On the relation between visual quality and landscape characteristics: a case study application to the waterfront linear parks in Shenyang, China

Dong Sun 1,3, Qingyu Li 1, Weijun Gao 2,3, Gonghu Huang 1, Ning Tang 1, Mei Lyu 3,4 and Yiqing Yu 1

1 School of Architecture and Urban Planning, Shenyang Jianzhu University, Shenyang, People’s Republic of China
2 ISMART, Qingdao University of Technology, Qingdao, People’s Republic of China
3 Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan
4 School of Design and Art, Shenyang Jianzhu University, Shenyang, People’s Republic of China

E-mail: gaoweijun@me.com

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Abstract

In recent years, Chinese cities have begun to pay attention to their rivers, and a large number of waterfront linear parks have been built in the riverside areas, so that the public can easily enjoy their landscape and entertainment functions. In this study, the visual quality of the waterfront trails and the greenbelt trails in the Waterfront linear Park around the Hunhe river in Shenyang was evaluated the basis of the Scenic Beauty Estimation Method and Semantic Differential Method, and the principal components of the landscape characteristics were extracted and a regression model of the visual quality and the landscape characteristics was established. Results show that the natural feature and the formal feature have a positive influence on the visual quality in waterfront linear parks, and the man-made feature has a negative impact on the visual quality. The six landscape characteristics are Sense of seclusion, ecology, intactness, uniqueness, unity and vitality, which are the main factors which affect the visual quality. This study puts forward improvement measures for the waterfront trails and the greenbelt trails, and the results can be applied to the planning, construction, and management of waterfront linear parks.

1. Introduction

As an crucial part of the urban green space and water systems, the waterfront linear parks have an important impact on the environmental and social benefits (Bülent 2013, Francis 2012, Everard et al 2012, Asakawa et al 2004, Attia and Asmaa Abdel Ibrahim 2018), which was an important space for the public to leisure, entertainment, fitness and communication (Prominski et al 2013, Alina 2015, Sun et al 2018, Wang et al 2020), and it has a unique and important significance to the urban environment (Zhao and Wang 2014, Rung-Jiun 2016). In the revitalization plan of Shenyang, the Hunhe riverside area is the most valuable waterfront space, and the development goal is to build the Hunhe riverside area into the ecological corridor and waterfront landscape zone (Gao et al 2020, Shi et al 2020). However, after on-the-spot investigation of more than 10 waterfront linear parks on both sides of Hunhe river, there are many problems in the landscape construction of riverside linear parks: riverside revetment is mostly artificial structure, with monotonous form, sparse vegetation; platforms and walkways are not hydrophilic; the pavement texture of the activity field is single; high-rise buildings outside the area cause landscape and visual impact, which seriously reduces the naturalness and quality of the park landscape.

It is prerequisite to fully display the aesthetic value of waterfront landscape (Jähnig et al 2011, Yumin et al 2012, Tan and Peng 2020); the spatial continuity of various landscape elements (Gobste and Lynne 2004); the conservation of ecosystems (Conine et al 2004), and the following user requirements (Asakawa et al 2004).
The most crucial problems needed to be solved were: (1) What are the main landscape elements? (2) What are the main landscape characteristics? (3) What is the relationship of landscape beauty with landscape elements and landscape characteristics?

Previous studies have shown that the waterfront linear park reflects the interaction between humans and the ecological environment (Kaplan 1977), has hydrophilic and green recreation space (Genoveva 1995, Liu and Zhou 2004), reflects spatial order with linear landscape characteristics, which can change the scenery with the visitors walking reflects the landscape continuity of park (Jiang et al. 2016), it can purify air (Zhu et al. 2013), improve the viability of aquatic ecosystems (Wang et al. 2021, Cengiz 2013) and upgrade ecological environmental quality and social culture (Erickson 2004). On the basis of the study of species diversity of urban waterfront landscape and the surrounding environment, it is indicated that biodiversity and ecosystem stability play a decisive role in landscape quality (Schirpke et al. 2013, Amici et al. 2015, Schuepbach et al. 2016); the establishment of waterfront plant landscape evaluation system has made the reaction to the aesthetic public aesthetic preferences (Gao et al. 2013, Yangting et al. 2016); some methods, such as big data and mobile phone location data have applied to analyze the vitality of the waterfront open space (Guan et al. 2020). The comprehensive evaluation of urban waterfront landscape by the POE method has can realize the public participation. The AHP method has been applied to construct urban river landscape evaluation model (Qiao et al. 2008, Cao et al. 2020), waterfront landscape evaluation and suitability analysis (Conine et al. 2004, Uy and Nakagoshi 2008, Du et al. 2012). The GIS technology has determined the stability of watershed environment (Cengiz et al. 2011, Durán et al. 2021), and Scenic Beauty Estimation (SBE) Method has been applied to quantitatively analyze the waterfront landscape (Wang et al. 2020, Gong et al. 2019, Zhu et al. 2015).

Landscape visual quality (LVQ) is a product of the interaction landscape characteristics with the perception and emotional psychological process of the observer. It can be characterized as ‘relatively aesthetic impeccability of a landscape’ and it can be measured through the appreciation of the observer (Lothian 1999, Daniel 2001, Fuente de Val et al. 2006). Some various methods have been developed, among which the most accurate and rigorous method has been the analysis of a psychophysical model (Daniel Terry and Boster Ron 1976, Roger 1986, Ervin Zube 1987, Kaplan and Kaplan 1989, Terrence Purcella Richard Lamb 1998, Daniel 2001). In 1976, Daniel and Boster proposed the SBE method, which is scientific and sensitive and has been widely applied in the study of landscape aesthetic quality (Daniel 2001, Hands and Brown 2002, Meitner 2004, Clay and Smidt 2004, Arriaza et al. 2004, Acar et al. 2006). Based on SBE method, it was found that the ecology, diversity, vividness and maintainability (Kaplan et al. 1998, Junker and Buchecker 2008, Frank et al. 2013, Gündor and Polat 2018) and other landscape characteristics have a positive influence on visual quality, and determines the correlation of aesthetic value through the interaction between ecological quality and visual quality (Mirghaed et al. 2020). Visual quality assessment has developed to multi-sensory experience, multi-scale and multi-angle simulation, and Ease of user evaluation (Tang and Liu 2015). In order to explore the influence of forest landscape (Sheppard and Picard 2005, Yong 2013), landscape spatial pattern (Fuente de Val et al. 2006), park landscape (Kongjian 1994, Acar et al. 2006), vegetable landscape (Ayala Misgav 2000, Weng et al. 2002), rural landscape (Arriaza M et al. 2004) and highway landscape on public aesthetic preference, a relationship model between visual quality and quantification of landscape element was built through regression analysis. Semantic difference method is a psychological research method proposed by American psychologist Osgood (1967), also known as Semantic Differential (SD) Method method (Osgood et al. 1967, Echelberger 1979). SD method emphasizes the importance of choosing alternative landscape elements and semantic description to evaluate the visual landscape characteristics of landscape space and entertainment space, and it uses the descriptive scale of language to explore the psychological feelings of evaluators. To evaluate the public’s preference (Junhua 2004, Cao et al. 2020). In this study, SBE and SD methods were used to evaluate the visual quality of five waterfront linear parks around Hunhe river in Shenyang, and the citizens’ preference for landscape beauty was summarized, which was beneficial to improving the landscape construction and urban renewal level of waterfront linear park in Shenyang, and not only protected the waterfront ecology, but also optimized the landscape function.

