land

Article

Walk Score, Environmental Quality and Walking in a Campus Setting

Zhehao Zhang [1], Thomas Fisher [2] and Haiming Wang [3,*]

1 School of Architecture, Yantai University, Yantai 264005, China; zhangzh@ytu.edu.cn
2 School of Architecture, University of Minnesota, Minneapolis, MN 55455, USA
3 School of Architecture and Engineering, Yantai Institute of Technology, Yantai 264003, China
* Correspondence: wanghaiming@yitsd.edu.cn

Abstract: A small amount of campus walkability research has considered facility layout and environmental quality. The aim of this paper is to use a Walk Score and Urban Design Quality to assess campus walkability and investigate the impact of a campus Walk Score, environmental quality and other streetscape features on walking activity. This paper optimizes the Walk Score method based on the frequency, variety, and distance of students' walking to and from public facilities. A total of 157 campus street segments from the Weijin Road Campus of Tianjin University in China were selected to assess campus Walk Scores and environmental quality through the use of GIS and field audits. The effect of campus walkability and environmental features on pedestrian volume was examined by negative binomial regression. We found that Walk Score, transparency, street furniture, the number of buildings and noise level have a positive effect on walking activity, while enclosure and building basic color show a negative relationship with pedestrian volume. The results will be used to propose strategies to improve campus walkability and promote walking activity.

Keywords: Walk Score; urban design quality; university campus; walking activity; walkability

check for updates

Citation: Zhang, Z.; Fisher, T.; Wang, H. Walk Score, Environmental Quality and Walking in a Campus Setting. *Land* **2023**, *12*, 732. https://doi.org/10.3390/land12040732

Academic Editor: Teodoro Semeraro

Received: 4 March 2023
Revised: 22 March 2023
Accepted: 22 March 2023
Published: 24 March 2023

1. Introduction

As a low-carbon method of travel in the city, walking can promote social interaction, economic development, environmental protection, and public health. Walking also reduces the incidence of non-communicable diseases, energy consumption, and dependence on motor vehicles [1,2]. University campuses are an indispensable component of college towns and urban education zones. Although relatively less important to the city than residential areas and business districts, the campus is an important place to spread culture, receive an education and impart knowledge, and serve as a place to enhance students' physical health [3]. Because of rapid urbanization and transformations in lifestyle due to economic development, students' sedentary habits have become increasingly common, leading to a gradual decline in physical activity levels, which affects the development of students' physical and mental health [3]. In particular, the obesity rate of Chinese college students and young adults has increased from 0.1% in 1976 to 8.5% in 2016 [4].

As a readily available form of physical activity and the primary mode of travel on university campuses, walking remarkably influences students' daily lives. Improving campus walkability plays a vital role in optimizing the quality of the campus environment, upgrading the campus walking system, and inducing various walking behaviors. Moreover, campus walkability enhancements can help students meet the weekly physical activity recommendation, maintain a healthy body weight and shape, and promote their sense of campus belonging, better grades, retention and graduation rate, and other benefits, including lower stress and less depression [5–7]. Therefore, studying and improving campus environment walkability is crucial.

The motivation of this study is to systematically optimize the corresponding indicator systems and tools for measuring urban walkability based on the campus's unique environmental characteristics and the needs of students to use public service facilities. This study applies an optimized comprehensive measurement tool to evaluate the environmental walkability of the case campus and to explore its distribution pattern and its impact on walking activities.

Walkability can be widely understood as promoting walking activities by the environment and the degree of walking friendliness. As a spatial attribute, walkability has different meanings [8–11]. It measures the traversability, compactness and safety of the walking environment, helps create a dynamic space and built environment, provides a variety of sustainable transportation options, and promotes the development of various physical activities. Concurrently, walkability can also be used as a holistic solution to urban problems by quantifying diversified spaces [8]. Many scholars have defined walkability differently regarding the socioeconomic attributes of pedestrians, built and natural environmental features and social factors [9–11]. Leslie et al. defined the walkability of neighborhood communities as the ability of the living environment to induce walking activities [9]. Townshend described walkability as having a pleasant walking environment that is easy to pass and satisfying daily living needs through comfortable walking distances [10]. Southworth believes that walkability measures the built environment by creating a comfortable and safe walking environment to support and encourage walking activities while providing various facilities and pleasant scenery within a reasonable distance [11].

Several theories associated with walkability have been systematically discussed in academia. Scholars who have conducted walkability studies have mostly followed the "D" theory presented by Cervero, Kockelman, and Ewing [12,13]. This theoretical system focuses on attributes of density, diversity, and design, supplemented by two significant attributes: distance to transit and destination accessibility. As a valid and reliable proxy to evaluate destination (facility) accessibility, Walk Score has been widely used to measure the built environment's walkability [14,15]. It considers the number and types of facilities, walking time and street connectivity. Furthermore, other researchers have optimized the "D" theory and presented other new research frameworks or models. Kang put forward the research model of "S+5D" to study the impact of environmental features on pedestrian activity [16]. Lee and Moudon proposed the Behavioral Model of Environment (BME) theoretical framework and combined the elements of density, diversity, design, and route and built a "3D+R" research model to measure the walkability correlates that significantly affect walking [17]. In particular, Ewing's team elaborated on the "design" attribute and proposed the Urban Design Quality (UDQ) theory to measure the street micro-perspective environmental features [18], which will be illustrated in the following paragraph. Moreover, the associations between walkability correlates and walking behaviors are frequently investigated by regression models [13]. In particular, negative binomial regression and multiple linear regression are the main analytical methods to explore the influence of the walkability features on pedestrian activity.

Although academics have studied walkability from different viewpoints and found that the built environment features may affect walking activity, there are still two main research gaps. 1. Little research has assessed campus walkability regarding facility accessibility and environmental quality. 2. The influence of campus facility layout and design quality on street walking activity has yet to be systematically investigated. Consequently, the overall objective of this paper is to (1) apply the Walk Score method and UDQ to assess campus walkability from the perspective of facility accessibility and environmental quality, map the relationship between these two critical factors, and detect the location of the low walkable and poor environmental quality streets, and (2) use negative binomial regression models to analyze the impact of Walk Score and the quality of the street environment on pedestrian volume.

2. Literature Review

2.1. Measuring Walkability

There are many methods to objectively measure walkability in terms of destination accessibility, residential density, land use mix, and safety. It can be divided into two primary metrics: walkability score and walk score [19]. While scholars have proposed different walkability score indexes, such as the Walkability Index, Pedestrian Environment Index, Walk Opportunities Index, and Pedestrian Index of the Environment, these methods' applicability to different environments has yet to be systematically and comprehensively verified [19]. Compared with the walkability index, Walk Score studies mainly concentrate on (1) verifying the measurement method by analyzing the relationship between Walk Score and built environment variables, such as street patterns and land use mix; and (2) exploring its impact on walking purpose, travel mode, physical activity, real estate, and other dependent variables. Pearson correlation analysis was used to verify the Walk Score method and found a significant correlation between Walk Score and street connectivity, residential density, facility accessibility and other factors [20,21]. Further research found that Walk Score positively affects property value [22,23]. Moreover, research has shown that Walk Score directly influences the promotion of physical activity and health [24,25].

Additionally, walkability can also be measured from a micro-perspective by field audits, such as the Irvine–Minnesota Inventory (IMI), the Sidewalk Assessment Tool (SAT), and the Pedestrian Environmental Data Scan Tool (PEDS), to assess streetscape features and design qualities [26]. Ewing proposed the UDQ measurement system from an objective, quantitative viewpoint by combining the sense of safety, comfort, and level of interest from personal subjective perception and the street environmental features [18,27]. The theory contains five qualities: imageability, enclosure, human scale, transparency, and complexity. Currently, scholars have used this measurement system to assess street qualities in different regions and analyze its effect on walking activity. The scope of the assessment areas ranges from highly walkable city centers and downtown improvement districts to small cities under construction and suburbs with low-density areas or a small number of streets. One study measured the urban design quality of 588 walkable streets in New York City. It proposed a valid, optimized method to measure each quality [28], while another study used the UDQ method to assess the quality and walkability of suburban high streets in an Australian city [29]. Another study took the Walk Score as the control variable and qualitatively analyzed the influence of different qualities on street walking activity [30]. Other research found that enclosure and human scale significantly affect walking activity, and imageability and transparency have a close relationship with pedestrian volume [18,31–33].

