A Study of Negative Space Accessibility of University Campus Based on Spatial Syntax Theory Take Hubei University of Technology as an Example

Xin Zhou(✉), Gewei Zheng, and Yuxiang Cao

Department of Environmental Design, Hubei University of Technology, Nanli Road, Wuhan, China
271035600@qq.com

Abstract. Spatial accessibility is one of the important factors to determine whether a space is dynamic or not, and is a measure of effective infrastructure configuration. The study of accessibility of negative spaces on university campuses can activate the campus negative spaces and enable equitable access to infrastructure for different populations. This paper takes the campus negative space of Hubei University of Technology as the research object, and uses spatial syntax theory and Depthmap software to conduct an in-depth quantitative analysis of the integration and comprehensibility parameters of the campus negative space and conclude that the global integration degree varies significantly, the local integration degree is high and the comprehensibility level of the campus negative space is low, so as to provide reference for future campus construction and renewal development.

Keywords: Campus Negative Space · Spatial Syntax · Accessibility · Integration · Comprehensibility

1 Introduction

The campus is an important carrier of higher education, and the quality of high campus space is one of the important factors affecting the level of higher education. The teachers and students on campus are the main users of campus activity space. Most of the campus spaces only take into account the use of some functions and do not pay attention to the real needs of teachers and students. As the interaction pattern of teachers and students in modern universities changes and the time for study and rest is fragmented, it is difficult to meet the requirements of diversified uses with a single function and gradually forms a negative form of space that no one cares about. Such spaces are scattered in all corners of the campus, which have damaged the quality of campus space to different degrees and reduced the comfort of campus environment. The accessibility of space plays a crucial role in the revitalization of public space, and how to use the accessibility of space to activate negative spaces and meet the needs of users has become an important way to transform and utilize space. This paper uses the theory of spatial syntax to quantitatively

K. Subramanian et al. (Eds.): CTMCD 2022, ACSR 99, pp. 678–688, 2023.
https://doi.org/10.2991/978-94-6463-046-6_79

analyze the accessibility of negative spaces on college campuses and study the structural relationship between negative spaces and the overall campus space in order to improve the quality of campus public spaces and better guide the overall development of college campuses.

2 Related Concepts

2.1 Negative Space on Campus

The concept of "negative space" was first introduced by Japanese architect Yoshinobu Ashihara in his book "Design of External Space". Yoshinobu Ashihara defines negative space as "when external space is framed and centripetal order is established, the space becomes a positive space that satisfies human intentions and functions. Conversely, the infinite extension of nature is centrifugal space, which can be defined as negative space" [5]. According to Yoshinobu Ashihara, the centripetal nature of space has a certain positive effect on the use, positive and negative are both relative to the person, and positive space satisfies the person's intentions and needs. There are two main reasons for the formation of negative space on campus. On the one hand, large-scale campus construction emphasizes large-scale planning and design, neglecting appropriate scales for faculty and student activities, resulting in many spaces initially designed for users not being fully utilized, inaccurate positioning of space functions, small service radius, and lack of humane design. On the other hand, the complexity of the behavioral activities and psychological needs of modern university students and teachers have led to a disconnect between the design of university campuses and the actual needs of campus life, resulting in the emergence of spaces that are not integrated into campus life and lack of vitality. There are four reasons for the formation of negative spaces on campus: 1. Weak accessibility of the space; 2. Lack of attention to the cultural atmosphere of the space; 3. Unclear attributes of the space caused by improper site selection; 4. Inadequate operation and management of the space afterwards. Campus negative spaces can be divided into three types: 1. Spaces with unclear functions; 2. Spaces with negative forms; 3. Spaces with clear and underutilized functions, these spaces are distributed indoors or outdoors. The negative spaces on university campuses covered in this paper are mainly outdoor negative spaces. However, these negative spaces have a certain value in the campus and are important for the improvement of the vitality of the campus public space.

2.2 Accessibility

"Spatial accessibility" refers to the accessibility of a space to other spaces, and is a concept that describes the structural properties of a space. From the perspective of daily transportation, accessibility analysis is a measure of effective infrastructure allocation, and from the perspective of urban planning, accessibility assessment is conducive to deepening the rationalization and fairness of urban public service facilities.