2. Materials and methods

2.1. Study area

The study area is located in both sides of Hunhe River in Hunnan District, Shenyang, China. The south bank of Hunhe River is not only an emerging area of urban development in Shenyang but also a key point in construction of Hunhe riverside area. According to analysed survey which residents’ utilization situation of Hunhe Waterfront Linear Park in Shenyang and construction situation of parks in Hunhe riverside (please refer to appendix A), five typical waterfront linear parks were selected as the research objects on both sides of the Hunhe river (Hunhe Park), there were Olympic Park, Hunnan Citizen Park, Wulhe Park, Changbai Park and Changqing Park, each park includes a waterfront trail and a greenbelt trail.
Distribution map of the waterfront linear parks (figure 1) displays that the Olympic Park is on south side of the Hunhe river, the length of the shoreline is 1.3 kilometers, average width of the park is 140 meters. A wide walkway connects some viewing platforms in the waterfront trail, lush reeds were planted around the shore. Deciduous trees is the main vegetation in the greenbelt trail, the green area ratio is 87%. The greenbelt trail includes a running lane, a bike lane. Olympic Park has fantastic scenery and natural beauty that makes it most popular for local residents.

Hunnan Citizen Park is located in the southwest of the Olympic Park, with a coastline of 1.1 kilometers and an average width of 270 meters. There are hard revetments and dense aquatic plants in the waterfront trail. The greenbelt trail is dominated by sparse forest and grassland. In addition the activity areas include sports areas and leisure areas. The high-rise buildings outside the park are in sharp contrast with the grasslands inside the park.

Wulihe Park is on the north side of the Hunhe river, the coastline is 1.9 kilometers long, average width of the park is 320 meters. The waterfront trail includes artificial beaches, waterfront walkways and hydrophilic platforms. The greenbelt trail has a various natural landscape and activity field, with botanic gardens, sports fields and recreation areas.

Changqing Park is located in the easternmost part of the Hunhe Park. The coastline is 0.7 km long with an average width of 212 meters. There are wooden walkways in the waterfront trail, and some aquatic plants are planted on the shore. Silver poplars and colorful shrubs are the main vegetation of the greenbelt trail, and the activity venues include leisure square, football field and several sports fields.

2.2. Samples acquisition and selection
In this study, photographs were applied as surrogates for real landscapes because they possessed the advantages of fast progression, low cost and comparing multiple landscapes simultaneously (Zhao et al 2013). It has been applied frequently in previous studies (Arriaza et al 2004, Cañas et al 2009, Zhao et al 2013). According to the trails distribution of the waterfront linear parks, the samples collection points were evenly distributed on the two trails in each park. 12 samples collection points (waterfront trail had 6 points, greenbelt trail had 6 points) (figure 2) were in every park, a total of 60 samples collection points were chose. The sample photos were taken at 45° regular intervals horizontally, they were evenly distributed on a circle. As a result of the terrain constraint, the photos quantities in some points were less than 8, a total of 420 photos were taken. The photos were all taken in the sunny morning (9:00–11:30) or afternoon (1:30–4:00) in October 2020. To ensure the consistency of technical specifications for photo shooting, the camera was Canon D600, with the camera at a horizontal height of about 1.6 meters and no flash was applied. Meanwhile GPS receivers were applied to measure the location of each sampling point. In the photographs that were taken from each sample collection point, a representative photo was chose which could reflect the real landscape information of this point. A total of 60 photos were used to SBE (figure 3). Meanwhile, field questionnaire survey was conducted at each sample collection point by inviting 8 observers to conduct visual quality evaluation. According to compare SBE results of field questionnaire survey with the sample photos, the accuracy of waterfront parks visual landscape evaluation was verified (appendix B).

2.3. Observers and evaluation methods
The research of Blasco et al proofed that the aesthetic preference of the general public can be presented by that of university students (Blasco et al 2009). Students were widely used as respondents in relevant studies because of their efficient work (Luis et al 1999; Clay and Daniel 2000; Real et al 2000; Bulut and Yilmaz 2008; Sevenant and Antrop 2009). Meanwhile, the LVQ preference of different major students had similarity (Yao et al 2012). In this study, 139 students from three majors (47 students from architecture, 55 students from landscape architecture...
and 37 students from Visual Communication Design) were invited to evaluate the visual quality of the waterfront linear park by using SBE method (Daniel Terry and Boster Ron 1976). In order to avoid the influence of the same type landscape on the aesthetic evaluation of observers, the 60 typical sample photos were randomly arranged and made a powerpoint, conducting visual quality evaluation in a multimedia classroom by projector.
of ultra-high resolution. The same powerpoint was played during each group evaluating. Before the experiment, all observers were pre-trained. Then each observer finished a printed evaluation questionnaire by personal preferences. Communication was forbidden. In addition, a presentation was shown before the formal evaluation. It provided all the typical sample photos information of waterfront linear parks to observers. The playing time of each photo was 3 s. This presentation aimed at helping observers to create their own criteria before the evaluation process. In the evaluation, each sample photo was shown 15 s apart, on a seven-point scale ranging from 1 (very dislike) to 7 (very like) (please refer to appendix D). 4 invalid questionnaires were deleted, a total of 135 valid questionnaires were obtained, the net response rate was 97.1%. The SBE result of LVQ evaluation from three majors students, were compared to verify their difference (appendix C). Finally, transform individual observer’s ratings to standard(z) scores by the general formula (1). Then, these dates were be used to get the final standardized SBE value of each sample photo (2).
Where: $Z_{ij}$ = standardized value given by the observer $j$ who had evaluated the sample photo $i$.

$R_{ij}$ = The score given by the observer $j$ who had looked over sample photo $i$.

$\overline{R}_j$ = mean value given by the observer $j$ who had seen all sample photos.

$S_j$ = standard deviation given by the observer $j$ who had looked all sample photos.

This study adopted the Delphi method by consulting experts in landscape architecture, combined with the current situation of the Hunhe Park, and finally decided to adopt 22 landscape characteristics (table 1). Because the evaluation is more meticulous for them, it is prerequisite to control the number of sample photos to improve the operability. Therefore, 25 representative pictures were selected according to the sort of landscape quality (high, medium and low) by experts, of which, 4 came from Olympic Park, 6 from Hunnan Citizen Park and Wulihe Park, 5 from Changbai Park, and 4 from Changqin Park. There are usually 20 to 50 assessors who need a certain amount of professional knowledge. 20 graduate students and 10 landscape architecture teachers volunteered to participate in the study. In the evaluation process, 30 evaluators were first explained the corresponding adjectives of landscape characteristics in the questionnaire, and they were asked to pay attention to landscape characteristics instead of photo quality. Each photo is played for 3 min, and the evaluation standard is divided into 5 points (1–5 points). The positive or negative adjectives expressions were compared with the
current event. In this case, the higher the score, the closer it is to the meaning of the adjective on the right (appendix F). After checking the evaluation results, 30 evaluation tables were obtained, all of which were valid.