2.2. Campus Walkability Studies

Considering that the campus built environment differs from other urban spaces in terms of space conformation, inhabitant characteristics, and commuting mode, many scholars have chosen factors from the existing assessments of neighborhood and community or from the workplace walkability method to present new ones to evaluate campus walkability and travel environment. One study presented a hybrid method combining accessibility and safety to assess campus route walkability and used a Saudi university campus as an example to verify the suitability of this tool [34]. Further research used a multi-approach to compare the consistency between students' perceptions of campus bikeability and objectively measured bikeability indicators based on the assessment of safety, quality, and comfort [35].

Additionally, other scholars explored the influence of the campus built environment on students' (1) well-being, satisfaction with college life and students' success, (2) physical activity and health condition. Specifically, students' physical activity significantly influences their academic performance and college life. For the first domain, researchers investigated the influence of physical activity intensity on students' drunkorexia behavior. They found that vigorous physical activity strongly correlates with students' severity of drunkorexia behaviors [36]. Further research distilled four main elements of campus built environment, which influence student well-being, including urban design qualities, safety, accessibility, and winter design strategies [37]. Moreover, researchers have explored the impact of moderate physical activity and student interaction on retention at a community college. However, they found no direct correlation between these two factors with retention [6]. For the second domain, one study examined the association between campus built environment and adiposity outcomes among Chinese undergraduate students and found that street connectivity, population density, and Normalized Difference Vegetation Index (NDVI) have a negative relationship with the odds of adiposity [3]. In addition to the campus's physical environment, researchers also combined students' perceptions of the social environment. They identified the influence of the built environment on student physical activity participation and active transport habits [38]. In contrast, other researchers integrated perceived psychological determinants to examine their impact on transport-related walking and cycling [39]. Although existing studies on campus walkability and the built environment have proposed various measurement tools and explored their effects on students' campus life and physical activity, and health, the distribution of facilities and environmental quality as essential environmental elements have yet to be explored in depth. Therefore, this study will focus on the applicability of Walk Score and UDQ to evaluate campus walkability and examine their effects on walking activities.

3. Materials and Methods

3.1. Study Setting

This paper takes the Weijin Road Campus of Tianjin University in China as the research object. Tianjin University also contains another new campus, the Beiyang Yuan Campus, located in the suburban Jinan district and built in 2015. The selected campus was established in 1952 and is located in the city center of Nankai District in Tianjin, China. It is adjacent to Nankai University in the south and the main city road Anshan West Road and Weijin Road to the north and east, respectively. The campus has 11 colleges, a population of 11,000 full-time undergraduates and graduates, and 4895 staff (in addition to classes at the new campus, most staff live and work at the Weijin Road campus). Because of the unique management mode of Chinese university campuses, universities provide dormitories on campus and enforce a relatively mandatory dormitory enrollment to reduce students' living expenses and facilitate management. Therefore, most students are living on campus. This campus can be divided into five parts. As shown in Figure 1, the central part is the public teaching area where some teaching buildings, the library, student activity center and other public-service facilities are located. The brown area on the map is the recreational and sports area, which has a gym, outdoor stadium, and arts center. The yellow and green areas on the map are the students' and teachers' residences, respectively, and the blue part contains squares, lakes, and green spaces where people can engage in entertainment activities. The campus has experienced many construction periods and has many historical buildings listed as cultural relic protection, and the built environment characteristics reflect different construction periods. As a comprehensive university with a long history, this campus's construction process, location, planning, facility layout, and built environment are typical of Chinese campuses.

For the urban environment, measuring the built environment features is always based on the scope of the neighborhood or administrative zone. However, for the campus environment, because the campus streets scale is much smaller than that of the city, and one or more buildings often occupy both sides of a street, the environments around the street can accurately reflect the land use, facility distribution, space quality and other environmental attributes. Moreover, some existing walkability and walking activity studies have chosen the street as the research object to measure the street's environmental characteristics [18,29–33]. Therefore, we chose the street segment as the measurement sample object. Specifically, we selected the midpoint position of the street segment and chose one side of the street with diversified built environmental features as the location for calculating the Walk Score and counting the pedestrian volume along the same side.

However, for measuring the street environmental quality, as each quality is composed of various streetscape features, different features need to be audited based on one or both sides of the street (the table in Section 3.2.2 will signify the audit method of environmental features in detail). Therefore, it is necessary to simultaneously consider the environmental features on one or both sides of the street. In order to cover a comprehensive range of streets located in different types of lands on the campus, we selected 202 street segments. Furthermore, we eliminated the segments without allocating buildings and street amenities and ultimately chose 157 street segments to study. Considering that students may use some off-campus daily service facilities near the campus, the research scope is expanded by 1000 m from the campus boundary.

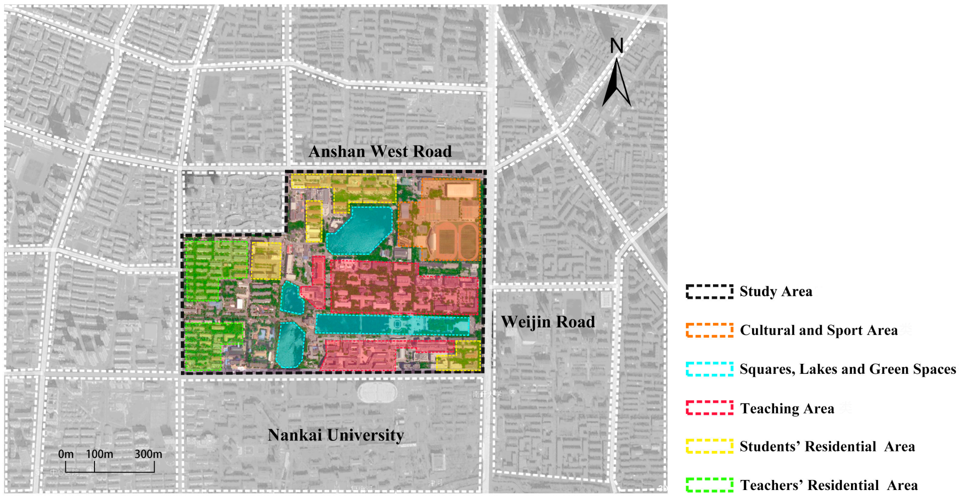

Figure 1. Functional analysis of the campus.

3.2. Study Design

Firstly, we obtained the required data through questionnaires to optimize the Walk Score measurement method and use the new method to assess campus street walkability. Additionally, we used the UDQ system to rate the environmental quality of the same street segments and mapped the association between campus Walk Score and environmental qualities. Secondly, we used correlation analysis to verify the rationality of the optimized Walk Score and UDQ method. Finally, we used regression models to explore the effect of campus Walk Score, environmental quality, and streetscape features on pedestrian volume.

3.2.1. Walk Score

The calculation of the Walk Score is based on a gravity model, with measurements based on two significant factors: the attenuation coefficient of the distance from the evaluation point to the closest destination (public service facility) and the facility weight. Subsequently, we adjusted the raw score according to the intersection density and block length around the evaluation point [14]. According to the Walk Score measurement algorithm and Zhang et al.' s method [14,40], we designed the questionnaire and related questions about establishing facility weight and the curve of time decay. The questionnaire contains three sections. First, we investigated the students' demographic attributes, such as sex, age, grade, apartment address and other information; second, for the establishment of facility weight, we surveyed the frequency of walking to different types of facilities (e.g., retail store, gym, library, etc.) on campus each week and the preference of various facilities of the same category. Finally, for the fit of the curve of time-decay, we investigated three types of walking time: (1) Walking comfort time; (2) Walking tolerance time; (3) Walking resistance time.

