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Evaluating the Equity of Urban Streetscapes in Promoting Human Health—Taking Shanghai Inner City as an Example

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Abstract: Environmental justice research largely focuses on the allocation of public resources in terms of quantified distribution and accessibility. This study suggests that the quality of landscape equity, an important urban resource, should be evaluated as it typically appears as a combination of elements. This brings another perspective to the attention of landscape equity in addition to the provision equity: the equity in the quality and level of provision. From this perspective, this study explores the equitable role of streetscape qualities in promoting human physical, mental, and social health. Using street view images, questionnaires, artificial intelligence-based image analysis, geographic information system-based cluster analysis, and correlational analysis, the spatial distribution of health promotion streetscapes and health-influential streetscape elements were presented and compared within the scope of the Shanghai Outer Ring Road. The results disclosed an uneven distribution of streetscapes that can promote human health within research sites. Streets with poor health ratings are concentrated in the Huangpu, Hongkou, and Yangpu districts, primarily in the western part of Shanghai around Shanghai Railway Station, People's Square, and Yuyuan Garden, where the old city centre is located. Compared with the distribution of health-influential elements, less healthy streets are more likely to be accompanied by low visibility of 'vegetation' and a high proportion of 'buildings'. Streetscape design implications were then discussed in terms of providing people with equal health opportunities. Research outcomes inspired an essential quality perspective in health equity research, and it can be especially helpful when the provision and accessibility can hardly be moderated in high-density cities.

Keywords: equity; visual landscape; urban street; human health; spatial distribution

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1. Introduction

Over 30.5% of Chinese residents now suffer from chronic health issues such as depression, obesity, loneliness, and isolation [1]. Natural settings have long been confirmed to be beneficial to human health [2–4], but there is an apparent mismatch between green space provision and population density in most Chinese megacities [5]. Being an elementary open space in cities, the street has an intimate relationship with people's outdoor life, which in turn determines the potential social significance of designing streetscapes to improve human health. Although the spatial provision of urban streets is even within a city, the quality of streetscapes in promoting human health may differ. This will bring another perspective to the attention given to landscape equity in addition to the provision equity: equity in the quality of provision. Setting out from this perspective, this study attempts to explore the equity of streetscape qualities in promoting physical, mental, and social health.

1.1. Visual Landscape and Human Health

The effects of the landscape on human health have been observed for a long time and explored for centuries, from healing gardens [6,7]—such as Greek asklepieia, which

promoted patients to recover by arranging wards with southern orientation, and Roman valetudinarium hospitals, in which central courtyards were provided for patients to enjoy fresh air and take a walk [8]—to a broader concept of restorative environments [9,10] that has emerged in recent decades which emphasises the restorativeness of certain environmental features. The World Health Organization [11] defines health as 'a state of complete physical, mental and social well-being' and encourages people to change or cope with the environment for satisfying their health needs. Lalonde later proposed the 'health field' concept to delimit the causes of health issues into four aspects: human biology, environment, lifestyle, and health care institutions [12]. Among which, human biology refers to the physical and mental health status of the human body, and environment 'includes all those matters related to health' [12]. These initiatives promote 'Healthy Cities Movements' [11] in the planning and design arena and also numerous academic and practical efforts to explore ways of benefiting human wellbeing through environmental interventions.

From the design perspective, the majority of relevant efforts have been made to identify the visual attributes of environments that can facilitate health outcomes, since the visual perception takes over 80% of human landscape perceptions [13]. For example, openness, which refers to how open a setting appears to be [13], has proved to be an effective indicator of both natural and urban settings [13–15] in providing relaxed experiences to users. Visual indicators concerning the quality level of a healthy environment also include complexity [16,17], visual depth [18], enclosure [19,20], mystery [21,22], and upkeep [23]. A set of visual indicators describing the environmental content, such as vegetation [22–24], waterscapes [24–26], visual landmarks [27,28], facilities [19,29,30], people [31,32], and traffic [33] have also been confirmed to be health-related. From the health perspective, the reported health outcomes of viewing positive landscapes are mostly focused on their physical, mental, and social aspects, referring to the WHO definition. The presence of and people's access to physical activity-promoting facilities [34–36] can help improve brain activities [37], help manage weight, reduce the risk of cardiovascular disease, and strengthen bones and muscles [38]. Psychological health and landscape studies tend to focus on the short-term recovery from stress or mental fatigue triggered by certain environmental attributes, such as the observed positive emotional responses after viewing trees [37,39] and the increased power of concentration after resting in a garden [38]. Psychological benefits also include fewer attentional and concentration problems, relaxation, less frustration, stress reduction, higher enthusiasm, and life satisfaction [37,40]. Moreover, increased social interaction and the reduction of aggressive behaviour [41] were also confirmed as health outcomes positively related with the amount of green vegetation in neighbourhood common spaces and along streets [42].

This health-related evidence was largely found in the contexts of nature or natural-dominated urban settings, for example, the accessibility to forests [43], the presence of nearby parks [44], the chance of viewing vegetations [45], and the affordance of playgrounds and sports fields in primary schools [35]. However, these were mostly disclosed in comparative studies between the urban/nature and landscape/no-landscape settings, with less clear results being observed in research conducted within the urban landscape subcategories. This impedes the exploration of health benefits in wider urban settings and limits the efficient delivery of the healthy cities agenda. In addition, the lack of green resources and the mismatched distribution of green resources and residences in highly densified megacities may significantly influence the effectiveness of natural landscapes as a public resource and the positive role they play in the residents' health and well-being. This has also forced researchers to look for alternatives with potential physical, mental, and social health benefits as urban green spaces (UGSs).

1.2. Urban Streetscape and Environmental Equity

As a kind of urban space with high accessibility and uniform distribution, the street has become the focus of relevant studies. Previous studies have already confirmed that streets can promote the physical, psychological, and social health of urban residents [46].

Streets with high accessibility and connectivity [47], well-maintained pavements, sufficient pedestrian spaces and facilities [48], and the visibility of sky [49] are regarded as walkable streets and thus beneficial to residents' physical health through encouraging their walking behaviour. 'Walkability' has gradually become a common indicator to measure the quality of streets in promoting people's physical activities [50]. Moreover, people can obtain psychological restoration in street settings. The visibility of streetscape greenery has proven to be most relevant to people's perceived restorativeness [51]. Relevant indicators also include pavements, the presence of other people, coloured flowers, streetside buildings, and cars [52]. These streetscape elements, as well as certain quality indicators (i.e., openness, enclosure, and legibility [53]), are considered to be effective in influencing the four fundamental aspects that can facilitate the restoration process proposed in attention restoration theory (ART): being away, fascination, extent, and compatibility [20–22]. Streets also sustain important social functions which are determined by their essence of being a type of open space. Evidence suggests that resting spaces, the existence of streetside parks, exercise facilities, accessible grasslands, and outdoor seats at streetside shops could increase the staying behaviour of people, which implies that people will have more opportunities to encounter social activities [54], especially accidental ones.

