Research Paper

Research on Evaluation and Optimization of Campus-City Boundary Space Based on Symbiosis Theory

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Abstract

With the development of urbanization and transformation of educational philosophy, the relationship between campus and cities have become much closer. As an important public space embedded in the city, the campus boundary space plays a vital role in the connection and communication between campus and city. High-quality boundary space can produce a strong boundary effect to realize the benign interaction between campus and city, and can also promote the common development of each other. Therefore, how to effectively deal with the boundary isolation and penetration relationship is a valuable issue.

This research takes the symbiosis theory as the breakthrough point, takes campus space and urban space as the complete symbiosis system to study the organic integration and connectivity between them. This research summarizes the literature and case data, and analyses under the combination of multi-source big data such as traffic network data and POIs data. Using ArcGIS and depthmap tools, this research extracts eight key factors from three factor layers: openness, penetration and integration. The results of three factor layer make up the evaluation of campus-city symbiosis. Then we study Harvard University and Hunan University boundary space using the evaluation framework. And we try to find the gaps and deficiencies of campus boundary space in China and propose the optimization approaches of boundary space based on the O-P-I theory.

The boundary space is an important carrier for the interaction and communication between campus and city. The organically integrated interface can effectively stimulate the vitality of the boundary space and create a positive and effective cultural atmosphere. This research conducts an in-depth study on the penetration, integration and connection of boundary space, aim to add more potentiality and vitality to public spaces in city.

Keywords

Symbiosis Theory, Symbiosis Evaluation, Campus-city Boundary, Space optimization

1. Introduction

1.1. Trends and challenges of campus-city integration

With the development and transformation of the university running philosophy, the exchanges between campus and cities are becoming more and more frequent. Campus and cities are mutually infiltrated, and the resources are shared. The integration of campus and city is becoming a new development trend. Looking at the world's top universities, they are not only the most famous schools, but also the active areas with the most frequent exchanges of ideas, important research institutions and famous tourist attractions. These universities have played an important role in promoting social development. With the widespread attention of open blocks, the call for universities boundary opening is increasing. However, based on the long-term teaching and management model of Chinese universities, a completely open campus boundary

will interfere with some research and teaching activities, and will also increase the difficulties of management. The key to solving the problem is to find a suitable open area on the boundary and construct a permeable and integrated boundary space.

1.2. Research progress of campus-city interaction

Universities abroad have formed an open pattern in the early progression stage, and naturally formed a good relationship between campus and surroundings. Therefore, many researches on campus-city interaction and integration are concentrated in the fields of sociology (Martin Meyerson et al, 1969; Jan Gehl, 2002; Kevin Lynch, 2001) and economics (Garrido Yserte et al, 2010; Pastor et al, 2013), and there are relatively few researches on space. With the expansion, merger and reorganization of Chinese universities, the trend of opening up to the outside world continues to strengthen. Domestic research on campus-city relations mostly explores the foundation and prospects for the interactive relations from multiple dimensions such as economy (Yang Yuzhen et al, 2019), society (Suo Kaifeng et al, 2019), and technological innovation (Liang Yue, 2020). Recently, many studies have begun to pay attention to campus boundary space. Researches on campus boundaries mostly use qualitative analysis methods such as spatial perception (Ma Xiaoxiao, 2007; Huang Xuanxuan, 2017), morphological analysis (Xu Ye, 2014), and spatial vitality analysis (Tan Haixia, 2017), and quantitative analysis method based on OD and behavior analysis (Zhang Xia, 2020; Li Xiao, 2018). Domestic research on campus-city interaction relationship lacks corresponding spatial parameters. The interaction relationship has not been explained through enough quantitative data, and an evaluation system based on the particularity of boundary itself has not been formed to analyse the boundary space comprehensively.

1.3. New contributions and innovation

Symbiosis is a biological concept. It is defined as a relationship in which different species living together, exchanging matter and transmitting energy continuously. Campus and city are systems that cannot be separated from each other. Symbiosis is the best way to achieve a win-win situation for both. Boundary space is an important carrier for symbiosis between the campus and city. This research innovatively combines the characteristics of symbiosis with the attributes of the boundary, and proposes the three attributes that the symbiosis boundary should have: openness, penetration, and integration. Additionally, we establish a boundary symbiosis evaluation system based on the above three attributes, which is called O-P-I theory. We use depthmap, Arcgis and other spatial analysis software to carry out quantitative analysis and compare the symbiosis of the boundaries in China and abroad. Based on the analysis, we propose the optimization approaches for boundary space improvement to activate the boundary space and realize the coordinated development of universities and cities.