We randomly selected 359 Chinese students from Tianjin University, with only students living on the campus considered in the survey. In order to have a balanced sample distribution, the chosen students live in the four different campus residential areas (The yellow regions in Figure 1). This study got approval from the university and then asked each participant to answer a questionnaire. We developed the questionnaire by "Questionnaire Star", a convenient and professional web-based survey platform that allows us to overcome geographical and spatial constraints and spread the questionnaire on different social platforms at any time. The study's questionnaire works both online and offline. Each participant took 10 min on average to complete the survey by scanning a QR code link, and most surveys were finished online. Students were informed that their information would remain confidential for this study, and they could choose to withdraw the information at any time. After completing the questionnaire, they could get a red envelope or a small gift. After eliminating the incomplete, abnormal, and error data, we finally collected 310 valid questionnaires finished by 124 graduate students and 186 undergraduate students to investigate the circumstances of students' using the public service facilities (Table 1). All the survey data were collected from April to May 2019.

Table 1. Demographic data of the campus.

Gender	**Data (% of Sample)**
Male	50.9
Female	49.1
Grade	
Undergraduate	60
Graduate	21.3
PhD candidate	18.7

On the one hand, based on the analysis of the survey data, we grouped the common public service facilities that students always use into 13 types:

1. Canteen and restaurant;
2. Public teaching building;
3. Retail store;
4. Gym;
5. Library;
6. Square and green space;
7. Bus station;
8. Outdoor stadium;
9. Coffee shop;
10. Student activity center;
11. Bank and post office;
12. Administrative building;
13. Barbershop.

This research used the optimization method from Lu and Huang et al. to modify the weight of the facilities table, which includes three factors: (1) establishing the diversity of facilities, (2) completing the demand distribution of diversity, and (3) calculating the satisfaction of requirements of classified facility [41,42]. To simplify the calculation method, the weight value of each classified facility was established by multiplying the proportion of the weekly use frequency of such facility in the use frequency of all facilities by 100 (Table 2). For example, the weight of the canteen and restaurant is 47.54, calculated by dividing the weekly usage frequency of the canteen by the total usage frequency of the overall facility, i.e., 21/44.17 = 47.54%.

On the other hand, in terms of fitting the curve of time decay, it can be seen from the attenuation algorithm of Walk Score that the facility weight does not attenuate within a distance of 5 min of walking, and the facility weight attenuates by 12% from 5 min to 20 min. When the walking time increases for more than 30 min, the attenuation coefficient exceeds 1, which means the Walk Score decreases to zero. It is worth noting that the time-decay principle needs to be adjusted for different populations, especially for college students.

Table 2. The weight and curve of time decay of each facility.

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			

Therefore, according to Liu's method [43], this study used a questionnaire survey to obtain the evaluation results of students': (1) walking comfort time (the willingness to travel on foot will not be affected by the increase in distance, with six response categories—less than 3 min, 3–4 min, 5–6 min, 7–8 min, 9–10 min, 11–12 min); (2) tolerance time (from comfort time to this time, the willingness to walk will decrease, with six response categories—11–12 min, 13–14 min, 15–16 min, 17–18 min, 19–20 min, 21–22 min) and (3) resistance time (students are no longer willing to walk to public facilities beyond this time, with six response categories—21–22 min, 23–24 min, 25–26 min, 27–28 min, 29–30 min, over 30 min) for different kind of facilities.

From this, we established the facility's curve of time decay. After averaging the value, we divided the intervals of time decay into three categories: (1) 6 min (walking comfort time), 17 min (walking tolerance time), 24 min (walking resistance time), Facility: public teaching building, canteen and restaurant, bus stop, retail store. (2) 7 min (walking comfort time), 18 min (walking tolerance time), 24 min (walking resistance time), Facility: library, coffee shop, bank and post office, square and green land. (3) 8 min (walking comfort time), 17 min (walking tolerance time), 24 min (walking resistance time), Facility: gym and outdoor stadium. We fit the final curve of time attenuation according to these categories.

Based on the facility weight and the curve of time decay, the 13 types of classified facilities' scores at the midpoint of the selected street were calculated and summed to get the initial total Walk Score. Furthermore, the raw score was adjusted by the value of the intersection density and block length around the street midpoint. The detailed attenuation principle is a maximum 5% penalty for <60 intersections per square mile and the same maximum of 5% penalty for >195 m length per block [14]. Because the campus form and block scale are smaller than the urban scale, we finally chose a 200 m actual road network buffer to calculate these two street connectivity attributes. After the adjustment according to this rule, the ultimate campus Walk Score was obtained. The scale of the Walk Score ranges from 0–100, with higher values indicating higher walkability. The Walk Score is computed as:

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

where wi is the facility weight of a specific type of facility, n is the category of facility, dij is the shortest walking distance from a specific location to facility i, g (dij) is the walking time attenuation coefficient based on the walking distance, ID is the attenuation coefficient of intersection density, and BL is the attenuation coefficient of the block length.

3.2.2. Urban Design Quality

This research applied Ewing's urban design quality theory to measure the quality of the campus street environment. Ewing's team, composed of 10 experts, analyzed the reliability of ratings of perceptual qualities and presented five urban design qualities: imageability, enclosure, human scale, transparency, and complexity. They gave the definitions of the five urban design qualities as follows [18]:

1. Imageability refers to what makes a place distinct, recognizable, and memorable. A high imageability street can capture attention, evoke feelings, and create a lasting impression.
2. Enclosure refers to the degree to which buildings, walls, trees, and other vertical elements visually define streets and other public spaces.
3. Human scale refers to the size, texture, and articulation of physical elements that match the size and proportions of humans and, equally important, correspond to the speed at which humans walk.
4. Transparency refers to the degree to which people can see or perceive what lies beyond the edge of a street or other public space and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street or other public space.
5. Complexity refers to the visual richness of a place and depends on the variety of the physical environment.

Ewing's team also correlated the coefficient of every streetscape characteristic to each urban design quality from the regression model and the field manual. Using Ewing's field manual, we collected data on 21 streetscape characteristics and pedestrian volumes. Next, we followed the coefficient of each characteristic to calculate the five design qualities (Table 3), and summed each quality score to obtain the overall quality score. Because we used pedestrian volume as the dependent variable, the imageability and complexity values were recalculated without considering pedestrian counts.

Table 3. Urban Design Qualities, Their Physical Features, Coefficients and *p*-Values (Adapted from source [18]).

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

Note: "#" refers to the number.

3.2.3. Pedestrian Activity

This paper followed Ewing's method to count the pedestrian volume for each street [18]. The method involves a person walking through the whole street and counting the individuals who were standing, walking, cycling, and running during typical weekdays from Monday to Friday. Because students' peak hour of commute is around midday, rather than employees' two peak hours around 7 a.m. and 5 p.m. [44], the counting time of this research was around 9 a.m.–12 a.m. and 1 p.m.–5 p.m. After counting each street four times, we used the average value of the data as the final street pedestrian volume. Counts were cancelled for any day with inclement weather (rain or high winds).

3.2.4. Statistical Analysis

In order to verify the rationality of the optimized Walk Score method and the suitability of applying UDQ to assess campus design quality, we used R 3.4.0 language to conduct Pearson correlation analysis to investigate the correlation between campus design quality and Walk Score as well as the relationship between each design quality. Because the critical objective of this research is to explore the effect of Walk Score and urban design qualities as well as streetscape characteristics on pedestrian volume, and the pedestrian count is a non-negative round number, the overall value is small, with only a few larger ones, so Poisson and negative binomial regression are suitable models to use. Considering the value of the pedestrian volume is over-dispersed, and the variance is higher than the mean, we used the dispersion test to find over-dispersion in the Poisson models and chose negative binominal regression to analyze the data.

Moreover, due to the spatial proximity between the measured streets, the pedestrian flow of a certain street will be affected by the adjacent streets, which leads to the problem of spatial autocorrelation in the regression model and affects the accuracy of the results. Therefore, we need to remove the influence of spatial autocorrelation. Prior research proved that the Spatial Filtering method can eliminate the spatial autocorrelation in the regression model [31,45]. The advantage of Spatial Filtering is that after the spatial autocorrelation is eliminated, the significance of independent variables in the model is corrected, but the coefficient remains unchanged, so we use this method to improve the accuracy of the final regression results.