However, though the distribution of streets is much more even within cities than the distribution of UGSs, the quality of streetscapes may differ as well as their ability to promote human health. This may also lead to the unequal provision of health benefits and raise issues in landscape equity. Landscape equity normally includes three different aspects: equity in the process of landscape planning and regulation, equity in the spatial distribution of landscape resources, and equity in the use of landscape resources [55]. Distribution equity is normally assessed by the accessibility, the quality, the quantity, the acreage, and the disaster prevention capability [56] of landscape resources, which are also measured as ecological services and public services in large-scale planning processes [57]. Using equity refers to the equal right and freedom people have to use landscape resources, while in turn, landscape resources should contain diverse and plural functions and also meet the needs of all potential users [58]. This aspect is more focused on people and is normally evaluated based on individuals' differences. In addition, the public should have the right to know, to make decisions, to supervise, and to create in the process of landscape planning and regulation, so as to ensure that the distribution equity and using equity can be achieved. Similarly, street equity research has also concentrated on these three aspects. The spatial allocation equity is influenced by the rights and conflicts between different road users. Obvious inequity in rights of way exists among pedestrians, cyclists, and drivers due to their chosen transportation mode. Naturally, motor vehicles are far superior to walking and non-motor vehicles in terms of speed and safety. Therefore, many countries enforce regulations in practice to balance this inequity, such as setting up street overlord lights and reducing lane width and turning radius to limit the speed of motor vehicles [59,60]. Accessibility equity is mainly approached through evaluations of the equity of using the street from the perspective of its accessibility and walkability [61]. For example, significant social inequalities in street walkability were found across the communities within the Hangzhou metropolitan area [62]. In terms of landscape uses, street trees were regarded as greenery resources in several studies, the distribution of which was used as an indicator to measure socioeconomic equality [63]. A significantly lower proportion of street tree cover was more likely to occur in neighbourhoods with a higher proportion of African Americans, low-income residents, and renters [64]. Brooks, Kelley, and Amiri also found a negative relation between higher amounts of street canopy and lower levels of the socioeconomic status of the neighbourhoods [65].

Most landscape justice research emphasises the uneven distribution of the landscape resource by regarding it as a 'result' of unequal socioeconomic status, while relatively less attention has been paid to treating the landscape resource as a 'cause' and to explore its consequences in equity evaluation. Accordingly, to date, very few studies have focused on the result brought by the uneven distribution of well-designed streetscapes and any

other equity issues related to streetscape quality. Only Shao et al. have explored the visual equity of streetscapes through the influence of streetscape compensation on the right-of-way conflict [66]. This has inspired researchers to take the visual quality of streetscape as an independent indicator in landscape equity research and start to see the potential of landscape as a 'mediator' or 'cause' in environmental justice research.

1.3. This Study

This study aims to investigate whether the landscape equity of urban streetscapes influences human physical, mental, and social health. Given the alternative function of urban streets in providing people with health benefits in high-density cities, which has been highlighted, an evaluation of the healthy quality equity of urban streetscapes was conducted in a typical Chinese megacity, Shanghai. With the help of open-sourced street view images, streetscapes in Shanghai's inner city were firstly categorised based on their landscape compositions using artificial intelligence (AI)-based semantic segmentation and Geographic-Information-System (GIS)-based cluster analysis. Typical street photos were then randomly selected from each street type as representatives. An online survey was carried out afterwards to find out whether and how people assess these typical street photos as health promotive. This was performed to correlate evaluation results with street landscape composition characteristics, and to find what and how streetscape elements influence human health. Through mapping health-promotive streetscapes and related streetscape elements, this study assessed and compared health equity provided by Shanghai streetscapes. See Figure 1.

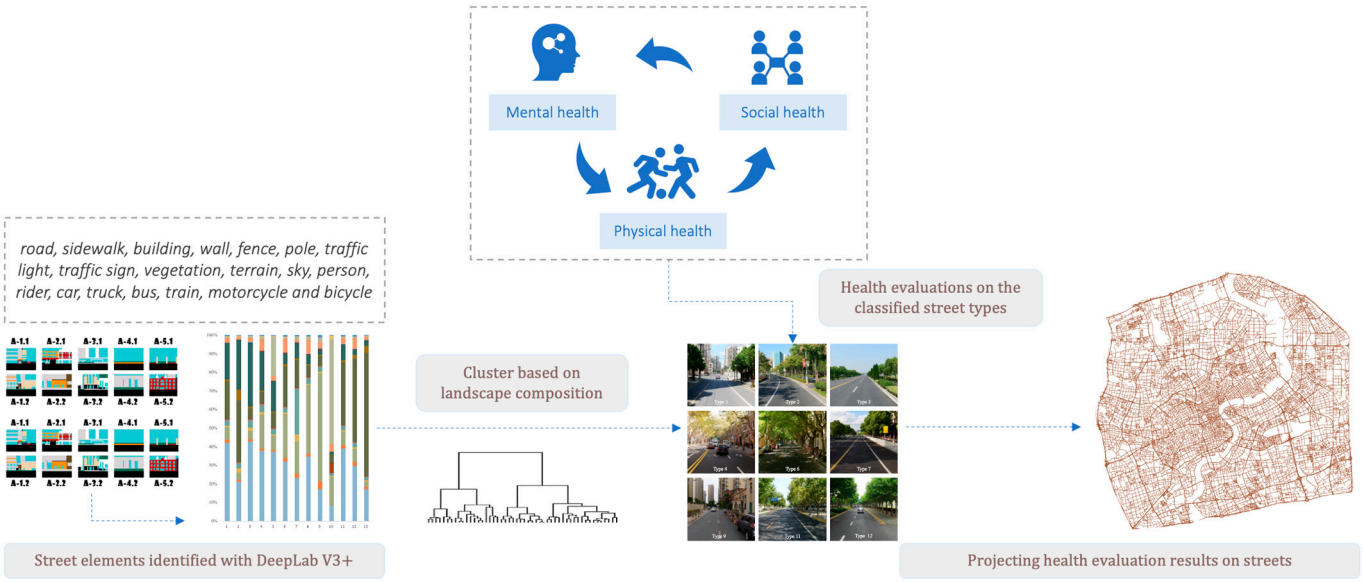


Figure 1. Research framework.

2. Research Methods

2.1. Study Site

Shanghai is one of the typical megacities in China with a population of over 2.4 billion and an area of 6340.5 km^2. The distribution of UGSs in the central city of Shanghai reveals a reverse tendency with population agglomerations [5], and thus, hinders people's regular use of and their opportunity to gain health benefits from interacting with these UGSs. Urban streets become an essential alternative for people who live in the central city of Shanghai, with their evident advantage of high accessibility and relatively even distribution. However, the qualities of streetscapes vary with regional characteristics and construction ages. It is therefore vital to investigate whether and how the differences in urban streetscapes influence people's health behaviours and preferences. This study takes

Shanghai Outer Ring Road as a boundary (Figure 2) and attempts to evaluate the quality equity of streetscapes within this area in promoting physical, mental, and social health.



Figure 2. Research site within Shanghai Outer Ring Road.

