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Visual Preference Analysis and Planning Responses Based on Street View Images: A Case Study of Gulangyu Island, China

Jingxiong Huang [1,2], Jiaqi Liang [1,3], Mengsheng Yang [1,3] and Yuan Li [1,3,*]

1 School of Architecture and Civil Engineering, Xiamen University, Xiamen 361005, China
2 School of Architecture, Tsinghua University, Beijing 100084, China
3 Xiamen Key Laboratory of Integrated Application of Intelligent Technology for Architectural Heritage Protection, Xiamen 361005, China
* Correspondence: liyuan79@xmu.edu.cn

Abstract: The features of a street environment play an essential role in human behavior, but predicting the preferred environment becomes challenging for city planning. This paper takes Gulangyu Island as an example and examines tourists' visual preferences through street view images and a stated preference survey. Based on the findings, planning responses were proposed to provide references for improving tourists' visual perception of the street's environment. The results show that tourists' preferences for the street environment are significantly affected by visual features. From highest to lowest are variety, the green view index, crowdedness, sky openness, and enclosure. The green view index, sky openness, and variety positively affect the visual utility, while crowdedness and enclosure have a negative effect. Among them, variety has the most potent positive effect on visual preference, while crowdedness has the most substantial negative effect. Moreover, there is a balance between green view and enclosure that is affected by green plants, and when the enclosure value is too high, the marginal effect of the green view index will be less effective. Last, the streets with high visual utility have an ideal natural environment, spacious roads, an open sky, and limited architecture.

Keywords: street environment; visual preference; fully convolutional network; stated preference; street view images; Gulangyu

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1. Introduction

The features of the environment play an essential role in human life. Numerous studies claim that the environment influences individuals' physical activity (PA) behavior, emotional and social indicators, thermal comfort, and people's perceptions [1–5]. People respond differently to the environment by choosing their preferred features and changing their behavioral performance. For example, people tend to be more physically active in walkable and interconnected streets [6]. Thus, the features of the environment are closely related to human behavior, and predicting the preferred environment becomes challenging for city planning.

Human behaviors are driven by many factors [7,8], with comfort perception being an essential personal variable [9]. Comfort is the pleasant state of three domains of human perception (behavioral adjustment, physiological acclimatization, and psychological habituation or expectations) [10,11], and the experience of comfort is associated with visual perception [12]. However, most research has mainly focused on the influence or perception measurement of the current environment on individuals rather than studying individuals' potential perceptions to predict their expectations. Miller, et al. [13] claimed that potential perceptions could be discerned by identifying the individual's behavior preference. Kaplan [14] also proved that visual preference for photographic material is a highly effective way to understand an individual's perception, which means the analysis of perception via visual preference is available. Furthermore, existing research has proven visual preferences are the combination of stimuli perception and learned interpretation [15]. Masahiro and

Toshikazu [16] proposed a visual cognition process model, indicating that different individuals may produce differences in impression and cognition when they face the same stimulus, which is manifested as different visual preferences. Hence, exploring subjective preference combined with the objective environment is crucial in further understanding human visual perception.

A tourism destination is a special kind of urban environment that aims to offer services with leisure and recreation to tourists. A tourism destination mainly serves tourists, whose perception of the environment should be considered when referring to the optimization of tourism sites. Meanwhile, visual information is the cornerstone of a human's perception of the environment, which offers a perspective to understand the mechanism between the environment and behavior [17]. Hence, from a visual perception perspective, this paper has three research objectives: How can the tourists' perception of the environment be measured? How can a model to measure the tourists' preference for the environment be constructed? How can the environmental optimization scheme from the perspective of visual perception be proposed?

The measurements of an individual's perception include the subjective psychological paradigm and the object physical paradigm [18]. Related studies based on the former paradigm have used questionnaires [19], wearable sensing [9], and unstructured interviews [20] to obtain evaluation and experience. The latter paradigm requires evaluation of the environment, and related studies have often constructed a system to directly quantify the environment quality and its support for behavior [21]. Among them, a street view image (SVI) objectively and comprehensively reflects the features of the environment [22]. It shows no significant differences compared to real-world experiences when referring to visual psychology [23,24]. Therefore, SVIs have gradually become a critical research foundation for evaluating the perceived environment. Scholars have focused on deep learning (DL) models to obtain the proportion of the features of the environment [25], such as the fully convolutional network (FCN). FCN is a kind of feedforward neural network with structural depth including convolutional computation; it is trained end-to-end and pixels-to-pixels. FCN performs well in terms of memory cost, computing time, low resolution, and natural object-level images [26,27]; it exceeds the state-of-the-art in semantic segmentation [28]. The results of segmentation helped related studies to construct a suitable quantitative evaluation system and quantify the perceived quality of the environment [21].

To measure the individuals' preference for environments, many studies have been conducted. The methods for data collection mainly include photography and observation [29], behavior mapping [30], VR panorama [31], questionnaire [32], etc. Moreover, most of them are based on the stated preference method (SP) and reveal preference method (RP) to construct the research framework. The SP method is based on the random utility theory (RUT) [33], which offers a feasible method to predict the future. In the empirical research, the SP method can generate virtual scenarios to build a discrete choice model (DCM) for the survey. Regarding expression methods, scholars use text description [34] and graphic description [35] to generate questionnaires. When the issues involve spatial design and perception disclosure, the graphic method improves the respondents' understanding of pre-designed scenarios. To conclude, the SP method with SVIs is a helpful tool for measuring respondents' preferences based on their visual perception and can be used to predict their potential needs.