Subsequently, we used Moran's I detect spatial autocorrelation by GIS and found the value is 0.201, $p < 0.001$, which means there is a need to control spatial autocorrelation. Further, we used the ME (Moran eigenvectors) function in the spatialreg package in R language to eliminate the influence of spatial autocorrelation in the negative binomial regression model. After the spatial filtering was applied, Moran's I statistic for the adjusted Model indicates no spatial autocorrelation and the validity of the results has been significantly improved.

4. Results

4.1. Evaluating Walk Score

The average Walk Score of the street is 94 (Figure 2), which belongs to the highest level of Walk Score (Walker's Paradise). In terms of spatial distribution, the streets with high scores are mainly concentrated in the middle, north and west areas of the campus, especially in the central part of the campus, with a Walk Score of more than 90, where students can meet their daily requirements, study, and exercise through short-distance walking. However, the street on the north side of the campus has a Walk Score of only 75 because of the single type of facility. Moreover, the closed campus boundary in the northeast blocks people from walking through the campus, making this region among the lowest in walkability. Other than that, the average Walk Score of the residential area on the west side of the campus is 85. Although the walkability of this area is lower than that of the central part, compared with the residential area on the north side of the campus, this area still has higher walkability due to the diversity of the public service facilities.

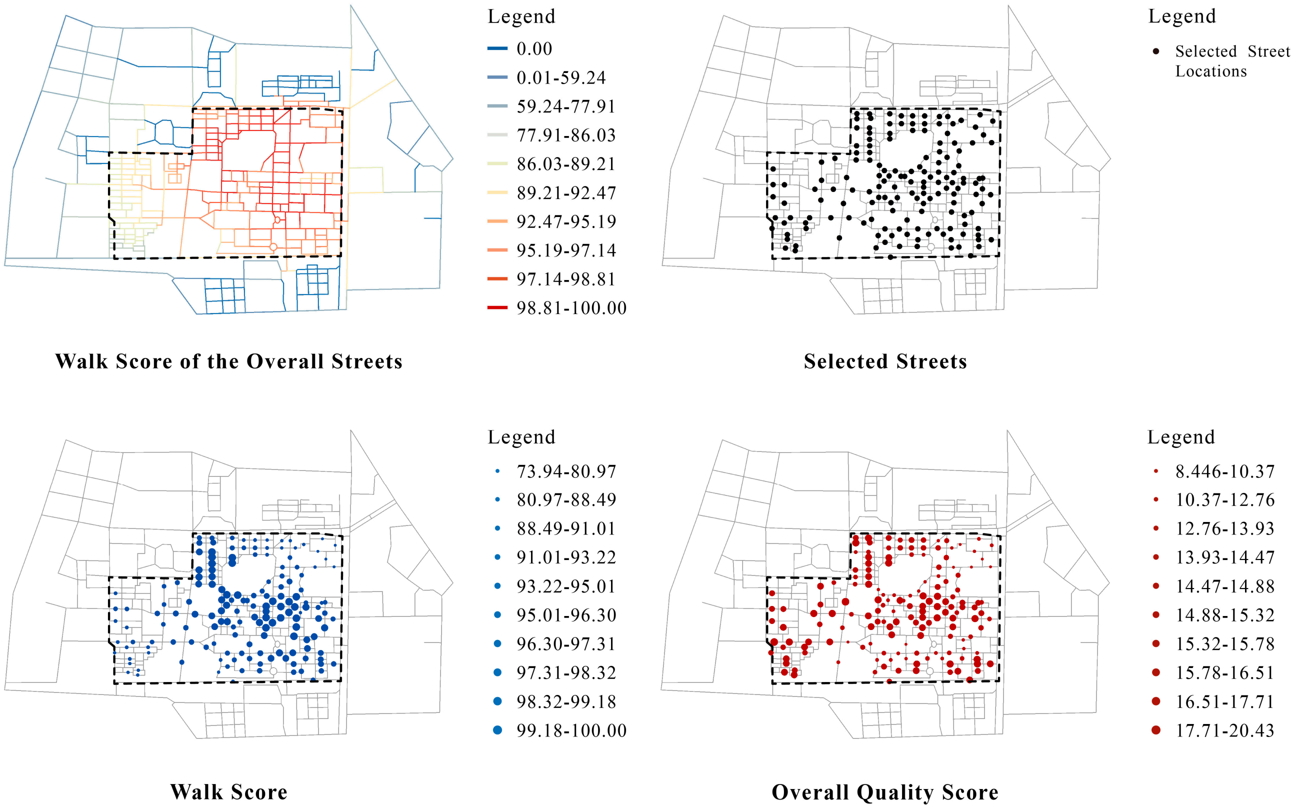

Figure 2. The location of the selected streets and their Walk Scores and overall quality.

4.2. Evaluating the Environmental Quality

The average streets' overall quality score is 14.95 (Figure 2, Table 4). For the distribution pattern, the pattern of the quality score has a strong relationship with the campus function. For instance, the streets with higher quality scores are concentrated in the central part of the campus due to different architectural styles, building colors, sophisticated details, delicate ornaments, street furniture, pleasant building heights, and street widths exist. However, in the northwest and southeast of the campus (Figures 3 and 4J,F), the students and staff residential area had a higher degree of enclosure, human scale, and transparency due to the high building density and road-network connectivity. However, its single function, fewer building identifiers, and accent colors reduced the imageability and complexity of the streets. In the northeast recreational and sports area (Figures 3 and 4B), owing to the unbalanced facility layout, low building density and special functional attributes, the imageability, enclosure, human scale, and complexity around this area score the lowest. Concurrently, the street adjacent to the lake and the square in front of the campus are characterized by a clear, long sightline, and open space (Figure 4E,I), which led to a decrease in the degree of enclosure, human scale, and complexity.

We also mapped the low walkability and poor environment quality streets on the campus to accurately explore the spatial distribution of the correlation between Walk Score and each quality on the campus to find out the inconsistent areas and diagnose the areas where streets had low quality and poor walkability. This endeavor will play a vital role in optimizing and improving street quality and walkability in the campus renovation. According to the classification method used by Bradley Bereitschaft in the study of the spatial and statistical correlation between walkability and social vulnerability [30], we removed the middle two parts and used the top and bottom quartile of each group for further analysis of the streets with low walkability and poor environment quality (Figure 5). We found that the red triangle area is a street with a low Walk Score and low-quality score, while a street in the green dot area has the best walkability and environment quality. The other color areas are mainly the areas with inconsistent correlation, namely, the street with a high Walk Score and low-quality score or with a low Walk Score and high-quality score.

Table 4. Mean, Standard Deviation, and Median for Urban Design Qualities and Individual Items for the selected streets.

Urban Design Qualities and Individual Items	Mean	Median	SD
Imageability	2.62	2.55	0.49
Number of courtyards, and parks (both sides)	0.47	0	0.61
Number of major landscape features (both sides)	0.19	0	0.43
Proportion of historic frontage (both sides)	0.15	0	0.31
Number of buildings with identifiers (both sides)	0.84	0	1.57
Number of buildings with non-rectangular shapes (both sides)	0.3	0	0.62
Outdoor dining (observer side)	0.01	0	0.11
Number of walking pedestrians (observer side)	5.7	4	5.43
Noise level (both sides)	2.93	3	1.09
Enclosure	2.68	2.68	0.89
Number of long sight lines (both sides)	0.34	0	0.55
Proportion street wall (observer side)	0.71	0.8	0.33
Proportion street wall (opposite side)	0.46	0.5	0.4
Proportion sky (ahead)	0.23	0.2	0.09
Proportion sky (along the street)	0.18	0.1	0.13
Human Scale	2.84	3.02	0.5
Number of long sight lines (both sides)	0.34	0	0.55
Proportion windows at street level (observer side)	0.4	0.4	0.2
Average buildings height (observer side)	14.35	15	7.92
Number of small planters (observer side)	0.28	0	1.07
Number of pieces street furniture and other street items (observer side)	2.55	2	2.47
Transparency	3.03	3.20	0.54
Proportion windows at street level (observer side)	0.4	0.4	0.2
Proportion street wall (observer side)	0.7	0.8	0.33
Proportion street wall (opposite side)	0.69	1	0.39
Complexity	3.78	3.75	0.57
Number of buildings (both sides)	2.48	2	1.71
Number of basic building colors (both sides)	2.66	2	1.55
Number of accent building colors (both sides)	1.42	1	1.26
Number of pieces of public art (both sides)	0.33	0	0.78
Outdoor dining (observer side)	0.01	0	0.11
Number of walking pedestrians (observer side)	5.71	4	5.43
Overall Quality	14.95	15.02	0.58

