Research on site selection of old campus bookstore based on the combination of space syntax and analytic hierarchy process——Take Huangjiahu Campus of Wuhan University of Science and Technology as an example

View the article online for updates and enhancements.

Research on site selection of old campus bookstore based on the combination of space syntax and analytic hierarchy process——Take Huangjiahu Campus of Wuhan University of Science and Technology as an example

Minghui He[1], Hong Xu[1, *], Rui Wang[1], JianJun Chen[1], SiWei Liu[1], TianYue Li[1]

[1]School of Urban Construction, Wuhan University of Science and Technology, Wuhan, China

Email: xuhong@wust.edu.cn

Abstract: The bookstore is an integral part of campus public service, and it is an essential place for reading, learning and spending for teachers and students. Provided the current management and development problems faced by old campus bookstores, this article takes the old campus bookstore in the Huangjiahu campus of Wuhan University of Science and Technology as a research case while uses space syntax theory, Depthmap software, and axis models to analyzes and evaluate accessibility, and then optimize campus old location and layout of bookstores. Simultaneously, by using the analytic hierarchy process, the simulated bookstore sites of selection in the campus are tested at the target level, decision level and plan level. This article aims to propose optimization methods for the management and development of old campus bookstores from the perspective of spatial location selection through qualitative quantification and provide constructive references for similar research.

1. Introduction

In the era of the Internet and the Internet of Things, the physical bookstore has changed from a book trading place to a multi-level, multi-directional, and multi-category cultural experience platform. The campus old bookstore is an essential part of the campus public service space and an important place to meet the reading, learning, and consumption of campus teachers and students. Reasonable site selection on campus is the first step in the operation of campus used bookstores. Whether the site selection is appropriate directly affects the success or failure of the operation. The reasonable location of the campus used bookstore can determine the future vitality of the used bookstore development and is related to the convenience of teachers and students' daily lives. It is an important part of the campus space composition and functional organization. The exploration of simulated site selection can have positive significance for the site selection of campus used bookstores in the future. This article takes the Huangjiahu campus of Wuhan University of Science and Technology as an example, uses spatial syntax and analytic hierarchy process techniques to compare the impact of different site selection schemes on the site selection of campus used bookstores, and analyzes and researches to get the best site selection plan for campus used bookstores.

2. The main factors affecting the location of campus used bookstores

The campus used bookstore has precise service targets, a clear product hierarchy, and distinct functional characteristics: first, the service population is teachers and students on campus, and second, the book

products match the school's teaching characteristics and positioning. Choosing where to open campus used bookstores on campus is the first consideration for operators. Whether the location is appropriate directly affects the success or failure of the [1]operation. Based on the research on the development status of campus used bookstores, this paper finds that there are mainly the following factors in the site selection of campus used bookstores:

(1) Cost The construction scale of the campus used bookstore and the venue's rent determine the higher operating costs. Starting from teachers and students' actual needs, adapting measures to local conditions, and comprehensively considering the cost of the bookstore.

(2) Traffic environment. Whether the campus used bookstore is located in a convenient surrounding traffic environment affects whether the bookstore can develop into a more convenient place for teachers and students to trade used books. The overall traffic environment of the bookstore on campus is an important factor in site selection.

(3) The flow of people. The greater the flow of people, the greater the market space. The campus used bookstore is located in an area with high population density, which can play a good role in gathering energy consumption and identifying consumer groups.

(4) Competitive environment. The campus old book market is a unique market. The dynamics and relative stability of the teachers and students on campus can ensure a good consumption environment, but there are also many campus bookstores, which leads to a high-intensity competitive environment.

3. Definition of related concepts

3.1. Related concepts of space syntax theory

Space syntax is a theory and method to study the relationship between the spatial organization and human society through the quantitative description of human settlements' spatial structure, including buildings, settlements, cities, and even landscapes. Barrett College, University of London developed it. Invented by Bill Hillier, Julienne Hanson and [2]others .Space syntax emphasizes the ontology and importance of space, returning to space itself. The core concept is configuration. Hillier defines configuration as "a set of mutually independent relational systems, and All other [3] relationships determine each relation. Reality is a connection between material form and non-material form; in linguistics, the term "syntax" refers to the arrangement and combination of sentences and clauses, as well as the rules governing the relationship between the various parts of the sentence, but in space From the perspective of, syntax refers to the effective combination relationship between spaces and the fundamental laws that form this [4]relationship. The space syntax decomposes the space and abstracts it as an axis unit expression, where the axis has the dual meaning of a line of sight perception and movement state—visibility analysis is the fundamental way of cognition of space, and axis is based on visibility analysis. Adopt the spatial decomposition mode required to maximize the space's cognition, and the axis decomposition means that the spatial perceiver can dynamically maximize the spatial [5]experience.