2. Materials and Methods

2.1. Study area: Harvard University and Hunan University boundary space

This study selects Harvard University in the United States and Hunan University in China as the cases to study campus boundary space. The main reasons for selecting these two universities for comparative analysis are as follows. Firstly, the campus structures of these two schools are in free network format, and the campus space is composed of multiple intersecting axes, which means these spatial structures have great similarities. Secondly, two universities adhere to the concept of open education and there is no clear wall outside the campus. Hunan University has the most open campus environment among Chinese universities. Finally, the core area of the Harvard University campus is about 713,380m^2, while the core area of Hunan University (South Campus) is about 754,770m^2. The area of two campus are relatively comparable.

Campus boundary spaces are complex and diverse. The boundary space is not only the edge between campus and cities, but also the area affected by the entrance and edge. In this study, the network analysis method in ArcGIS was used to delineate a 5-minute walk area from the boundary opening. Construct a simple traffic network model based on OSM roads (no consider one-way traffic, traffic lights, crossroads, etc). The time cost in the model is set according to walking time, and the walking speed is 70m/min. As for the boundary area without entrance, this study takes a buffer zone with a radius of 50m. The 5-minute walking area of entrances and the 50m buffer zone of inaccessible boundary are superimposed to form the finally campus boundary study area.

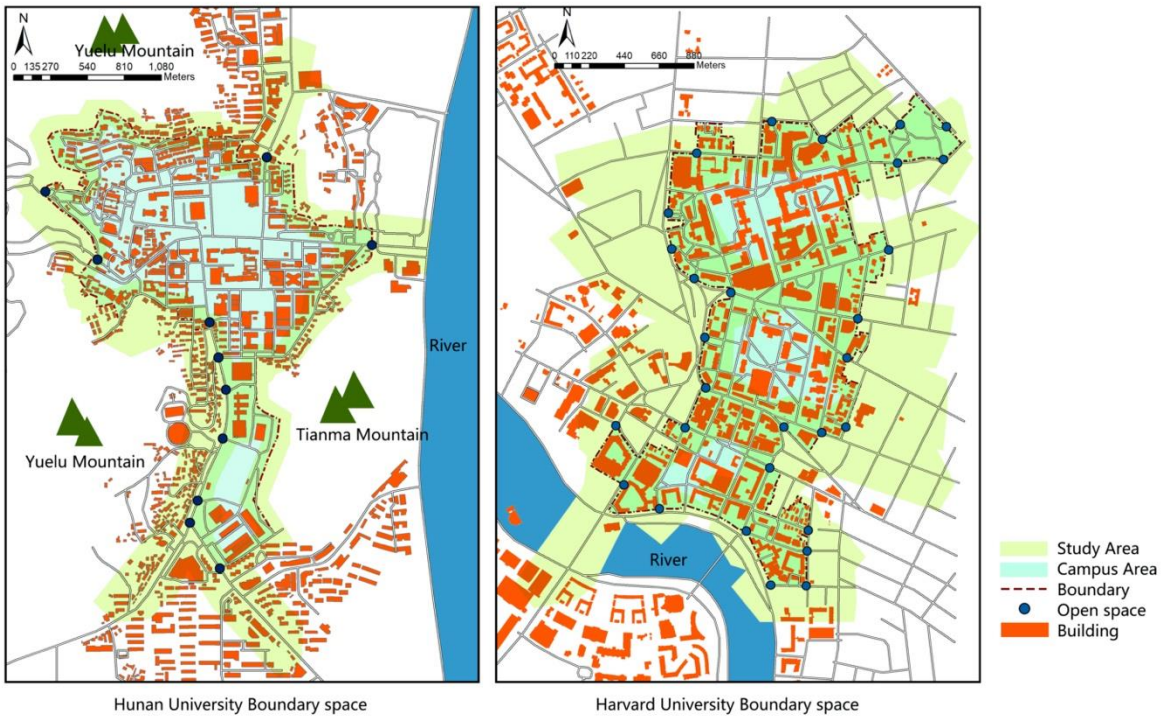

Fig1. The study Area

2.2 Analytical framework

This study comprised six major phases: data collection, campus-city boundary space extraction, key factors extraction, campus-city symbiosis evaluation, results comparison and analysis, and optimization approach study. First, street networks, building points of interest (Pois) and land-use maps of these two universities were collected. Second, campus-city boundary space was extracted