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Comparisons of Built Environment Correlates of Walking in Urban and Suburban Campuses: A Case Study of Tianjin, China

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Abstract: Current Chinese campus planning and design have neglected to promote walking activity (WA). Lacking WA and developing sedentary and physical inactivity habits can lead to obesity, diabetes, and other noncommunicable diseases. Academia has confirmed that WA can be facilitated by planning and designing built environment (BE) interventions. Accordingly, this study aims to explore the effect of campus BE features on walking in different regions' campuses and present nuanced campus planning and design strategies. We selected the objectively measured BE features of destination accessibility, land use, street connectivity, and spatial configuration. Environmental design qualities and pedestrian facilities were chosen as the micro-level BE features. We applied GIS 10.1 and sDNA to calculate gross BE features and field audit tools to measure street environmental features and pedestrian volume (PV). We built negative binomial regression models and eliminated spatial autocorrelation to investigate and compare the BE correlates of walking in urban and suburban campuses. Similarities and differences were found among the outcomes derived from the two regions. We found that campus Walk Score, land use attributes of facility density and park land ratio, complexity, and other features closely correlate with PV in the two types of campuses. Comparatively, closeness, transparency, and complexity only influence urban campuses' PV, while block length, entropy, facility land ratio, and sidewalk quality only correlate with PV on suburban campuses. According to these findings, we proposed different and targeted campus renewal and planning strategies for WA and walkability promotion.

Keywords: built environment; campus planning; pedestrian volume; walkability; walking activity

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1. Introduction

After the national strategy of "developing the country through science and education" was proposed in 1995, China's higher education flourished, and many universities began to expand, with new campuses springing up [1,2]. From 2000 to 2020, the number of higher education institutions increased from 1041 to 2738. In addition, the population of college students in China has increased from 5.56 million to 32.85 million in 20 years. Owing to the expansion of the scale and area of new campuses and the shortage and saturation of land in downtown areas, the suburbanization of new campuses has become an inevitable trend in college construction. Most new Chinese suburban campuses were built all at one time, with coarse land use, low-density development, and rapid construction modes. These campuses had a large spatial scale, scattered functional layout, and single-use facility types, with uneven distribution patterns, making it necessary for students to walk long distances to meet their daily living needs. Moreover, older Chinese urban campuses, built through multiple construction phases, owing to the slowness of campus renewal, have poorly configured pedestrian spaces and low environmental quality, reducing students' willingness to walk and resulting in a significant decrease in students' physical activity. Current campus construction and environmental conditions promote sedentary habits among students, leading to obesity, diabetes, and other noncommunicable diseases. As the primary mode of campus travel, walking significantly impacts students' daily lives as it enhances the importance of physical exercise and fitness and promotes communication activities and a sense of campus belonging. Building a walkable campus environment is imperative to encourage students to walk on campus and perform other physical activities in parks and public spaces, consequently leading to improved student health and enhanced academic performance and quality of life [3–5]. Built environment (BE) intervention as an important method to promote walking activity (WA) has been studied and validated by various disciplines, such as public health, urban and transportation planning, and urban design [6–9]. Therefore, with an increasing number of students engaging in sedentary behavior and lacking sufficient physical activity, it is critical to understand the determining campus BE correlates of walking and present targeted design strategies to positively influence their physical health through improving the campus environment walkability and students' WA.

Many theories and theoretical frameworks have been proposed to analyze the associations between BE and WA. Most studies have examined the impact of the BE on WA and health condition according to the Ecological Model of Behavior, which is based on the concept of active living [10]. As a complement to the Ecological Model, Lee and Moudon proposed the Behavioral Model of Environment (BME) theoretical framework, combining the BE features around the origin, destination, route, and area [9]. Regarding the specific categories of BE features, scholars have used the "D" theory (density, diversity, design, distance to transit, etc.) as the primary theoretical basis and framework [8]. According to this, Kang proposed the "S + 5D" research framework to study the impact of the BE on pedestrian flow [11]. Lee et al. proposed the Space Syntax metrics combined with Geographic Information System (GIS)-based measured "D" variables as a new way to comprehensively measure the impact of the BE on WA [12]. As a critical BE attribute, many scholars have analyzed the components of walkability and different walkability measurement indexes by combining different "D" elements and explored the impact of BE walkability on WA [13,14]. Specifically, two common measurement metrics adopted in the literature are the walkability index (combining population density, intersection density, and land use entropy) and the Walk Score (considering the facility weight, distance to facilities, and street connectivity) [15,16]. They are often used as the primary research variables to explore their effects with other BE features on WA in different regions [15–19]. Seminal research has been conducted on the correlation between campus BE and WA and campus planning, and many empirical studies have demonstrated that specific BE features can significantly impact students' WA. Vale et al. observed that students living in residential areas with dense service facilities and suitable walking environments preferred to walk or ride on campus [20]. Sisson et al. found that students living on campuses with core teaching areas, more on-campus services, and limited parking areas had higher WA intensities than campuses with low facility accessibility and on-campus streets open to motor vehicles [21]. Roemmich et al. found that paths and sports courts closely relate to walking and physical activity [22]. Further, academia has synthesized different campus planning and design strategies and guidelines [23–25]. Through a systematic analysis of the planning and design of 50 university campuses in the United States, Hajrasouliha summarized the four planning strategies and the eight characteristics that need to be focused on when designing and analyzing campus morphology [23]. Lau et al. proposed a design strategy for public open spaces on university campuses based on landscape design, spatial design, and green design [24]. Thomashow presented nine elements for designing sustainable campuses [25].

However, there are two main research gaps. First, only a few studies consider objective GIS-based measurement of environmental features, environmental qualities, and pedestrian facilities simultaneously to explore the relationship between campus BE and WA and compare the differential impact results between campuses in different regions. Second, campus planning and design strategies proposed by the existing research primarily apply to a broader geographical scope or the overall campus, but campus environmental renewal and design strategies for different campus categories or locations remain insufficient. Consequently, the primary goal of this study is to explore the influence of destination accessibility, land use, street connectivity, spatial configuration, street environmental qualities, and pedestrian facilities on WA and compare the BE correlates of walking in old urban and new suburban campuses. Furthermore, we aim to propose campus renewal and planning design strategies based on WA and walkability promotion that apply to different geographical environments and campus types. We hypothesize that the gross BE features and micro-level street environmental features will significantly impact PV and that the results of such impacts will vary across different categories of campuses. The remainder of this paper is organized as follows. Section 1 documents the current literature regarding the BE, WA, and campus BE studies. Section 2 provides further information with respect to the study area, data collection process, and data analysis method. Section 3 sets out the results of the regression analysis. Section 4 discusses the findings of this study. Section 5 provides the conclusion and discusses this study's limitations.

2. Literature Review

Several empirical research and review articles suggest that the BE as a predominant factor significantly impacts WA [13,14,26]. However, the effects of different BE correlates of walking vary depending on the purposefulness of the WA. Existing studies found that walking for transportation purposes was most strongly associated with density, distance to non-residential facilities, and land use diversity (proximity of non-residential facilities), while walking for recreational purposes significantly correlated with walking facilities and aesthetic quality [26]. As an essential indicator of the intensity of pedestrian activity and street vitality, the literature regarding the correlation between BE features and pedestrian volume (PV) is limited. Therefore, the remainder of this section will compile empirical studies of BE influence on PV. Several main issues can be summarized from the following sections.

First, this research type can be divided into two main directions: (1) proposing analysis models for predicting pedestrian demand and PV [27–29]. This mainly focuses on transportation planning, traffic engineering, and road safety analysis. The model can quantitatively analyze pedestrian travel safety, assess streets' commercial vitality, and predict the PV in a specific area. (2) The second direction entails exploring the association between BE variables and PV to propose strategies for building healthy cities based on promoting walking activities [30–33]. This direction focuses on urban planning and urban design, mainly evaluating the spatial form and quality of the BE and the microscopic street environment. Overall, the first direction focuses on the prediction of PV, supplemented by the BE measurement, while the second direction focuses on the measurement of the BE, complemented by the analysis of PV. Second, current research on BE and PV is mainly conducted in developed countries. Specifically, many studies are dominated by cities such as New York [31], Dallas [33], and Minneapolis [28] in the US. Moreover, Kang, Sung et al., Lee et al., and other scholars have conducted many empirical studies on PV using the city of Seoul in South Korea as the research object [34–36]. Most studies measure BE elements from gross objective and micro-level streetscape dimensions using GIS (D variables, e.g., density, diversity, design), sDNA and UNA (spatial configuration), street view images (street greenery), and field audit tools (pedestrian facilities) [27–30]. By contrast, few articles contain subjective perception attributes, most of which are based on Urban Design Quality (UDQ) theory [31–33,37]. Moreover, most research is predominantly based on the mesoscale and microscale, with many studies using a buffer zone of 50–400 m to measure BE features [36,38,39]. Third, negative binomial and multiple linear regression models are the primary statistical analysis methods, and only a few studies have used spatial regression models to eliminate spatial autocorrelation and improve the accuracy of results. Two studies conducted in Utah used the corresponding package in the R language to remove the negative influence of spatial autocorrelation on the regression results [32,37]. Finally, regarding the outcome of the relationship between BE and PV, existing studies found that the main BE features that significantly affect PV are facility accessibility, different types of land use proportions, street connectivity, environmental quality, and streetscape features [28–31,37]. Specifically, Miranda-Moreno et al. and Kang found that service facility accessibility is significantly associated with PV [29,34]. Sung et al. found that land use diversity and proportions significantly correlate with PV [35]. Hajrasouliha and Lin found that street network connectivity closely correlates with PV [40]. Different studies found that imageability [32,33,37], transparency [31–33], complexity [37], and other qualities significantly affect PV. Street furniture, sidewalk configuration, and other streetscape features are also found to have a significant relationship with PV [35,37,39]. Moreover, other studies considered the thermal comfort and microclimate factors [39,41,42]. Rodríguez et al. used the rainfall among the weather elements as a control variable and found a significant negative correlation between rainfall and PV [39]. Chung et al. and Kim's team found that PM10 concentration and precipitation significantly negatively affected PV [41,42].

However, PV-related research has the following limitations. Most research has focused on commercial and residential areas and urban public spaces in developed countries, whereas few evidence-based studies have been conducted in developing countries or have concentrated on university campuses. Moreover, different campus BEs and categories may have differential BE correlates of walking, and the influence of BE features on PV in old urban and new suburban campuses has not been carefully examined.