The spatial syntax methods in the specific analysis of spatial morphology mainly include the axis model, line segment model, and field of view model. The primary analysis parameters are integration, travel, connection value, control value, depth value, etc. Specific spatial syntax analysis software includes depthmap, axwoman, sdna, etc. This paper mainly uses Depthmap software, uses the axis model, analyzes and evaluates accessibility through integration, and further optimizes the campus old bookstore's location and layout.

3.2. Related concepts of analytic hierarchy process

The analytic hierarchy process is a decision-making method proposed by the American operations researcher Satty in the last century. Its basic principle is to decompose complex issues into different levels according to their main influencing factors, which can be divided into three levels: goals, criteria, and [6]plans. Then, through qualitative and quantitative methods, each level's influence weight on the previous level is obtained, and then the weighted sum is calculated to calculate the weight of each

scheme to the problem so as to provide decision-makers with a basis for decision-making. The specific approach can be divided into four steps:

(1) Establish a hierarchical structure

Clarify the indicators and their relationships at the target level, criterion level, and program level.

(2) Construct a judgment matrix

Index of each level is compared with each other in pairs to judge the mutual importance of the index and use the method of numerical assignment to show it. The scale is based on Table 1.

Table 1. Scale basis table

Scale value	meaning
1	Indicates that the two elements are equally important
3	Indicates that one element is slightly more important than the other
5	Indicates that one of the elements is stronger and more important than the other
7	Indicates that one element is more important than the other
9	Indicates that one element is more important than the other
2/4/6/8	Represents the middle value between the above two judgment values
The above scale is worth counting down	Represents the opposite comparison of two elements

(3) Calculate the index weights of different levels and do a consistency test

First, use the arithmetic average method to calculate the weight vector W. The formula is:

$$\omega_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}$$

Where i=1,2,3,…,n

Then calculate the consistency index CI, the formula is $CI = \frac{\lambda - n}{n-1}$

When CI=0, the matrix shows complete consistency. When the difference between CI and phase is greater, the consistency of the matrix is worse. In order to measure the size of CI, a random consistency index RI is introduced. The standard value of RI is shown in Table 2.

Table 2. Random consistency index table

Matrix order	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Finally, the tested coefficient CR is calculated, and the formula is $CR = \frac{CI}{RI}$

When CI≤0.1, it is considered to pass the consistency test.

(4) Seek the pros and cons of each plan

Calculate the plan layer's combined weight to the overall goal and select the optimal location plan by comparing the combined weight.

4. Simulated site selection of campus used bookstore

This paper selects the Huangjiahu campus of Wuhan University of Science and Technology as the research object. Firstly, it uses spatial syntax to conduct quantitative analysis to determine the suitable location of used bookstores on the campus and determine the site selection plan based on the campus's actual construction situation and the surrounding environment of the location. After initially selecting

the location plan, the analytic hierarchy process is further used to calculate the main influencing factors, and the final location plan is obtained.

4.1. Preliminary site selection based on quantitative analysis of space syntax

This article uses Google satellite imagery as a reference, combined with a Gaode map for supplementary correction, and draws a spatial syntactic axis analysis model for the Huangjiahu campus of Wuhan University of Science and Technology. Although the research area of this article is only on the Huangjiahu campus of Wuhan University of Science and Technology, to improve the accuracy of the axis model calculation, according to the principle of axis model establishment, a 1 km range outside the Huangjiahu campus of Wuhan University of Science and Technology was also drawn to ensure the axis model data. The space is social and scientific.