2.2. Categorising Streetscapes Based on Visual Landscape Compositions

Shanghai's street view image data were acquired from the open-sourced map database provided by Baidu using Python 3.10 in May 2023. Each street viewpoint recorded in the Baidu database contains a street image taken at the same front angle and its coordinates. Within the research scope, a total of 609,000 street view images were collected, each with a pixel of 478 × 444 dpi.

The set of street view images was first calculated for visual landscape compositions using DeepLab V3^{+} model. The Cityscape website delimits 19 streetscape element labels that can be identified with semantic segmentation that contain 'road, sidewalk, building, wall, fence, pole, traffic light, traffic sign, vegetation, terrain, sky, person, rider, car, truck, bus, train, motorcycle and bicycle'. These were assigned to the street view image obtained in this study and calculated for each of their proportions, namely, the landscape compositions. Then, two rounds of cluster analysis were conducted to categorise street view images according to their landscape compositions. The first round used k-means clustering algorithm and set the preset value of k (the number of classified types) as 30. The preset value of k was tried in reverse order from 60 to 5 with every 5 as an interval and results illustrated that composition differences started to show when k was set as 30. The second round adopted horizontal clustering to further merge the 30 types with high composition similarities. No preset value was given in the second round of cluster.

Cluster results disclosed nine distinct types of streetscapes within the research site. Type 1, 3, 4, and 6 are four streetscape types that are dominated by 'road' with slight differences in the percentage of 'vegetation', 'building', and 'sky'. The visibility of 'vegetation' (43%) in type 1 streetscape is also high, but the 'sky' (35.3%) in type 3 and the 'building' (37.3%) and 'sky' (5%) in type 4 reveal their contained 'vegetation'. Type 6 has relatively close percentages of 'road' (37.4%), 'sky' (0%), and 'building' (5.4%). There are

three streetscape types dominated by 'vegetation': types 2 (25.2%), 11 (27.8%), and 12 (42%). Type 11 and 12 are quite similar in compositions with only type 11 having higher visibility of 'sky'. In landscape compositions of type 2, 'road' (37.5%) and 'sky' (35.3%) take the second dominancy besides 'vegetation'. 'Road' (39.8%), 'vegetation' (25.4%), 'building' (16.8%), and 'sky' (5.3%) were evenly distributed in streetscapes of type 7. And for type 9, 'building' (5.7%) takes the highest account in its visual landscape. See Figure 3.



Figure 3. Streetscape categorisation results for research site.

2.3. Evaluating the Potential of Streetscapes in Promoting Human Health

Visual stimuli for the following health equity evaluation were randomly selected from the databases of each streetscape type. An online questionnaire was designed using the Tencent online questionnaire website, and nine questions (Table 1) were included to investigate people's perceived physical, mental, and social health opportunities in such streets. The nine questions were set to be filled out for each of the nine typical street view images and measured with a five-level Likert scale (Ref. [1] represented 'completely disagree', ref. [5] meant 'completely agree'). The elevated roads were manually given the lowest rating '1' since they are not accessible to pedestrians.

Table 1. Questions for evaluating street qualities in improving human health.

	Descriptive Questions
Physical Health (PH)	I would like to walk, jog and exercise along the street.
	When the weather is fine, I would like to walk or cycle on this street instead of driving to my destination.
	I would like to choose this street as my commuting route.
Mental Health (MH)	When I am here, I feel free from my work and daily troubles.
	This street contains many attractive things that makes me want to linger on here.
	What I like to do is aligned with what this environment can support.
Social Health (SH)	I would like to talk to my acquaintances here.
	I would like to watch or participate in nearby activities.
	I would like to choose here as a rendezvous to meet with my friends.

This set of questions was validated in a pilot study and confirmed to be efficient in this research. In the formal survey, two sets of questionnaires were performed with one of them functioning as the verification questionnaire. Questionnaires were spread out online through the WeChat platform and WeChat users who live in the Shanghai inner city for over 12 months were regarded as potential subjects. For those who were qualified for and interested in participating in this survey, the formal survey started only after they read the information sheet and signed the consent form. Cross-validation was performed by comparing the mean of the data collected from the two groups of questionnaires and no existence of difference was found. Thus, the evaluation results are representative. A total of 128 valid responses were collected with a male to female ratio of 1:1.95 and an average age of 29 years old (SD = 6.9).

2.4. Data Analysis

The obtained health evaluation results for each street type were first calculated for the means and compared within types and health aspects, respectively. Streets belonging to the same type were also assigned the same value of health ratings and the rating results were visually presented based on their coordinates with the help of GIS and discussed with Shanghai's spatial and development characteristics.

The health evaluation results of all streets within the whole research site were calculated as follows:

$$H = \sum_{i=1}^{n} (Hi \times Mi) \div Msum \quad (1)$$

where

H: is the average physical/mental/social health level of a city;
n: the number of street types in a city;
i: the type i city street;
Hi: the health level of the type i street;
Mi: the number of type i street spots in a city;
$Msum$: the total number of street spots in a city.

The Pearson correlation analysis was also carried out to find out what and how street elements influence the potential of Shanghai streetscapes in promoting human health. The nine street types were regarded as independent cases and the means of their physical, social, and mental health ratings and the percentages of the nineteen street elements were used.

To further visualise and analyse the distribution of the health-related street elements within the site, this study graded the percentage of influential street elements into three levels based on their rating thresholds and conducted kernel density analysis on streetscapes with different percentage levels, also using GIS.

3. Results

3.1. Manipulation Checks

The health evaluation results were analysed using SPSS V27.0. Internal consistency was first tested with Cronbach's α, respectively, for each dataset of the nine street view images. The α values were all above 0.9 and thus indicated sufficient reliability for further analysis. Individual perceptive differences were also checked between age and gender groups. The p-value suggested (>0.1) that no perceptive difference exists, and further analysis could be conducted without regard to age and gender groups.

3.2. The Potential of Streetscapes in Promoting Human Health

A descriptive analysis of the streetscapes' potential evaluations in promoting human physical, mental, and social health are concluded in Table 2.

Table 2. Descriptive analysis of Shanghai streetscape health evaluation results.