### 2.4. Statistical analysis

The data on the visual quality and landscape characteristics of the SD sample photographs were subjected to Pearson correlation analysis by using SPSS 25.0 software. The landscape characteristics with conspicuous correlation were identified and retained. Collinearity between variables may reduce the credibility of models therefore principal component analysis (PCA) was carried out. The visual quality was accepted as dependent variable and landscape quality evaluation models of the waterfront linear parks were established with multivariate linear regression analysis.

### 3. Result and analysis

#### 3.1. Verification of experimental accuracy

According to compare SBE results of field questionnaire survey with the sample photos, it showed that they were consistent (please refer to appendix B). It indicated the photos evaluation method could be used to LVQ evaluation of the waterfront parks which is consistent with result of other researches. (Meitner 2004, Schroeder and Daniel 1980, Zube E H 1984). The SBE result of three majors were compared and showed that they were consistent (please refer to appendix C). It indicated there is no significant difference in the aesthetic preferences of students from the different majors. It was consistent with 'the scores awarded to the different photographs by the different groups were homogeneous’ from I. Canas (Cañas 2009).

#### 3.2. Evaluation of SBE

By sorting the landscape quality of the 60 samples photos (table 2), the top 20 samples were classified as high-quality samples, and the bottom 20 samples were classified as low-quality samples. The analysis of the quantities of high-quality samples and low-quality samples distributed in each park and mean values of landscape quality of each park (table 3) could be concluded that overall landscape quality of the five parks ranked as follows: SBE Olympic Park > SBE Wulihe Park > SBE Changqing Park > SBE Changbai Park > SBE Hunnan Citizen Park. The overall landscape quality ranking order of each park is roughly consistent with the landscape quality of the waterfront trails and greenbelt trails.

| Table 1. Characteristics of landscape and adjective groups in SD method. |
|-----------------------------|-----------------------------|
| Evaluated item              | Adjectives in pair          |
| Sense of space              | Cramped—wide                |
| Landscape layering          | Single-layer—multi-layer    |
| Unity                       | Divisive—uniform            |
| Conspicuousness             | Indistinctive—conspicuous   |
| Intactness                  | Fragmentized—Intact         |
| Harmony                     | Inharmonious—harmonious     |
| Degree of spatial variation | Single spatial variation—rich space variation |
| Sense of rhythm             | Unrhythmic—rhythmic         |
| Sense of order              | Disorderly—orderly          |
| Ecology                     | Artificial—ecological       |
| Approach                    | Unapproachable—approachable  |
| Comfort                     | Depressive—comfortable      |
| Tidiness                    | Dirty—tidy                  |
| Density                     | Sparse—dense                |
| Attractiveness              | Unattractive—attractive     |
| Mystery                     | Common—mysterious           |
| Uniqueness                  | Ordinary—unique             |
| Sense of seclusion          | Exposed—sealed              |
| Vitality                    | Unvital—vital               |
| Sense of safety             | Dangerous—safe              |
| Element richness            | Scenic components are single—scenic components are rich |
| Interestingness             | Boring—interesting          |

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By comparing the landscape quality mean values of the waterfront trails with the greenbelt trails in table 2, indicating the landscape quality of the waterfront trails was higher than the greenbelt trails in all the parks except Wulihe Park.

According to a comparative analysis of the trail landscape quality of waterfront and greenbelt in each park, it could be seen that the landscape quality of the waterfront trail and the greenbelt trail were outstanding in the Olympic Park. In the waterfront trail, there was vast sky and waters, ecology revetment and beautiful skyline, a superior visual experience was established for the public. In the greenbelt trail, there were tall and luxuriant vegetation to make green space full of vitality, and the harmonious relations between the plants and pavements improved landscape integrity, in the Wulihe Park, there were abundant vegetation, open access lawns and comfortable activity fields. The various plant communities enriched the spatial layering and the activity fields had a harmonious coordination with surrounding natural environment. These factors making the landscape quality of the greenbelt trail in Wulihe Park was the most outstanding.

The landscape quality of the waterfront trail was high in Changqing Park. The naturally meandering and clear-flowing rivers and the abundant aquatic plants constituted a quiet waterfront space. In Changbai Park, nearly barren revetment led to the quality of the waterfront trail was common. The cluttered plant communities and sparsely distributed trees in the greenbelt trail led to the landscape quality was worse. In Hunnan Citizen Park, the landscape quality of the waterfront and the green trails were the worst caused by the dirty revetments, muddy water, obstructed views, non-hydrophilic activity fields and overgrown weed.

The high-quality samples of the waterfront trails showed that the open and tidy spaces have an unobstructed view to the water (8,52); the proportion of water area was high and the water was clear (5); the landscape content

### Table 2. Ranking order of landscape quality for the 60 samples and trails classification.

| Sample No. | Trail type | Standardized value | Sample No. | Trail type | Standardized value | Sample No. | Trail type | Standardized value |
|------------|------------|--------------------|------------|------------|--------------------|------------|------------|--------------------|
| 25         | G          | 0.965              | 4          | W          | 0.142              | 18         | G          | −0.224             |
| 26         | G          | 0.728              | 59         | W          | 0.111              | 47         | W          | −0.225             |
| 3          | W          | 0.659              | 49         | G          | 0.107              | 45         | G          | −0.226             |
| 55         | G          | 0.610              | 27         | W          | 0.106              | 60         | W          | −0.242             |
| 1          | G          | 0.578              | 9          | G          | 0.100              | 41         | G          | −0.280             |
| 39         | W          | 0.527              | 28         | G          | 0.059              | 29         | G          | −0.291             |
| 12         | G          | 0.519              | 17         | G          | 0.052              | 58         | G          | −0.313             |
| 50         | W          | 0.481              | 2          | G          | 0.045              | 42         | G          | −0.314             |
| 40         | W          | 0.458              | 35         | W          | 0.038              | 24         | G          | −0.321             |
| 51         | G          | 0.447              | 34         | W          | 0.029              | 14         | W          | −0.348             |
| 36         | G          | 0.437              | 11         | G          | 0.017              | 23         | W          | −0.373             |
| 10         | G          | 0.314              | 53         | G          | 0.000              | 19         | W          | −0.378             |
| 5          | W          | 0.308              | 32         | G          | −0.005             | 38         | W          | −0.483             |
| 30         | G          | 0.293              | 31         | G          | −0.022             | 22         | G          | −0.510             |
| 16         | G          | 0.290              | 56         | G          | −0.059             | 43         | W          | −0.514             |
| 52         | W          | 0.276              | 44         | G          | −0.076             | 37         | G          | −0.517             |
| 6          | G          | 0.229              | 57         | G          | −0.146             | 21         | G          | −0.606             |
| 54         | W          | 0.212              | 15         | G          | −0.186             | 48         | W          | −0.653             |
| 46         | W          | 0.195              | 33         | G          | −0.187             | 13         | G          | −0.697             |
| 8          | W          | 0.171              | 7          | G          | −0.212             | 20         | G          | −1.147             |

Note: 1–12 locates in Olympic Park; 13–24 locates in Hunnan Citizen Park; 25–36 locates in Wuli River Park; 37–48 locates in Changbai Park; 49–60 locates in Changqing Park; W stands for waterfront trail; G stands for greenbelt trail.