According to this paper's research needs, the integration degree of space syntax is selected as the main calculation variable. The integration value can directly reflect the degree of agglomeration or dispersion of the designated space and the remaining space in the analyzed system. We quantify the accessibility of a certain location through the overall integration value within the [7]campus. The Depthmap software is used to calculate the overall integration level map and the corresponding numerical table through the establishment of the campus road axis model. The integration level is divided into five sections, from high to low. Generally, the warm colour expresses a high level of integration, and the cold colour on the contrary, can be intuitively understood—accessibility of the road around the location of the old campus bookstore. Locations with high overall integration have strong aggregation of spatial objects and the best accessibility. Otherwise, the opposite is true (as shown in Figure 1).
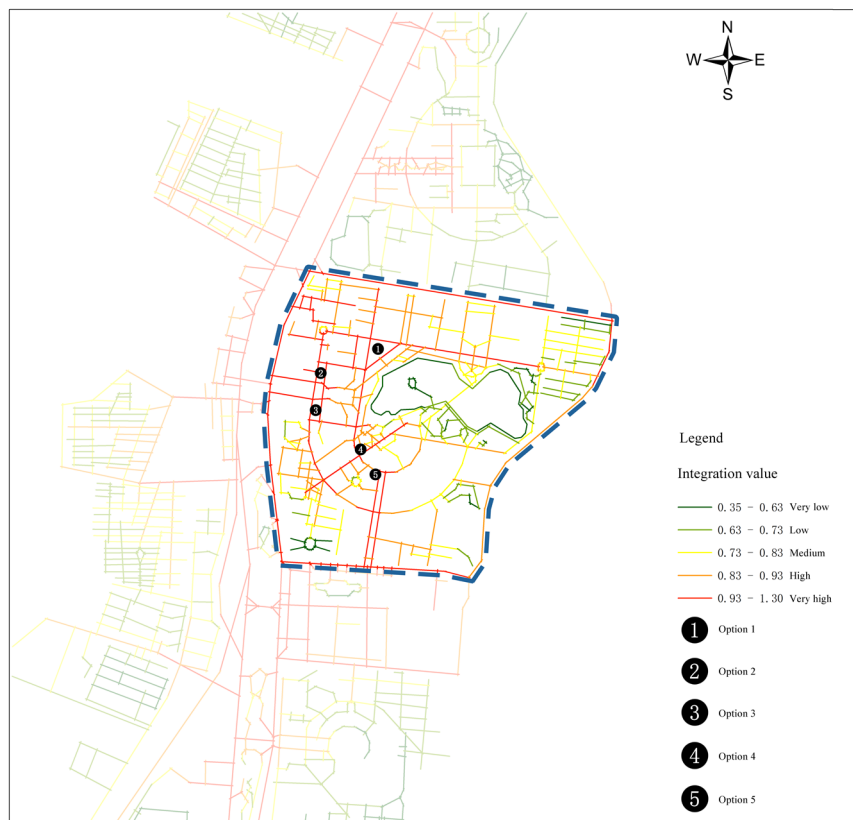

Figure 1. Figure with Campus integration distribution.

According to the analysis diagram of the integration degree of Wuhan University of Science and Technology Huangjiahu campus, this article can find that the red axis indicates that the integration

degree of the area is exceptionally high, and combined with the analysis of the actual construction situation of the campus, five highly integrated scheme locations are initially selected. They are located at the intersection of the second floor of the teaching building and the dormitory of the north area (option 1), the northwest corner area of the first floor of the teaching floor (option 2), the southwest corner area of the first floor of the teaching floor (option 3), and the intersection of the library and the tenth floor (Scheme 4), in the northeast corner of the 9th floor of the teaching area (Scheme 5), the specific characteristics of the addresses of the 5 primary options are shown in Table 3.

Through statistical analysis of the integration value of all axes in the campus (as shown in Table 3), the higher the integration value, the better the accessibility. The campus's average integration degree is calculated to be about 0.779, and the average integration degree can be found. The value is at a medium level; combined with the five primary selection scheme sites' integration degree, the five primary selection scheme sites are all much higher than the overall integration level average of the campus. Overall, the five primary selection schemes' locations are all in a highly integrated position, which meets the intense needs of the campus used bookstore in terms of road traffic environment and human flow.