Campus BE and WA studies mainly include evaluating campus BE walkability, disentangling BE factors associated with walkability, and exploring campus BE features that influence WA. Studies in the walkability domain mainly reflect in the proposed various metrics the evaluation of the walkability of the campus environment. These include objective GIS-based quantitative tools such as the optimized campus Walk Score (WS) [43,44] and instruments measured by field audits [45,46]. For the former, Zhang et al. and Mu's team proposed the WS method for evaluating campus walkability by combining students' facility usage needs and campus BE characteristics [43,44]. For the latter, focusing on the impact of street furniture and accessibility on the walkability of campus streets, Asadi-Shekari's team proposed a field audit evaluation system called Pedestrian Level of Service and validated its rationality [45]. Scholars from 13 colleges and universities proposed the Physical Activity Campus Environmental Supports (PACES) field audit tool for evaluating campus walkability and tested its feasibility by applying it on 13 campuses [46]. Additionally, scholars used comprehensive methods combining the objective and subjective BE features to measure campus walkability [47,48]. Zhang and Mu constructed an integrated campus walkability measurement system by subjectively measuring the campus walkability through a web-based questionnaire and supplemented it with field observations of the campus physical environmental elements [47]. Alhajaj and Daghistani combined accessibility assessed by a subjective rated questionnaire and safety measured by a checklist to present a hybrid walkability measurement method [48]. Moreover, studies have explored BE elements that influence campus walkability [49]. Ramakreshnan et al. used a questionnaire to disclose students' walking motivation, BEs associated with walkability, and the relative importance of the studied BE factors with socio-demographic characteristics using a tropical campus as an example [49].

Through correlation analysis, various researchers investigated campus BE correlates of walking in different regions. The following content will systematically review this issue from both transportation and public health perspectives. First, researchers have mainly explored the influence of destination diversity, density of service facilities, street connectivity, and other campus BE features on travel behavior related to walking, including choice of travel mode, travel time, travel frequency, and other travel requirements [20,50–52]. Taking the University of California, Los Angeles (UCLA) as an example, Zhou used a questionnaire survey to investigate the effects of the campus environmental characteristics and the students' attributes (age, gender, and their residential choices) on their travel patterns and found that the college students were more willing to share their residence to reduce the burden of renting and to choose residences that were close to the public transit facilities to shorten the commuting time. Meanwhile, there is a strong correlation between gender, age, and AT behavior [50,51]. Bopp's team found that students living in residential areas with dense service facilities and a good walking environment prefer to walk or ride to campus [52]. Second, evidence-based studies have mainly analyzed campus location, campus scale, the difference between the on-campus and off-campus BEs, and other factors to explore their impact on walking and physical activities and health issues [21,53–55]. Peachey and Baller found that the self-assessed quality of the campus BE and the physical activity intensity of students on campus are better than those living outside the campus [53]. Reed and Ainsworth found a significant correlation between students' perception of pedestrian walkways, campus safety, and moderate physical activity [55]. Finally, other researchers have explored the effects of destination (stores, canteens, sports, and other facilities) accessibility and street environmental features on students' WA [19,56–58]. Zhang et al. found that campus micro street environmental qualities and streetscape features significantly affect WA [19]. Kapinos et al. explored the effects of the campus BE on students' body weight, body mass index, and number of workouts and found that accessibility to the gymnasium and proximity to the grocery store significantly contributed to female students' weight reduction [57]. Moreover, they also found that the exercise frequency of freshman female students was positively correlated with the proximity of gyms but negatively correlated with the proximity of the central campus location [58].

In general, many empirical studies have made remarkable achievements and have proven that specific BE features and complex indicators significantly influence students' WA. However, there were significant differences in the selected categories of environmental features among different studies. The chosen variables in campus BE studies often involve only a few aspects (accessibility, street design, etc.), and there is little research-based reason for selecting BE features that can be widely referred to. Simultaneously, although many articles have proposed design strategies for university campuses in terms of their spatial form, planning structure, and landscape, the development of differentiated pedestrian-friendly design strategies for different locational environments and campus types based on WA promotion remains incomplete.

3. Method

3.1. Study Area

In this study, we selected four typical Chinese campuses in Tianjin as the research object (Figure 1). These included (1) urban campuses: the Weijinlu Campus of Tianjin University (WCTU) and the Balitai Campus of Nankai University (BCNU) and (2) suburban campuses: the Beiyangyuan Campus of Tianjin University (BCTU) and the Jinnan Campus of Nankai University (JCNU). Table 1 presents the basic information regarding each campus.

Table 1. The basic information of the eight case campuses.

University Campus	Location	Land Area/10,000 m^2	Population/10,000	Construction Period	Number of Selected Streets	Average Length of the Selected Streets/m
WCTU	Downtown	136	1.89	1952	151	83.75
BCNU	Downtown	121	1.90	1946	121	81.17
BCTU	Suburb	244	1.98	2015	152	117.21
JCNU	Suburb	246	1.41	2015	93	112.85

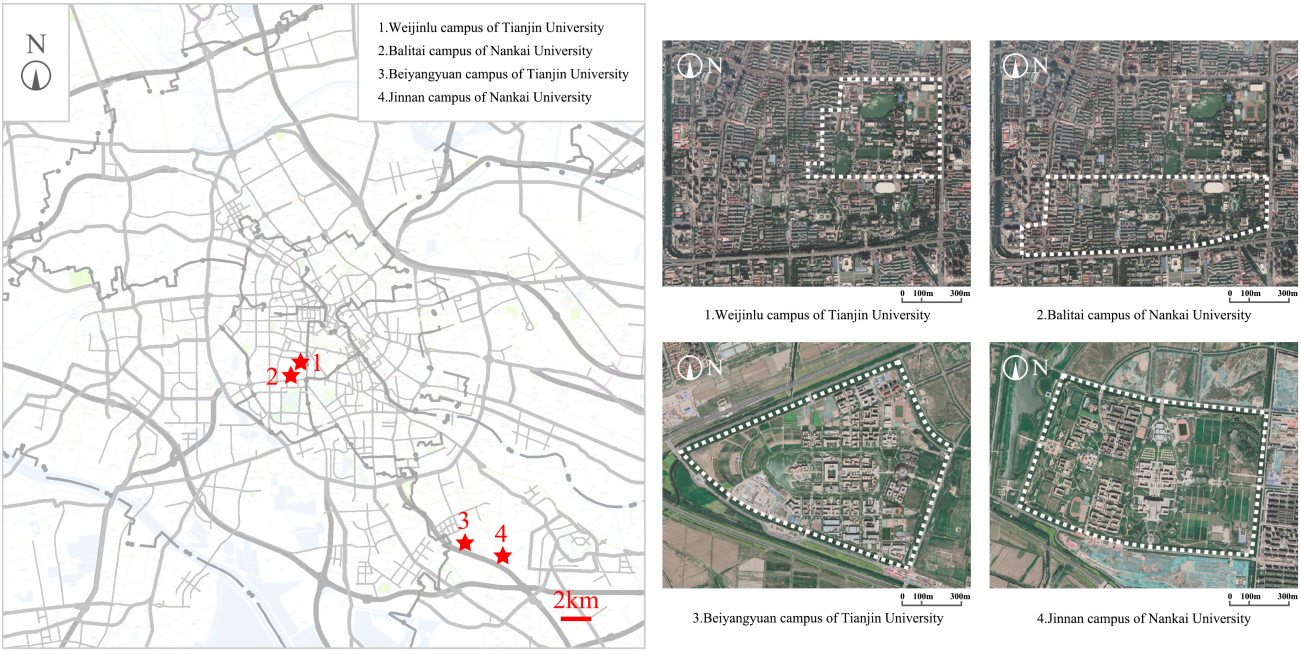


Figure 1. The map of the location of the chosen campus.

WCTU and BCNU are located in the Tianjin Central area of the Nankai District. They have been planned and constructed over many years and have a variety of architectural styles from different historical periods. The overall planning is based on a group layout, with a weak axial arrangement of local areas. In particular, the eastern and northern parts of the WCTU are adjacent to the main road of the city, with its various service facilities (e.g., restaurants, stores). The west of the campus is dominated by apartments for faculty and staff, and the south of the campus is adjacent to BCNU and connected by a comprehensive experimental building shared by the two campuses. For BCNU, except for the northern part of the campus, which is adjacent to WCTU, the other three sides are all connected to the urban arterial road, which has high land-use diversity and large traffic flow.

Regarding the suburban campuses, BCTU and JCNU are located in Tianjin's suburban Jinan District. Similar to their urban counterparts, the suburban campuses are also spatially close to each other. They were built in a short space of time and put into use through unified planning and centralized construction in 2015. However, their correlation with the urban environment is weak. The planning pattern of BCTU is a combination of single-axis group and group layout, while JCNU has a cross-axis planning pattern. Meanwhile, both campuses have large vacant lands for future development. These vacant spaces contain two parts. One occupies a portion of the campus, such as the west part of BCTU and the east part of JCNU, both of which have large areas of vacant land as future planning sites. This portion of the area is mainly unused by students because of the lack of facilities located in this area. Another part of the vacant land lies between the campus buildings as a temporary open space. Students often walk through this area, dominated by shortcuts, which increase pedestrian accessibility and facilitate daily travel for students. Since this study aims to investigate the association between the campus BE and WA, we combine sidewalks with shortcuts, park paths, and other pedestrian systems and use actual pedestrian paths as the measurement network. Moreover, the surrounding environment of the two suburban campuses is residential land under construction, agricultural land, and undeveloped land with undefined functions.

Regarding campus location, planning structure, spatial form, surrounding environments, and other spatial and environmental attributes, the selected campuses typically represent the essential characteristics of the old urban and new suburban campuses in China. Chinese university campuses have closed walls and compulsory dormitory policies, and students mainly study and live on campus. However, students can still leave campus to access stores, coffee shops, and other facilities that meet their daily needs. To consider the impact of the off-campus urban environment on students' WA, we combined the urban area to calculate the land use, spatial configuration, and street connectivity features and extended it 1000 m from the campus perimeter to include public service facilities to measure destination accessibility indicators.

Considering streets can help in measuring environmental design qualities and streets' PV can represent the WA intensity; street segments were chosen to investigate the influence of the campus BE features on PV. The selected streets covered areas with diverse functions to ensure rationality of choice. After eliminating the street segments without buildings and street amenities, we finally selected 517 street segments to measure the campus BE features and PV. Table 1 and Figure 2 present each campus's street number, location, and other attributes. Specifically, the lengths of urban campus streets are 83.75 m and 81.17 m of WCTU and BCNU, respectively. In contrast, due to lower land use diversity and larger block sizes, suburban campuses have a higher length of campus streets than urban campuses, which are 117.21 m and 112.85 m of BCTU and JCNU, respectively. Moreover, WCTU and BCNU have high building density in the campus main part and diverse land uses, which can be used to study a larger sample of streets. Although BCTU belongs to the suburban campus, it has a larger construction area than JCNU, and many streets can be analyzed. Therefore, we selected 151, 121, and 152 streets from these three campuses. Comparatively, JCNU has a relatively low building density, with large areas of green landscape and vacant land, so a smaller number of 93 streets were selected for the study.