### Table 3. Quantity distribution of high and low quality samples and comparison of visitor trails in different parks.

| Park name        | High-quality samples quantities | Low-quality samples quantities | Total mean value | Waterfront mean value | Greenbelt mean value |
|------------------|--------------------------------|--------------------------------|-----------------|-----------------------|---------------------|
| Olympic Park     | 7                              | 0                              | 0.238           | 0.315                 | 0.199               |
| Wulihe Park      | 4                              | 1                              | 0.179           | 0.058                 | 0.220               |
| Changbai Park    | 5                              | 2                              | 0.124           | 0.168                 | 0.093               |
| Changqing Park   | 3                              | 8                              | −0.176          | −0.099                | −0.283              |
| Hunnan Citizen   | 1                              | 9                              | −0.371          | −0.366                | −0.372              |
was rich, landscape permeability and layering were good (39); the coverage for waterfront plants was high, plant communities were distinct layers and rich posture (46,54); the plants arranged well alongside the revetment (50); the hydrophilicity of path space was strong (40); the skyline was wavy and spatial layers were varied (3). The low-quality samples of the waterfront trail showed that the space was depressed and the views of water were blocked (23); the waterfront landscape lacked certain layers and the canopy line of waterfront plants did not fluctuate and change (14,47); the waterfront revetment was bare (48); the water area was not only cramp but also turbid (19); the activity fields and roads lacked hydrophilicity (38,60); the straight skyline was boring as well as the waterfront landscape was seriously influence by buildings (43).

The high-quality samples of the greenbelt trail showed that the green coverage ratio was high (1,25); the plant were rich in species, lush, beautiful and varied (26,36,55); landscape depth and permeability were good (6,10,16); the pavements were clean and tidy, as well as it was harmonious and unified with surrounding environment (12,30,51). The low-quality samples of the greenbelt trail showed that the species-poor lawns were full of uncovered soil (13,20); the monotonous and heavy artificial traces caused the lack of natural ecological charm (29,41); the landscapes elements were disorganized (22,58); the activity fields and facilities were lacked (24,42); the roads and paths were untidy (18,37); the wild lawns were seriously disturbed by buildings (21,45).

### 3.3. Evaluation of SD

The values of landscape characteristics for each sample, the mean values of landscape characteristics for each park samples and all 25 samples were counted by Excel, and then the landscape characteristics of 25 samples were compared (appendix F1-F5).

In the Olympic Park, except for ecology (3.142 < 3.145) and uniqueness (2.625 < 2.655), the mean values of other landscape characteristics were higher than the mean values of the overall samples characteristics; in Wulihe Park, except for sense of space (2.989 < 3.388), landscape layering (2.956 < 2.997), sense of rhythm (2.735 < 2.829), the mean values of other landscape characteristics were higher than the mean values of the overall samples characteristics; in Changqing Park, except for approach (3.092 < 3.273), sense of safety (2.975 < 3.088), and comfort (3.200 < 3.208), the mean values of other landscape characteristics were higher than the mean values of the overall samples characteristics; in Changbai Park, except for sense of space (3.453 > 3.388), element richness (3.000 > 2.887), uniqueness (2.840 > 2.655), and interestingness (2.860 > 2.755), the mean values of all other landscape characteristics were lower than the mean values of the overall samples characteristics; the landscape characteristics of Hunnan Citizen Park were all lower than the mean values of the overall samples landscape characteristics. The above results indicated that the landscapes of the five parks were different in some extent.

By comparing the maximum values of the 22 landscape characteristics factors (table 4), it was found that the mean values of 8 landscape characteristics in sample No. 25 were the maximum of the mean values of all samples landscape characteristics, including naturalness, intactness and the other six landscape characteristics, this sample was located in a more secluded green space in Wulihe Park. The mean values of 8 landscape characteristics such as unity and conspicuousness in sample No. 55 were the maximum values of the mean values of all samples landscape characteristics, it was located in a square in Changqing Park.

By analyzing the lowest values of 22 landscape characteristics, it was found that sample No. 20 had the highest frequency, and the 12 landscape characteristics such as unity and conspicuousness were the lowest scores; the five landscape characteristics such as sense of layering in sample No. 13 had the lowest evaluation estimate. The above two low-scoring samples were located in a green space of Hunnan Citizen Park. Most of the highest and lowest characteristics values were located on the greenbelt trail, indicating that the landscape characteristics were more prominent on it.

The comparison of the mean values of 22 landscape characteristics showed the sense of space, tidiness, intactness were outstanding in waterfront linear parks. The waterfront trails had wide field of vision, attractive landscapes, clear water and clean roads; the high proportion of water area made the waterfront landscape uniform and complete. The bottom three landscape characteristics of uniqueness, interestingness and sense of rhythm were not obvious in the waterfront linear parks, which also showed that the present problems of the Hunhe Park: spaces lacked variability; skylines were straight; the landscapes were not prominent and boring.

The standard deviations of sense of space, attractiveness, mystery, uniqueness and interestingness were high, which meaning these characteristics differ greatly in 25 samples, and evaluators had stronger perception for them, therefore the design expectation of the landscape was easy to consistent with the public perception. The standard deviation of unity, conspicuousness, intactness, sense of seclusion and sense of safety were low, which indicating that the performance of these landscape characteristics in the 25 samples had little difference, and the evaluators’ perceptions for them were weak, the design expectation of the landscape was prone to deviation with the public perception, therefore it was necessary to pay attention to them during the design.
By comparing the mean values of landscape characteristics of the waterfront trails with the greenbelt trails (Table 9), it was found that the mean values of the landscape characteristics (sense of space, landscape layering, harmony, degree of spatial variation, sense of rhythm, element richness, attractiveness, mystery, uniqueness, and interestingness) in the waterfront trails were higher than these in the greenbelt trails. The mean values of landscape characteristics (unity, conspicuousness, intactness, sense of order, ecology, approach, tidiness, density, sense of seclusion, vitality, sense of safety and comfort) in the greenbelt trails were higher than these in the waterfront trails.

3.4. Landscape visual quality model

SPSS 25.0 was used to analyze correlation between visual quality and landscape characteristics of 25 sample photos. Table 5 indicated that the sense of space p-value was bigger than the significance level (significance level of $\alpha = 0.05$), indicating there was no correlation significant between landscape quality and the sense of space, it was removed. Whereas other landscape characteristics were correlation significant with visual quality (P values were lower than 0.05).

The visual quality was taken as the dependent variable and the retained 21 landscape characteristics were taken as the independent variable to conduct stepwise, forward, and backward regression analysis. The results of stepwise and forward regression analysis showed that 19 landscape characteristics were removed, only vitality and harmony entered the model for landscape evaluation, which obviously could not fully reflecting the impact of visual quality on those.