		Type 1	Type 2	Type 3	Type 4	Type 6	Type 7	Type 9	Type 11	Type 12
PH1	Mean	3.1	5.2	3.5	3.9	4.5	4.2	4.4	4.2	4.4
	Std.Dev.	1.8	1.5	2.1	1.9	2.0	2.0	1.9	1.7	1.9
PH2	Mean	3.5	5.3	3.7	4.5	4.7	4.8	4.6	4.4	4.6
	Std.Dev.	1.8	1.5	2.0	1.9	1.9	1.8	1.7	1.7	1.7
PH3	Mean	3.9	5.2	4.4	4.2	4.4	5.2	4.8	4.6	4.8
	Std.Dev.	1.7	1.4	2.1	1.8	1.9	1.5	1.5	1.6	1.5
PH-Mean	Mean	2.5	4.2	2.9	3.2	4.5	4.7	2.6	4.2	4.6
	Std.Dev.	--	--	--	--	--	--	--	--	--
SH1	Mean	3.2	4.8	3.0	4.3	4.4	3.9	4.3	3.8	4.3
	Std.Dev.	1.7	1.7	2.0	1.8	1.9	1.8	1.8	1.8	1.8
SH2	Mean	3.1	4.6	3.0	4.3	4.4	3.5	4.1	3.9	4.1
	Std.Dev.	1.7	1.8	2.0	1.8	1.9	1.9	1.9	1.8	1.9
SH3	Mean	3.0	4.3	2.9	4.5	4.3	3.3	3.9	3.8	3.9
	Std.Dev.	1.7	1.9	1.9	1.9	2.0	1.9	3.9	1.9	1.9
SH-Mean	Mean	2.1	3.6	2.0	3.4	4.3	3.5	3.0	4.4	4.1
	Std.Dev.	--	--	--	--	--	--	--	--	--
MH1	Mean	3.0	4.7	3.3	3.9	4.4	4.2	4.1	3.7	4.1
	Std.Dev.	1.7	1.9	1.9	1.7	1.9	1.9	1.8	1.7	1.8
MH2	Mean	2.9	4.3	3.2	4.1	4.2	3.5	4.0	3.6	4.0
	Std.Dev.	1.7	1.7	1.9	1.9	1.9	1.9	1.8	1.7	1.8
MH3	Mean	3.0	4.5	3.4	4.0	4.2	3.9	4.0	3.7	4.0
	Std.Dev.	1.7	1.7	1.9	1.7	1.9	1.9	1.8	1.8	1.8
MH-Mean	Mean	2.0	3.5	2.3	3.0	4.3	3.8	2.6	4.0	4.0
	Std.Dev.	--	--	--	--	--	--	--	--	--

Among the nine typical Shanghai streetscapes, types 6, 11, and 12 had relatively higher evaluations for all three health aspects while types 1 and 3 scored lower. For the physical health aspect, streetscape type 7 was rated with the best potential (Mean = 4.7), followed by type 12 (Mean = 4.6) and type 6 (Mean = 4.5). Streetscape types that are least likely to promote human physical health were type 1 (Mean = 2.5) and type 9 (Mean = 2.6). Type 6 (Mean = 4.3) had the greatest potential to benefit people's mental health, while type 1 (Mean = 2.0) was rated the lowest in this respect. Type 11 (Mean = 4.4) was rated as the best in encouraging social interactions and, in this respect, type 1 (Mean = 2.1) and 3 (Mean = 2.0) were still ranked as the last two in Figure 4.

When comparing the health-promotive ratings with the landscape compositions of streetscapes, streets with a higher visibility of 'vegetation' are more likely to benefit human physical, mental, and social health while streetscapes with a high percentage of 'road' and 'building' offer the least health-promotive effects. Besides 'vegetation', the existence of 'fences' in streets may also be useful in encouraging people to do physical activities. In addition, the higher the visibility of the 'sidewalk', the more likely people can experience restoration and interact with others in the streets. See Table 2 and Figure 4.

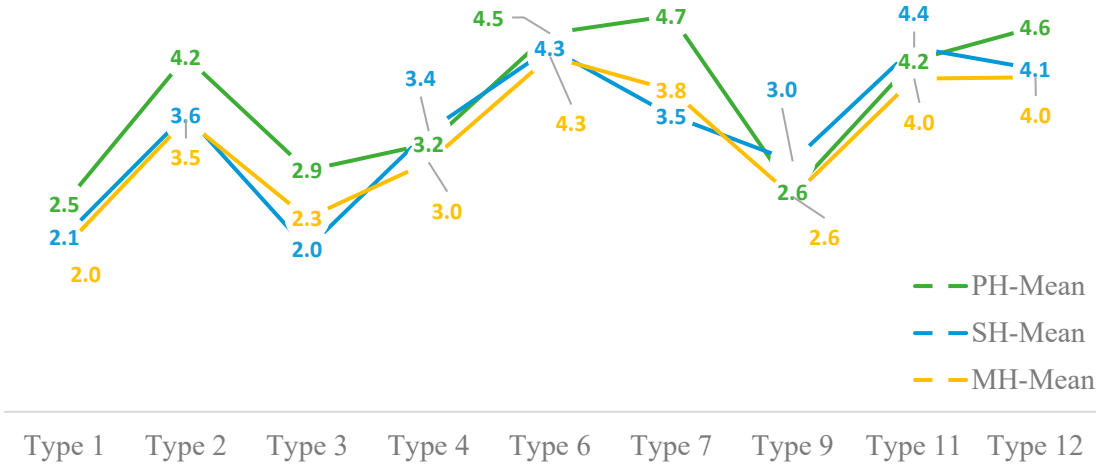


Figure 4. The health potential of nine typical Shanghai streetscapes.

3.3. The Distribution of Health-Promotive Streetscapes and Influential Elements

3.3.1. The Distribution of Streetscapes That Can Promote Human Health

The mapping results disclosed an uneven distribution of streetscapes that can promote human physical, mental, and social health within the research site, but the distribution of the three health aspects appeared to be quite similar. It can be observed that the streetscapes with lower health ratings were mostly concentrated in the Huangpu, Hongkou, and Yangpu districts in Puxi, the western part of Shanghai, especially around Shanghai Railway Station, People's Square, and Yuyuan Garden where the old city centre is located. These less healthy streets are also densely distributed along the west side of the Huangpu River, while for the east side of the Huangpu River, the health evaluation results were evidently higher. The northern part of Pudong, especially the Lujiazui Central Business District (CBD) and the residential aggregation around Central Park, had streetscapes that can best promote human health within the research site. Streetscapes with higher healthy street levels could also be found in most areas of the Jing'an, Changning, and Xuhui districts, and also the western part of the Huangpu district, while streetscapes with lower health ratings became dense again in the peripheral areas near the Outer Ring Road. See Figures 5–7.

It can be seen from the street mapping of the physical health ratings, the area around Shanghai Railway Station, People's Square, and Yuyuan Garden, where the heart of Shanghai's old town is located, forms a distinct lowland. These areas are characterised by highly densified road networks and buildings, and narrowed roads and sidewalk widths, as well as relatively lower levels of greenery. Between 1970 and 2000, several buildings were constructed around Shanghai Station. Now, some of the old residences are in the process of urban regeneration. Therefore, residents who live in these areas have fewer opportunities to carry out physical activities, such as jogging, dog walking, and cycling, because the streets they regularly interact with cannot satisfy their needs in terms of the width of sidewalks, the visibility of vegetation, and the maintenance of pavements [36,66]. Also, the negative delivery of these street design elements may encourage people to choose to drive cars instead of walking, while these daily physical activities and healthy methods of travel are essential in maintaining and improving the physical health of urban residents in their everyday lives. Inequities in the provision of physical health benefits are evident among residents living in the west side of the Hongkou and Yangpu districts, which were constructed early in the development of Shanghai city. Similarly, residents living on the north side of the Pudong New District, which has fewer green spaces and is less developed than the central city, also experience disparities in physical health benefits. See Figure 5.