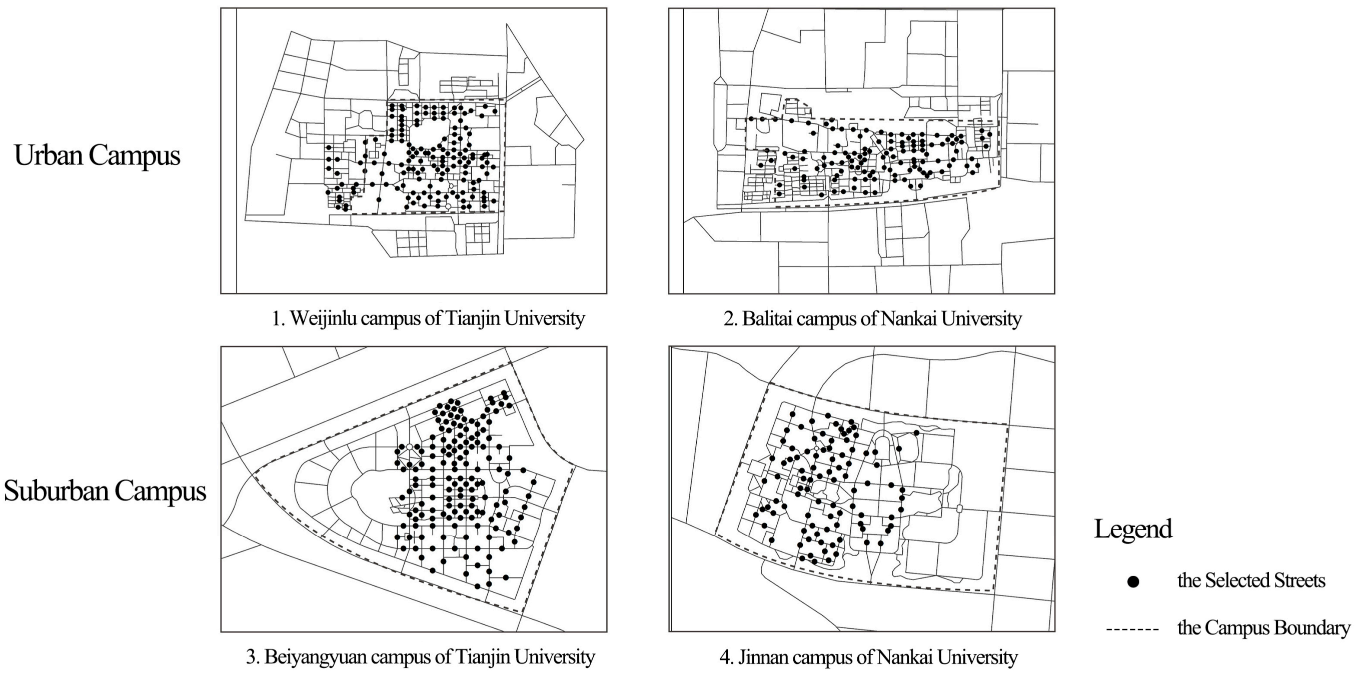


Figure 2. The map of the location of the selected street segments.

3.2. Independent Variable

The variables selected in this study are widely used in the literature. Specifically, we chose the WS as the destination accessibility indicator, land use entropy and different types of land proportions as the land use attribute, and four street connectivity and two spatial configuration indicators. These features are calculated by GIS 10.1 and its plug-ins. We selected five environmental design qualities and three pedestrian facility indicators to represent the micro-level BE features. We measured these features by using field audit tools. Specifically, regarding the GIS-based calculated variables, we used the New Closest Facility of the Network Analyst function to measure the actual walking distance from the street's midpoint to different destinations to calculate the distance-related indicators. We applied the New Service Area of the Network Analyst function and the Intersect of Overlay function from the Analysis Tools to calculate the number of intersections and the area of different lands' proportions in the buffer zones to obtain the values of specific street connectivity and land use features. Additionally, we used the Spatial Design Network Analysis (sDNA) plug-in in QGIS 3.12 to measure the spatial structure attributes. The following paragraphs will illustrate detailed information on the calculation of different variables.

3.2.1. Destination Accessibility

Considering the closed boundaries of Chinese university campuses, the location of public service facilities as walking destinations for students' daily on-campus trips closely affects the street WA. Therefore, we considered destination accessibility in the measurement system. WS, an international metric for evaluating the accessibility of facilities, combines walker facility usage characteristics and willingness to walk, as well as street connectivity factors, and can be optimized for a particular sub-group and then used to more accurately reflect the impact of a particular region's destination accessibility on a specific population's walking activities. Consequently, we chose WS to represent the destination accessibility variable. Zhang et al. optimized the WS method considering students' use of facilities and their willingness to walk and presented the GIS-based campus WS measurement system; the campus WS tool has been verified through quantitative analysis [19,43].

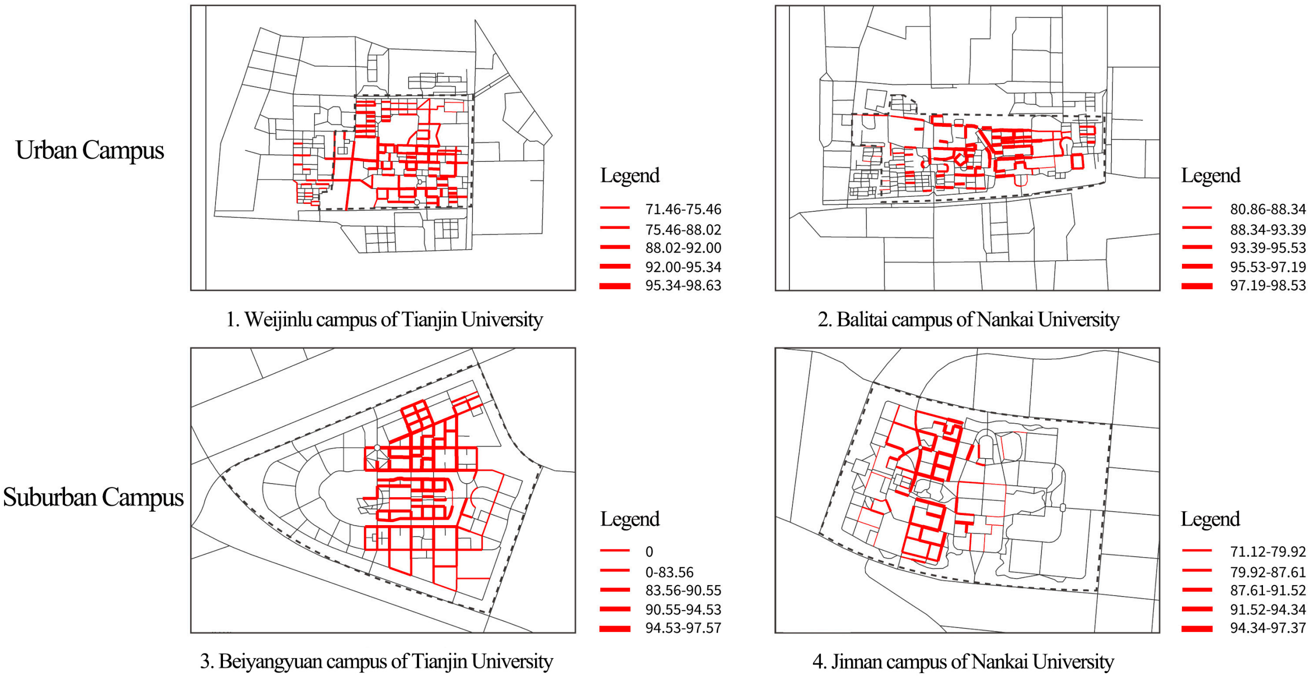
Accordingly, based on the algorithm of the WS and Zhang et al.'s method [16,19,43] (Table 2), we first used the facility weight and three types of walking time to obtain the original score of the midpoint of the street segment and attenuated it with the intersection density and block length. The attenuation range of each element is 0–5%, and their maximum attenuation is 10% of the original value [16]. Considering the small scale of the campus street network, we used a buffer zone with a radius of 200 m to calculate intersection density and block length. The calculation formula for campus WS is as follows:

$$\text{Campus Walk Score} = \sum_{i=1}^{n} wi \times g(dij) \times (1\text{-}ID) \times (1\text{-}BL)$$

where wi is the facility weight of a specific facility type, n is the category of facilities, dij is the shortest sidewalk network distance from an evaluation location to facility i, and g(dij) is the attenuation coefficient of walking time based on this distance, while ID and BL are the attenuation coefficients of intersection density and block length, respectively. Figure 3 shows the distribution of the calculated WS on each campus.

Table 2. The weight and curve of time decay of each facility (Adapted from source: [19]).

The Type of Facilities	Using Frequency	Weight of Facilities	Comfortable Time (min)	Tolerance Time (min)	Resistance Time (min)
Canteen and Restaurant	21	47.54	6	17	24
Public Teaching Building	5.06	47.54	6	17	24
Retail Store	4.31	11.46	6	17	24
Gym	2.08	9.76	8	17	24
Library	2.03	4.71	7	18	24
Square and Green Space	2	4.6	7	18	24
Bus Stop	1.81	4.53	6	17	24
Outdoor Stadium	1.4	4.1	8	17	24
Coffee Shop	1.32	3.17	7	18	24
Student Activity Center	1.07	2.98	6	17	24
Bank and Post Office	0.98	2.42	7	18	24
Administrative Building	0.86	2.22	6	17	24
Barber Shop	0.25	1.95	7	18	24
Sum	44.17	100			



Note: The value of campus WS ranges from 0-100. It evaluates the level of facility accessibility. The higher the value, the better the walkability. It can positively influence walking activity.

Figure 3. The distribution of campus WS on each campus.

3.2.2. Land Use

Campus land was divided into four types: facility, residential, office, and parks and squares. Among them, the land for facilities includes stores, libraries, public teaching buildings, and other public facilities; residential land includes dormitories, faculty apartments, and residential areas; office land contains office and training buildings, college buildings, and other office buildings; and park and square land includes parks, squares, and water bodies. Two primary categories were established to reflect the campus land use attribute: facility density represents the land use density and land use entropy embodies the land use diversity. The entropy index is calculated as follows:

$$Entropy = -\frac{\sum_{i=1}^{n} Piln(Pi)}{ln(n)}$$

where n represents the four land types, and Pi represents the area proportion of land i in the total land. Moreover, to systematically explore each land use type's effect on PV, we added the four types of land use ratio to compose the land use attributes.