In general, existing research on the measurement of visual perception and behavioral preference has a relatively mature theoretical basis. Facing the demands of the development of the tourism industry and human-oriented concept, the visual environment in tourism destinations should balance better visual perception and tourism needs [36]. It poses a significant challenge to the planning and management of tourist destinations. Therefore, this paper focuses on improving the visual perception of the environment and explores the tourists' visual preferences based on the semantic segmentation of the SVIs. At the street scale, an intersection is an important place for tourists to make decisions, where the preference can be measured by their choice [37]. Hence, based on DL with the FCN and SP methods and using the SVIs collected from the intersections at the tourism destination, this paper aims to deeply understand the decision-making mechanism under the appearance of tourists' behavior. The result can provide decision support and references for generating environmental optimization strategies.

The remainder of this paper is structured as follows: Section 2 introduces the study area and research framework, as well as the stated preference questionnaire design and the data collection and proceeding; Section 3 presents the results, including the tourists' visual preference results and the typical intersections analysis; Section 4 discusses the main findings and contributions to the existing research and then proposes visual optimization strategies for street space design; and Section 5 concludes with the results and limitations of this work.

2. Materials and Methods

2.1. Study Area

This paper selected Gulangyu, an island in the southeast of China, as the study case (Figure 1). It is a national 5A-level tourist attraction with an area of 1.87 km^2 and it is located on the estuary of the Chiu-lung River, facing Xiamen Island. In July 2017, it was inscribed as a historic international settlement on the World Heritage List.

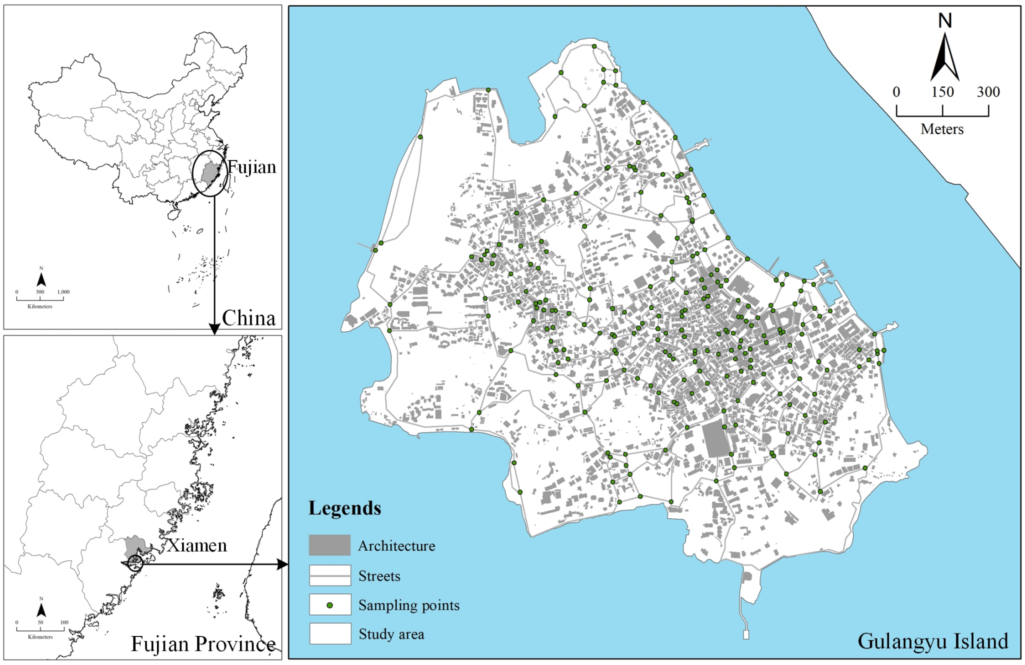

Figure 1. Study area.

Gulangyu is not only one of the most visited tourism destinations in China but it is also a UNESCO World Heritage Site, which means the tourism development in Gulangyu needs to observe more restrictions. Therefore, understanding tourists' preferences and proposing optimization schemes is needed for balancing tourism development and heritage protection. Moreover, Gulangyu is a pedestrian-only island, which helps understand the relationship between tourists and the environment without the limitation of vehicles. Meanwhile, Gulangyu is an island destination, its scale is moderate for walking, and it consists of many street elements, such as commercial, residential, and heritage areas and the landscape, allowing tourists to obtain a variety of different street visual experiences in one day. These elements constitute Gulangyu's tourism value and facilitate the movement of tourists in the street space. Gulangyu is a representative study case, and the results have significant reference value for the improvement of tourists' experience and the sustainable development of a heritage tourism site.

Furthermore, the research scope is limited to the main tourism streets to understand tourists' perceptions better. The tourism streets are shown in the Panoramic View of Gulangyu, the guidance issued by the officials for tourists. It is confirmed that more than thirty streets on Gulangyu Island are in the research scope, and a geographic information database was established in ArcGIS 10.7. All of the streets were interrupted at each road section's intersection, and a total of 358 line elements and 227 sampling points were obtained (Figure 1).

2.2. Research Framework

To fill the research gap, measuring the visual perception of the environment and revealing the visual features that affect tourists' preferences are the key points in this paper. First, for perception measurement, extracting and quantifying the visual elements and features of the street environment from SVIs is necessary. Second, for visual utility, conducting a DCM to reveal different visual elements' positive and negative effects on tourists is helpful. Third, for visual preference, the visual utility of each intersection presents the estimation level of preference, and the classical intersection analysis helps to understand and explain the reasons for tourists' preferences. Last, there is a discussion and explore the based on the results mentioned above, and propose optimization strategies for the environment as planning responses. The result can provide references for environmental optimization in the tourism destination. The research framework of this paper is shown in Figure 2.