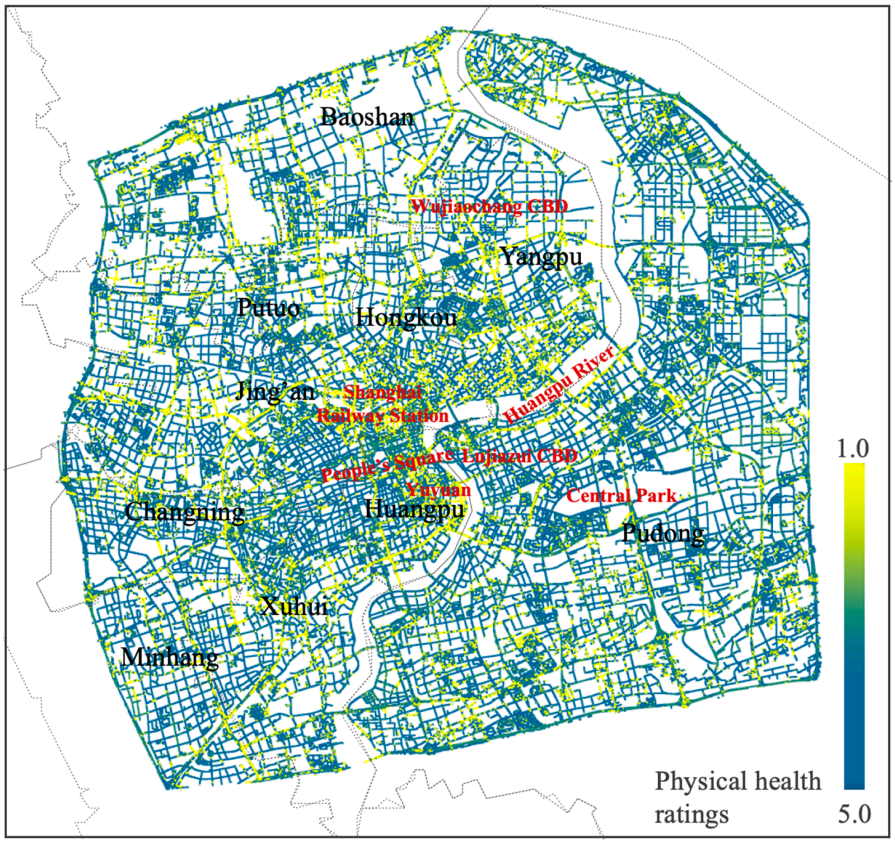


Figure 5. The distribution of physical-health-promotive streetscapes in Shanghai.

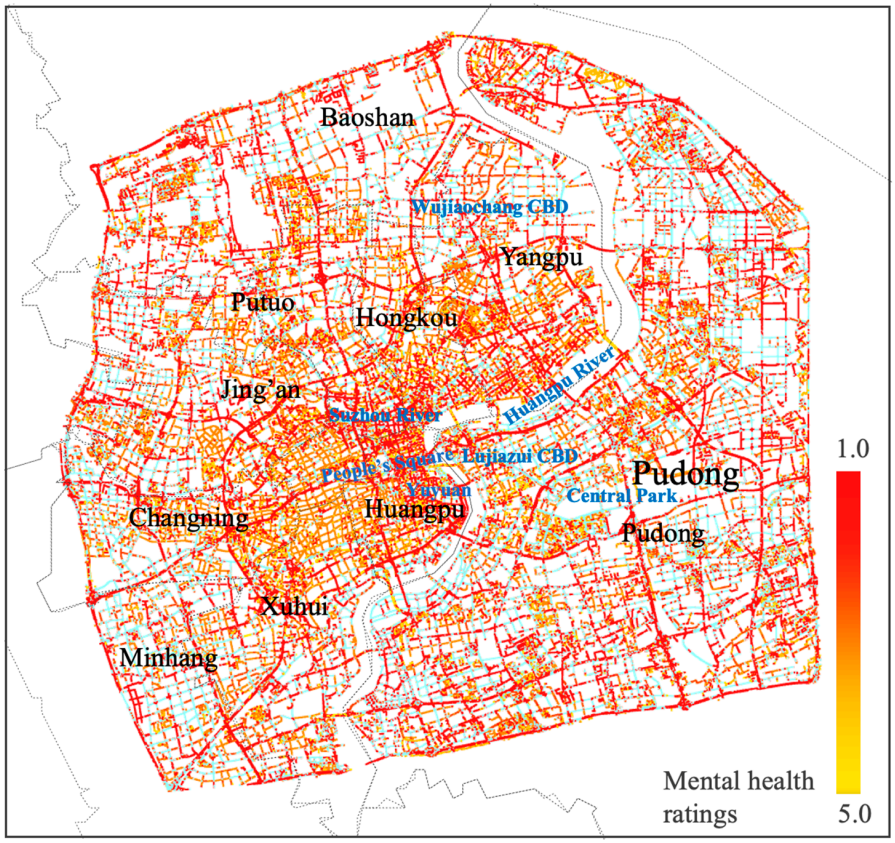


Figure 6. The distribution of mental-health-promotive streetscapes in Shanghai.

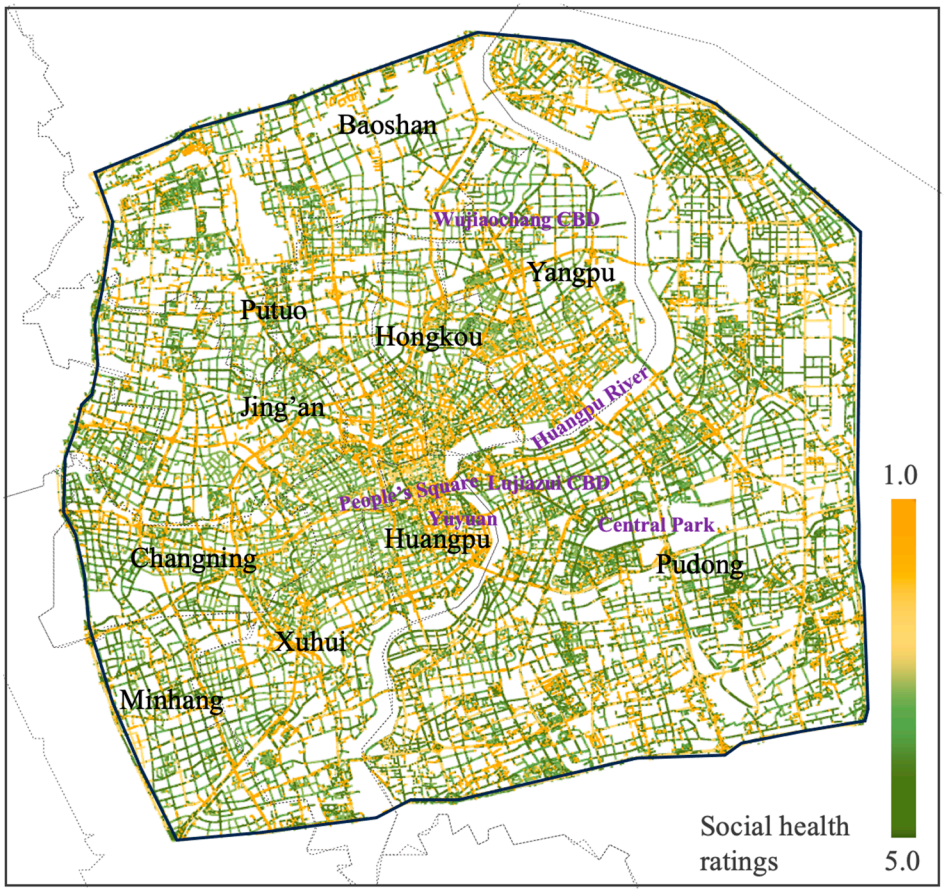


Figure 7. The distribution of social-health-promotive streetscapes in Shanghai.