The table 6 showed the result of backward regression analysis. After removal four times, the three independent variables which low results for significance test of regression coefficients: density, element richness, conspicuousness were removed, and other 18 landscape characteristics were retained. Meanwhile, table 6 showed that the regression analysis was statistically significant because R square was 0.999. However, 16 characteristics in table 6 had tolerance lower than 0.1 and VIF higher than 10. The result indicated that there was severe multicollinearity between landscape characteristics, it could not establish an effective evaluation model. So it was necessary to carry out principal component regression analysis for 18 landscape characteristics. In order to ensure the reliability of the research, KMO and Bartlett tests were conducted on each variable. The results indicated the KMO test value was 0.807 (higher than 0.7) and Bartlett’s test of sphericity is significant.

### Table 4. Comparison of landscape characteristics of 25 samples and visitor trails.

| Landscape characteristics | The highest value | Corresponding sample No. | The lowest value | Corresponding sample No. | Mean value of waterfront trails | Mean value of greenbelt trails | Overall mean value of 25 samples | Standard deviation |
|---------------------------|-------------------|--------------------------|-----------------|--------------------------|-------------------------------|-------------------------------|-------------------------------|------------------|
| Sense of space            | 4.530             | 3                        | 2.170           | 23                       | 3.682                         | 3.157                         | 3.388                         | 0.714            |
| Landscape layering        | 4.030             | 3                        | 1.830           | 13                       | 3.145                         | 2.881                         | 2.997                         | 0.537            |
| Unity                     | 4.270             | 55                       | 2.400           | 20                       | 3.312                         | 3.141                         | 3.269                         | 0.463            |
| Conspicuousness           | 4.100             | 55                       | 2.430           | 20                       | 3.334                         | 3.144                         | 3.184                         | 0.449            |
| Intactness                | 3.930             | 25                       | 2.400           | 20                       | 3.224                         | 3.317                         | 3.276                         | 0.422            |
| Harmony                   | 4.130             | 55                       | 1.830           | 20                       | 3.315                         | 3.214                         | 3.259                         | 0.548            |
| Degree of spatial variation| 3.800             | 3                        | 1.530           | 13                       | 3.000                         | 2.700                         | 2.832                         | 0.558            |
| Sense of rhythm           | 4.030             | 3                        | 1.900           | 13                       | 2.967                         | 2.721                         | 2.829                         | 0.487            |
| Sense of order            | 4.130             | 55                       | 2.100           | 20                       | 3.088                         | 3.140                         | 3.117                         | 0.474            |
| Ecology                   | 4.630             | 25                       | 2.030           | 3                        | 3.000                         | 3.260                         | 3.145                         | 0.587            |
| Approach                  | 4.170             | 16                       | 2.230           | 20                       | 3.133                         | 3.383                         | 3.273                         | 0.508            |
| Element richness          | 3.930             | 3                        | 1.470           | 13                       | 3.070                         | 2.743                         | 2.887                         | 0.561            |
| Tidiness                  | 4.230             | 55                       | 2.200           | 48                       | 3.245                         | 3.405                         | 3.335                         | 0.563            |
| Density                   | 4.300             | 25                       | 1.600           | 20                       | 2.879                         | 3.157                         | 3.035                         | 0.585            |
| Attractiveness            | 4.200             | 25                       | 1.530           | 20                       | 3.027                         | 2.926                         | 2.971                         | 0.684            |
| Mystery                   | 4.070             | 25                       | 1.670           | 20                       | 3.039                         | 2.938                         | 2.983                         | 0.622            |
| Uniqueness                | 3.870             | 55                       | 1.370           | 13                       | 2.855                         | 2.498                         | 2.655                         | 0.592            |
| Sense of seclusion        | 4.335             | 25                       | 2.567           | 3                        | 2.994                         | 3.15                          | 3.081                         | 0.472            |
| Vitality                  | 4.170             | 25                       | 1.600           | 20                       | 3.112                         | 3.174                         | 3.147                         | 0.579            |
| Sense of safety           | 3.730             | 55                       | 2.170           | 50                       | 2.703                         | 3.390                         | 3.088                         | 0.448            |
| Comfort                   | 4.300             | 25                       | 1.970           | 20                       | 3.158                         | 3.248                         | 3.208                         | 0.567            |
| Interestingness          | 3.830             | 55                       | 1.470           | 20                       | 2.906                         | 2.636                         | 2.755                         | 0.603            |
The variables had a high correlation and it were independent of each other, which could be used for principal component analysis.

The total variance explained (table 7) indicated that the eigenvalues of the top three principal components were higher than 1 and the cumulative contribution was 85.76%. Therefore, these three principal components

### Table 5. Correlation analysis.

| Landscape characteristics | Pearson correlation | Sig. |
|---------------------------|---------------------|------|
| Sense of space            | −0.051              | 0.808|
| Landscape layering        | 0.619†              | 0.001|
| Unity                     | 0.745§              | 0.000|
| Conspicuousness           | 0.756‡              | 0.000|
| Intactness                | 0.811†              | 0.000|
| Harmony                   | 0.836‡              | 0.000|
| Degree of spatial Variation| 0.620†             | 0.001|
| Sense of rhythm           | 0.507§              | 0.010|
| Sense of order            | 0.532‡              | 0.006|
| Ecology                   | 0.461³              | 0.020|
| Approach                  | 0.717†              | 0.000|
| Element richness          | 0.486²              | 0.014|
| Tidiness                  | 0.671†              | 0.000|
| Density                   | 0.745§              | 0.000|
| Attractiveness            | 0.834§              | 0.000|
| Mystery                   | 0.826§              | 0.000|
| Uniqueness                | 0.724⁴              | 0.000|
| Sense of seclusion        | 0.597²              | 0.002|
| Vitality                  | 0.881†              | 0.000|
| Sense of safety           | 0.403³              | 0.046|
| Comfort                   | 0.798⁵              | 0.000|
| Interestingness           | 0.759⁵              | 0.000|

| | | |
|---|---|---|

* Correlation is significant at the 0.01 level (2-tailed).  
† Correlation is significant at the 0.05 level (2-tailed).

### Table 6. Backward regression coefficient.

| Model | B      | Unstandardized coefficients | Standardized coefficients | Collinearity statistics |
|-------|--------|------------------------------|---------------------------|-------------------------|
|       |        | Std. Error                   | Beta                      | T   | Sig. | Tolerance | VIF |
| 4     | (Constant) | −1.89                        | 0.251                     | −7.516 | 0    | 0.02     | 49.801 |
|       | landscape layering | −0.288                  | 0.128                     | −0.302 | −2.242 | 0.066     | 0.074 | 13.584 |
|       | Unity   | 0.236                        | 0.078                     | 0.213 | 3.032 | 0.023     | 0.038 | 26.356 |
|       | Intactness | −0.625                 | 0.119                     | −0.514 | −5.253 | 0.002     | 0.038 | 28.433 |
|       | Harmony | 0.649                        | 0.095                     | 0.694 | 6.823 | 0         | 0.035 | 28.047 |
|       | Degree of spatial Variation | −0.297                | 0.093                     | −0.323 | −3.202 | 0.019     | 0.036 | 28.047 |
|       | Sense of rhythm | 0.467                   | 0.076                     | 0.443 | 6.162 | 0.001     | 0.07 | 14.203 |
|       | Sense of order | −0.467                  | 0.068                     | −0.431 | −6.887 | 0         | 0.093 | 10.773 |
|       | Ecology  | −0.354                      | 0.052                     | −0.406 | −6.781 | 0.001     | 0.102 | 9.835  |
|       | Approach | −0.967                    | 0.101                     | −0.958 | −9.543 | 0         | 0.036 | 27.732 |
|       | Tidiness | 0.434                        | 0.048                     | 0.477 | 9.114 | 0         | 0.133 | 7.517  |
|       | Attractiveness | 0.381                   | 0.134                     | 0.308 | 2.852 | 0.029     | 0.011 | 87.386 |
|       | Mystery  | 0.726                        | 0.171                     | 0.881 | 4.252 | 0.005     | 0.008 | 117.922|
|       | Uniqueness | −0.958                  | 0.09                      | −1.105 | −10.6 | 0         | 0.033 | 29.901 |
|       | Sense of seclusion | 0.349               | 0.07                      | 0.324 | 4.976 | 0.003     | 0.086 | 11.639 |
|       | Vitality | 1.296                        | 0.079                     | 1.463 | 16.352 | 0         | 0.045 | 22.006 |
|       | Sense of safety | 0.581                  | 0.063                     | 0.508 | 9.28  | 0         | 0.122 | 8.228  |
|       | Comfort  | −1.474                      | 0.112                     | −1.632 | −13.143 | 0         | 0.024 | 42.374 |
|       | Interestingness | 0.995                   | 0.167                     | 1.17 | 5.963 | 0.001     | 0.009 | 105.862 |