based on the analysis of GIS. This boundary space comprised the 5-minutes accessible area and boundary buffer mentioned in 2.1. Third, three major factor layers representing the O-P-I theory were extracted from the data set. Three factor layer comprised eight key factors, which were more convenient for calculation and evaluation under the using of GIS-based tools and depthmap tools. Next, a campus-city symbiosis evaluation based on O-P-I theory was conducted. Then, this study compared symbiosis scores of Harvard University and Hunan University. The comparison composed overall scores and every key factors' differences. Finally, three optimization approaches about campus-city boundary space were proposed based on the comparison of symbiosis evaluation scores.

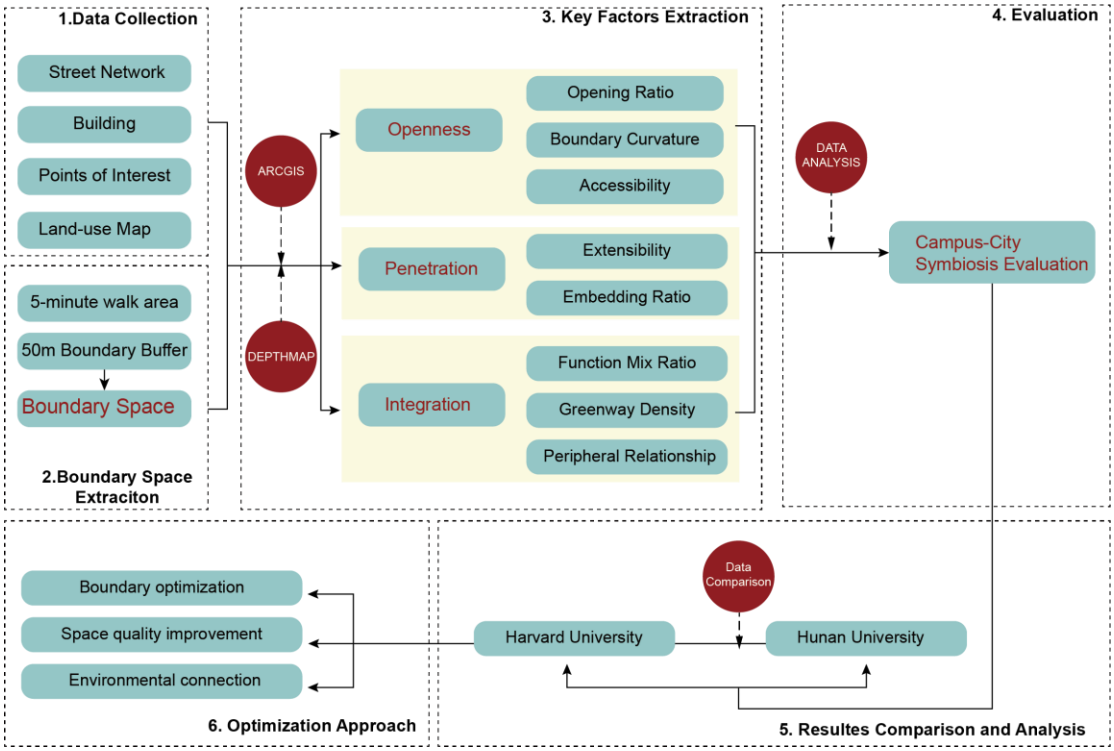

Fig2. The analytical framework

2.3 Extracting key factors applicable to campus-city symbiosis analysis

(1) Openness

Openness is the basic condition of campus-city symbiosis and depends on the morphological characteristics of boundary. In this study, openness was measured by boundary opening ratio, curvature and accessibility using morphological analysis and Arcgis-based tools.

Opening ratio is measured by the sum of the length of effective opening area of the campus to the campus perimeter. Herein effective opening area includes car and pedestrian entrance, square and green open space. With the increase of this ratio, openness is rising, which means more communication properties between campus and city. The formula is as follows:

$$BO=LK/D \quad (1)$$

where BO represents the opening ratio, LK represents effective opening area length, D represents campus perimeter.

Boundary curvature reflects the meandering degree of the boundary. It is measured by the ratio of the actual length of the boundary to the length of the straight line between nodes. The higher the curvature, the lower the contact surface with the city and the lower the possibility of opening. The formula is as follows:

$$BC=Li/Lj \quad (2)$$

where BC represents boundary curvature, Li represents actual length and Lj represents the straight length between the same two nodes.