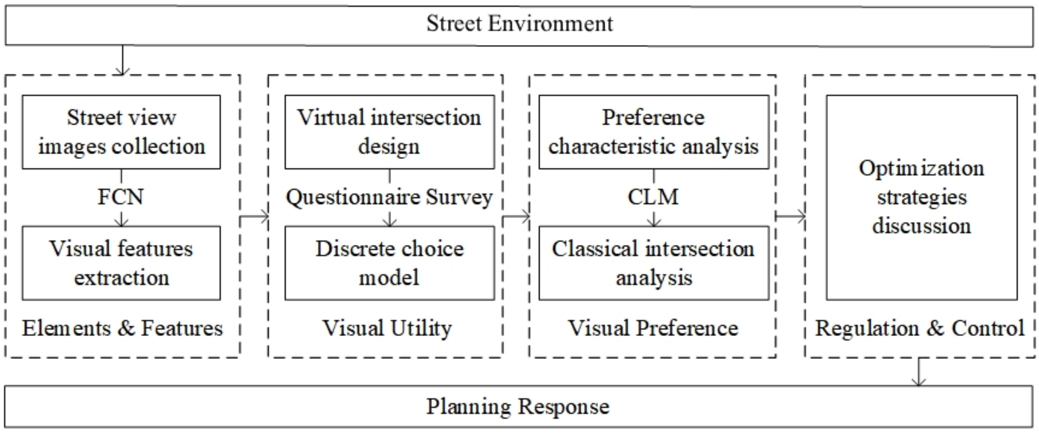

Figure 2. Research framework.

2.3. Data Collection and Processing

According to Figure 2, the collection and processing of data in this paper are mainly based on SVIs and questionnaires data. For the SVIs, we selected all the intersections of the tourism streets in Gulangyu. As a pedestrian-only island, the traditional vehicle-based street view databases are unavailable in Gulangyu. Moreover, to ensure the collected SVIs fit tourists' perspectives, we used a lens with a 24 mm focal length (35 mm-equivalent) to collect data from different directions towards other streets by simulating tourists walking, and the acquisition height was 1.6 m from the ground.

The SVIs' collection was carried out on sunny days from late October to early November 2021 and 852 images were collected. After comparing the acquisition perspective and photo-shooting conditions, we used 739 images for image segmentation and visual perception measurement as the original data. Then, we conducted an FCN model to extract visual features from the SVIs [28,38] and establish a geographic information database including visual features of Gulangyu's tourism streets' intersection.

For the questionnaire data collection, a questionnaire design was necessary. The SP method measures the respondents' preferences by making situational assumptions through a combination of different elements. The method is based on the DCM proposed by McFadden [39]. In an SP survey, respondents are asked to choose the best solution for themselves from the given options. Each element's weight will be estimated through the model, reflecting the influence of multiple factors on the respondent's decision-making behavior. The utility value is calculated as follows:

$$V = \sum_{i=1}^{n} \alpha_i x_i \tag{1}$$

where V represents the total visual utility tourists obtained in the street intersection according to the visual fields and α_i is the coefficient of the visual element x_i. According to the RUT, individuals tend to choose the options with maximum utility.

The SP questionnaire contains two parts in this paper: personal attributes and preference options. The frontier includes gender, age, and education. The latter has the SVIs regenerated according to the semantic segmentation results, and the combination of different levels of the visual features determines the details. In detail, the authors conducted an orthogonal design according to the extracted visual features of the environment; each visual feature was randomly combined as options; the tourists' visual preference can be measured through the DCM [40]. In accordance with Huang, et al. [41], this paper selected five visual indicators for the measurement of tourists' visual perception: the green view index (GVI), sky openness, crowdedness, enclosure, and variety. In detail, they contain visual features including green trees and plants; the sky; pedestrians; architecture, walls, green trees and plants, and roads; and street facilities. The visual indicators and features are proposed in Table 1.

Table 1. Visual indicators and features of street space in Gulangyu.

Visual Indicators	Features	Formula
Green View Index	Green trees and plants	$G_i = \frac{1}{n}\sum_{i=1}^{n} T_n (i \epsilon N^*)$
Sky Openness	The sky	$O_i = \frac{1}{n}\sum_{i=1}^{n} S_n (i \epsilon N^*)$
Crowdedness	Pedestrians	$C_i = \frac{1}{n}\sum_{i=1}^{n} H_n (i \epsilon N^*)$
Enclosure	Architecture, walls, green trees and plants, and roads	$E_i = \frac{\frac{1}{n}\sum_{i=1}^{n} A_n + \frac{1}{n}\sum_{i=1}^{n} T_n}{\frac{1}{n}\sum_{i=1}^{n} R_n} (i \epsilon N^*)$
Variety	Street facilities	$V_i = \frac{\sum_{i=1}^{n} B_n + \sum_{i=1}^{n} Ce_n (i \epsilon N^*)}{n}$

Note: G_i is the green view index of the SVI and T_n is the proportion of the pixels identified as trees, grass, and green plants in the image. The sum represents the total number of green pixels in each image. E_i is the enclosure of the SVI; A_n is the proportion of architecture (wall) pixels in the image; R_n is the proportion of road pixels in the image; O_i is the sky openness of the SVI; S_n is the proportion of sky pixels in the image and the sum represents the total number of sky pixels in each image; C_i means the crowdedness of the SVI; H_n is the proportion of pixels identified as pedestrians and the sum represents the total number of pedestrians pixels in the image; and V_i means the variety of the SVIs, B_n, and Ce_n are all of the identified street facilities, including store billboards, ceilings, etc. The sum represents the total number of street facilities' pixels in each image. n is the total number of pixels in each image.