Dependent variable: standardized value R Square = 0.999 F = 152.419.
were noted as f1, f2 and f3, they could represent the 18 landscape characteristics to analyze the visual quality of the waterfront linear parks.

By table 8, it could be seen that f1 was mainly consisted of nine landscape characteristics: degree of spatial variation, landscape layering, interestingness, uniqueness, sense of rhythm, attractiveness, mystery, harmony, comfort, among them the factor loading of variation degree was the highest, which was 0.911. F1 was named formal feature. F2 was mainly consisted of five landscape characteristics: sense of seclusion, ecology, unity, vitality, and intactness. Among them the factor loading of sense of seclusion was the highest, which was 0.926. F2 was named natural feature. F3 was mainly consisted of four landscape characteristics: the sense of safety, tidiness,
approach, and sense of order. The factor loading of safety sense was the highest, which was 0.886. F3 was named man-made feature.

A linear regression model was created with visual quality as the dependent variable and f1, f2, f3 as the independent variables (The calculation process of f1, f2, f3 is referred to appendix G). The regression standardized residual (Figure 4) showed that the standardized residual approximate followed a normal distribution with a mean of 0 and a variance of 1. In the standardized residuals, the scatter fluctuations range was not vary with the change of the standardized predicted values. Therefore it was no clear relationship between residuals and predicted values, which showed the assumption of homoscedasticity was met. The results of the linear regression analysis were presented in table 9 and yielded the linear regression equation.

\[ Y = 0.130f_1 + 0.064f_2 + 0.064f_3 - 0.024 \]

The standardized Beta coefficient (table 9) of f1 was 0.853, indicating that the landscape characteristics in f1 were the main factors affecting the visual quality of the waterfront linear parks; f1 and f2 were positively correlated with the visual quality; f3 was negatively correlated with the visual quality and it was -0.064. The finally model which by bringing the expressions of f1, f2 and f3 into the linear regression equation for quality evaluation was the following:

\[ Y = 0.031x_1 + 0.097x_2 + 0.108x_3 + 0.071x_4 + 0.035x_5 + 0.028x_6 + 0.010x_7 + 0.099x_8 + 0.033x_9 + 0.009x_{10} + 0.055x_{11} + 0.06x_{12} + 0.078x_{13} + 0.134x_{14} + 0.086x_{15} - 0.031x_{16} + 0.064x_{17} + 0.066x_{18} - 3.224 \]

The model indicated 18 landscape characteristics’ contribution rate of the waterfront linear parks visual quality in the following: Sense of seclusion, intactness, ecology, unity, vitality, uniqueness, harmony, mystery, interestingness, comfort, attractiveness, degree of spatial variation, approach, landscape layering, sense of rhythm, sense of order, tidiness, sense of safety.
4. Discussion

4.1. Landscape elements
The study confirmed that the water had a significant impact on landscape aesthetic preferences (Wherrett 2000, Faggi et al. 2013, Wang et al. 2019). In the waterfront trails, the water occupied a dominant position in the field of vision and played an important role in improving delight of physical and psychological (Roger 1981). Wide and clear water could positively enhance public perception of the visual quality of the waterfront landscape (Steinwender et al. 2008), in agreement with results from Bulut and Yilmaz, Dramstad et al. and Howley’s demonstrated that water had an important effect on it. Kaplan et al. (1998) considered that public preferences for water landscapes were not only influenced by the water itself, but also strongly influenced by the riverside areas. ‘Hydrophilic’ was a preference for water and it was a visible characteristic (Thomas 1985). Research shows that the design of the waterfront revetments and walkways greatly improve the interaction between the public and water landscape, meanwhile improving the sense of scale and visual openness of the waterfront space, water visibility was a decisive factor in the utilization rate of riversides (Pflüger et al. 2010). Rich waterfront plant species and reasonable vegetation configuration can enhance the vitality of the waterfront space and effectively improve the public satisfaction with the visual quality of the landscape along the waterfront trails. Steinwender et al. emphasized the positive influence of waterfront plants on the landscape quality of waterfront in his research (Steinwender et al. 2008). The construction of high-rise buildings was inevitable for the development of the urban waterfront areas (Tavernor 2007). It was found that high-rise buildings had negative effect on the visual quality, which caused landscape destruction and visual pollution to become more and more serious in the survey of public preference for the visual quality of large-scale waterfront areas.

Vegetation, pavement, and man-made structures in the greenbelt trails are the main elements affecting the visual quality. The public’s visual landscape preferences increased with the area covered by vegetation (Bulut and Yilmaz 2008). Other research based on perception suggests: plant community was a important factor affecting the landscape aesthetic value (Orzechowska-Szajda 2019) and abundant plant species and reasonable proportion of trees, shrubs and herbs could effectively improve the visual quality of the greenbelt trails (Sun et al. 2018). The importance of ecology was fully supported by the literature of landscape perceptions and evaluations (Bruce et al. 2001), through effective management to ensure the vitality of plants and the cleanliness of the surrounding environment that playing a vital role in improving people’s physical and psychological health and public well-being: the quality, size, color and shape of pavement material in the greenbelt trails were the important factors that affecting the visual quality (Ostoić et al. 2017). But the man-made structures might be a negative impact on the visual quality of the landscape (Acar et al. 2006, Arriaza et al. 2004). For designing and managing in the greenbelt trails, the pavement material should combine with the environment and the maintenance of pavements should be concerned. The design of the roads and activity fields through combining with landscape elements such as plants, rocks, landscape, architecture etc to achieve balance and create a harmonious green spaces, it was not only can protect the landscape naturalness in space but also enrich the landscape layers to meet the requirements of people. The high-rise buildings’ outline and facade caused visual pollution to the landscape within the parks (Li et al. 2018), Bulut and Yilmaz (Bulut and Yilmaz 2009) emphasized its negative impact on visual quality.