3 Spatial Syntax Research Methods

Spatial syntax is a theory and method for studying the relationship between spatial organization and human society through the quantitative description of the spatial structure of human settlements, including buildings, settlements, cities and even landscapes. Spatial syntax was proposed by Professor Bill Hillier and his research group at Barrett College, University of London. The entry point of spatial syntax theory is to "go back to space itself" [1]. The core concept is configuration, which Hillier defines as "a system of mutually independent relations, each of which is determined by all other relations", which is in fact a connection between material or immaterial forms [2]. In linguistics, the term "syntax" refers to the way in which sentences and clauses are arranged and combined, as well as the laws that control the relationship between the parts of a sentence, but from a spatial point of view, syntax refers to the effective combinatorial relationships between spaces and the fundamental laws that shape them. Spatial syntax decomposes space and abstracts it into axial unit expressions, where axes have the dual meaning of sight perception and motion state - visibility analysis is the basic spatial perception way, while axes are the spatial decomposition mode needed to take the maximum perception of space based on visibility analysis, and axial decomposition means spatial. The axial decomposition implies a dynamic way of maximizing spatial experience for the perceiver. Its calculation method is based on the topological and graphical principles of mathematics, which has the advantage of quantitative analysis.

The main methods of spatial syntax in the specific analysis of spatial morphology are: Axial analysis, Convex space analysis, and Field of view analysis. The important topological morphological calculation parameters of quantification are: connectivity value, control value, depth value, integration value, and Intelligibility.

4 Study on the Negative Spatial Accessibility of Hubei University of Technology Campus Based on Spatial Syntax

4.1 Overview of the Study Population

Hubei University of Technology is the former Hubei Engineering College, renamed Hubei University of Technology in 2004. The overall planning pattern of the campus is in the form of grid streets, and the campus roads are in the form of horizontal and vertical. The campus landscape is a garden-style campus landscape, covering an area of more than 1,400 mu, with a building area of more than 1 million square meters. The campus is adjacent to Wunan Road in the south, Nanli Road in the east, and Wuhan Metro Line 7 in the east. There are two iconic landscape belts on the campus - the landscape belt of the Xunsi River and the landscape belt of the industrial culture promenade. The campus is planned to unfold along the Xunsi River, which runs through the campus in a north-south direction. The Roushi River landscape belt is located on the east bank of the Xunsi River, from the Houde Bridge at the east gate of the university in the north to the Boxue Bridge in the south, and mainly consists of "three scenes, two pavilions and one pavilion", reflecting the spirit of cultivation in the university spirit. The landscape belt of the Xunsi River is an important place for teachers and students to visit and rest.

Fig. 1. Map of Hubei University of Technology campus.

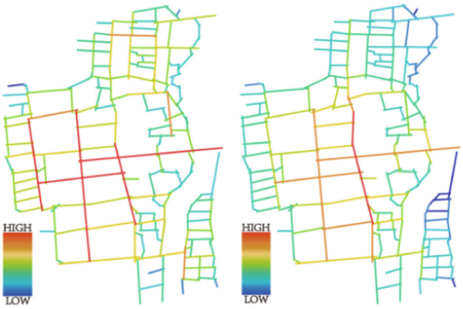
The Industrial Cultural Promenade is another landmark cultural landscape of Hubei University of Technology, located on the third north-south main road of the campus, with the main east-west axis of the university compared to the library, the overall landscape presents "one belt with five scenes". The industrial promenade is deeply integrated into the adjacent campus buildings, landscapes and roads, interacting with visitors and becoming an open-air museum displaying the achievements of Chinese and foreign industrial civilization by integrating culture, art and education. The campus road system is a grid pattern, with the library and the central square in front of the library as the center, extending in all directions to connect the college office buildings, teaching units, sports venues, administrative offices and student dormitories. The campus is designed with a variety of open spaces (Fig. 1).

4.2 Research Data Collection

The data required for the study were collected from the CAD mapping of Hubei University of Technology campus, Baidu map image data and the site survey to determine its authenticity and then selected, screening out the negative space (the open space on the north side of the library) caused by the uncompleted or closed, and finally sorted out 20 negative spaces on campus as the research object (see Table 1). According to the requirements of Depthmap software, we drew the axis map and imported the spatial axis map into Depthmap software to analyze each axis, and calculated the axis syntax related variables to get the data.

4.3 Integration-Based Data Analysis

Integration Rn reflects the degree of aggregation or dispersion of a unit space with all other spaces in the system. The larger the integration value, the higher the core position of the space in the system, the stronger the aggregation force and the stronger the ability of self-organization to expand outward, the closer it is to other spaces, the less there are obstacles between them affecting their connection, the greater the convenience, and vice versa [4]. Local integration (Integration R3) reflects the relative accessibility of an axis



Integration[HH]R3 Integration[HH]

Fig. 2. This caption has one line so it is centered.