Accessibility depends on the integration of boundary space. Integration measured in depthmap refers to the degree of agglomeration or dispersion between a certain element and other elements in a space system. It measures the ability of a space as a destination to attract arriving traffic, and reflects the centrality of

the space in the entire system. The more integrated the space, the higher the accessibility and the higher the possibility of campus-city symbiosis.

(2) Penetration

Soft boundaries can provide more communication possibilities between the campus and the city. Penetration is one of the basic attributes of soft boundaries. In this study, we takes penetration as the second factor layer of symbiosis evaluation, which comprises two key factors: boundary extension and embedding ratio.

Boundary extension depends on the ratio of boundary length to space width. The lower the results, the higher the extension of boundary and the more conducive to the interaction between inside and outside area, which is conducive to enhancing the symbiosis between the campus and the city. The formula is as follows:

BE=Lk/Wk (3)

where BE represents boundary extension, Lk represents boundary length and Wk represents the width of the same boundary area.

Embedding ratio expresses the degree of irregularity of the boundary itself, which is measured by the ratio of perimeter to area. Generally, the more irregular the shape, the more conducive to the marginal effect and the better the penetration. The formula is as follows:

ED=D/S (4)

where ED represents embedding ratio, D represents campus perimeter and S represents campus area.

(3) Integration

The campus boundary space is a carrier that realizes the complementary functions of campus and city, the improvement of space vitality, and the integration of the environment. So function and environment integration is essential for campus-city symbiosis. In this study, integration is measured by function mix ratio, greenway density and peripheral relationship index.

Function mix ratio is calculated based the POI data source. First, dividing boundary space further into a fine-scale grid of 10m×10m. Then, this study measures the function mix ratio of POI types by calculating the diversity of POI classes within each single grid. The larger the value, the more types of POI functions and the better integration in study area. The formula is as follows:

$H_{mn}=-\sum_{i=1}^{n}(p_i \times lnp_i)$ (5)

where H_{mn} represents function mix ratio in the m-th row and n-column grid, n represents the number of POI types, p_i is the proportion of the number type i POIs to the number of all POIs in the grid.

The connection between the campus green space and the outside area mainly relies on the greenway. Greenway density is convenient to calculate and can represent the integration degree between campus and city. Herein greenway density refers to the ratio of the total length of the integrated belt-shaped green space to the campus area. The green space is built or reserved within the campus and can be used to connect the green patches inside the campus or the integrated green space resources inside and outside the boundary. The formula is as follows:

IG=Lg/S (6)

where IG represents greenway density, Lg represents the length of greenway and S represents campus area.

Peripheral relationship index refers to the layout of public transportation stations inside the campus, which is measured by the density of public transportation connection facilities inside the campus. The higher the index, the more frequent the exchange of people between the campus and the city area or other areas, which means the higher the degree of integration between the campus and the city.

IR=TN/S (7)

where IR represents peripheral relationship index, TN represents the number of transport connection facilities and S represents campus area.

3. Results

According to the key factor calculating results in table 1, the differences between Harvard University boundary space and Hunan University boundary space can be revealed clearly.

(1) Openness of Hunan University is weaker than Harvard University.

Opening ratio of Hunan University is a little bit lower. As for the spatial distribution, opening spaces are mainly distributed at the junction with urban roads, and less distributed adjacent to natural mountains. The boundary curvature of the two schools is not much different. But boundary accessibility of Hunan University is relatively inadequate. In summary, openness of Hunan University is weak and the opening space and entrances are inadequate.

(2) Penetration of Hunan University is much inadequate.

The results of two key factors in penetration measuring are not optimistic. Boundary extension of Hunan University is not as good as Harvard University. And there is a big gap between the embedding ratio of these two schools. According to the results of boundary extension and embedding ratio, we can know that the penetration-condition in Harvard University is much better than Hunan University, which means more possibilities for communication between campus and city.

(3) Integration of campus and city in Hunan University is remarkable.

The distribution of functions around Hunan University is diversified, which contributs to the better results of functional mix index. Resulting from the famous scenery Yuelu Mountain, which is located in Hunan University campus, many greenways are built for tourists and citizens. What's more, the campus has a good traffic connection with the scenic spot. So, the greenway density in Hunan University is much better than Harvard University. As for peripheral relationship index, the result of Hunan University is not so good, which reflecting the insufficiency of transport connection facilities between the boundary space.