3.2.3. Street Connectivity

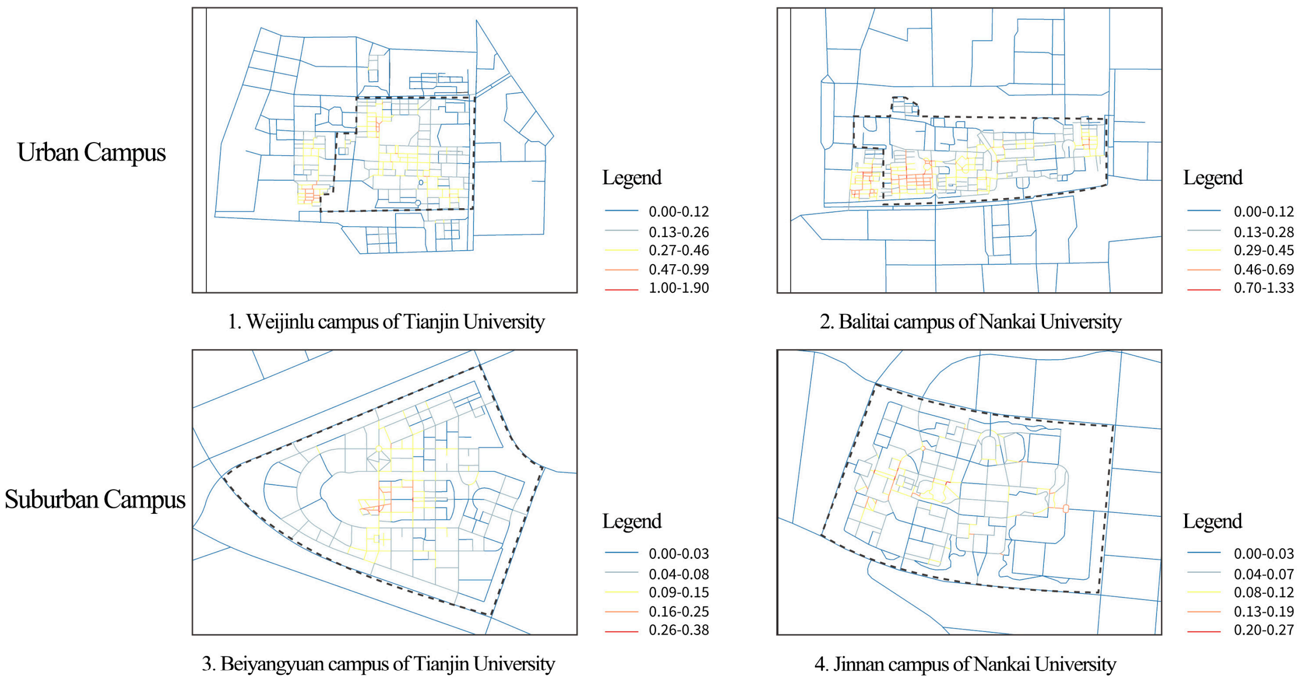
We selected four indicators to measure street connectivity attributes: intersection density, the Four-way intersection ratio, block length (the ratio of the total length of pedestrian paths in the buffer zone to the number of intersections), and pedestrian route diversity (PRD, the ratio of the actual walking distance from the origin to the destination to the straight-line distance). When calculating the PRD in urban environments, researchers often select large public service facilities, such as commercial complexes or cultural and political centers, as the main destinations. Considering that Chinese campuses' typical landmark buildings are libraries, administrative buildings, student activity centers, and stadiums, this study establishes these four types of facilities to calculate the PRD and considers the average value as the final PRD. The formula for the PRD index is as follows:

$$PRD = average\frac{Dird}{Digd}$$

where Dird is the actual distance and Digd is the straight-line distance.

3.2.4. Spatial Configuration

As an essential spatial element, spatial configuration attributes can influence people's walking choices and activity intensities [34,59]. Based on the classification standard of sDNA elements by Cooper et al. and Kang [34,59], we chose closeness (Network Quantity Penalized by Distance, calculated as the number of network links divided by the Euclidean distance between the origin and all reachable destinations within each radius) and betweenness (assesses all possible trips passing through a network link) as the campus spatial configuration variables. Figures 4 and 5 show the distribution of closeness and betweenness on each campus, respectively.

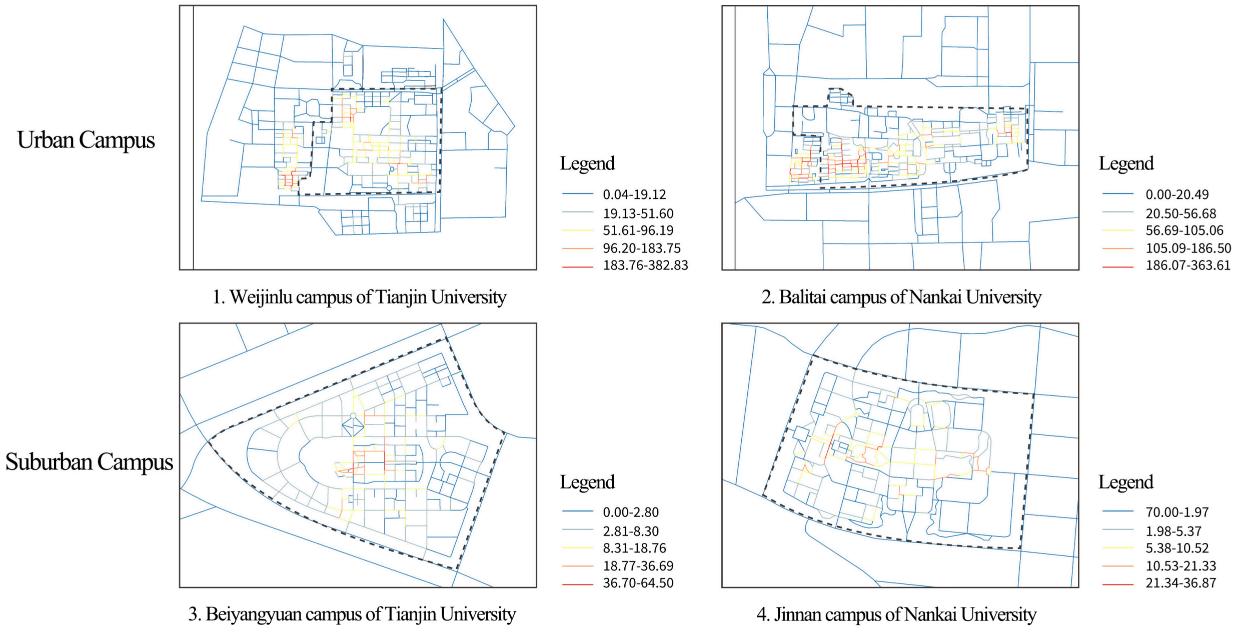


Note: Closeness is calculated as the number of network links divided by the Euclidean distance between the origin and all reachable destinations within each radius. Higher values indicate better connectivity of the road network and higher walking accessibility.

Figure 4. The distribution of closeness on each campus.

3.2.5. Environmental Quality

We followed Ewing et al.'s method and calculation formulas to measure and evaluate environmental design qualities using the UDQ field audit tool [31]. Owing to the wide variety of elements, the average time required to audit a street was 20 min. Audit work was conducted between March and October 2019, and was canceled if there was bad weather (rain or strong winds). Table 3 and Figure 6 present the definitions and examples of each quality. Finally, the five classified qualities were measured as environmental quality variables. Because we selected PV as the dependent variable, the imageability and complexity values were recalculated without considering PV.



Note: Betweenness is calculated by assessing all possible trips passing through a network link. Higher values indicate that pedestrians may select the street segment more often.

Figure 5. The distribution of betweenness on each campus.

Table 3. UDQ, their physical features, coefficients, and *p*-Values (Adapted from source: [31]).

UDQ	Significant Physical Features	Coefficient	*p*-Value
Imageability	People (#)	0.0239	<0.001
	Proportion of historic buildings	0.97	<0.001
	Courtyards/plazas/parks (#)	0.414	<0.001
	Outdoor dining (yes/no)	0.644	<0.001
	Buildings with non-rectangular shapes (#)	0.0795	0.036
	Noise level (rating)	−0.183	0.045
	Major landscape features (#)	0.722	0.049
	Buildings with identifiers (#)	0.111	0.083
Enclosure	Proportion street wall—same side	0.716	<0.001
	Proportion street wall—opposite side	0.94	0.002
	Proportion sky across	−2.193	0.021
	Long sight lines (#)	−0.308	0.035
	Proportion sky ahead	−1.418	0.055
Human Scale	Long sight lines (#)	−0.744	<0.001
	All street furniture and other street items (#)	0.0364	<0.001
	Proportion first floor with windows	1.099	<0.001
	Building height—same side	−0.00304	0.033
	Small planters (#)	0.0496	0.047
Transparency	Proportion of first floor with windows	1.219	0.002
	Proportion of active uses	0.533	0.004
	Proportion of street wall—same side	0.666	0.011
Complexity	People (#)	0.0268	<0.001
	Buildings (#)	0.051	0.008
	Dominant building colors (#)	0.177	0.031
	Accent colors (#)	0.108	0.043
	Outdoor dining (yes/no)	0.367	0.045
	Public art (#)	0.272	0.066

Note: “#” refers to the number.

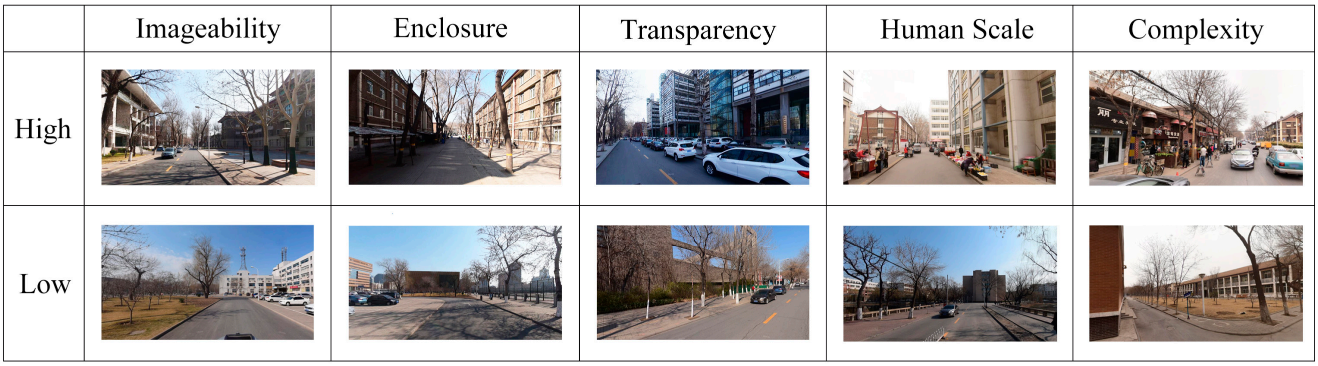
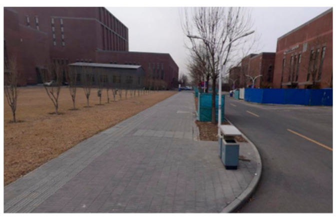


Figure 6. Examples of each design quality.

3.2.6. Pedestrian Facility

Many scholars have strengthened the critical role of sidewalk configurations and street trees in influencing WA [31,39,60–62]. Rodríguez et al. considered sidewalk quality and other BE features and investigated their influence on PV [39]. McCormack et al. took sidewalk length as the primary variable to explore its relationships with WA [60]. Ewing's team and Ozbil et al. took street trees into the association of street design features with PV [31,61]. Moreover, Arnold stressed the importance of street trees in urban design [62]. Therefore, we chose sidewalk quality, street tree conditions, and sidewalk length as the pedestrian facility variables. Moreover, we also measured other streetscape features (street furniture, street arts, etc.) shown in Table 3 to measure environmental qualities. To reduce the multicollinearity in the regression models when taking environmental qualities and their related streetscape features and complement the overlooked features in the UDQ theory, we finally selected the three variables widely adopted in the literature. Specifically, we assessed the sidewalk quality according to Rodríguez et al.'s method [39]. Table 4 shows a detailed illustration. In terms of Ewing's team and Ozbil et al.'s method [31,61], we used 0 = no or few street trees and 1 = more or continuously arranged street trees to assess the street tree conditions. Figure 7 displays the street tree's legend and distribution pattern, respectively.