The visual features in Table 1 are regarded as the elements that measure visual perception and preference. According to the requirements of the SP method, each feature should be divided into two or four levels; each level represents the feature's proportions in visual fields. Every level means a specific fluctuation range of each element instead of the exact proportion, and the value of each element increases from level 1 to level 4. The finally constructed SP choice attributes and the levels are shown in Table 2.

The division of each feature's level is described as follows, and the examples are shown in Figure 3:

(1) The GVI describes the proportion of green trees and plants in the visual fields from Aoki [42]. Scholars have emphasized the critical role of green plants in measuring visual perception and considered them a catalyst for pedestrian activities [43]. According to Li, et al. [44], the GVI can be classified into five levels: very low (<0.05), low (0.05–0.15), medium (0.15–0.25), high (0.25–0.35), and very high (>0.35). Accordingly, the GVI is divided into four thresholds: 0.05, 0.15, 0.25, and 0.35.

(2) The sky, pedestrians, architecture (including walls), and roads are related to tourists' visual perception. They are also connected with the indicators such as sky openness and enclosure [45,46]. However, there is no specific threshold for the proportion of the visual features above to affect an individual's visual perception or measure the degree of pleasure they produce. Moreover, there are street intersections with no architecture and no pedestrians in Gulangyu; the first level can be selected as zero. As for other features, the authors use the value of the lower quartiles and the median and the upper quartiles of each visual feature as measured results to divide each level according to the field survey.

(3) The proportion of street facilities in the visual field is generally low. Due to the difference in accuracy, the segmentation results of street facilities may fluctuate. Therefore, various street facilities are combined into one feature and participate in a preference survey. In detail, the value of the upper quartiles, the lower quartiles, and the median quartiles of the street facilities are similar; hence, the authors divided them into two levels in this survey.

Table 2. Preference features and level.

Visual Features	Levels			
	Level 1	Level 2	Level 3	Level 4
Green trees and plants	0.05	0.15	0.25	0.35
The sky	0.05	0.10	0.15	0.20
Pedestrians	0.00	0.05	0.10	0.15
Architecture	0.00	0.15	0.25	0.35
Roads	0.20	0.25	0.30	0.35
Street facilities	0.00	0.05	—	—

Figure 3. Examples of each level of the visual features.

Furthermore, this paper used IBM SPSS V22.0 (Statistical Product and Service Solutions) to conduct the orthogonal design and generated twenty-five combinations. Then, the combination of visual features that were not normal or the sum of each visual feature proportion that was more than one were screened out. After screening, twelve independent scenes remained and were randomly combined into six selection pairs. The combination was also the reference for image processing and questionnaire design. Finally, before the formal questionnaire survey, a small-scale preliminary survey of thirty samples was conducted. We adjusted the questionnaire according to the pretest results; for example, we combined the selections with similar features into the same set and removed the visual features that can affect respondents' choice too much.

3. Results

3.1. Fitting Results Analysis

The questionnaires were distributed through the "Wenjuanxing" online survey platform by the snowball sampling method and they were started in November 2021. Finally, 302 questionnaires were distributed, with 240 valid ones, and the effective rate was 79.47%. The basic situation of the respondents is shown in Table 3.

Table 3. Basic situation of the respondents (N = 240).

Attributes		Count	Percentage/%
Gender	Male	116	48.33
	Female	124	51.67
Age	Below 18	6	2.50
	18–34	178	74.17
	35–60	48	20.00
	Above 60	8	3.33
Education	Primary	1	0.42
	Junior	10	4.17
	Senior	28	11.67
	High vocation\Undergraduate	140	58.33
	Above graduate	61	25.42

This paper used the conditional logit model (CLM) in Stata/MP 16.0 to fit the collected 2776 valid data from 240 questionnaires; the fitting results are shown in Table 4. The CLM assumes all virtual scenes have the same utility value. It sequentially estimates the direction and coefficient of different visual features in tourists' preferences, which provides references for design strategies in refining the street environment optimization scheme.

Table 4. Fitting results of the stated preference survey (N = 240).

Visual Features	Coefficient α	Z	P
Green view index	107.3453	8.57	0.000
Sky openness	52.8163	8.87	0.000
Crowdedness	−103.7304	−8.29	0.000
Enclosure	−11.3134	−8.32	0.000
Variety	123.0995	8.55	0.000
Log likelihood		−823.1502	
Prob > chi2		0.0000	
Pseudo R^2		0.1444	

The overall model passed the significance test, and the pseudo R^2 was 0.1444, indicating that the fitting result was acceptable. All of the visual features were significant at the 99% confidence level. The GVI, sky openness, and variety positively affect the visual utility, while crowdedness and enclosure have a negative effect. Among them, the influence levels on visual utility from high to low are variety, the GVI, crowdedness, sky openness, and enclosure. Crowdedness ($\alpha = -103.7304$, $P < 0.000$) has the strongest negative impact on tourists' willingness to visit a street, while variety ($\alpha = 123.0995$, $P < 0.000$) has the strongest positive impact on it. Variety involves the setting of street facilities and represents the richness of the visual perception experience of the street environment. The results indicated that streets with more facilities could attract more tourists, and too many people in the street would decrease the attraction.