Table 3. Comparison of integration degree and the average value of campus integration

	Program address features	Integration value	Global integration average
Option 1	Pedestrian recreational green space, located at the intersection of major traffic arteries, with dense road network and high accessibility.	0.963	
Option 2	The affiliated green space of the teaching building is also close to the central square of the campus, and several teaching buildings are adjacent to it.	1.077	
Option 3	The affiliated green area of the teaching building is relatively symmetrical to the second location. The students in the southern district reach the important area where the main teaching building of the campus passes.	1.056	0.779
Option 4	The main intersection of the north and south areas of the campus, and has a good walking and vehicular traffic environment.	0.891	
Option 5	The enclosed teaching area's small plot area is closer to the library, and the road directly connects the south gate of the campus and the surrounding off-campus business circle.	0.880	

4.2. Decision-making site selection based on analytic hierarchy process

4.2.1. Establish a hierarchical structure model. After the initial site selection through integration, considering that the single traffic accessibility index evaluation is not objective enough, the analytic hierarchy process is used to build a model to calculate the main influencing factors and comprehensively select the site. This paper uses the Analytic Hierarchy Process to divide the model into three levels: target level, decision level and program level. The decision level corresponds to the site selection factors that need to be considered, and the program level includes various measures and decision-making programs that can be selected to achieve the goal. At the same time, five pre-selected plots were selected based on the above road accessibility analysis, and four significant factors for the bookstore location were determined based on the situation on the campus of Wuhan University of Science and Technology. Finally, the following hierarchical structure model was established.

4.2.2. Establish judgment matrix and consistency test. In this study, five professionals were invited to give expert scores at various levels. They analyzed five bookstores' location from the four perspectives of cost, traffic environment, the flow of people, and competitive environment, and formed a judgment matrix, and they all passed the consensus. The judgment matrix and weight of each evaluation factor for bookstore location are shown in Table 4. The judgment matrix and weight of each element of the project layer relative to each evaluation factor are shown in Table 5, Table 6, Table 7, and Table 8.

Table 4. Weights of various indicators

Evaluation factor	Cost	Traffic environment	human traffic	The competitive environment	Weight (ω_i)
Cost	1	0.5	0.33	1	0.14114
Traffic environment	2	1	0.5	2	0.26270
human traffic	3	2	1	3	0.45501
The competitive environment	1	0.5	0.33	1	0.14114
λ_{max}=4.01 CI=0.00345 CR=0.00388 < 0.1					

Table 5. Judgment matrix of the traffic environment layer

Traffic environment	Option 1	Option 2	Option 3	Option 4	Option 5	Weight (ω_i)
Option 1	1	0.2	0.33	0.33	0.5	0.48712
Option 2	5	1	2	2	3	0.19144
Option 3	3	0.5	1	1	2	0.19144
Option 4	3	0.5	1	1	2	0.04482
Option 5	2	0.33	0.5	0.5	1	0.08516
λ_{max}=5.3 CI=0.073824 CR=0.065914 < 0.1						

Table 6. Judgment matrix of each element of the cost layer related to the cost

Cost	Option 1	Option 2	Option 3	Option 4	Option 5	Weight (ω_i)
Option 1	1	0.33	0.33	5	3	0.17816
Option 2	3	1	1	4	3	0.33072
Option 3	3	1	1	4	3	0.33072
Option 4	0.2	0.33	0.25	1	0.33	0.05693
Option 5	0.33	0.33	0.33	3	1	0.10345
λ_{max}=5.40 CI=0.098757 CR=0.088176 < 0.1						

Table 7. Judgment matrix of of the human flow layer

human traffic	Option 1	Option 2	Option 3	Option 4	Option 5	Weight (ω_i)
Option 1	1	4	4	2	3	0.42631
Option 2	0.25	1	1	3	2	0.18556
Option 3	0.25	1	1	3	2	0.18556
Option 4	0.5	0.33	0.33	1	0.5	0.08322
Option 5	0.33	0.5	0.5	2	1	0.11933
λ_{max}=5.40 CI=0.100144 CR=0.089415 < 0.1						

Table 8. Judgment matrix of the competitive environment layer

	Option1	Option 2	Option 3	Option 4	Option 5	Weight (ωi)
Option 1	1	0.20	0.33	0.33	0.50	0.06908
Option 2	5	1	2.00	2.00	3.00	0.38690
Option 3	3	0.50	1	1.00	2.00	0.21252
Option 4	3	0.50	1.00	1	2.00	0.21252
Option 5	2	0.33	0.50	0.50	1	0.11898
λmax=5.01 CI=0.00275 CR=0.00245 < 0.1						

Finally, the weight of the overall goal is calculated, and the final weight of each plan is obtained by multiplying the weight of the criterion layer with the weight of the corresponding plan layer. Other schemes are calculated according to similar methods, and the final results are shown in Table 8.