The distribution of streets showing mental health ratings shows a similar tendency to the one showing physical health ratings, but the area with the lowest mental health benefits appears on the west side of Suzhou River. It is the clusters of exotic buildings near the Bund and streets there that are mostly composed of hardscapes with very little vegetation provided. The restorative effects of environments are rooted in the benefits of nature and, to be more specific, the benefits of greenery [20]. Thus, the low visibility of street trees makes this area unequal in providing people with restorative benefits. The Bund's impressive building clusters attract many tourists and serve as one of Shanghai's financial centres. However, residents in the area have limited opportunities to relieve their mental fatigue during daily walks. The low percentage of vegetation and the high visibility of buildings together are responsible for the worse provision of mental health benefits in the areas around People's Square, Yuyuan Garde, and the North Bund, while people who live in Jing'an, Changning, and the Pudong New District are more likely to obtain psychological recovery during their walks on streets. See Figure 6.

The equal provision of social health-promotive streetscapes was also found in the above-mentioned areas: commercial blocks near the Bund and Yuyuan Garden, old residences in the Hongkou and Putuo districts, and urban villages within the northern Pudong New District. Similar distribution characteristics were found between social health and the other two health aspects, potentially explained by shared health indicators such as vegetation, buildings, pavement, and traffic. Also, the occurrence of social activities is influenced by streetside functions and surrounding land uses [67]. Therefore, residential neighbourhoods and business office aggregations where people gather most and stay longer are far ahead of other areas in terms of social health and equity. See Figure 7.

3.3.2. The Influence of Streetscapes Elements in Promoting Human Health

Five of the nineteen streetscape elements were confirmed to be influential in human-perceived health benefits. Among these, only 'vegetation' was found to have positive influences, while 'building', 'wall', 'car', and 'bicycle' were negatively related. Comparing the three aspects of human health, consistent effects can be observed for the positive element of 'vegetation', and also, two negative elements, 'building' and 'wall'. 'Car' and 'bicycle' were only found to have negative influences on aspects of physical health. See Table 3.

Table 3. Streetscape elements that can influence human physical, mental, and social health.

		Road	Sidewalk	Building	Wall	Fence	Pole	Traffic Light	Traffic Sign	Vegetation	Terrain	Sky	Person	Rider	Car	Motorcycle	Bicycle
PH	Pearson correlation	0.53	−0.10	−0.840 **	−0.753 *	0.12	−0.14	−0.34	0.38	0.795 *	0.47	−0.10	−0.44	−0.04	−0.675 *	0.08	−0.766 *
	sig.	0.14	0.80	0.01	0.02	0.75	0.72	0.37	0.32	0.01	0.20	0.80	0.24	0.93	0.05	0.85	0.02
SH	Pearson correlation	0.06	0.23	−0.48	−0.45	−0.28	−0.10	−0.39	0.14	0.883 **	0.32	−0.57	0.09	−0.06	−0.12	0.30	−0.40
	sig.	0.87	0.55	0.19	0.22	0.46	0.80	0.30	0.72	0.00	0.40	0.11	0.81	0.89	0.76	0.43	0.29
MH	Pearson correlation	0.30	−0.05	−0.743 *	−0.677 *	−0.11	−0.20	−0.43	0.23	0.886 **	0.43	−0.26	−0.21	−0.13	−0.44	0.27	−0.63
	sig.	0.43	0.91	0.02	0.05	0.77	0.61	0.25	0.56	0.00	0.25	0.51	0.58	0.74	0.23	0.49	0.07

* Correlation analysis between health ratings and three elements, 'truck', 'bus', and 'train', cannot be calculated since they were counted as 0.00% in the segmentation. ** indicates elements with significant correlations with health ratings.

The correlational analysis results suggested that for promoting physical health, 'vegetation' has positive influences while the existence of 'building', 'wall', 'car', and 'bicycle' can hinder people's physical activities in streets. Social health benefits that people may obtain in the streets, however, were only related with 'vegetation' in a positive way. No negative streetscape element was found for this aspect of human social health. In terms of mental health, the promotive impact of 'vegetation' still exists, as do the negative influences of 'building' and 'wall'.

3.3.3. The Distribution of Health-Related Streetscape Elements

The mapping results illustrated that streetscapes with a high percentage of 'vegetation' can mostly be found in the Pudong, Yangpu, and Changning districts. Also, these streetscapes are more likely to concentrate on residential areas and universities. In the Changning and Pudong districts, more vegetation can be observed on streets around residential areas near Changfeng Park, Central Park, and Pudong Library. Streets close to universities in Yangpu, north of the Putuo district, and south of the Minghang district are also shown with a high visibility of 'vegetation'. Additionally, a high percentage of 'vegetation' elements were also found on streets scattering around Zhangjiang High-tech Park. See Figure 8.

The distribution of streetscape elements that negatively relate to human health was quite different within the site. The high visibility of 'building' was mostly found in streets inside of CBDs, such as 930 High-tech Park and Wujiachang High-tech Park in the Yangpu district, The North Bund in the Hongkou district, and Huangpu Riverside in the Huangpu district. Several commercial areas, including People's Square in the Huangpu district, Xujiahui Park, and the Shanghai Indoor Stadium in the Xuhui district, were also observed with streets containing a high proportion of 'building'. See Figure 9.