Table 4. Legend for the evaluation of sidewalk quality.

The Evaluation of Sidewalk Quality			
0—No sidewalk	1—Poor quality	2—Moderate quality	3—Good quality
There are no sidewalks on the street, and the street is entirely occupied by motorways or parking areas.	The sidewalk is of poor quality, with protrusions and litter on it. It is also in disrepair. Pedestrians always have a poor walking experience when walking on them.	Sidewalks are moderately wide and neat and have fewer breaks or protrusions. People will perceive a moderate walking experience when walking on them.	Sidewalks have appropriate width and good cleanliness, utilizing materials with smooth interfaces, such as concrete, and without street litter, bumps, and other barriers affecting pedestrian's walking comfort.
			
The four pictures show examples of different levels of sidewalk quality.			

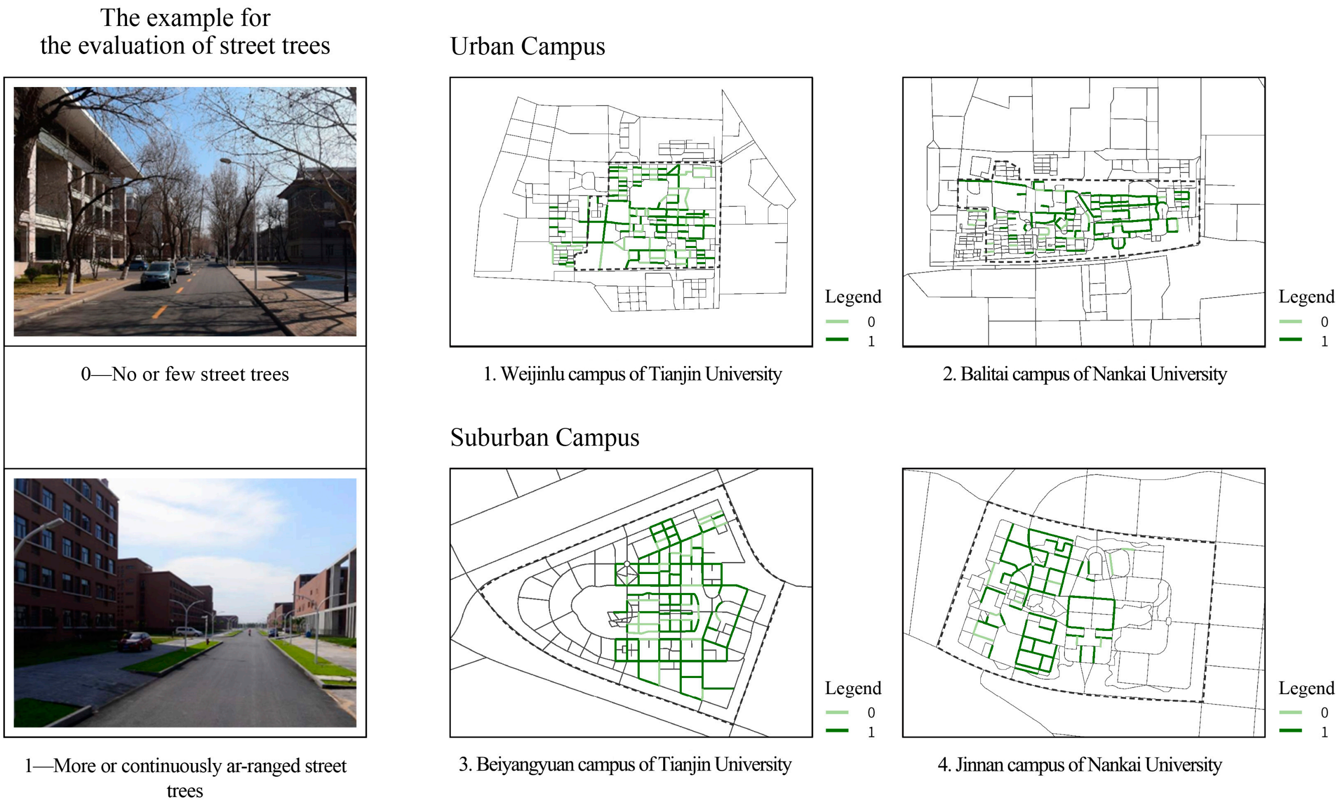


Figure 7. The figure of the example of evaluating street trees and their distribution on each campus.

3.3. Dependent Variable

This study applied Ewing et al.'s method, widely used in the study of the UDQ system, to calculate the PV of campus streets [31]. The recorded walking activities included sitting, standing, walking, running, and riding, while people sitting in outdoor dining establishments were excluded. To avoid the impact of a single accidental statistical result on data accuracy, this study selected different weekdays and times to collect data. The average of the four values was considered the PV value of the measured street. Data were collected from March to October 2019. Unlike urban travel situations, campus peak walking time is when students leave classes at noon to walk to canteens and dormitories. Therefore, to avoid the impact of this specific walking flow on the measured data, the statistical time of this study was from 9 a.m. to 12 p.m. and from 1 p.m. to 5 p.m. Counts were canceled in case of bad weather (rain or strong winds). Figure 8 shows the distribution of PV on each campus.

3.4. Data Analysis

Table 5 shows the descriptive statistics of campus BE variables and PV. To extract the campus BE correlates of walking in different regions, we used regression models to explore the influence of campus BE features on PV. We first developed models relating to the entire campuses and subsequently built the urban and suburban campuses' models. To effectively and precisely discover the BE correlates of walking, the process of building regression models contains four main aspects (Figure 9). First, due to the fact that land use entropy consists of four types of land use ratios, taking entropy and different types of land use ratios into the regression models simultaneously may produce the multicollinearity problem. Therefore, to avoid this problem and investigate the effects of land use diversity and the attributes of different land uses on walking activities separately and obtain a more nuanced design strategy, we further developed two types of models to analyze the impact of land use attributes on PV. One model considered land use entropy and other BE elements, while the other included the classified land use ratio and other BE elements. Second, we used the

Pearson correlation analysis in SPSS 26 to check the multi-level data structure of the two types of built models. Figures A1–A3 in Appendix A show the interrelationships between the independent variables in the entire campus and the urban and suburban campuses. We found that except for the correlation coefficient between intersection density and block length in the entire campus and the correlation coefficient between residential land ratio and office land ratio in the urban campus, which are higher than 0.6, all the other significant correlation coefficients are under 0.6, illustrating that this study does not have the main multi-level data structure problem, ensuring the rationality of the data structure. Although the two pairs of variables' correlation coefficients are higher than 0.6, they were the primary variables in this study; therefore, they were retained for further analysis. Third, we tested the collinearity problem and found that the variance inflation factor (VIF) of each feature in the fitted regression models was less than 10, indicating no significant collinearity between the variables in the fitted models.

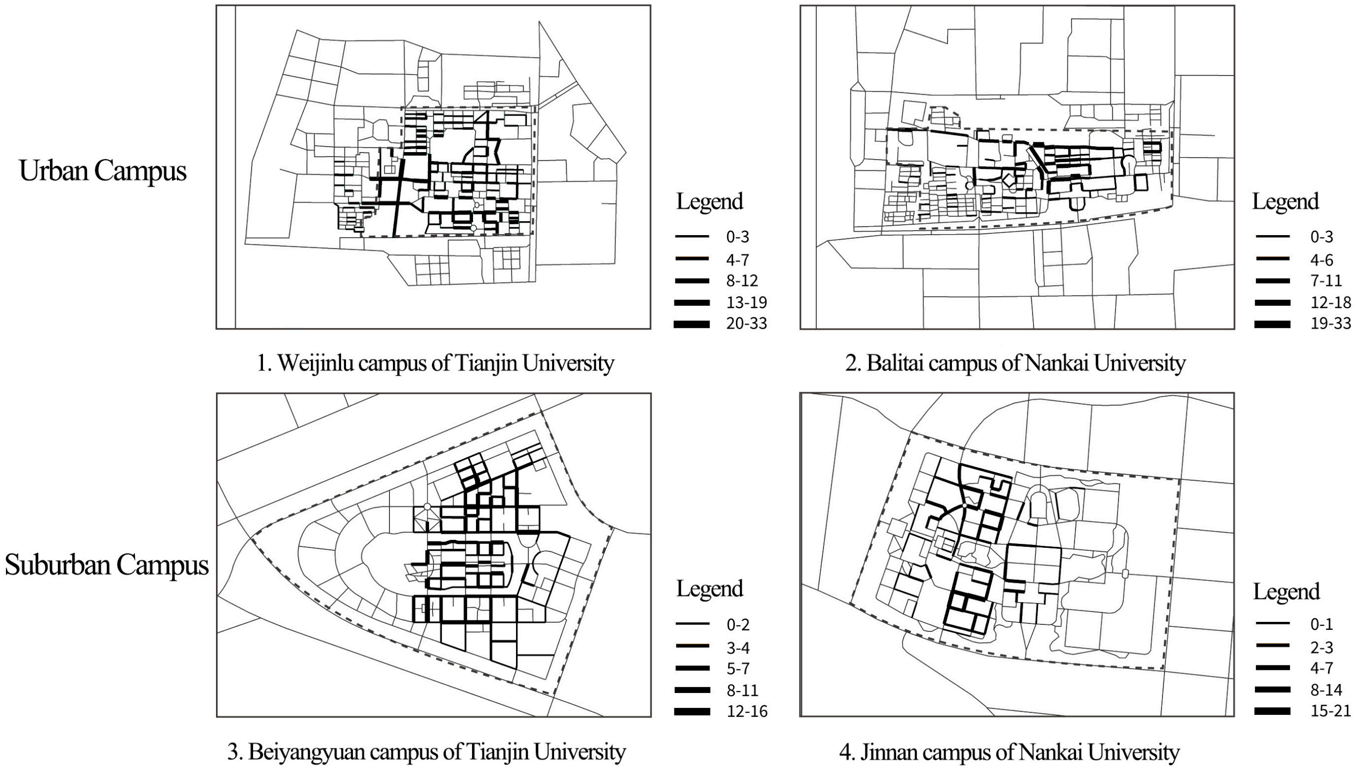


Figure 8. The map of the distribution of PV on each campus.

Table 5. Descriptive statistics in urban and suburban campuses.