4.2. Landscape characteristics
By analyzing the maximum and minimum values of landscape characteristics in the 25 SD samples, it shows that the samples with higher frequency of maximum values of landscape characteristic factors have higher values of SBE and the samples with higher frequency of minimum values of landscape characteristic factors have lower values of SBE. The result indicates that the landscape characteristics have obvious impact on the LVQ of the samples.

By comparing the mean value of a single characteristic in each park with that of a single characteristic in all five parks, it is found that the parks with more high-scoring characteristics have higher values of SBE. The result indicates that the landscape characteristics in each park have significant impact on the overall landscape quality of the park.

4.3. Principal component features
The principal component analysis shows that the landscape characteristics have three principal components: the formal feature, the natural feature and the man-made feature. The characteristics in the formal feature have high repeatability with the high mean values characteristics of the waterfront trails. The formal feature is positively correlated with the visual quality. The characteristics in the natural feature are consistent with the high mean values characteristics of the greenbelt trails. The natural feature is positively correlated with visual quality. The view that naturalness was the main factor influencing visual quality of the landscape (Fuente de Val et al. 2006, Qi et al. 2017) is consistent with this paper. Meanwhile, Wherrett (2000), Wang et al. (2019) and Purcell (1998) had determined that there was a negative correlation between artificial elements and visual quality. Yang et al. (2009),...
Jim et al (2018) also deemed that artificial elements such as buildings and roads could affect the public perception of green. These research conclusions are consistent with the views of this paper. Therefore, it is prerequisite to strengthen formal feature factors (landscape layering, attractiveness, interestingness etc) and natural feature factors (sense of seclusion, vitality etc) while weaken man-made feature factors (sense of order, sense of safety etc) in the process of waterfront linear park planning or construction. The landscape layering can be enhanced by a reasonable combination of distant, medium and close scenery. Reasonably adjusting the proportions of trees, shrubs and herbs helps form attractive. Using abundant vegetation to replace the desolation on both sides of the stream not only enhance the coverage of waterfront plants but also boost the attractiveness of the waterfront trails. The diversity and abundance of the landscape elements can enhance the interestingness of the field. People preferred landscapes that looked more ‘natural’ and less ‘built’ (Hodgson and Thayer Jr 1980, Purcell et al 1994, Kaplan et al 1998, van den Berg et al 2003). Therefore, the natural feature is an important factor affecting the visual quality of the greenbelt trails. The activity fields rely on arounding luxuriant and abundant plants to improve the green coverage ratio. Reasonable configuration of plant communities can increase the sense of seclusion of space. The mixture of aquatic and terrestrial plants can enrich the natural riparian vegetation and enhance the landscape vitality. From a social and economic point of view, the addition of artificial elements was inevitable (Vries et al 2012). Therefore, promoting the integration of the man-made feature with the natural environment is a major measure for enhancing visual quality. The high-rise buildings surrounding the landscape are a major factor in the man-made feature. ‘All-natural landscapes made the visual impact of building height less obvious’ (Misgav 2000, Vries et al 2012). Thus, the negative impact of high-rise buildings on visual quality can be reduced by controlling the height and density of plant communities. Weaken the sense of order and regularity of the road by focusing on arranging plant communities along the road and enhancing the sense of plant layers. Using ecological waterside plants replaces the waterfront fence to improve the river bank landscape, create soft water edges, eliminate the man-made sense and enhance hydrophilicity.

4.4. Limitations
The study has some limitations: the research analyzed the visual quality of the autumn landscape in the waterfront linear parks as the samples were obtained in October. In future studies, representative samples of the four seasons will be collected and selected. The sampling point distribution was relatively uniform, the important landscape nodes and the ordinary landscape nodes were treated equally. The problem will be solved by combining the IPA method (importance-performance analysis) in further studies. The research only selected the landscape characteristics with significant influence. Consequently, it is impossible to control all of the confounding factors. Subtle differences in environmental attributes also affect landscape preferences. Finally, the evaluation samples used are urban river of Shenyang, Liaoning province, China. Considering the river type and urban environment, the regression model may not be fully applicable to all the waterfront linear parks.

5. Conclusions
In this study, SBE method and SD method were combined to extract 18 landscape characteristic factors and evaluate the visual quality of two types of trails in Hunhe Park, then a principal component analysis regression model of visual quality and landscape characteristics was established. It reveals that the visual quality of the waterfront linear park is mainly affected by three principal components: natural feature, formal features and man-made feature. Natural feature and formal features have positive effect on visual quality, while man-made feature has negative effect on visual quality. According to the contribution rate, the top six landscape characteristics are sense of seclusion, ecology, intactness, uniqueness, unity and vitality.

In the design of the waterfront linear parks, the original natural ecological berms should be maintained as much as possible. The premise of ecological design focused on the elaborate design and the reasonable combination of plant layers and plant species, to plant a color richness and well-organized vegetation communities. There were some suggestions to improve the LVQ and meet the needs of the public: applying the combination of plant layers and plant species, to plant a color richness and well-organized vegetation communities. The research results reveal the aesthetic rules of the public for the landscape features of Hunhe parks, which can be applied to the planning, design and management of urban waterfront parks, improve the visual quality of the waterfront parks, reduce the negative impact of urban architecture on the urban environment, and improve the quality of life and well-being for the public. It will contribute to the construction of a sustainable and resilient ‘Hunhe riverside area’ urban design in Shenyang and the realization of urban ecological civilization.
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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Appendix A

| Personal Information |
|----------------------|
| Name:               | Gender: Male Female |
| Age:                | A. Less than 14 years old B. 15-22 years old C. 23-30 years old D. 31-40 years old E. 41-50 years old F. 51-60 years old G. More than 65 years old |
| Where do you live in Shenyang? |
| A. Heping District   | B. Shenhe District   | C. Tiexi District   | D. Huanggu District   |
| E. Dadong District   | F. Yuhong District   | G. Hunnan District  | H. Suijiatun District |
| I. Shenyi New District |
| Occupation:          | A. The student       | B. The teacher      | C. The doctor         | D. Civil servant      | E. The Company staff |
| Educational background. |
| A. Primary Education | B. Higher Education  | C. Bachelor         | D. Master            | E. Doctor            |

The Public Utilization Questionnaire of the Hunhe Park

Q1. How often do you visit Hunhe parks?
   A. Once a day       B. Once a week      C. Once a month    D. Seldom       E. Never

Q2. What is the distance between your house and Hunhe Parks?
   A. < 1Km           B. 1-3Km           C. > 3Km

Q3. What type of transportation do you go to the park?
   A. On foot         B. By bicycle      C. By bus        D. Drive a car

Q4. How long is your average length of time of visiting in Hunhe Parks?
   A. < 30 minutes    B. 30 minutes-120 minutes C. > 120 minutes

Q5. When do you go to the Hunhe parks in a day?
   A. In the morning  B. In the afternoon C. In the evening  D. Unfixed time

Q6. Why you went to the Hunhe parks?
   A. Fitness and Exercise  B. Sightseeing and entertainment C. Social activity  D. Stroll  E. Group activities

Q7. What season do you like to go to Hunhe Parks?
   A. Spring         B. Summer        C. Autumn        D. Winter
The questionnaire results

We investigated the public utilization questionnaire of the Hunhe Park by questionnaires. 106 valid questionnaires were obtained after eliminating invalid questionnaires. The respondents contained 49 males and 57 females. Most of them were aged from 15 to 65. They lived mainly in Heping District, Shenhe District, Hunnan District and Dadong District.