Table 1. Statistics of the distribution interval of the negative spatial integration degree.

Global integration degree		Local integration degree	
Maximum value	1.326	Maximum value	2.656
Minimum value	0.457	Minimum value	0.333
Average value	0.815	Average value	1.486
Number	190	Number	190
< 0.544	7	< 0.566	1
[0.544,0.631]	20	[0.566,0.798]	5
[0.631,0.717]	26	[0.798,1.030]	19
[0.717,0.804]	40	[1.030,1.263]	34
[0.804,0.891]	43	[1.263,1.494]	44
[0.891,0.978]	21	[1.494,1.726]	39
[0.978,1.065]	15	[1.726,1.959]	25
[1.065,1.152]	10	[1.959,2.191]	14
[1.152,1.239]	6	[2.191,2.423]	4
> 1.239	2	> 2.423	5

to other axes within a distance of topological radius or more, the degree of aggregation or dispersion of a unit space from other spaces within three steps or other steps of the unit space [6]. The concept of integration degree in spatial syntax is one of the variables that quantitatively describes the properties of spatial structure in conformational analysis, and it describes the degree of integration between space and its surroundings in a topological sense; higher integration degree means stronger spatial accessibility, so the accessibility of campus negative space is evaluated by integration degree in this paper. The spatial structure of Hubei University of Technology campus is quantified and analyzed by Depthmap software to obtain Fig. 2.

The results of the spatial axis integration of the campus are shown in Table 2. The highest value of global integration degree is 1.326, the lowest value is 0.457, and the average value is 0.815; the spatial structure of the campus is extended in a grid pattern as the basic unit. The area with the highest spatial integration degree is the library, the central playground and the industrial culture promenade, which are mainly enclosed by the east-west Central Avenue, the industrial culture promenade and the north-south Industrial Road 6, Industrial Road 5, Industrial Road 4 and Morning Road, which are also the roads with a high degree of aggregation in the whole campus; in terms of spatial layout, this area is also the central area of the spatial pattern of the whole campus, with a relatively In terms of spatial layout, this area is also the center of the spatial pattern of the campus, with a complete road system and a clear spatial structure; therefore, it forms the core of the spatial structure, which means that it has the strongest spatial penetration and integration, representing the most central area in the syntactic sense, and is also the most dynamic area. In the northwest, northeast and southeast corners of the campus, the axes are in a cool color, and the blue color shows that the integration is low here; the southeast area of the campus is the student dormitory area of Strawberry Park, which is located on the east bank of the Xunsi River and connected to the main campus through the Boxue Bridge. The layout structure of the dormitory buildings takes the form of joint rows, with moderate building density and regular roads, and the overall spatial structure adapts to the regional topography, while organically integrating with the whole campus structure to create different spaces. The analysis of the local integration degree of the campus spatial junction is shown in Fig. 4. In this study, the highest value of local integration degree is 2.656, the lowest value is 0.333, and the average value is 1.486 when the number of topological steps is set to 3. The integration degree is reasonably distributed, the layers are overly uniform, and the roads with higher integration degree connect different functional areas to ensure the traffic connection of different areas.

In order to obtain the integration data of the negative space of the campus, the integration data of the axis where the actual entrance is located were taken as the reference, and the maximum, minimum and average values were extracted and distributed in intervals to obtain Tables 2 and 3. The integration of the 20 negative spaces and the axis integration were superimposed to obtain Fig. 3.

From Fig. 2, Table 1 and Table 2, it can be seen that the integration degree of 20 negative spaces on campus is ranked as $7 > 15 > 8 > 19 > 9 > 4 > 12 > 13 > 10 > 20 > 14 > 16 > 5 > 6 > 11 > 1 > 3 > 18 > 2 > 17$, the negative spaces with higher values are No. 7 negative space, No. 15 negative space, No. 8 negative space and No. 19 negative space, which have relatively high accessibility in the negative space of the campus, which is close to the central location of the campus and near the main road of the campus-Central Avenue, No. 7 and No. 15 negative spaces are located in the central area of the campus, there are cafeteria, dormitories, sports venues and college office buildings near this area, which belong to the campus the negative space. No. 15 negative spaces is located near the east gate of the university, adjacent to the main road of the campus, and has a high accessibility. No. 19 is an open space next to the bridge of the East District, which is an essential place for the students and teachers to go. The negative space No. 17 and No. 18 are located in the living area of the East District, and can only be reached by a single road due to the obstruction of the Xunsi River, so their accessibility is low.

Table 2. Negative spatial global integration statistics.