Table 9. Weights of each scheme

	Project location	Combination weight
Option 1	The crossroads of the second floor of the teaching building and the North District dormitory	0.35684
Option 2	The northwest corner of the first floor	0.23601
Option 3	The southwest corner area on the first floor of the teaching	0.21139
Option 4	The crossroads of the library and the tenth floor of the teaching	0.08767
Option 5	The northeast corner of the teaching ninth floor	0.10806

It can be seen from Table 8 that Option 1 has the largest weight, followed by Option 2, Option 3, Option 5, and Option 4 has the smallest weight. Therefore, Option 1 is the best location for the bookstore, and it is in the most advantageous traffic environment. The place with the most traffic.

4.3. Summary of the combination of space syntax and analytic hierarchy process to simulate site selection
Based on space syntax and analytic hierarchy process, this paper conducts an empirical study on the layout of campus used bookstores, taking the Huangjiahu campus of Wuhan University of Science and Technology as an example. Use space syntax theory and Depthmap, and other software to construct and analyze the current situation of the campus axis model, analyze the location of used bookstores on the campus and analyze the global integration degree. The construction situation is compared and referenced, and 5 kinds of suitable site selection schemes for the construction of used bookstores are initially proposed. Then use the analytic hierarchy process to establish a three-level hierarchical model of the target layer, decision-making layer, and plan layer, and then analyze the four angles of the decision-making layer to form a judgment matrix, and then conduct an in-depth comparative analysis of the 5 plans for each factor, and finally select a site selection plan that can better satisfy the campus used bookstore. Spatial syntax analysis provides better technical means for the site selection of campus used bookstores, can quantitatively study the global integration degree in the campus; the analytic hierarchy process further provides in-depth calculation and analysis for the preliminary site selection plan, and can make more intuitive analysis and comparison of the differences in different proposed site selection schemes, and then select the preferred site.

5. Conclusion
This article mainly combines space syntax theory and analytic hierarchy process in the site selection of campus used bookstores. It can better refer to and compare the quantitative and qualitative analysis results of different site selection plans so as to determine the site selection plan of campus used bookstores and try to be on campus. The limited space of the campus makes the site selection and layout

of the campus used bookstore more reasonable, promotes the operation status of the campus used bookstore, and at the same time makes the site selection and planning of the campus bookstore more scientific and practical, and provides a new way for its site selection and layout Ideas.

Acknowledgments

References

[1]   Zhong Xia, Liu Yang, Liu Shanbin. The Development Status and Breakthrough Paths of Campus Bookstore——Taking Xinhua Wenxuan Campus Store as an Example[J]. Publishing Wide Angle, 2020, No.356(02):59-61.

[2]   Zhang Yu, Wang Jianguo. Discuss "Space Syntax" Again[J]. Architect, 2004(3): 33-44.

[3]   Bill Hillier. Space is a machine-architectural fabric theory: Spaceisthe machine:aconfigurational theory of architecture[M]. Yang Tao, Zhang Ji, Wang Xiaojing, translated. China Construction Industry Press, 2008.

[4]   Yang Tao. Shuo Wen Jie Zi: Spatial Syntax[J]. Beijing Planning and Construction, 2008(1): 75-81

[5]   Wang Jingwen, Lei Yun, Liang Zhao. Discussion on the accessibility of multi-scale urban parks based on space syntax[J].Huazhong Architecture, 2013(12): 74-77.

[6]   Xu Shubai. Practical decision-making method: the principle of analytic hierarchy process[M]. Tianjin University Press, 1988.

[7]   Zhao Xiyuan. Research on site selection of primary and middle schools in Chengdu based on space syntax[D]. 2019.