Variables	Max	Min	Mean	SD
PV	33.00 (21.00)	0.00 (0.00)	5.53 (3.78)	4.59 (3.21)
Destination Accessibility				
Campus WS	98.63 (97.57)	71.46 (68.72)	93.97 (90.76)	4.33 (6.00)
Street connectivity				
Intersection density	34.00 (29.00)	8.00 (5.00)	22.89 (13.87)	5.56 (4.63)
Four-way intersection ratio	0.65 (0.70)	0.00 (0.00)	0.38 (0.36)	0.14 (0.16)
Block length	248.40 (420.70)	94.65 (102.20)	133.11 (180.00)	20.50 (46.52)
PRD	2.48 (3.15)	1.02 (1.13)	1.33 (1.46)	0.18 (0.23)

Table 5. *Cont.*

Variables	**Max**	**Min**	**Mean**	**SD**
Land use				
Facility density	18.00 (13.00)	0.00 (0.00)	4.22 (2.47)	2.97 (2.35)
Entropy	0.97 (1.00)	0.13 (0.27)	0.73 (0.71)	0.17 (0.18)
Residential land %	0.89 (0.54)	0.00 (0.00)	0.22 (0.18)	0.22 (0.15)
Facility land %	0.34 (0.52)	0.00 (0.00)	0.15 (0.15)	0.08 (0.12)
Office land %	0.52 (0.77)	0.00 (0.00)	0.19 (0.25)	0.16 (0.18)
Park land %	0.63 (0.60)	0.00 (0.00)	0.26 (0.23)	0.14 (0.16)
Spatial Configuration				
Closeness	197.10 (0.166)	0.10 (0.00)	38.80 (0.06)	31.92 (0.03)
Betweenness	2.22 (31.52)	1.00 (0.03)	1.39 (5.00)	0.16 (5.34)
Environmental design quality				
Imageability	4.80 (5.85)	1.51 (1.90)	2.48 (2.65)	0.47 (0.54)
Enclosure	4.09 (4.00)	0.51 (0.29)	2.80 (2.18)	0.86 (0.99)
Human Scale	3.89 (4.15)	1.17 (1.27)	2.91 (2.76)	0.44 (0.65)
Transparency	3.76 (3.77)	1.71 (1.71)	2.99 (2.90)	0.47 (0.40)
Complexity	4.94 (4.90)	2.61 (2.88)	3.56 (3.28)	0.40 (0.28)
Pedestrian facility				
Sidewalk quality	3.00 (3.00)	0.00 (0.00)	1.84 (2.29)	0.94 (1.09)
Sidewalk length	244.30 (265.10)	45.06 (51.57)	82.60 (111.93)	24.98 (37.93)
Street tree	1.00 (1.00)	0.00 (0.00)	0.73 (0.82)	0.45 (0.39)

Note: values outside and inside the bracket belong to the urban and suburban campuses, respectively.

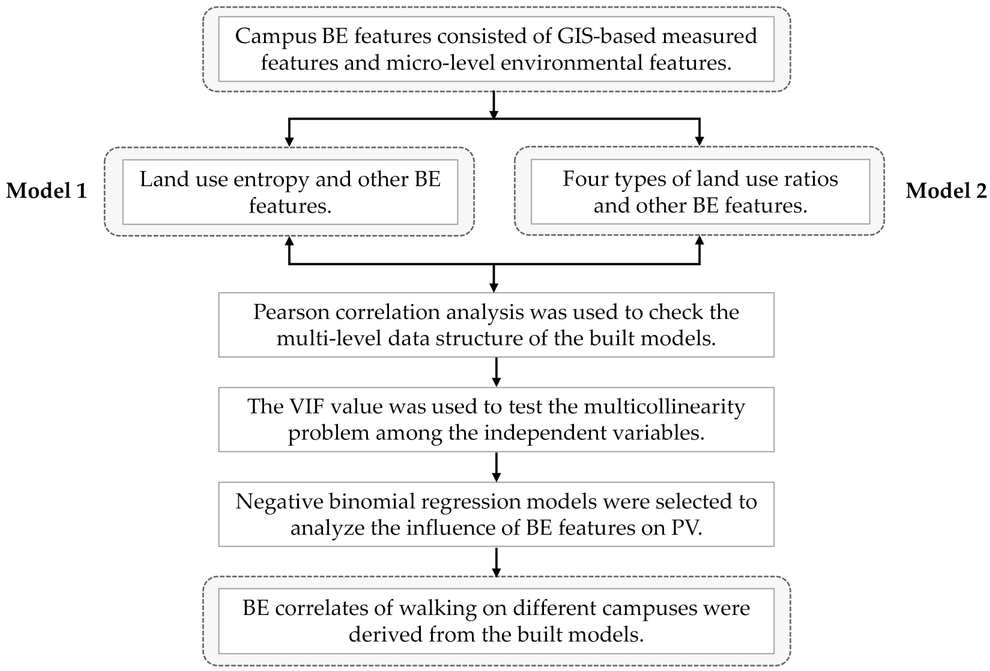


Figure 9. The workflow for the process of the model analysis.

Finally, the PV in our study had continuous positive values; the mean value was larger than the standard deviation and the overall value was small, with a few streets exhibiting large values. Furthermore, we used the dispersion test to determine the over-dispersion in the Poisson models. Consequently, negative binomial regression was selected for subsequent regression analysis. Considering the PV of a specific street was affected by the adjacent streets, leading to spatial autocorrelation in the regression model, we calculated the fitted models' Moran's I using GIS 10.1 and found that the P values were all notable, implying that the models have spatial autocorrelation. Previous studies have shown that the spatial filtering function can effectively eliminate spatial autocorrelation, and the advantage of this method is that the significance of the independent variables in the model is corrected, but the coefficient is not affected [32,37]. Therefore, we used the Moran Eigenvectors (ME) function in the spatialreg package in R 4.1.0 language to remove the spatial autocorrelation of the models and obtain a certain number of spatial filtering eigenvectors. We further checked Moran's I of the residues and found no spatial autocorrelation in the built models.

4. Results

Before exploring and comparing the urban and suburban campuses' BE correlates of walking, we analyzed the campus BE features closely correlating with PV over the entire campus. We found that most BE features significantly affected PV from Table 6. Destination accessibility, land use density and diversity, environmental qualities, and pedestrian facility were closely correlated with PV in the two models. Notably, campus WS, facility density, entropy, facility and office land ratio, complexity, and three pedestrian facility features positively affected PV at $p < 0.001$. In contrast, street connectivity and spatial configuration features had a weak association with PV. The significance of street connectivity is only represented in Model 2 at $p < 0.01$ (block length and PRD) and $p < 0.05$ (intersection density). Moreover, closeness influences PV at $p < 0.01$ (Model 1) and $p < 0.1$ (Model 2), while betweenness only affected PV in Model 1 at $p < 0.1$.

Table 6. Regression modes of the PV and BE correlates of walking for the entire campus.

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Intercept	−8.534 ***	0.888	<0.001	−7.464 ***	0.867	<0.001
Destination Accessibility						
Campus WS	0.078 ***	0.009	<0.001	0.071 ***	0.008	<0.001
Street connectivity						
Intersection density	−0.005	0.009	0.591	−0.024 *	0.009	0.012
Four-way intersection%	−0.099	0.219	0.651	0.315	0.222	0.155
Block length	−0.002	0.001	0.101	−0.004 **	0.001	0.004
PRD	−0.259	0.157	0.100	−0.484 **	0.161	0.003
Land use						
Facility density	0.041 ***	0.009	<0.001	0.043 ***	0.010	<0.001
Entropy	0.690 ***	0.198	<0.001			
Residential land %				0.882 **	0.276	0.001
Facility land %				1.910 ***	0.351	<0.001
Office land %				1.008 ***	0.249	<0.001
Park land %				0.632 **	0.236	0.007
Spatial Configuration						
Closeness	−2.054 **	0.751	0.006	−1.378 [a]	0.741	0.063
Betweenness	0.004 [a]	0.002	0.061	0.003	0.002	0.242
Environmental design quality						
Imageability	0.065	0.052	0.210	0.050	0.051	0.336
Enclosure	−0.095 *	0.052	0.010	−0.084 *	0.038	0.028
Human Scale	0.173 *	0.070	0.014	0.146 *	0.069	0.035
Transparency	0.170 *	0.070	0.015	0.147 *	0.069	0.033
Complexity	0.328 ***	0.069	<0.001	0.342 ***	0.068	<0.001
Pedestrian facility						
Sidewalk quality	0.164 ***	0.029	<0.001	0.150 ***	0.029	<0.001
Sidewalk length	0.005 ***	0.001	<0.001	0.005 ***	0.001	<0.001
Street tree	0.253 ***	0.064	<0.001	0.240 ***	0.063	<0.001

Table 6. *Cont.*

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Spatial filtering eigenvector						
Fit (ME)	−2.517 ***	0.605	<0.001	−2.326 ***	0.628	<0.001
Fit (ME)	1.477 **	0.543	0.007	1.323 *	0.538	0.013
Fit (ME)	−2.464 ***	0.581	<0.001	−2.965 ***	0.612	<0.001
Fit (ME)	2.106 ***	0.577	<0.001	−4.134 ***	1.089	<0.001
Fit (ME)	−3.948 ***	0.626	<0.001	3.042 ***	0.598	<0.001
Fit (ME)	−3.407 ***	1.021	<0.001			
N		517			517	
2 × log-likelihood (df)		−2158.45 (488)			−2142.80 (487)	
AIC		2219			2205	

Note: [a] $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

For the regression models of the urban campus (Table 7), we found that all five types of environmental features significantly affected WA. BE correlates of walking were equally significant in both models, except for closeness. Compared with the environmental quality and sidewalk features, objective GIS-based environmental features had a weaker effect on PV. Only campus WS and facility density positively influenced PV at a significance of $p < 0.001$, while closeness in spatial configuration had a weaker association with PV. Furthermore, only PRD exerted a significant negative influence on PV, indicating that the increase in detour distance played a suppressive role in the occurrence of WA. In addition, only the park land ratio positively influenced PV for the land use attribute. Regarding environmental design quality, four out of five qualities affected PV dramatically, while only human scale did not correlate with PV. In particular, the significance of enclosure, transparency, and complexity was recorded as $p < 0.001$, while imageability's P level belongs to $p < 0.1$. Moreover, transparency and complexity significantly promoted WA; in contrast, imageability and enclosure negatively correlated with PV. Finally, we found that sidewalk length and street trees positively impacted PV for pedestrian facility features.

Table 7. Regression modes of the PV and BE correlates of walking for the urban campuses.