Campus Negative Space Serial Number	Global integration degree		
	Maximum value	Minimum value	Average value
1	0.784	0.620	0.702
2	0.614	0.553	0.583
3	0.737	0.567	0.652
4	1.012	0.716	0.864
5	0.83	0.723	0.777
6	0.83	0.723	0.777
7	1.220	0.911	1.066
8	1.211	1.003	1.107
9	1.031	0.936	0.984
10	0.945	0.881	0.913
11	0.805	0.696	0.751
12	1.007	0.768	0.888
13	1.007	0.845	0.926
14	0.843	0.731	0.787
15	1.219	0.991	1.105
16	0.836	0.798	0.817
17	0.459	0.456	0.458
18	0.616	0.553	0.585
19	1.047	0.913	0.980
20	0.869	0.744	0.807

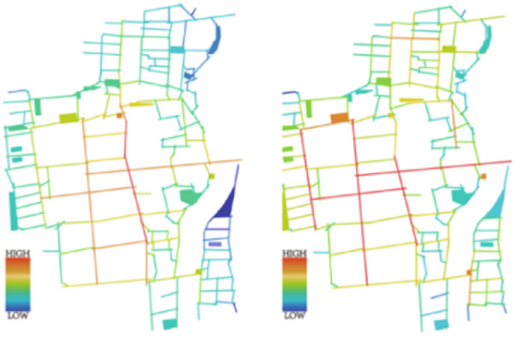
The road accessibility and road view accessibility of this negative space are both poor. Overall, the average global integration degree of the campus space axis is 0.815, and the global integration degree of 14 negative spaces is above the average, which means that the accessibility of the campus negative spaces is reasonable.

4.4 Comprehensibility-Based Data Analysis

Intelligibility is a measure of whether the local spatial structure seen from a space helps to build a picture of the whole spatial system, whether the local space is related to the overall space, and is a variable used to describe the relationship between global and local integration. The level of comprehensibility is represented by the linear regression coefficient R^2 (between 0 and 1) between the two types of spatial variables, and R^2 represents the spatial fit in mathematics. The closer the value of comprehensibility R^2 is to 1, the higher the level of comprehensibility on campus. The linear regression analysis of the global integration degree and the local integration degree was carried out, and

Table 3. Negative spatial local integration statistics.

Campus Negative Space Serial Number	Local integration degree		
	Maximum value	Minimum value	Average value
1	2.063	1.500	1.782
2	1.238	1.224	1.231
3	1.560	1.000	1.280
4	1.930	1.300	1.615
5	1.360	1.255	1.308
6	1.613	1.255	1.434
7	1.978	1.632	1.805
8	1.725	1.238	1.482
9	2.379	1.545	1.962
10	1.821	1.613	1.717
11	1.541	0.947	1.244
12	2.574	1.511	2.043
13	2.574	1.511	2.043
14	1.472	1.849	1.661
15	1.573	1.070	1.322
16	1.206	1.00	1.103
17	0.887	0.861	0.874
18	1.681	1.205	1.443
19	2.222	2.172	2.197
20	1.345	0.887	1.116



Global integration degree Local integration degree

Fig. 3. Negative space integration analysis.

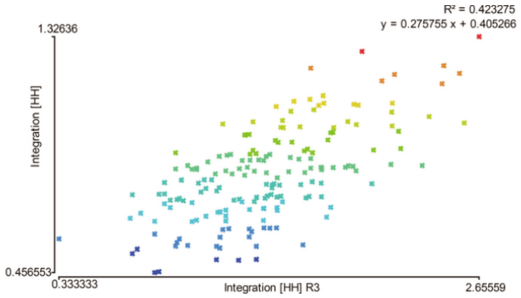


Fig. 4. Negative spatial comprehensibility analysis.

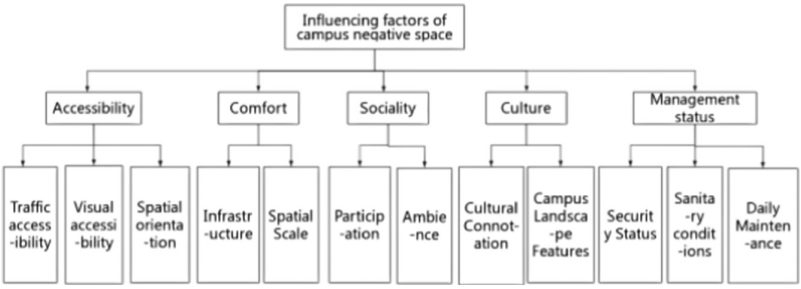


Fig. 5. Influencing factors of campus negative space.

the comprehensibility of the campus axis system was obtained by XY scatter diagram in Fig. 4. It is not clear enough to further feel the overall campus structure through the local space, which is not conducive to the various activities of students and teachers in the campus. If the space is more orderly, the more the local space can be integrated into the overall space, which means that the space is easier to identify and be recognized.

