimensional shape index, settlement form types can be determined and the shape characteristics can be quickly evaluated. Settlement forms can further be classified into four types: radiation type of mountain plain, deep valley belt type, hillside cluster type and loose type of mountain plain (as shown in Table 3).

The conservation of landscape pattern of western Sichuan Diqiang traditional settlements includes relative positional relationship between landscape and settlements and site selection, the sight corridor between villages and surrounding landscape, and the defense system and disaster prevention system formed by combining the landscape. The two-dimensional shape index limits the size and characteristics of settlement space forms, and also shows the integration degree between settlements and surrounding environment. Landscape pattern reflects the internal and external physical space agglomeration of traditional settlements and historical towns at the macro level, including external natural environment such as mountain shape and water system, rivers and streams, as well as internal artificial environment such as contour axis and road network. In the process of conservation and renewal, it is necessary to evaluate the original natural background conditions, explore the dialogue between space pattern and macro landscape topography, and find its growth vein and mode. In the process of settlement expansion and development, the layout of new land should emphasize the coordination with the overall structure and growth logic of existing settlements. For deep valley belt type, it is advisable to develop new land in accordance with the ecological corridor, and form an integrated and naturally growing landscape space pattern.

Table 3. Diagram of development strategies of different settlement form types

Radiation type of mountain plain	Deep valley belt type	Hillside cluster type	Loose type of mountain plain
			

For the loose type of mountain plain, it is appropriate to make use of every tiny space to distribute new houses, consistent with the old houses in style, without changing the settlement boundary to enhance its compact degree for intensive land use. For the radiation type of mountain plain, since development space is relatively ample, and villages are more likely to be expanded. The hillside cluster type is restricted by external landscape pattern and internal factors of cultural customs, and its space form is relatively intact. It is advisable to maintain the characteristics of cluster development so as to avoid the pressure on the ecological environment caused by concentrated contiguous areas.

3.2. Conservation of the space contour lines of the traditional settlements

Through the above analysis of the vertical space of the settlements, it is found that the space features of the Diqiang settlements in western Sichuan highlight the coupling relationship between the settlements and the natural topography, and the role of landmarks such as watchtowers and boulders in strengthening the space contour lines 3.of the settlements, thus reflecting the humanistic connotation. In the conservation of the space contour lines of the settlements, the natural landscape characteristics of the mountains should be strengthened, the natural areas should be preserved in their original states, the function, scale and intensity should be strictly controlled, and the coordination between the local artificial development areas and the natural environmental protection should be emphasized. The conservation and control of architectural contour lines, including mountain lines, water borderlines and building contour lines should be strengthened, the conservation and control of mountain contour lines should be strengthened, the conservation and utilization of river water lines should be strengthened, and the architectural contour lines and natural contour landscapes with distinct layers and undulating conditions should be maintained. In the conservation of mountain lines, important mountain contour lines and commanding heights with cultural connotations should be strictly protected, as well as the mutual-view corridors among the mountains and between the mountains and the villages and towns. In the conservation of the water borderlines, the relationship between the waterfront area of the building complex and the natural water bodies should be maintained as much as possible, and important natural elements such as green plants, tidal flats and moraines in the waterfront area should be conserved. In the conservation of architectural contour lines, the commanding heights of the building complex, the space positions of important buildings in the group, and the platforms, roofs and other spaces with viewing functions in the mountain building complex should be mainly conserved (as shown in Table 4).

Table 4. Analysis of the Conservation Points of the Space Contour Lines of the Typical Traditional Diqiang Settlements

Ganbao Tibetan Village	Taoping Qiang Village	Songgang Chieftain Tibetan Village
		
Protect the contour line and the counterpoint relationship between the watchtower and the isolated peak; protect the steep cliffs and the vertical greening between the upper and lower villages.	Protect and control the counterpoint relationship between the two watchtowers and the back mountain; protect the prominent roof terraces between the watchtower groups.	Protect the space relationship between the two watchtowers and the Tuwu Mountain in the Chieftain Tibetan Village; protect the vertical drop between the watchtowers and the residential groups.

3.3. Conservation of the Integrity and systematic ness of the space structures of the traditional settlements

The formation of the internal planar structure of the settlement is a natural evolution process from disorder to order, and it develops spontaneously to a stable structural state on the basis of the production and living needs, culture and Feng Shui concepts and other factors of the local ethnic groups. The streets and alleys, the shapes of settlement edges, the topography, the ethnic and religious culture, and the climatic conditions influence the formation of settlement planes. The box dimension reflects the self-similarity between the space layout of the building units, public places and main roadways inside the settlement and the growth of the settlement in the natural environment as a whole. The greater the building density is, the stronger the sense of space and continuity is and the stronger the structural features are.