It is worth noting that the GVI ($\alpha = -103.7304,\ P < 0.000$) ranked second in positive influencing features, indicating that streets with more trees planted meet tourists' preferences more. The sky openness ($\alpha = 52.8163,\ P < 0.000$) and enclosure ($\alpha = -11.3134,\ P < 0.000$) ranked fourth and fifth, respectively. Sky openness positively impacts tourists' selection, indicating that tourists prefer a more open and transparent street environment in Gulangyu. However, the coefficient of the enclosure shows a negative effect on tourists' selection. From the calculation formula, the enclosure is related to the proportion of green plants, architecture, and roads in the field of vision. The coefficient indicated that there might be a balance between the GVI and enclosure affected by green plants, which helps to design the environment better. To test this hypothesis, the authors further calculated the green view's marginal effect on visual utility under the constraints of different levels of enclosure. The result is shown in Figure 4.

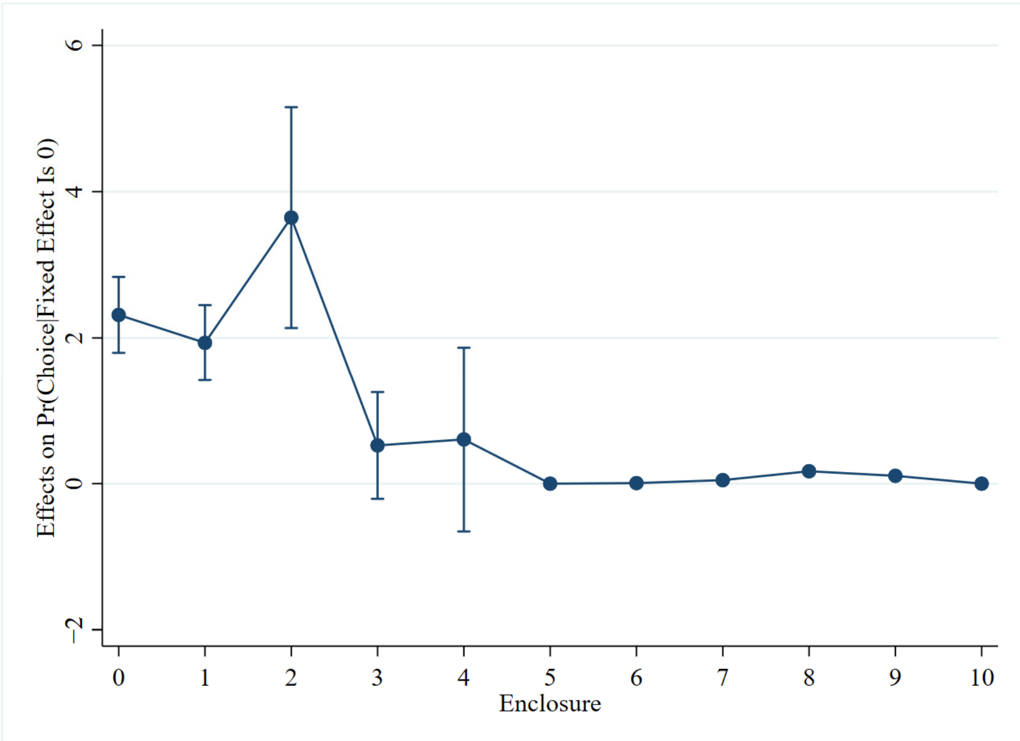

Figure 4. Marginal effect of green in different enclosure levels with 95% confidence levels.

When the enclosure value is in the range of one and two, the marginal effect of the GVI increases overall, and the gain of a unit of GVI to the visual utility gradually increases and reaches a relatively high level when the enclosure value equals two. Therefore, when facing a street intersection with a low degree of enclosure, the environment can be decorated with more green plants to ensure it meets the tourists' preference and forms a better visual experience for them. However, the GVI's marginal effect reaches an inflection point when the enclosure value exceeds two. At this time, a street space design with a high GVI can be far less effective than before. The marginal effect of the GVI gradually decays.

Furthermore, with the growth of the enclosure value, the GVI's marginal effect decreases and gradually approaches zero. The negative effect of the enclosure will be the critical feature in the visual experience of tourists instead of the positive effect of the GVI. To conclude, although the GVI positively affects visual utility, designers should use green plants with caution in the environment design when the enclosure value reaches a certain high level.

3.2. Typical Intersection Analysis

The visual utility calculation results and the typical intersections with high or low visual utility are shown in Figure 5. From the perspective of visual perception, the intersections with high utility are mainly concentrated in the roundabout of Gulangyu, with some streets even extending inward. For tourists, the intersection with higher visual utility is Yanwei Road, mainly around Yanwei Mountain Ecological Park on the north of the island, including Yanping Road and Xinghua Road. Meanwhile, the intersection with lower visual utility is located near Neicuoao Road, Ganghou Road, Quanzhou Road, Shichang Road, and some sections inside Yanwei Mountain Ecological Park.