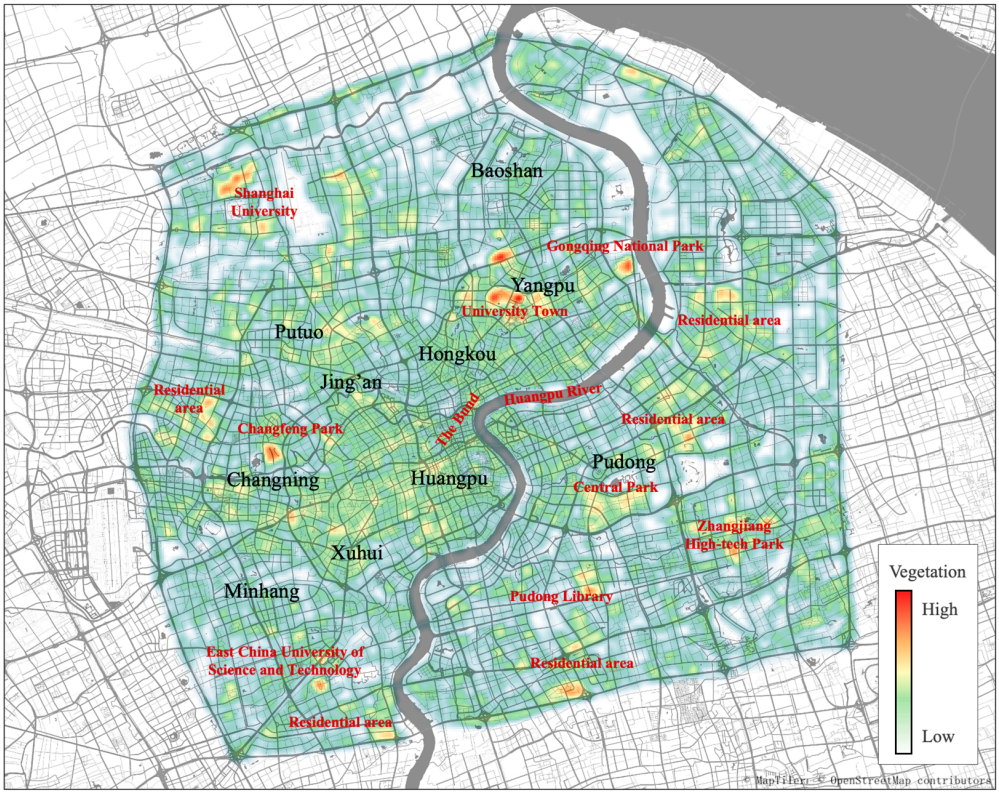


Figure 8. The distribution of streetscape elements positively related to health potential.

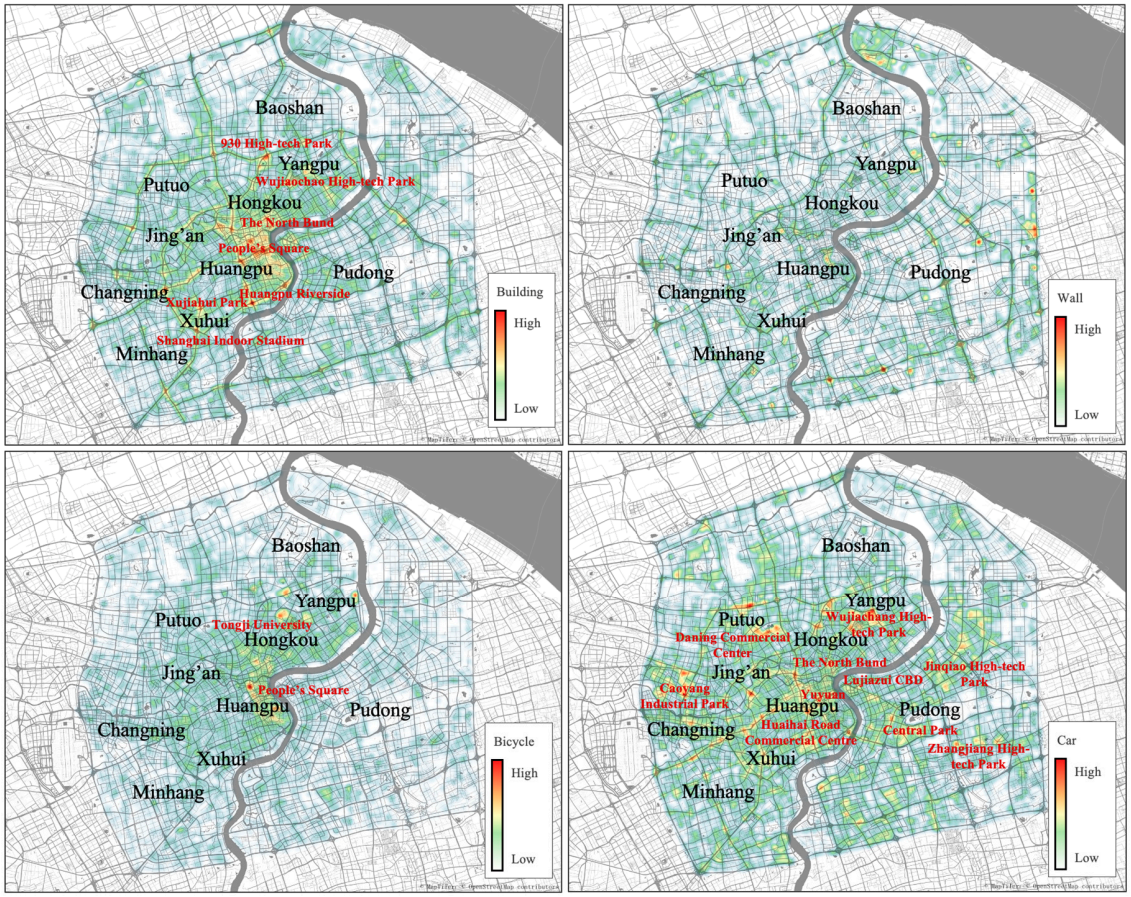


Figure 9. The distribution of streetscape elements negatively related with health potential.

Similar to the distribution characteristics of 'building', the distribution of the street element 'car' was also scattered around business and commercial areas: business areas including Lujiazui CBD, Jinqiao High-tech Park, and Zhangjiang High-tech Park in Pudong New District, Wujiaochang High-tech Park in the Yangpu district, the North Bund in the Hongkou district, and Chaoyang Industrial Park in the Putuo district and commercial areas including the Huaihai Road Commercial Center in the Xuhui district, Yuyuan Garden in the Huangpu district, and the Daning Commercial Centre in the Putuo district. See Figure 9.

Less evident aggregations can be identified within the site for the negative-related street element 'wall', while the high percentage of street 'bicycle' was only found within the area of People's Square and around Tongji University. See Figure 9.

4. Discussion

4.1. The Health Equity Promoted by Urban Streetscape

This study managed to indicate health equity within Shanghai's inner city through evaluating the quality of streetscapes in promoting human health. Most landscape justice research focuses on the allocation, accessibility, and services of green spaces [68], especially in highly densified urban areas where green spaces are scarce and, in most cases, unevenly distributed. Very little attention has been paid to identify other potential landscape resources and to evaluate their equity in relevant research arenas. This research proposed streetscapes as a kind of important urban landscape resource with the ability to promote human physical, mental, and social health. Given the fairly even distribution and accessibility of urban streets, the varied streetscape qualities are the key to determine how much and how fair human health can be promoted. The mapping results of this study revealed the disproportionate distributions of healthy streets within the inner city of Shanghai and, therefore, supports the assertion that there is a health equity issue caused by the differences in streetscape quality.