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Intercept	−5.502 ***	1.422	<0.001	−6.111 ***	1.472	<0.001
Destination Accessibility						
Campus WS	0.056 ***	0.014	<0.001	0.063 ***	0.014	<0.001
Street connectivity						
Intersection density	0.016	0.010	0.111	0.016	0.011	0.167
Four-way intersection%	0.026	0.329	0.936	−0.315	0.346	0.362
Block length	0.001	0.002	0.660	-0.0003	0.002	0.848
PRD	−0.758 **	0.280	0.007	−0.792 **	0.285	0.006
Land use						
Facility density	0.044 ***	0.012	<0.001	0.070 ***	0.014	<0.001
Entropy	0.366	0.297	0.217			
Residential land %				0.517	0.494	0.295
Facility land %				0.456	0.552	0.409
Office land %				0.428	0.547	0.435
Park land %				0.888 *	0.425	0.037
Spatial Configuration						
Closeness	−1.841 *	0.927	0.047	−1.732 [a]	0.945	0.067
Betweenness	0.004	0.003	0.165	0.003	0.003	0.247

Table 7. *Cont.*

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Environmental design quality						
Imageability	−0.137 [a]	0.082	0.095	−0.163 [a]	0.083	0.050
Enclosure	−0.258 ***	0.052	<0.001	−0.263 ***	0.055	<0.001
Human Scale	−0.151	0.102	0.138	-0.156	0.102	0.127
Transparency	0456 ***	0.091	<0.001	0.440 ***	0.091	<0.001
Complexity	0.395 ***	0.086	<0.001	0.404 ***	0.091	<0.001
Pedestrian facility						
Sidewalk quality	0.063	0.039	0.109	0.063	0.041	0.122
Sidewalk length	0.007 ***	0.001	<0.001	0.007 ***	0.002	<0.001
Street tree	0.232 **	0.084	0.005	0.251 **	0.083	0.003
Spatial filtering eigenvector						
Fit (ME)	3.606 ***	0.651	<0.001	3.568 ***	0.736	<0.001
Fit (ME)	1.920 ***	0.571	<0.001	1.895 ***	0.575	<0.001
Fit (ME)	−1.719 **	0.628	0.006	−1.324 *	0.561	0.018
Fit (ME)	0.244	0.562	0.664	1.020 [a]	0.564	0.070
N		272			272	
2 × log-likelihood (df)		−1237.05 (250)			−1233.37 (247)	
AIC		1283			1285	

Note: [a] $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Regarding the suburban campuses' regression results (Table 8), we found that the categories of the campus BE correlates of walking have similarities and differences with those of urban campuses. We also found that the five categories of environmental elements had significant BE correlates of walking. Additionally, similar to urban campuses, campus WS, facility density, park land ratio, complexity, sidewalk length, and street trees positively influenced PV. However, block length in street connectivity is only closely correlated with suburban campuses' PV. Furthermore, unlike urban campuses, land use entropy and facility land ratio positively influenced PV in suburban campuses. Thus, except for imageability and complexity, we did not find spatial configuration indicators and other environmental qualities that significantly impacted PV. Even though imageability influenced PV at $p < 0.1$, similar to the urban campuses' result, it was found to have a positive relationship with PV. Finally, we established that sidewalk quality only promoted WA in suburban campuses.

Table 8. Regression modes of the PV and BE correlates of walking for the suburban campuses.

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Intercept	−8.132 ***	1.363	<0.001	−4.645 ***	1.532	<0.001
Destination accessibility						
Campus WS	0.077 ***	0.012	<0.001	0.059 ***	0.014	<0.001
Street connectivity						
Intersection density	−0.014	0.018	0.426	−0.031	0.020	0.114
Four-way intersection%	0.193	0.325	0.553	0.525	0.366	0.152
Block length	−0.003 [a]	0.018	0.084	−0.007 **	0.002	0.001
PRD	−0.351	0.231	0.129	−0.803 **	0.254	0.002
Land use						
Facility density	0.045 **	0.017	0.007	1.748 ***	0.464	<0.001
Entropy	0.747 *	0.301	0.013			
Residential land %				0.846	0.515	0.101
Facility land %				1.748 ***	0.464	<0.001
Office land %				0.312	0.333	0.348

Table 8. *Cont.*

	Model 1			Model 2		
	Coefficient	**Standard Error**	***p***	**Coefficient**	**Standard Error**	***p***
Park land %				0.777 *	0.368	0.035
Spatial configuration						
Closeness	0.793	2.562	0.757	0.013	2.498	0.996
Betweenness	−0.004	0.015	0.806	−0.002	0.015	0.876
Environmental design quality						
Imageability	0.138 [a]	0.071	0.052	0.132 [a]	0.072	0.067
Enclosure	0.017	0.066	0.796	0.030	0.066	0.646
Human Scale	0.171	0.108	0.113	0.161	0.107	0.130
Transparency	−0.053	0.134	0.691	−0.091	0.132	0.488
Complexity	0.370 **	0.133	0.005	0.266 *	0.132	0.045
Pedestrian facility						
Sidewalk quality	0.124 **	0.043	0.004	0.130 **	0.044	0.003
Sidewalk length	0.003 **	0.001	0.002	0.003 **	0.001	0.006
Street tree	0.191 [a]	0.107	0.074	0.190 *	0.105	0.069
Spatial filtering eigenvector						
Fit (ME)	1.830 *	0.717	0.011	−1.860 *	0.740	0.012
N		245			245	
2 × log-likelihood (df)		−940.47 (226)			−928.13 (223)	
AIC		980			974	

Note: [a] $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5. Discussion

Given the problems of the suburbanized and rapid construction of new campuses and the lagging environmental renewal of old campuses in downtown areas in China, students' walking activities and physical health and the imperfect formulation of campus planning and design strategies for different regions and categories have lacked attention. This study first calculated the objective campus BE features through GIS and sDNA and used field audits to measure street environmental quality and pedestrian facility features. Subsequently, we investigated the influence of campus BE features on PV and compared the BE correlates of walking in urban and suburban campuses using negative binomial regression models without spatial autocorrelation. We found that objective GIS-based measured destination accessibility, land use attributes, environmental design qualities, and pedestrian facilities significantly affect PV in the entire campus. For comparing the BE correlates of walking in the two types of campuses, we found that campus WS, PRD, facility density, park land ratio, complexity, sidewalk length, and street trees impact PV in both types of campuses. In contrast, closeness, enclosure, and transparency only correlated with PV in urban campuses, while block length, land use entropy, facility land ratio, and sidewalk quality only influenced suburban campuses' WA. According to our findings, two major issues are discussed in the following paragraphs.

First, with respect to the correlation between objective GIS-based measured BE features and PV, our finding regarding the close association between campus WS and PV is similar to that of other evidence-based studies. Park et al. and Maxwell also found that WS can significantly promote PV [37,63]. Furthermore, Duncan et al. and Twardzik et al. stated that WS is vital for improving WA [17,18]. Moreover, we established that PRD negatively influences PV in both types of campuses, implying that building a highly connected walking path network can provide various path options, thereby reducing walking detour distances and promoting WA. Regarding land use attributes, we found that entropy, facility density, facility, and park land ratio significantly influence campus WA, indicating that the diversity of campus land functions and the distribution of services positively affect pedestrian activities. However, except for the park land ratio, we did not observe this effect in urban campuses, mainly due to the closed boundaries of Chinese campuses.

Students need to travel a long distance to reach off-campus destinations, even though these destinations may appear close on a map. When calculating land use indicators for the streets surrounding a campus, including urban BE environments tends to skew the results to reflect the actual land use environment used by students in their daily lives. In contrast, suburban campuses are generally surrounded by undeveloped land and have no facility distribution; thus, the results obtained in the calculation are based on the on-campus BE. Off-campus land conditions do not influence them; thus, these results can be used to explore the relationship between campus BE and PV more accurately. Finally, the closeness of spatial configuration affects campus WA; this finding aligns with those in other urban studies [34,64]. However, this correlation was only found in urban campuses because the spatial network density in urban campuses is much higher than in suburban campuses. Meanwhile, the spectrum of closeness in suburban campuses is low, making the influence of closeness on PV insignificant.

Second, we obtained results consistent with those of the previous studies conducted on the influence of environmental qualities and pedestrian facilities on PV. We found that complexity positively affects PV in both urban and suburban campuses, implying that the number of buildings present on the street and the variety of materials and colors of the building's façades induce street WA, congruent with the results of other urban studies. Park et al.'s study also found a close relationship between complexity and PV in an American city [37]. Except for complexity, we also found that enclosure and transparency strongly correlated with PV, similar to the findings of the studies conducted in Utah and New York [31,37], implying that enclosure inhibits WA while transparency promotes WA. Nevertheless, this relationship is only recorded in urban campuses. As seen in Table 3, the enclosure factor is mainly determined by the proportion of the building interface and sky. Owing to the compact street network in urban campuses, the proportion of street walls is higher, while the proportion of sky is lower than that in suburban campuses. Meanwhile, the enclosure in urban campuses (2.80) is higher than that in suburban campuses (2.18). Therefore, the negative impact of enclosure on PV is more evident in urban campuses. In addition, transparency primarily relates to the windows in buildings and the active use of buildings. In contrast to urban campuses, suburban campuses are generally planned and built rapidly in one session, resulting in many buildings on campus not being used at the time of official opening, leading to low transparency in suburban campuses; moreover, its influence on PV is not significant. Finally, congruent with the previous urban studies conducted [62,65], we also found that the pedestrian facility of sidewalk length and street trees can promote PV, meaning that effective sidewalk configuration with trees providing shade and visual interest can enhance WA. However, sidewalk quality only positively influences PV in suburban campuses. As the average value of sidewalk quality in urban campuses is 1.84 lower than the value for suburban campuses and its spectrum is low, the association between sidewalk quality and PV becomes insignificant in urban campuses.

6. Conclusions

This study disentangled and compared the campus BE correlates of walking in different regions' campuses and verified the hypothesis that different BE features significantly influence PV in urban and suburban campuses. This study makes two main contributions to the literature. First, we disclosed the similarities and differences between the associations of campus BE features and PV in different areas. Second, according to the nuanced relationships derived from the models, campus renewal and planning strategies based on the perspective of WA and walkability promotion were put forward. Specifically, among the outcomes derived from the two types of campuses' models, the main different findings represent the land use and environmental quality features. In particular, we found that enclosure and transparency significantly influence urban campus WA, while the primary BE features that strongly affect PV in suburban campuses are land use entropy and facility land ratio. These findings reinforce the conclusions of previous studies and provide concrete evidence for campus planning. The following paragraphs will illustrate the detailed proposed strategies. The associated strategy was associated with the selected campus BE features significantly influencing walking from Table 9.

Table 9. The comparisons of BE correlates of walking between urban and suburban campuses.

Variables	Urban Campus		Suburban Campus	
	Model 1	Model 2	Model 1	Model 2
Destination accessibility				
Campus WS	0.056 ***	0.063 ***	0.077 ***	0.059 ***
Street connectivity				
Intersection density	—	—	—	—
Four-way intersection%	—	—	—	—
Block length	—	—	−0.003 [a]	−0.007 **
PRD	−0.758 **	−0.792 **	—	−0.803 **
Land use				
Facility density	0.044 ***	0.070 ***	0.045 **	1.748 ***
Entropy	—	—	0.747 *	—
Residential land %	—	—	—	—
Facility land %	—	—	—	1.748 ***
Office land %	—	—	—	—
Park land %	—	0.888 *	—	0.777 *
Spatial configuration				
Closeness	−1.841 *	−1.732 [a]	—	—
Betweenness	—	—	—	—
Environmental design quality				
Imageability	−0.137 [a]	−0.163 [a]	0.138 [a]	0.132 [a]
Enclosure	−0.258 ***	−0.263 ***	—	—
Human Scale	—	—	—	—
Transparency	0456 ***	0.440 ***	—	—
Complexity	0.395 ***	0.404 ***	0.370 **	0.266 *
Pedestrian facility				
Sidewalk quality	—	—	0.124 **	0.130 **
Sidewalk length	0.007 ***	0.007 ***	0.003 **	0.003 **
Street tree	0.232 **	0.251 **	0.191 [a]	0.190 *

Note: [a] $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

First, we proposed several design strategies suitable for both urban and suburban campuses: (1) paying attention to the balanced distribution of campus services and facilities to improve walking accessibility; (2) providing direct pedestrian access and multiple route options between services, wherever possible, to reduce detour distances; (3) increasing the number of facilities and the ratio of park land to improve the efficiency of facility and park services; (4) focusing on combining different building materials, increasing the number of decorative colors used, and enriching the material variations of the building façades, thus enhancing the complexity of campus streets; (5) emphasizing the appropriate configuration of walking paths and placement of trees such that they provide shade and visual interest, with both regularly maintained.