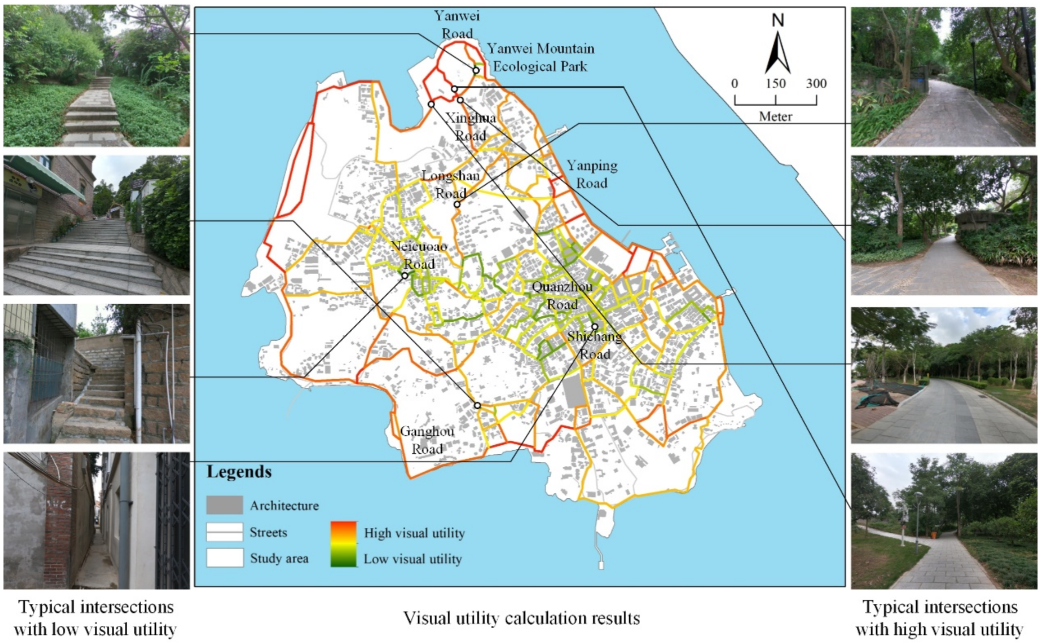

Figure 5. Visual utility and the typical intersections with high and low utility.

As Figure 5 shows, the typical intersections with high visual utility values generally have superior natural environments and little or no architecture. The enclosure is low, and the GVI is generally high. These results show that in the absence of specific tourism destinations, tourists' behavior preference on Gulangyu is more easily affected by the natural environment. Tourists are more inclined to choose streets with many green plants, spacious roads, and low enclosures for a better walking environment. In comparison, Figure 5 also shows the typical intersections with low visual utility, which are generally narrow and occluded. The sky openness and the variety are poor; the architecture on both sides is mainly residential, with no or few shops; and most are non-commercial streets and cluttered. Meanwhile, most visual features enclosing the street are gables of architecture or the walls that enclose courtyards, with fewer green plant embellishments. Tourists are not active in such areas.

However, the street intersection at Yanwei Road is worth noting, with its higher GVI but lower visual utility. In this intersection, the trees' crowns are too large and contribute to increasing the enclosure and reducing the sky openness; to some extent, this forms a low visual utility value and indirectly reduces the tourists' willingness to visit this area. The main reason is that the pavement area of the ground is small, and the landscape is dominated by natural features, which characterizes the environment as dark and silent. For tourists unfamiliar with the tourism destination, it will undoubtedly reduce their willingness to visit such a street. This conclusion is consistent with the previous results in Section 3.1.

4. Discussion

4.1. Main Findings

This paper explores tourists' visual preferences based on the semantic segmentation of SVIs and aims to improve their visual perception of the environment. It provides an understanding of tourists' preferences based on the visual sense and could guide the planning response for the street environment. The path to realizing the optimization of the street environment is shown in Figure 6. The visual elements of the street environment determine its visual features, which affect the environment's visual utility. According to the random utility theory, tourists preferred to choose environments with high visual utility. Therefore, visual utility can indicate tourists' potential preferences and guide the strategies for planning responses. The perception of the environment can be improved by directly or indirectly regulating and controlling the elements, especially the elements of features with a high effect on visual utility.