Though very limited evidence has been paid to the quality equity of streetscapes, congruencies were observed between the distribution of health-promotive streetscape, green spaces, and population density within the research site. In a study to compare population aggregation and the green space allocation within Shanghai inner city [5], it was found that the residential population were mostly gathered around People's Square and Yuyuan Garden in the Huangpu district, Suzhou River in the Hongkou district and, also, the south area of the Yangpu district. This feature was generally in line with the distribution of streetscapes with low levels of health-promotive potential. Similarly, districts with higher per capita green spaces, such as the south-east area of the Pudong New District, the north side of the Yangpu district, and areas close to the Outer Ring Road, are also districts with higher levels of health-promotive streetscapes. Inconsistencies were also disclosed. For example, People's Square in the Huangpu district and Lujiazui CBD in Pudong New District have lower health ratings for their streetscapes but higher per capita green spaces. The similar tendency observed between the distribution of green spaces and the quality of health-promotive streets further supported that the inequity of streetscape quality is worth academic and practical attention. Moreover, the reverse characteristics found between the distribution of population and of per capita green spaces and health-promotive streetscapes further specified where the inequities exist.

Comparing research outcomes with streetscape quality studies conducted within Shanghai inner city, streets rated with a higher level of perceived comfort are basically those with higher levels of health-promotive benefits, for example, those streets around Central Park and in the Hengfu Landscape Preservation Area [66]. Also, streets in the areas of Yuyuan Garden and Shanghai Railway Stations have low ratings for both of their comfort and health-promotive qualities. On the contrary, in another study exploring the justice of streetscape visual compensation, streetscapes with positive compensation effects on relieving road anger were mainly gathered around People's Square and Yuyuan Gardem where less health-promotive streets were found [66]. The observed positive benefits of urban streetscapes proved their importance in improving environmental quality

and people's perceptions [51–53]. Relevant research findings also confirmed their role as an essential landscape resource and, thus, the equity that is a key aspect in the pursuit of environmental justice.

4.2. Street Planning and Design Implications for Improving Health Equity

Design improvements on streetscape health equity should be made according to the influential street elements. The results suggested there are five street elements, 'vegetation', 'building', 'wall', 'car', and 'bicycle', that were found to be related to human health. By comparing the distribution of influential elements with the distribution of healthy streets, equity instructions can be developed for the design of 'vegetation', 'building', and 'wall', while for the elements of 'car' and 'bicycle', design might not be able to intervene. In general, the low visibility of 'vegetation' is accompanied by streetscapes with lower levels of health-promotive effects. Therefore, an increase in greenery should help improve the health equity of people who live in or near the Bund area. Given that the widths of pavements are relatively narrow in this area and the setbacks of streetside buildings are extremely limited, the use of small and removable flowerbeds should be encouraged. With the urban regeneration taking place in the Huangpu, Hongkou, and Yangpu districts, more streetside spaces should be planned for pocket parks, greenways, and grasslands. As for the area near the Outer Ring Road, land resources are not strained. Low health equity is a natural result of developing areas. As long as planning leaves sufficient spaces for street vegetation and streetside greenery, the current situation can gradually be improved as the regeneration proceeds. The percentage of 'building' also revealed a negative relationship with the health evaluation. High building densities in areas around People's Square and Yuyuan Garden can also be slightly modified during the regeneration process. In addition, the good maintenance of building frontages and the increased use of transparent street frontages might weaken the negative health effects brought on by densified buildings [68]. The distribution rule between health-promotive streetscapes and the visibility of 'wall', however, is less obvious. See Figures 8 and 9.

In addition to design interventions, the achievement of health equity should also be delivered with policy and planning regulations. Given that 'car' and 'bicycle' are influential but are not design elements, suggestions on traffic regulations may help improve the health equity of the old city centre area, which may include the following: (1) to encourage people to travel by public transportation; (2) to delimit zones for bicycle parking and avoid its interference for pedestrians; and (3) to set clear isolations between cars, bicycles, and pedestrians using coloured pavements, flower beds, and barriers. Moreover, though this study focused on the quality equity of urban streetscapes, the equity purpose can hardly be realised simply through street quality interventions. The street is not an independent urban space. Instead, it sustains complex urban functions and interacts closely with adjacent lands. Thus, considerations at the planning level about whether there is sufficient space for carrying out the proposed design interventions; whether the proposed design interventions influence the designated functions and characteristics of this area; and how the proposed design interventions can be delivered without interrupting people's life in the developed area are also needed. Street quality equity in promoting human health is also encouraged to be supplemented as a topic in street design guidelines. The current street design guidelines promoted by the city of Shanghai [69], London [70], New York City [71], and Abu Dhabi [72] have overlooked the equity theme. Health equity should also be emphasised in relevant policy agendas from a comprehensive top-down perspective to include both resources (i.e., spaces, services, and quality) and the pathways (i.e., provision, participation process, and social-economic status) equity, so that planning and design implementations can efficiently follow accordingly.

4.3. Limitations

Although the research outcomes met the study's aim, some limitations were identified in the experimental design and data analysis process. To understand the distribution

of health-promotive streetscapes at the city level, this study used street view images as visual stimuli. Street view images were obtained from the drivers' perspectives rather than the pedestrians' perspectives, while the streetscape health evaluation was focused on streetwalkers. The difference in visual angles may affect people's evaluation results to a certain extent. Typical street view images selected at random in the questionnaire may also affect the health evaluation results of the entire site if the images selected happen to be special in that type. Although manual validation has been conducted to ensure that these images are typical, bias cannot be eliminated. As for the data analysis, the technical precision that the semantic segmentation algorithm can currently achieve may limit the accuracy of the categorisation results. This study used the health ratings of each typical street view image to predict the health ratings for all the streets of the whole type. Though a rigorous calculation model was adopted, this is still a compromise for bridging between individual perceptions and city-scale evaluations. Differences undoubtedly exist between the real evaluation and the prediction results. Further attempts should be made to find more accurate models that can predict large-scale urban quality based on individual levels of environmental perceptions. It is also necessary to explore methods of involving real settings to obtain more precise evaluation results. The method developed in this research is also applicable to future similar studies, but the limitations need to be further refined. For example, it might be necessary to adopt a more comprehensive classification method so that health design improvements that are in line with streets functions and their traffic hierarchical needs can be suggested. Moreover, local development planning agendas should be consulted in practical applications to distinguish when and where street design interventions are advisable.

5. Conclusions

Environmental justice research focuses on the allocation of public resources in terms of quantified distribution and accessibility. This study suggests evaluating the quality of the visible, available, and perceptible urban resource of landscape equity, as it is typically a combination of elements. However, little evidence has been found because visual landscape equity is difficult to define and quantify. Taking streetscape as an essential visual landscape resource, this study evaluates its potential in promoting physical, psychological, and social health by integrating street view images, questionnaires, AI-based image analysis, cluster analysis, and correlational analysis. Setting out from a quality perspective, the health equity provided by urban streetscapes was discussed based on the spatial distribution of health-promotive streetscapes and health-influential streetscape elements. The results of this study indicate where in Shanghai's inner city health opportunities can be improved to provide residents with more equal opportunities of obtaining health outcomes. Streetscape design implications developed in this study inspired alternative quality interventions in achieving urban health equity when the provision and accessibility of positive resources can hardly be moderated. The research outcomes also implies a feasibility to be applied in other large-scale street quality evaluations and in other city contexts.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: cityscapes-dataset.com (accessed on 1 October 2019), lbsyun.baidu.com/index.php?title=static (accessed on 1 October 2019).

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