From Figure 5, we can tell that the streets with low Walk Scores and poor environment quality were located in the students' residential area and recreational and sports area on the north side of the campus (Figure 4B), where the spatial distribution of imageability, enclosure, human scale and complexity were the most significant. In addition to the sports' area on the northeast side, there are two other streets on the west side of the 26th teaching building where the streets' human scale is still low. This area is mainly equipped with electromechanical buildings and several developing lands, and it lacks street furniture such as street lamps, tables, and chairs. In addition, both sides of the south–north street had a lower proportion of windows. All of these factors result in a lower human scale in this area. Unlike the first four types of qualities, the areas with lower Walk Scores and transparency scores are widely distributed on campus. In addition to the Northeast cultural and sports area, where all the urban design qualities had a low-quality score, there are also streets with low transparency in the public teaching area in the centre of the campus and the staff residential area in the west (Figure 4E,H). This is because the central area has few windows, and many historic buildings have not been actively used. Additionally, the residents have transformed the ground floors of several apartments in the west residential area into closed interior spaces, hence the low ratio of window to wall, resulting in its low transparency.

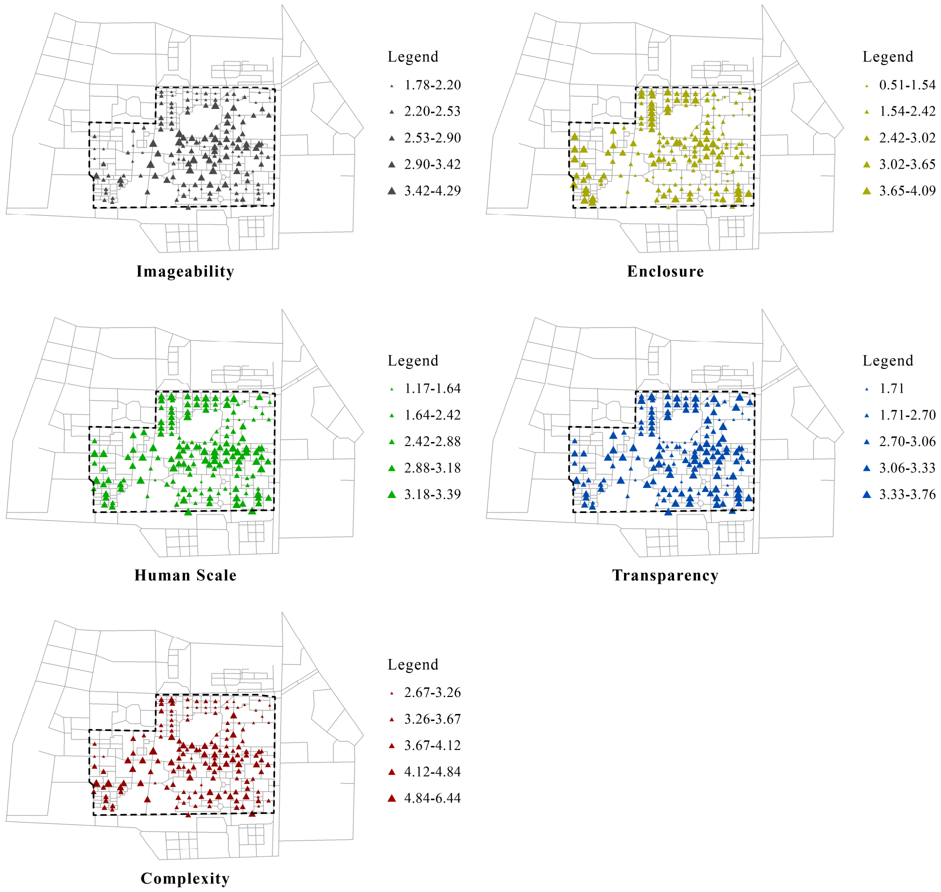

Figure 3. The results of the calculation of each design quality.

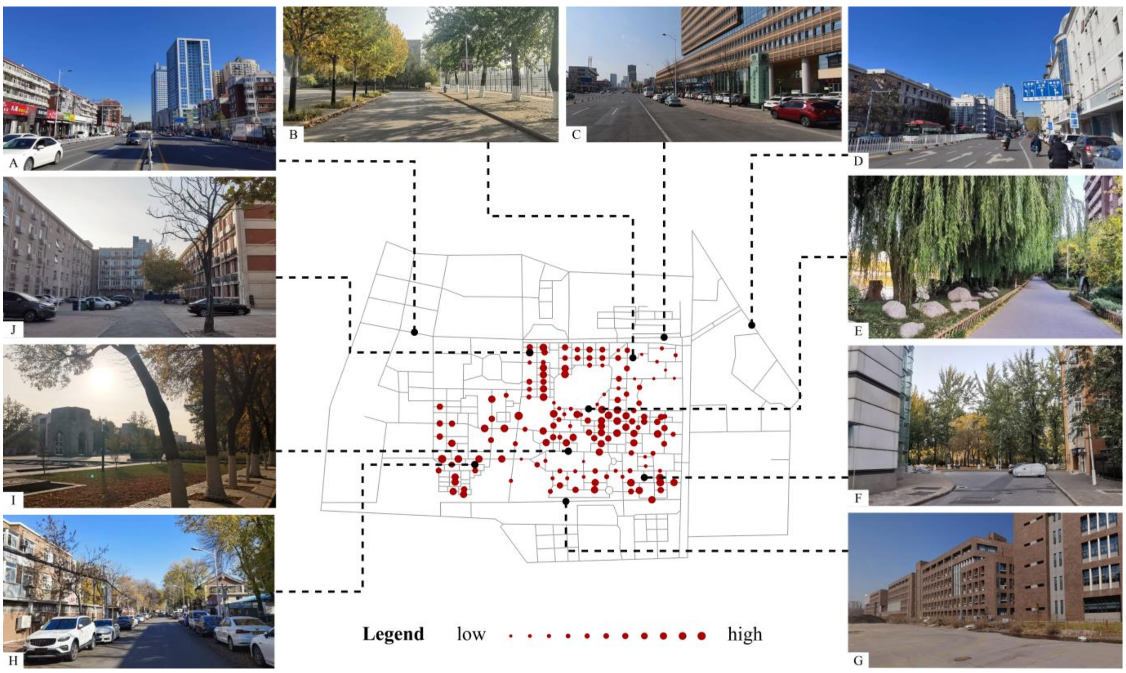

Figure 4. Photo collage illustrating the quality of the street environment. All the photos were taken by the first author. (**A**) West side of the Anshan West Road. (**B**) The east side of Jixian Road. (**C**) The east side of Anshan West Road. (**D**) Xinxing Road. (**E**) The road on the south side of the lake. (**F**) The road in the student residential area on the southeast of the campus. (**G**) The road connecting Tianjin University and Nankai University. (**H**) Hubin Road. (**I**) Jingye Road. (**J**) The west side of Jixian Road.

Figure 5. The map of the association between Walk Score and Overall quality score.

4.3. Correlation and Regression Analysis

The internal correlation analysis of the five design qualities (Table 5) found a positive correlation between each quality except for imageability and enclosure, and enclosure and complexity. However, the significance and correlation coefficient differ from 0.087 (enclosure and human scale) to −0.892 (imageability and transparency). Nevertheless, only imageability has a significant negative correlation with complexity, human scale and transparency. The reason is that many public squares and lakes are on the campus, so it improves street imageability. Nevertheless, its low building density also leads to the reduction of enclosure quality. In addition, the long, horizontal sightlines on both sides of the street reduce the human scale and transparency. Hence, the imageability is negatively linked with these three qualities.

Table 5. Correlation among the five qualities.