4.5 Building the Model

According to the characteristics and causes of the negative campus space, the evaluation model of the negative campus space is constructed by selecting five primary indicators and 12 secondary indicators, namely, accessibility, comfort, sociality, culture and management status (Fig. 5).

5 Conclusion and Reflection

This paper is a quantitative study of the accessibility of negative spaces on campus, which is related to the vitality of negative spaces and whether they can function appropriately. In terms of the whole campus, there are many problems in the campus public space, such as poor permeability of negative space, weak accessibility of public space to each other, and low comprehensibility. In this paper, we analyze the negative spaces on the

campus of Hubei University of Technology through global integration, local integration and comprehensibility, and draw two conclusions.

The degree of integration has a certain influence on the distribution of negative spaces on campus. The global integration degree of negative spaces on the campus of Hubei University of Technology varies significantly, in general, the main roads, the vicinity of the library and the central area of the campus have a higher flow of people, and the accessibility of negative spaces located in the central area of the campus is relatively high, such as No. 7, No. 15 and No. 8. Negative spaces near the periphery of the campus have poor accessibility, such as No. 18, No. 2, No. 17 and other negative spaces; the local integration degree has higher values and better accessibility, and the local integration degree of negative spaces shows a trend of high integration degree in the central area of the campus and decreasing toward the periphery of the campus. Different teaching areas are connected by roads with a high degree of integration to ensure the accessibility of each functional area. The negative space near the four dormitory areas is less integrated, less accessible and relatively quiet, which is consistent with the characteristics of the dormitory areas.

(2)According to the previous analysis, R^2(comprehensibility) is 0.423275, the low level of comprehensibility of the negative space on campus indicates that the local space of the negative space has poor correlation with the overall space. The reason for this is that there are public spaces with low utilization rate in the scattered building layout, the overall structure of the campus presents an unbalanced state, the visual accessibility of space is weak, and the similarity of spatial layout is high, for example, the dormitory area adopts an arranged distribution form, which lacks hierarchy and freshness and makes people easily get visual fatigue.

Spatial syntax, as a tool for spatial analysis, is ultimately linked to reflect to the actual economic, cultural and social activities. Through the analysis of the accessibility of the negative space on the campus of Hubei University of Technology, two suggestions are made in relation to the actual situation.

(1)On the one hand, by improving, optimizing and upgrading the negative spaces in the campus, the vitality of the campus open space is stimulated, the sense of belonging and identity of teachers and students is enhanced, teachers and students can experience the campus space better; on the other hand, there are still some plots in the campus that have not yet been built and developed, which can be combined with the results of syntactic analysis to guide the specific development and construction.

(2)It is suggested to renovate and optimize to encourage the occurrence of spontaneous interaction activities between teachers and students, thus improve the quality of the open space on campus. It can be combined with greenery, seats and lawns to create semi-open nook spaces, increase multi-level green landscape design, break the monotony of the original large area of hard paving, and form rich and diverse open communication spaces [2]. Combine with the campus culture of the school to design recognizable sculptures and structures to form a public open communication space with the spirit of place culture.

References

1. Duan Jin, Bill Hillier. Spatial Studies 3: Spatial Syntax and Urban Planning [M]. Nanjing:Southeast University Press, 2007:25-27.
2. Duan Jin, ed. Spatial Studies 14: Spatial Syntax in China [M]. Nanjing: Southeast University Press, 2015, 6.
3. Sheng, Lu-Ming, Wang, Yun. In Search of Lost Spaces: Changes and Development of Spatial Form and Place Characteristics of University Campuses [J] . Journal of Shanghai Jiaotong University, 2007(6): 203–208 .
4. Xu Hui. Research on public open space of campus based on spatial syntax - taking the new campus of Yancheng Engineering College as an example[J]. Chinese and foreign architecture,2019(05):88-90.
5. Yoshiharu Ashihara. External space design [M]. Yin Peitong, Translation. Beijing: China Construction Industry Press, 1985.
6. Zhang Hao. Accessibility analysis of campus green space activity space based on spatial syntax-an example of Wuhan University Informatics Campus [J]. Southern Architecture, 2015(01): 114-118.