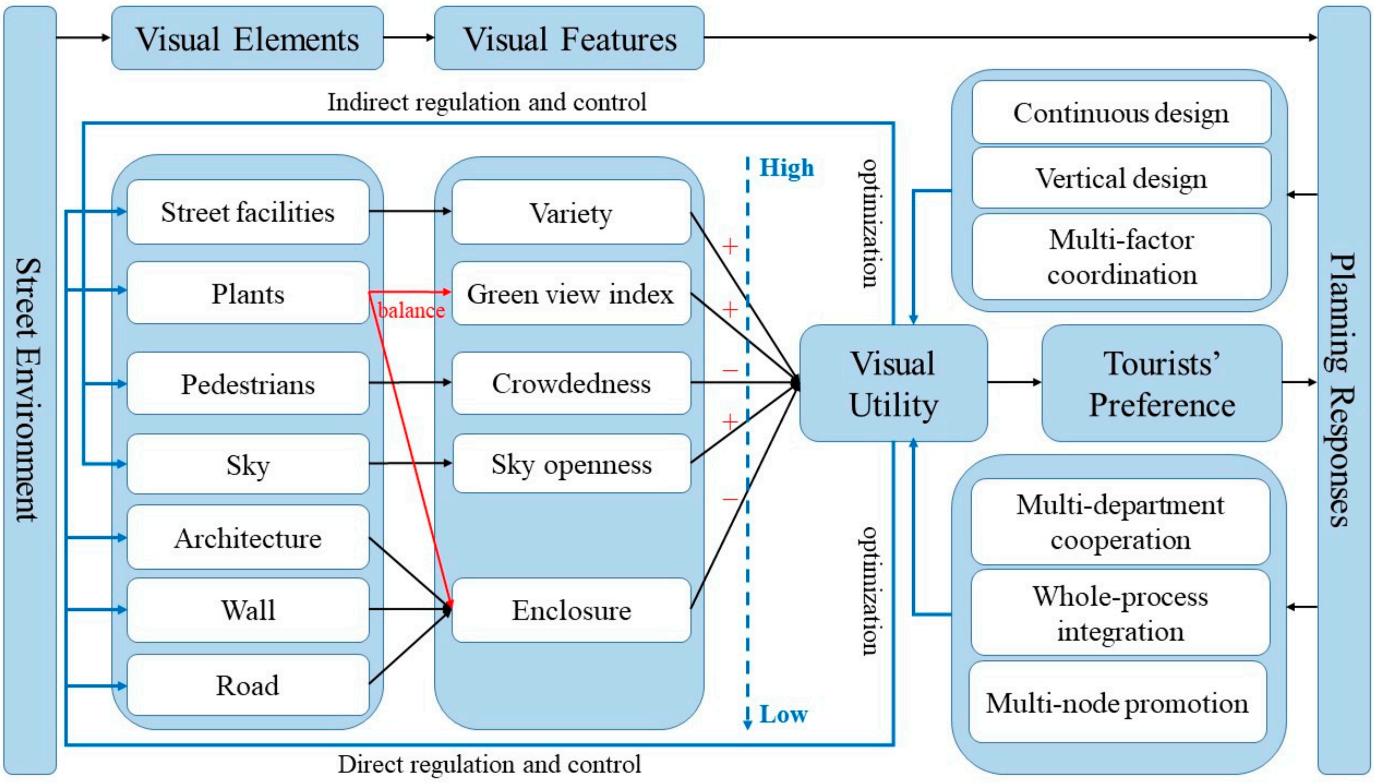

Figure 6. Optimization paths of street environments based on visual preference.

In detail, this paper found that: (1) tourists' preference for the street environment are significantly affected by the visual features to different degrees; their order from high to low is variety, the GVI, crowdedness, sky openness, and enclosure. (2) The GVI, sky openness, and variety positively affect the visual utility, while crowdedness and enclosure have negative effects. Among them, variety has the most substantial positive effect on visual preference, while crowdedness has the most substantial negative effect. (3) There is a balance between the GVI and enclosure affected by green plants, and when the enclosure is too high, the marginal effect of the GVI will be less effective. (4) The streets with high visual utility have ideal natural environments, spacious roads, open sky, and limited architecture. At the same time, the streets with low visual utility are narrow and surrounded by too much architecture or too many green plants. The findings can guide planning and design as the response for optimization.

The variety of visual structures and components reflects the high value of the environment [47]. Places with various land use types provide diverse destinations for people to walk to [48]. When the variety in a place can be seen clearly by observers, it can present a place's visual wealth [49]. From a more internal perspective, pedestrians require a high level of variety to be interested in activities in the place [50]. These reasons can explain tourists' preference for a more varied street environment. In detail, the variety corresponds to the streets with rich facilities and commercial functions. In other words, commercial streets with rich facilities are more attractive to tourists. Based on this finding, the specific reasons why variety attracts tourists are refined to the level of tourism facilities and commercial tourism activities. Therefore, the attractiveness of the commercial elements and service facilities should be taken seriously. However, proper planning is also essential to avoid over the presence of too many businesses, which may cause a negative perception of narrowness and roughness [37].

The GVI is directly dependent on green plants. At the same time, green plants can also affect the enclosure of the environment in a street space. However, as previously indicated, aesthetic, ecological, economic, and environmental factors are the main criteria for tree species' selection for the greenspace of the street environment [51,52]. Species' characteristics, management and maintenance issues, visual and aesthetic benefits, and site factors are criteria for species selection of green plants [53]. However, these criteria mainly focus on functional and management issues, ignoring the individuals' preferences and perceptions [54]. Our findings on visual preferences can be a supplement. On the one hand, tourists prefer streets with an ideal natural environment decorated by green plants; on the other hand, they also prefer to choose narrow streets enclosed by fewer plants. Moreover, if the plants are taller and denser, the open sky would also be sheltered, decreasing tourists' preference. Therefore, it is crucial to consider preferences and perceptions when selecting plant species for street planning in tourism destinations.

Other evidence might explain the negative effects of crowdedness and enclosure by existing empirical studies. Earlier leisure field studies have pointed out that a visual approach can yield higher crowding norms [55]. Some studies in environmental psychology also argue that the participant can acquire a better restorative experience when the place is less crowded, and crowded places may influence the perception of whether the environment is safe [56]. Moreover, a well-established fact is that the enclosure can bring people a more intuitive and profound psychological experience linked to the visual quality of the street space as opposed to other indicators [21]. The enclosure denotes how the environment encapsulates the pedestrian and relates to people's perception of spatial confinement [46]. As Yin and Wang [46] have proven, this work also found a street with wider roads, fewer buildings, and fewer trees, with a relatively high level of sky openness and a low level of visual enclosure. Based on this, tourists' preferences will be more stimulated when increasing the number of green plants to a suitable level. Reduced visibility should be of great concern; however, only a few participants provide this response [57]. Further research is needed for tourism destination planning.