	Imageability	Enclosure	Human Scale	Transparency	Complexity
Imageability	1				
Enclosure	0.149	1			
Human Scale	−0.577 **	0.087 *	1		
Transparency	−0.336 *	0.37 *	0.691 **	1	
Complexity	−0.892 **	0.087	0.625 **	0.361 *	1

Note: Boldface font indicates that the coefficient is statistically significant at the $p < 0.05$ level, and * $p < 0.01$, ** $p < 0.001$. The number of observations in the model is 157.

Through the result of the correlation between Walk Score and environmental qualities (Table 6), we found that there is a significant positive relationship between the campus Walk Score and the overall quality score; the coefficient is 0.209, which means that the higher the quality of the street, the better its walkability. There was also a positive correlation between Walk Score and the classified quality (Table 6), particularly imageability, human scale and complexity. The coefficient of complexity with the Walk Score was the highest. Consequently, these two groups of correlation analysis have preliminary validated the rationality of the optimized Walk Score and UDQ method.

Table 6. Correlation between Walk Score and environmental qualities.

Overall Quality	Imageability	Enclosure	Human Scale	Transparency	Complexity
0.209 *	0.254 **	0.052	0.092 *	0.014	0.286 **

Note: Boldface font indicates that the coefficient is statistically significant at the $p < 0.05$ level, and * $p < 0.01$, ** $p < 0.001$. The number of observations in the model is 157.

For the analysis of the effect of streets walkability and environmental quality as well as streetscape characteristics on walking activity because the overall quality consists of five classified qualities and each quality is influenced by different streetscape characteristics, in order to avoid the collinearity problem between independent variables, we conducted three negative binominal regression models (Table 7). Model 1 is comprised of Walk Score and overall quality score. Model 2 contains Walk Score and five classified quality scores. Model 3 includes the streetscape variables in addition to Walk Score. In Model 1, the results show both Walk Score and overall quality score positively correlate with pedestrian volume. In Model 2, Walk Score is also significant and has an expected relationship with pedestrian volume. Moreover, two environmental qualities are significant, with transparency showing a positive relation to pedestrian volume and enclosure having a negative effect on pedestrian activity, which indicates that a street environment with high walkability, low enclosure and high complexity is more likely to induce walking behaviors. In Model 3, five variables are significant. In addition to Walk Score, three streetscape features have a positive correlation with pedestrian volume: noise level, the number of pieces of furniture and the number of buildings. However, only the number of basic building colors negatively correlates with pedestrian counts.

Table 7. Regression Model of Pedestrian volume.

Variable	Model 1			Model 2			Model 3		
	Coefficient	**Std. Error**	**Sig.**	**Coefficient**	**Std. Error**	**Sig.**	**Coefficient**	**Std. Error**	**Sig.**
Intercept	−4.297	1.204	<0.001	−6.378	1.098	<0.001	−5.304	1.001	<0.001
Walk Score	0.076 ***	0.013	<0.001	0.090 ***	0.109	<0.001	0.057 ***	0.011	<0.001
Environmental Quality									
Overall Quality	0.074 *	0.031	0.018						
Imageability				−0.198	1.141	0.121			
Enclosure				−0.276 ***	6.733	<0.001			
Human Scale				−0.151	1.365	0.130			
Transparency				0.361 ***	0.206	<0.001			
Complexity				0.224	0.107	0.362			
Streetscape Features									
Noise level							0.325 ***	0.048	<0.001
Street furniture							0.021 ***	0.019	<0.001
Number of buildings							0.130 **	0.043	0.003
Number of basic building colors							−0.100 **	0.035	0.002
Spatial filtering eigenvector									
Fitted (ME) (1)	2.207	0.575	<0.001	−1.984	0.603	0.001	−0.316	0.541	0.560
Fitted (ME) (2)	−1.215	0.612	0.049	2.527	0.566	<0.001	0.016	0.505	0.945
Fitted (ME) (3)				1.669	0.559	0.003			
N	157			157			157		
AIC	795.52			794.75			793.63		

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The variables of streetscape characteristics that have no significant correlation with pedestrian counts were eliminated in the table.

5. Discussion

In this paper, we optimized the Walk Score method based on students' on-campus living and the campus built environment, and used the new methodology to calculate the street Walk Score and evaluate the overall walkability of the Weijin Road campus of Tianjin University. Additionally, we assessed the street's environmental qualities based on the UDQ theory. The results found that there are differences in the walkability and environmental quality between different areas of the campus. It can be seen that the street on the northeast side of the campus has low walkability and poor environmental quality because of the closed campus wall blocking people walking through the campus and weakening the vitality of the business facilities around the street. In China, enclosing the campus with a wall is a routine measure of campus planning. Although it has the advantages of easy management, improving campus safety and creating an independent and pure academic environment, a perimeter wall blocks the connection between the on-campus and off-campus built environment and the possibility of inducing various walking activities. This outcome aligns with Liu's study, which also found that regions with good permeable boundaries have a better walkability level [43]. Therefore, for the university campus located in the central urban area, the enclosed wall should be removed, or the number of gates should be increased to improve the permeability and openness of the boundary environment to provide convenience for the students to use the off-campus service facilities and to allow the citizens to go into the campus to use the recreational and sports and other teaching facilities.

For the verification of the optimized Walk Score and UDQ method, there is a positive correlation between Walk Score and quality score. Moreover, improving each quality will increase the streets' walkability to a different degree. This result is consistent with other scholars' Walk Score research. Li calculated the quality score of Buffalo using the combination of two-dimensional and three-dimensional methods in GIS and also found a significant positive correlation between urban design quality and Walk Score [46]. Pearce also found that Walk Score has a strong relationship with the overall quality score, and this correlation is more significant in urban areas [47]. Additionally, many qualities are significantly related, especially in human scale, transparency and complexity. This general outcome also accords with Ewing and Clemente's study; they also found that the improvement of one kind of quality will promote the increase of other qualities [18].

Moreover, we found that facility layout has a close relationship with walkability. This finding is consistent with that of another study, which optimized the Walk Score method based on the facility use demand and walking willingness of the elderly and evaluated the walkability of the areas with different facility distribution modes [42]. We all found that compared with the centralized facility layout, the uniform distribution has a more significant impact on Walk Score. Furthermore, Peachey and Baller found that due to the reasonable distribution and accessibility of campus facilities, the walking activity intensity of students living on campus is higher than those living outside [48]. Accordingly, other scholars also found that facility accessibility may influence walking activity differently. One research team found Walk Score has a close positive relationship with pedestrian volume [31,33], while another found that Walk Score has a significant impact on the promotion of physical activity [24,25].

Furthermore, for the influence of environmental quality on walking activity, we found that transparency will positively influence pedestrians' walking behavior, while enclosure has a negative effect on pedestrian volume. This outcome is also similar to the existing research that analyzes the relationship between environmental quality and pedestrian volume. Hooi and Pojani also found the overall quality score is closely correlated with pedestrian activity [29]. In the study of the UDQ in Salt Lake City, Park et al. also found that enclosure negatively affects pedestrian volume [31]. Additionally, other researchers found that transparency positively affects walking activity in different cities [32,33,45].

For the association between streetscape characteristics and pedestrian counts, this research found that the number of pieces of street furniture and the number of buildings are significantly and positively associated with the walking activity. Concurrently, Park et al. and Ewing's team also found that these two features have a close relationship with pedestrian volume in their Salt Lake City and New York City research [31,49]. Furthermore, regarding UDQ theory, only those two teams have tested the association between streetscape characteristics and pedestrian volume. Moreover, other scholars also found that street furniture can influence the promotion of pedestrian volume, although they use the configuration of street furniture as the independent variable instead of the number [50,51]. Furthermore, this study also found that the number of basic colors negatively influences walking activity, and this outcome accords with Park et al.' study, which found this relationship significant [31]. However, in addition to the number of the streetscape characteristics affecting pedestrian volume (Park et al. and Ewing et al. found three and seven characteristics, respectively [31,49]), the other difference of this paper from these two studies is that noise level also has a significant positive effect on pedestrian volume, which means that a campus street environment that is too quiet does not easily induce walking activity.