FACTOR LAYER	KEY FACTORS	STUDY AREA	
		Harvard University	Hunan University
Openness	Opening ratio	78.20%	67.50%
	Boundary curvature	1.02	1.06
	Accessibility	3.408	2.562
Penetration	Boundary extension	0.0063	0.0047
	Embedding ratio	0.0101	0.0079
Integration	Functional mix index	1.05	1.21
	Greenway density	1.13	1.35
	Peripheral relationship index	7.41	3.54

Tab1. Results of symbiosis key factors calculation

4. Discussion

4.1 Overall evaluation of campus-city symbiosis

According to the calculating results of openness, penetration and integration, we can find that the campus-city symbiosis condition of Harvard University is better than Hunan University. Although there are kinds of function area and many positive open spaces around the boundary, the form, structure, and space of the boundary space still need to be further improved.

Hunan University is located at the foot of Yuelu Mountain, which provides beautiful scenery, kinds of open space and attractive historical and cultural relics. Open and positive boundary space can not only provide students and teachers better campus environment, but also expand the radiation range of the famous scenic spot and activate the surrounding area. So, the boundary space deserves more attention. How to create the positive boundary space, which can realize resource sharing, environmental integrating, and can also reflect the characteristics of itself and the surrounding environment?

4.2 Optimization approaches for Hunan University

(1) Boundary optimization

On the premise of ensuring the safety of the campus environment, increase the density of openings in specific areas. If the border is close to the city's express passage, isolation needs to be established to ensure the internal safety of the campus. If the border is adjacent to the urban residential area and business district, the border can be opened as much as possible.

(2) Space quality improvement

Increase diversified activities and communication spaces at entrances and important spatial nodes to form well-reached and dynamic boundaries. Open space should be hierarchical designed according to the surrounding environment and the different users. What's more, we should try to implant multiple functions in public spaces to improve the use efficiency and service quality.

(3) Environmental connection

Environmental connection contains two aspects. On the one hand, integrate green resources inside and outside the campus boundary, which can contribute to enhancing the stability of the ecological security. On the other hand, strengthen the connection between inside and outside the campus, such as greenway and public transport conversion. The site selection of the greenway should take into consideration natural and cultural attractions, so as to construct a slow-moving system with site characteristics and create the well-reached and dynamic boundary space.

4.3 Limitations and next steps

(1) The evaluation system needs to be further scientifically improved

This research only analyses the form, function, and spatial characteristics of campus-city boundary space in a superficial way, and does not analyse the demands combined with specific statistics on the flow of people and the trajectory of actions. These reasons may lead to an incomplete and scientific evaluation system. In the next research, we should try to use the frequency and behavior data of different people to analyse the boundary-opening demands. In addition, we will try to use SPSS for data relevance analysis and regression analyses to explore the relationship between the boundary space and various behaviors of students, teachers, surrounding residents, and urban residents. Combined with these analyses, a more scientific and complete evaluation system of campus-city symbiosis will be established.

(2) The boundary space should be further studied in segments

In this study, we only carried out an overall measurement of the boundary space of the two universities. But when extracting the boundary space, we found that the campus boundary space is not uniform. Different internal and external environments will produce boundary spaces of different shapes, functions, and scales. The further segmentation of the boundary space is conducive to the longitudinal comparison of the research object itself, which is helpful for finding the symbiosis-weak area. In this way, we can propose more practical and feasible specific space improvement strategies.

(3) Verification of improved results should be added

This research mainly proposes optimization approaches for the lack of symbiosis of the current campus boundary in Hunan University, and has not simulated and verified the improved boundary space based on O-P-I theory. In the next study, we will combine segmented evaluation to achieve further implementation in boundary improvement. Additionally, we will simulate the improved boundary space and conduct the campus-city symbiosis verification.

5. Conclusions

The boundary space is an important carrier for the interaction and communication between campus and city. The organically integrated interface can effectively stimulate the vitality of the boundary space and create a positive and effective social and educational atmosphere. In this study, we combined the biological concept of symbiosis with the attributes and needs of the campus-city boundary to construct a symbiosis evaluation framework. Based on this evaluation, a comparative study was conducted between Harvard University and Hunan University, which are both typical open universities in domestic and foreign. Based on the study, we try to discover the insufficiency of campus boundaries in China and proposed optimization approaches, in order to build well-reached and dynamic boundaries and create urban public spaces with greater potential and vitality.

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