4.2. Implications for Optimization of Street Space Design

This paper divided the street environment into visual elements and combined them as visual features to measure tourists' visual preferences. The visual features and tourists' preferences finally contribute to the planning response to provide a reference for designers to use the related elements and guide tourists' behavior on purpose. As Figure 6 shows, the GVI, enclosure, and variety are the visual indicators that optimization strategies can directly regulate and control. Related to these three indicators, the visual features, including architecture, green plants, roads, and street facilities, can be optimized directly to improve the tourists' visual perception. Based on the main findings above, this paper has the following implications based on the different features for street space design optimization:

(1) Selective use of green plants, combining continuous and vertical design. From the perspective of green plants in street spaces, the higher GVI positively impacts tourists' visual perception. Therefore, different levels of green plants or designs can be used at street intersections where tourism routes pass to enhance visual perception or strengthen direction guidance. Generally, there are two types of areas on both sides of

the street space in Gulangyu: bare land and hard pavement. For example, for bare land, designers can use trees and shrubs to strengthen the continuity of green plants for landscaping. For the hard pavement, managers can use greening sketches with shrubs, herbs, or ground cover plants, combined with rest facilities at fixed modulus intervals on both sides to improve visual perception. More green plants can improve tourists' visual perception to some extent, but too high of a GVI will also negatively affect perceptions due to reduced sky openness and increased enclosure. Therefore, if the designers use trees and shrubs for landscaping, trees with large crowns should not be used in the street environment that needs to be improved. Moreover, if there are buildings, walls, or structures on both sides of the street, climbing plants with landscape decorations or vertical greening designs can be considered. They ensure the optimization measures increase not only the GVI but also avoid the excessive improvement of the enclosure reducing the visual utility.

(2) Adjusting the visual features in a targeted manner and unifying multi-features coordination with multi-department cooperation. For example, the enclosure is related to the architecture, green plants, and roads at street intersections. Among them, the changes in architecture are often restricted due to the cultural heritage protection requirement; therefore, green plants and roads can regulate the features affecting the enclosure. Meanwhile, managers can also clean the sundries on the road or wall surface to optimize the enclosure. Specifically, the streets' boundaries can be strengthened and limited by closely arranged green pieces, plant sequences, or by the design and adjustment of structures. The optimization and adjustment of the enclosure need to be considered and designed as a unified whole. Furthermore, different visual features belong to different management authorities, so coordinating their cooperation is necessary.

(3) Control the whole function layout of street space and coordinate functional integration and multi-intersection promotion. For variety, designers can lay street facilities out in combination with the main functions of the streets. Optimizing the environment can be designed through the flexible use of environmental sketches and facilities such as advertising signs, lighting equipment, garbage bins, landscape sketches, rest facilities, sculptures, and guide cards, to enrich the tourists' activities and beautify the street to some extent. In addition, managers can control the whole design, placement, construction, and maintenance process, based on the landscape's integrity. A street facility has limited influence on tourists' vision. However, a designed sign system can reflect the cultural characteristics of tourist destinations and can be developed to attract tourists' attention and further optimize the surrounding landscape features. In addition, managers should build a multidisciplinary platform of integrate planning and collaborative adjustment to optimize and refine the visual perception of the environment and improve the sustainable development pattern.

5. Conclusions and Limitations

This paper starts with the relationship between the environment and human life, focuses on the research objects of improving tourists' visual perception of the street's environment, and examines space, behavior, and perception from the perspective of visual features. In detail, this work collected SVIs of tourism streets' intersections on Gulangyu Island by artificially simulating tourists walking. It measured the subjective and objective perception data by DL with the FCN and SP methods. The SP questionnaires were designed and distributed based on the extracted visual features from the SVIs. The visual utility was calculated by estimating the visual preference of tourists through the CLM. Last, an analysis and discussion were conducted around the preference data and typical scenarios, which aim to provide decision support and planning reference for the sustainable development and street environment design of the tourism destination.

The contributions of this paper include: first, from the perspective of research, the paper combines subjective and objective perceptions, discusses the relationship between the environment and the tourists' behavioral preferences, and offers references for visual optimization based on the tourists' visual preferences. Second, from the perspective of the method, the paper collected SVIs by walking and used the DL methods to analyze and represent tourists' visual perception of the environment; moreover, it used the SP method to design and distribute questionnaires to represent subjective behavior preference data. Overall, it not only takes advantage of the SVIs to describe the characteristics of the objective environment but also the advantages of the questionnaire data to summarize the subjective individual cognitive laws. Last, from the perspective of practice, this paper puts forward the path of environment optimization based on visual perception and preference. The framework can be extended to other similar tourism destinations for environment measurement and optimization. Furthermore, visual preference plays a crucial role in behavioral decisions; therefore, this research is also helpful in guiding tourists' behavior in tourism destinations excepting to improve their environmental quality and is beneficial to heritage sites' management and heritage protection.

Limited by the research objects and methods, this paper still has the following limitations: in a related analysis, space and time need to be considered as the two factors that affect an individual's behavior; different seasons or weather may have an impact on tourists' visual preference. In future research, this issue should be discussed further combined with time. Moreover, this work assumed that visual perception is the only factor that affects tourists' behavior. Tourists' behavior is not only affected by a single factor; future research can further consider the comprehensive influence of more factors, such as soundscape, terrain, and color. Moreover, the questionnaires were collected by snowball sampling. There may be a bias in the attributes and preferences between the respondents and all of the tourists. In the future, research can further expand the samples to accommodate more tourists to obtain a more accurate estimation.

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Abbreviation

CLM, conditional logit model; CNNs, convolutional neural network; DCM, discrete choice model; DL, deep learning; FCN, fully convolutional network; GVI, green view index; PA, physical activity; PSPNet, pyramid scene parsing network; RP, reveal preference method; SP, stated preference method; RUT, random utility theory; SVI, street view image.

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