In particular, for urban planners and policymakers, the comprehensive walkability measurement tool optimized in this study can be further adjusted in different regions based on the demand characteristics for public service facilities and the walking willingness of specific populations to propose new metrics to evaluate the walkability of neighborhoods, communities, and other functional areas. Importantly, it could provide references and insightful optimization suggestions for measuring 15 min (15 m) walkable neighborhoods and constructing the framework and evaluation model of the 15 m community life circle [52,53]. The Chinese government presents the conception of 15 m walkable neighborhoods and community life circles. It provides essential public services for citizens on a 15 m walk to improve walking activity and public health [52]. Therefore, further optimized measurement tools can be used to evaluate the walkability of the community environment in the urban 15 min life circle, and based on the visualized analysis results to assess the status of neighborhood walkability and detect the social inequalities, and ultimately propose corresponding 15 m walkable neighborhoods interventions to eliminate social inequalities and promote walkability and overall health and build healthy city environments under the theme of sustainable development [52].

This study still has the following limitations:

(1) This research was studied to assess the comprehensive university built in central urban areas over several periods. In a different geographical location, the influence of the environment quality on walking behavior might also differ. Therefore, the applicability of this conclusion to other new suburban campuses built in a short period should be further studied and tested.

(2) While pedestrian counts represented the intensity of walking activity in this paper, it ignored the effect of different travel purposes (functional or entertainment) on walkability and the relationship between the street environment and the type of walking activity (solitary behavior, or temporary and continuous walking activities). Therefore, future research should consider the type of walking activity and explore the influence of different environmental qualities and walkability on various walking behaviors.

6. Conclusions

Based on the systematic analysis and discussion, although there may be an inconsistency between Walk Score and environmental quality, we verified the rationality of the optimized Walk Score and UDQ methods to assess campus walkability. Moreover, this paper found that facility layout and environmental quality could influence campus walkability and walking activity. Therefore, for campus researchers, the campus Walk Score, and UDQ method can be mixed and used to rate the walkability and the environmental quality of any university campus worldwide with similar conditions. Moreover, based on the GIS results, planners can accurately diagnose the spatial regions and street locations with low Walk Score and poor environment quality to present the targeted improvement for the disadvantaged streets on campus, such as weakening the closed boundary of campus, balancing the layout of public service facilities, optimizing the architectural form and improving the architectural function, and secondarily make the walkable areas more walkable. What's more, UDQ theory can further consider other factors influencing street walking activity, such as street width, street material, green space and other characteristics, to optimize the methodology of evaluating campus design quality. Specifically, researchers could conduct a longitudinal comparison of the walkability of the campus areas built in different periods or among different campuses. Other than that, this mixed tool can also be used to investigate the association of campus walkability and a series of outcomes, such as students' travel mode, housing options, college life satisfaction, academic performance, etc.

More importantly, we proposed the following campus planning strategies to improve street quality and walkability and promote walking activity. For the improvement of facility layout (Figure 6) and campus Walk Score, planners should:

Figure 6. The map of the distribution of public service facilities within and around the campus.

(1) Improve the balanced distribution of campus public service facilities based on the multi-center layout pattern and locate the high-demand commercial facilities, such as canteens and retail stores in different functional cluster centers and adjacent to student apartments, to meet students' demand for the diversity of service facilities and improve the quality of students' on-campus living.
(2) Formulate a compact and high accessibility layout and distribute the smallest facilities in the appropriate location based on the supply and demand matching to serve the largest number of students and reduce the waste of resources, and improve diversified facility services to enhance the facility service efficiency and maximize service benefits.
(3) Pay attention to the various distribution of public transportation and commercial facilities around the campus surrounding regions, and the edge areas and gates of the campus should be close to streets with high facility diversity to facilitate students to walk to meet daily off-campus travel needs and improve students' living convenience and life satisfaction.

To promote the street's environmental quality, planners should:

(1) Improve the quality of the green space, public square, and water landscape, and increase the number of street furniture and other street items;
(2) Increase the application of diversified building materials and different building colors in the residential areas to promote the street environment's vitality;
(3) Improve street transparency, focus on the renovation of the non-actively used historic buildings, and increase the application of transparent materials in transforming old buildings, which can promote the visual connection between indoor and outdoor spaces and induce a variety of walking activities.

This strategy provides a new design direction and a decision-making basis for campus planners and policymakers when planning a new campus or optimizing and updating the existing campus environment. Further, incorporating the criteria of Walk Score and environmental quality into the design guidelines of campus planning is imperative to improve the design and planning methods of campus from the three aspects of (1) the pedestrian-friendly and sustainable campus environment, (2) positive and healthy learning and living, and (3) environmental protection and low-carbon travel modes.

Above all, these endeavors can provide a robust framework for formulating a complete welcoming campus planning scheme, optimizing the overall spatial form, and improving the design and transformation of the existing architectural space and features based on their walkability and quality impact on users while improving the final decision-making process.

Author Contributions: Conceptualization, Z.Z. and T.F.; methodology, Z.Z.; software, Z.Z.; validation, Z.Z., T.F. and H.W.; formal analysis, Z.Z. and H.W.; investigation, Z.Z. and H.W.; resources, Z.Z.; data curation, Z.Z.; writing—original draft preparation, Z.Z.; writing—review and editing, T.F. and H.W.; visualization, Z.Z.; supervision, T.F. and H.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available because it contains non-public data.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Litman, T. Economic value of walkability. *World Transp. Policy Pract.* **2004**, *10*, 5–14.
2. Lee, S.; Talen, E. Measuring walkability: A note on auditing methods. *J. Urban Des.* **2014**, *19*, 368–388. [CrossRef]
3. Yang, H.; He, D.; Lu, Y.; Ren, C.; Huang, X. Disentangling residential self-selection from the influence of built environment characteristics on adiposity outcomes among undergraduate students in China. *Cities* **2021**, *113*, 103165. [CrossRef]
4. Global Health Observatory Data Repository. 2017. Available online: http://apps.who.int/gho/data/view.main.BMIPLUS2C10-19v?lang=en (accessed on 29 September 2017).
5. King, S.B.; Kaczynski, A.T.; Knight Wilt, J.; Stowe, E.W. Walkability 101: A multi-method assessment of the walkability at a university campus. *Sage Open* **2020**, *10*, 2158244020917954. [CrossRef]
6. Prial, A.; Zhu, X.; Bol, L.; Williams, M.R. The impact of moderate physical activity and student interaction on retention at a community college. *J. Am. Coll. Health* **2021**, *71*, 154–161. [CrossRef] [PubMed]
7. Hajrasouliha, A. Connecting the Dots: Campus Form, Student Perceptions, and Academic Performance. *Focus* **2019**, *15*, 12.
8. Forsyth, A. What is a walkable place? The walkability debate in urban design. *Urban Des. Int.* **2015**, *20*, 274–292. [CrossRef]
9. Leslie, E.; Coffee, N.; Frank, L.; Owen, N.; Bauman, A.; Hugo, G. Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. *Health Place* **2007**, *13*, 111–122. [CrossRef]
10. Townshend, T.G. *Walkable Neighborhoods: Principles, Measures, and Health Impacts. Wellbeing: A Complete Reference Guide*; Wiley: Hoboken, NJ, USA, 2014; Volume 2, pp. 1–30.
11. Southworth, M. Designing the walkable city. *J. Urban Plan Dev.* **2005**, *131*, 246–257. [CrossRef]
12. Cervero, R.; Kockelman, K. Travel demand and the 3Ds: Density, diversity, and design. *Transp. Res. D Tr. E* **1997**, *2*, 199–219. [CrossRef]
13. Ewing, R.; Cervero, R. Travel and the built environment: A meta-analysis. *J. Am. Plann. Assoc.* **2010**, *76*, 265–294. [CrossRef]
14. Walk Score. Walk Score Methodology. 2011. Available online: https://www.walkscore.com/methodology.shtml (accessed on 7 June 2011).
15. Hall, M.C.; Ram, Y. Walk score® and its potential contribution to the study of active transport and walkability: A critical and systematic review. *Transp. Res. Part D* **2018**, *61*, 310–324. [CrossRef]
16. Kang, C.D. The S+ 5Ds: Spatial access to pedestrian environments and walking in Seoul, Korea. *Cities* **2018**, *77*, 130–141. [CrossRef]
17. Lee, C.; Moudon, A.V. The 3Ds+ R: Quantifying land use and urban form correlates of walking. *Transp. Res. Part D* **2006**, *11*, 204–215. [CrossRef]
18. Ewing, R.; Clemente, O. *Measuring Urban Design: Metrics for Livable Places*; Island Press: Washington, DC, USA, 2013.
19. Manaugh, K.; Ahmed, E.-G. Validating walkability indices: How do different households respond to the walkability of their neighborhood? *Transp. Res. Part D* **2011**, *16*, 309–315. [CrossRef]
20. Carr, L.J.; Dunsiger, S.I.; Marcus, B.H. Validation of Walk Score for estimating access to walkable amenities. *Brit. J. Sport Med.* **2011**, *45*, 1144–1148. [CrossRef]
21. Duncan, D.T.; Aldstadt, J.; Whalen, J.; Melly, S.J. Validation of Walk Scores and Transit Scores for estimating neighborhood walkability and transit availability: A small-area analysis. *GeoJournal* **2013**, *78*, 407–416. [CrossRef]
22. Kim, Y.J.; Woo, A. What's the score? Walkable environments and subsidized households. *Sustainability* **2016**, *8*, 396. [CrossRef]
23. Pivo, G.; Fisher, J.D. The walkability premium in commercial real estate investments. *Real Estate Econ.* **2011**, *39*, 185–219. [CrossRef]
24. Towne, S.D.; Won, J.; Lee, S.; Ory, M.G.; Forjuoh, S.N.; Wang, S.; Lee, C. Using Walk Score™ and neighborhood perceptions to assess walking among middle-aged and older adults. *J. Commun. Health* **2016**, *41*, 977–988. [CrossRef]
25. Tuckel, P.; Milczarski, W. Walk Score™, perceived neighborhood walkability, and walking in the US. *Am. J. Health Behav.* **2015**, *39*, 242–256. [CrossRef]
26. Aghaabbasi, M.; Moeinaddini, M.; Shah, M.Z.; Asadi-Shekari, Z.; Kermani, M.A. Evaluating the capability of walkability audit tools for assessing sidewalks. *Sustain. Cities Soc.* **2018**, *37*, 475–484. [CrossRef]
27. Ewing, R.; Handy, S. Measuring the unmeasurable: Urban design qualities related to walkability. *J. Urban Des.* **2009**, *14*, 65–84. [CrossRef]