In the historical evolution, the street and alley spaces of the traditional Diqiang settlements in western Sichuan are important factors that constitute the space framework of the settlements. Therefore, in the settlement protection, the protection of street and alley spaces helps to establish the authenticity of the space structure. The rich and diverse street and alley spaces such as hill-climbing streets and half-side streets constitute an important part of the traditional characteristics of the traditional Diqiang settlements in western Sichuan. There is a close correspondence between the trends of traditional streets and the surrounding mountains and water bodies, forming a unique cultural landscape. The conservation of streets and alleys focuses on their structures, trends, widths and the scales of buildings. The location and space of the religious buildings such as the Tu Lord Temples and Mani piles in the settlement, as well as public buildings such as watchtowers and dry bridges, reflect the historical development of the settlements and have rich cultural content. The focus of its conservation is to maintain the relative position and space field of the important buildings, and to sort out the paths to these important buildings in the villages and towns.

In the traditional settlements, the strong vitality of the public area composed of temples, Feng Shui trees and field dams lies in the mixture of its space use. Under the seemingly chaotic appearance, various functions support and supplement to each other to form a strong stability. However, in the development and construction of the traditional settlements, the requirements of the control indicators such as the fire separation distance between buildings, the high green rate, the low building density and the low plot ratio are inevitably difficult to conform to the space texture of the traditional streets. In this case, taking the quantitative index value of the traditional settlement form as the goal and the inheritance and continuation of the history and culture as the starting point, it is of great help to emphasize the continuation of the traditional texture and scale while meeting the requirements of modern space use.

Table 5. Comparison of Quantitative Data of Space Texture and forms in Taoping Qiang Village

	The Old Taoping Qiang Village			The New Taoping Qiang Village		
Planar Layout						
Space form						
	aspect ratio of the external rectangle	two-dimensional shape index	building density	box dimension	surface roughness	relief amplitude
The New Village	1.72	1.57	0.57	1.70	1.0224	1.1139
The Old Village	1.27	1.90	0.47	1.60	1.0146	1.2188

Due to the needs of commercial tourism development functions, the Taoping Qiang New Village adopts a large space throughout the whole ground floor, and the second and even partial third floors connect the scattered volumes to each other through the arcades and corridors to form a rich pedestrian system, corresponding to different space use and combination. The space texture simulates the row upon row of houses in the old villages and the cluster layout centered on the watchtowers, which allows the settlement space to continue. Based on the empirical calculation, the difference between the building density and the value of box dimension between the old and new Taoping Qiang Village is very small, which proves that the new village can provide similar space perception experience to the old village (as shown in Table 5).

4. CONCLUSION

The quantitative analysis of the space forms of the traditional settlements is helpful to explore the regional factors of the space structure evolution, thus providing a reference for the conservation of the space pattern and local environment. "Combing the categories, optimizing the evaluation" is the key link in the conservation and renewal of the traditional settlements. Based on the typological resolution of quantitative form analysis, this paper combs the planar characteristics of Diqiang traditional settlement forms in western Sichuan from a scientific perspective, and on this basis puts forward corresponding renewal suggestions, so as to promote the conservation of the settlement patterns and the construction strategies consistent with the type characteristics, to continue the long historical and cultural characteristics of the local area, to highlight the regional cultural characteristics, create a livable and tourist-friendly village space, and to stimulate the growth of the regional economy.

Acknowledgement

The research has been funded by the grant named Planning, Investment and Construction Dynamics of the Logistics Hubs of China Railway Express in Germany and Poland, Research Project of European Research Center of Chongqing Jiaotong University, 2022, Project NO. 2022ESC01 as well it was financialed by the research on the Improvement of International Communication Ability and the Cultivation Modes of Foreign Language Talents , Key Project of the Foreign Language Teaching Research Branch of Higher Education Academy of China, 2021, Project No. 21WYJYZD12.

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BADANIA NA TEMAT KONSERWACJI I RENOWACJI TRADYCYJNYCH FORM OSADNICZYCH GRUPY ETNICZNEJ W ZACHODNIM SYCZUAN W OPARCIU O ICH ANALIZĘ ILOŚCIOWĄ

Streszczenie

Zwracając szczególną uwagę na tradycyjne formy osadnicze grupy etnicznej Diqiang, niniejsza praca analizuje takie formy osadnicze z ilościowego punktu widzenia pod kątem trzech aspektów: modelowego obrysu, płaszczyzny dwuwymiarowej oraz rzutu perspektywicznego (3D). Celem badań jest zebranie danych opisujących cechy charakterystyczne osad górskich i przedstawienie ich w sposób trójwymiarowy. Taki zbiór danych będzie można przekształcić w zestaw mierzalnych parametrów, co umożliwi zachowanie cech charakterystycznych form osadniczych, a także odkrycie czynników, które pozostały niezmienne w procesie ewolucji osad. Dodatkowo badania umożliwią promocję konserwacji form osadniczych oraz pozwolą przeanalizować strategie budowlane, tak by w procesie konserwacji i renowacji osad można było zachować ich cechy charakterystyczne.

Słowa kluczowe: ilościowe wskaźniki form, modelowy obrys, płaszczyzna dwuwymiarowa, rzut perspektywiczny (3D), strategie konserwacji i renowacji