Second, we presented the differential strategies applicable to urban campuses only: (1) increasing the number of green squares and landscape features on both sides of the street, thus reducing the enclosure of the street; (2) focusing on the renewal and utilization of historical buildings to improve the efficiency of campus buildings; (3) increasing the proportion of glass interface on the first floor of facilities, such as supermarkets and restaurants, to strengthen the spatial and visual connection between the interior and exterior, thus enhancing the street transparency. Furthermore, we proposed several strategies that would be appropriate for suburban campuses only: (1) shortening block length by adding pedestrian access to the existing street network to improve campus pedestrian accessibility; (2) enhancing the mixed pattern of land use on campus with a mixed layout of residential, office, commercial, and park land, while increasing the proportion of land area used for facilities; (3) improving the quality of sidewalks by ensuring the appropriate sidewalk widths, maintaining street cleanliness, and reducing bulges and other obstructions.

This study had some limitations. First, our results and conclusions were based on data obtained from four campuses based in Tianjin, China. Although the selected campus's BEs comprised various categories, the number of research samples was relatively small, and whether the strategies proposed in this study are suitable for application in campuses in other regions and countries requires further verification. Second, since the studied campuses are all flat and there is no terrain change within the campuses, this study did not consider the effect of the natural environment of topography on PV. Considering that different terrains may have an impact on walkability, we will select campuses in different areas with terrain differences and increase the research samples in the follow-up study and explore the association with PV by quantifying the terrain attribute of the campus streets and examining the generalizability of the outcomes and strategies obtained from this study. Third, this study focuses on the association between BE features and PV, and the variables measured are cross-sectional data without considering the effects of temperature and climate environmental features on WA. Meanwhile, due to limited resources, this study only used 0 and 1 variables to assess street tree conditions and selected only a few elements to represent streetscape features. In future research, to comprehensively investigate the impact of campus BE features on WA, we intend to refine the street tree indicators by counting the number of street trees through field audits, measure climatic and natural environmental factors, and supplement this study's overlooked streetscape elements that may have a correlation with PV to achieve widely used planning and design strategies based on walkability and WA promotion that are suitable for different campus environments.

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Appendix A

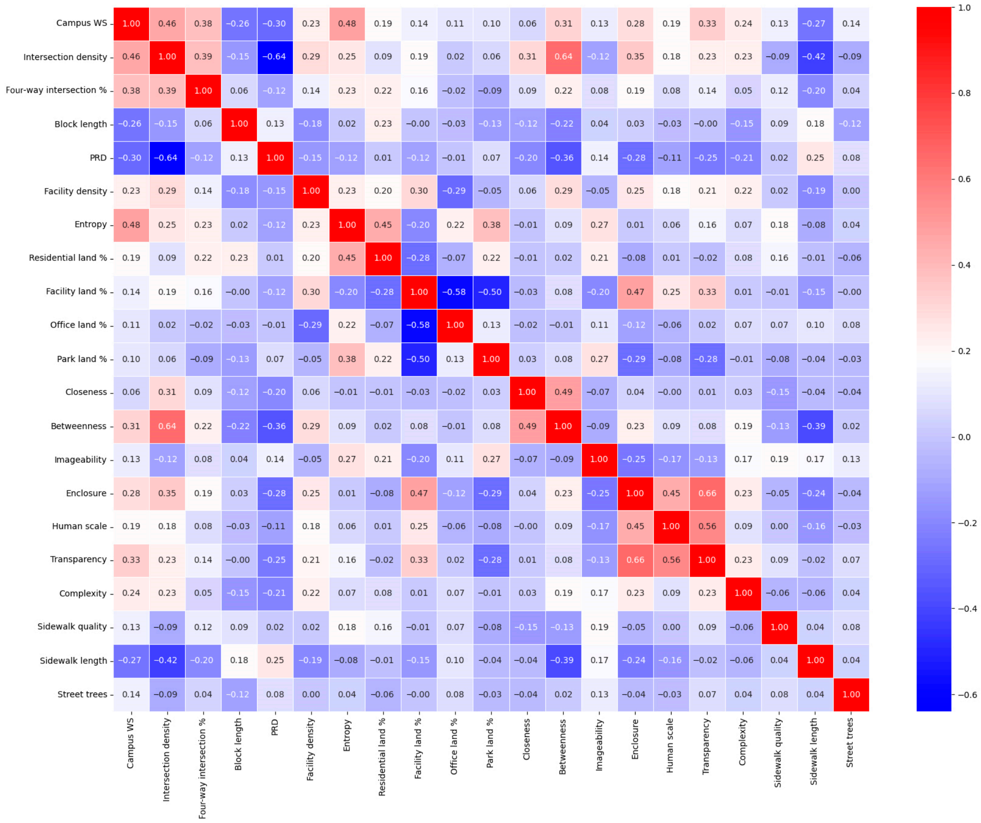

Figure A1. The result of the correlation between the independent variables in the entire campus.

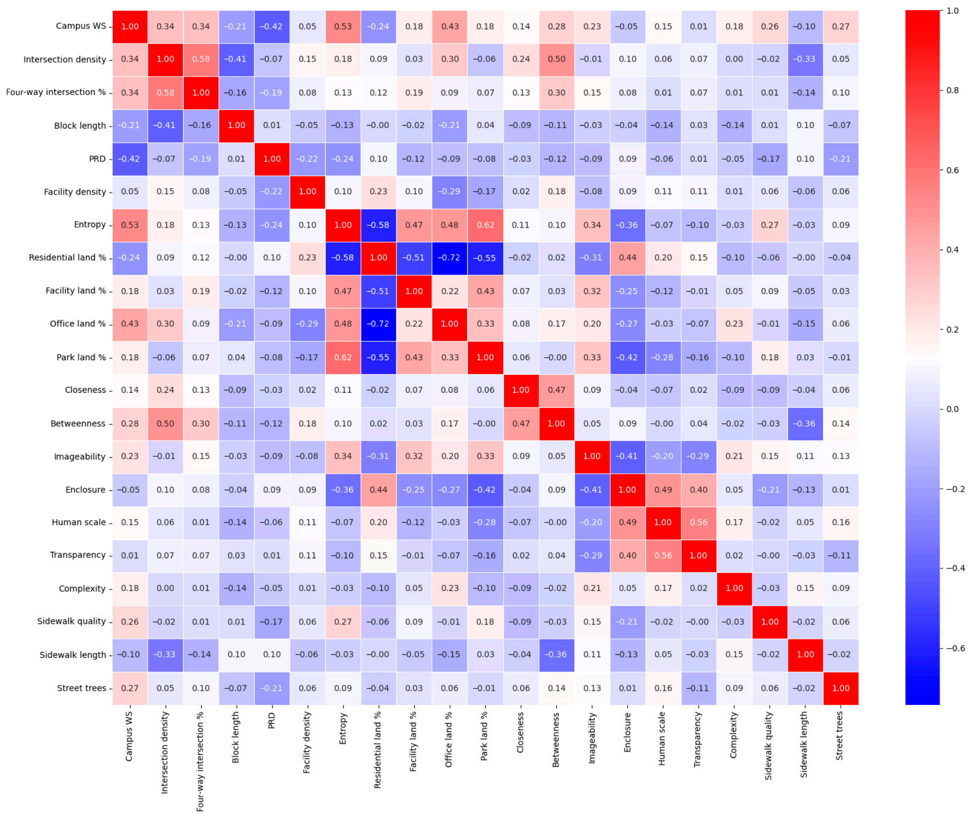

Figure A2. The result of the correlation between the independent variables in the urban campus.

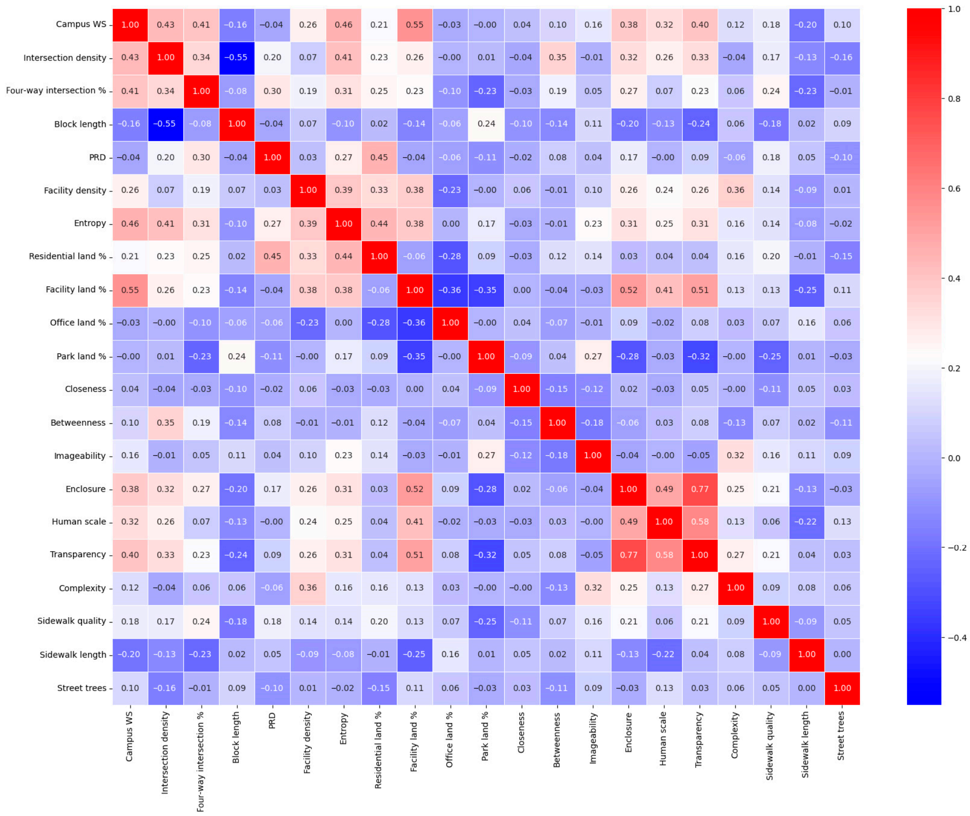

Figure A3. The result of the correlation between the independent variables in the suburban campus.

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