28. Purciel, M.L.; Neckerman, K.M.; Lovasi, G.S.; Quinn, J.W.; Weiss, C.; Ewing, R.; Rundle, A. Creating and Validating GIS Measures of Urban Design for Health Research. *J. Env. Psychol.* **2009**, *29*, 457–466. [CrossRef] [PubMed]
29. Hooi, E.; Pojani, D. Urban design quality and walkability: An audit of suburban high streets in an Australian city. *J. Urban Des.* **2020**, *25*, 155–179. [CrossRef]
30. Bereitschaft, B. Equity in Microscale Urban Design and Walkability: A Photographic Survey of Six Pittsburgh Streetscapes. *Sustainability* **2017**, *9*, 1233. [CrossRef]
31. Park, K.; Ewing, R.; Sabouri, S.; Larsen, J. Street life and the built environment in an auto-oriented US region. *Cities* **2019**, *88*, 243–251. [CrossRef]
32. Ameli, S.H.; Hamidi, D.; Garfinkel-Castro, A.; Ewing, R. Do better urban design qualities lead to more walking in Salt Lake City, Utah? *J. Urban Des.* **2015**, *20*, 393–410. [CrossRef]
33. Maxwell, J.A. Designing for 'Life between Buildings': Modeling the Relationship between Streetscape Qualities and Pedestrian Activity in Glasgow, Scotland. Ph.D. Thesis, University of Strathclyde, Glasgow, UK, 2016.
34. Alhajaj, N.; Daghistani, F. Hybrid method for measuring the accessibility and safety of students' walking routes in car-dominated campuses. *Urban Des. Int.* **2021**, *26*, 53–66. [CrossRef]
35. Kellstedt, D.K.; Spengler, J.O.; Maddock, J.E. Comparing Perceived and Objective Measures of Bikeability on a University Campus: A Case Study. *Sage Open* **2021**, *11*, 21582440211018685. [CrossRef]
36. Booker, R.; Novik, M.; Galloway, R.; Holmes, M.E. Relationship between physical activity intensities and drunkorexia severity among first-year college students. *J. Am. Coll. Health* **2021**, *69*, 689–692. [CrossRef] [PubMed]
37. McDonald-Yale, E.; Birchall, S.J. The built environment in a winter climate: Improving university campus design for student wellbeing. *Landsc. Res.* **2021**, *46*, 638–652. [CrossRef]
38. Bopp, M.; Wilson, O.W.; Elliott, L.D.; Holland, K.E.; Duffey, M. The Role of The Physical and Social Environment for Physical Activity for College Students During the COVID-19 Pandemic. *Build. Healthy Acad. Communities J.* **2021**, *5*, 13–30. [CrossRef]
39. Teuber, M.; Sudeck, G. Why do students walk or cycle for transportation? Perceived study environment and psychological determinants as predictors of active transportation by university students. *Int. J. Env. Res. Pub. Health* **2021**, *18*, 1390. [CrossRef] [PubMed]
40. Zhang, Z.; Fisher, T.; Feng, G. Assessing the Rationality and Walkability of Campus Layouts. *Sustainability* **2020**, *12*, 10116. [CrossRef]
41. Yintao, L. Walkability Evaluation Based on People's Use of Facilities by Walking. *Urban Plan. Forum* **2013**, *5*, 113–118.
42. Huang, J.; Hu, G.; Li, M. The Allocative Suitability of Community Facilities from the Perspective of the Elderly—Based on Walk Score Method. *Urban Plan. Forum* **2017**, *6*, 45–53.
43. Yingbin, L. The Walkability Measurement and the Validation Study of the Taoyuan District in Shenzhen. Master's Thesis, Harbin Institute of Technology, Harbin, China, 2013.
44. Khattak, A.; Wang, X.; Son, S.; Agnello, P. University student travel in Virginia: Is it different from the general population. *Transp. Res. Rec.* **2011**, *2255*, 137–145. [CrossRef]
45. Hamidi, S.; Moazzeni, S. Examining the relationship between urban design qualities and walking behavior: Empirical evidence from Dallas, TX. *Sustainability* **2019**, *11*, 2720. [CrossRef]
46. Yin, L. Street level urban design qualities for walkability: Combining 2D and 3D GIS measures. *Comput. Env. Urban* **2017**, *64*, 288–296. [CrossRef]
47. Pearce, D. *Painting the Picture: The Validity of Walk Score in Addressing Subjective Urban Design Qualities in the Built Environment*; University of Oregon: Eugene, OR, USA, 2015.
48. Peachey, A.A.; Baller, S.L. Perceived Built Environment Characteristics of On-Campus and Off-Campus Neighborhoods Associated with Physical Activity of College Students. *J. Am. Coll. Health* **2015**, *63*, 337–342. [CrossRef]
49. Ewing, R.; Hajrasouliha, A.; Neckerman, K.M.; Purciel-Hill, M.; Greene, W. Streetscape features related to pedestrian activity. *J. Plan. Educ. Res.* **2016**, *36*, 5–15. [CrossRef]
50. Kang, C.D. Measuring the effects of street network configurations on walking in Seoul, Korea. *Cities* **2017**, *71*, 30–40. [CrossRef]
51. Im, H.N.; Choi, C.G. Measuring pedestrian volume by land use mix: Presenting a new entropy-based index by weighting walking generation units. *Env. Plan B Urban* **2020**, *47*, 1219–1236. [CrossRef]
52. Weng, M.; Ding, N.; Li, J.; Jin, X.; Xiao, H.; He, Z.; Su, S. The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China. *J. Public Transp.* **2019**, *13*, 259–273. [CrossRef]
53. Wu, H.; Wang, L.; Zhang, Z.; Gao, J. Analysis and optimization of 15-minute community life circle based on supply and demand matching: A case study of Shanghai. *PLoS ONE* **2021**, *16*, e0256904. [CrossRef] [PubMed]