According to the survey results, the main visiting time was in afternoon and evening. Respondents often went to the Hunhe Park in autumn and summer. We found that 25% the respondents lived within 1Km of the nearest Hunhe Park, 41% the respondents lived without 3Km away from the nearest Hunhe Park. Driving and walking were the main ways to reach parks.

We obtained the usage (figure A1), convenience (figure A2) and satisfaction (figure A3) of Hunhe Park.
In conclusion the five parks (Olympic Park, Hunnan Citizen Park, Wulihe Park, Changbai Park and Changqing Park) were usage, convenience and satisfaction. It indicated the five parks could fully reflect the public's perception for the Hunhe Park.
Appendix B

Figure B1. The SBE comparison of sample photos and field questionnaire survey.

|                       | SBE ranking of field questionnaire survey | SBE ranking of sample photos |
|-----------------------|------------------------------------------|-----------------------------|
| The top 20 samples    | 25.36.3.6.40                            | 25.26.3.55.1                |
|                       | 39.2.31.10.26                           | 39.12.50.40.51             |
|                       | 55.5.50.30.8                            | 36.10.5.30.16              |
|                       | 1.52.12.46.4                            | 52.6.34.46.8,              |
| The middle of 20      | 54.35.11.9.59                           | 4.59.49.27.9               |
| samples               | 34.53.17.33.43                          | 28.17.23.54                |
|                       | 27.51.16.47.29                          | 11.53.32.31.56             |
|                       | 44.49.28.56.32                          | 44.57.15.33.7              |
| The bottom 20 samples | 7.38.60.37.41                           | 18.47.45.60.41             |
|                       | 14.22.45.23.42                          | 29.58.42.24.14             |
|                       | 15.20.24.57.19                          | 23.19.38.22.43             |
|                       | 48.18.21.13.58                          | 37.21.48.13.20             |
Appendix C

![Figure C1. The SBE comparison of three majors students.]

Appendix D

Table D1. SBE questionnaire.

| Photo id | Score | Photo id | Score | Photo id | Score | Photo id | Score |
|----------|-------|----------|-------|----------|-------|----------|-------|
| 1        | 16    | 11       | 25    | 15       | 30    |
| 2        | 17    | 12       | 26    | 16       | 30    |
| 3        | 18    | 13       | 27    | 17       | 31    |
| 4        | 19    | 14       | 28    | 18       | 32    |
| 5        | 20    | 15       | 29    | 19       | 33    |
| 6        | 21    | 16       | 30    | 20       | 34    |
| 7        | 22    | 17       | 31    | 21       | 35    |
| 8        | 23    | 18       | 32    | 22       | 36    |
| 9        | 24    | 19       | 33    | 23       | 37    |
| 10       | 25    | 20       | 34    | 24       | 38    |
| 11       | 26    | 21       | 35    | 25       | 39    |
| 12       | 27    | 22       | 36    | 26       | 40    |
| 13       | 28    | 23       | 37    | 27       | 41    |
| 14       | 29    | 24       | 38    | 28       | 42    |
| 15       | 30    | 25       | 39    | 29       | 43    |

1 Point, Detest 2 Point, Hate 3 Point, Dislike 4 Point, Normal 5 Point, Like 6 Point, Prefer 7 Point, Love.
Appendix E

Table E1. SD questionnaire.

The evaluation standard is divided into 5 points (1–5 points). The positive or negative adjectives expressions were compared with the current event. The lower the score, the closer it is to the meaning of the adjective on the left. The higher the score, the closer it is to the meaning of the adjective on the right.

| Score of scale | Environ. Res. Commun. 3 (2021) 115013 D Sun et al | 1 | Engage | Evaluate | 2 | Evaluate | 3 | Evaluate | 4 | Evaluate | 5 | Evaluate | 1 | Engage | Approve | 2 | Engage | Approve | 3 | Engage | Approve | 4 | Engage | Approve | 5 | Engage | Approve |
|----------------|-----------------------------------------------|---|-------|--------|---|-------|---|-------|---|-------|---|-------|---|-------|--------|---|-------|--------|---|-------|--------|---|-------|--------|---|-------|--------|
| 1              |                                               |   |       |        | 2 |       |   |       | 4 |       | 5 |       | 1 |       |         |   |       |         | 2 |       |         | 3 |       |         | 4 |       |         | 5 |       |         |
| 2              |                                               |   |       |        | 3 |       |   |       | 5 |       | 1 |       | 2 |       |         |   |       |         | 3 |       |         | 4 |       |         | 5 |       |         |
| 3              |                                               |   |       |        | 4 |       |   |       | 1 |       | 2 |       | 3 |       |         |   |       |         | 4 |       |         | 5 |       |         |
| 4              |                                               |   |       |        | 5 |       |   |       | 3 |       | 4 |       | 5 |       |         |   |       |         | 2 |       |         | 3 |       |         |
| 5              |                                               |   |       |        | 1 |       |   |       | 4 |       | 5 |       | 1 |       |         |   |       |         | 2 |       |         | 3 |       |         |

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### Appendix F

#### Table F1. Olympic Park.

| Landscape characteristics       | Sample No. 3 | Sample No. 7 | Sample No. 8 | Sample No. 10 | Mean value |
|--------------------------------|--------------|--------------|--------------|---------------|------------|
| Sense of space                 | 4.533        | 2.867        | 4.433        | 3.100         | 3.733      |
| Landscape layering             | 4.033        | 3.633        | 3.000        | 3.500         | 3.542      |
| Unity                          | 3.100        | 2.900        | 3.767        | 3.833         | 3.400      |
| Conspicuousness                | 3.233        | 2.467        | 3.667        | 3.433         | 3.200      |
| Intactness                     | 3.400        | 2.635        | 3.700        | 3.533         | 3.317      |
| Harmony                        | 3.733        | 3.100        | 3.767        | 3.633         | 3.558      |
| Degree of spatial variation    | 3.800        | 3.300        | 2.967        | 3.167         | 3.308      |
| Sense of rhythm                | 4.033        | 2.900        | 2.733        | 3.200         | 3.217      |
| Sense of order                 | 3.400        | 2.900        | 3.767        | 3.300         | 3.342      |
| Ecology                        | 2.033        | 2.867        | 3.833        | 3.833         | 3.142      |
| Approach                       | 3.667        | 3.400        | 3.500        | 3.933         | 3.625      |
| Element richness               | 3.933        | 3.467        | 2.700        | 2.800         | 3.225      |
| Tidiness                       | 3.833        | 3.400        | 4.067        | 3.967         | 3.817      |
| Density                        | 2.400        | 3.033        | 3.000        | 3.733         | 3.042      |
| Attractiveness                 | 3.867        | 2.600        | 3.400        | 3.267         | 3.283      |
| Mystery                        | 3.633        | 2.667        | 3.467        | 3.233         | 3.250      |
| Uniqueness                     | 3.133        | 2.000        | 2.967        | 2.400         | 2.625      |
| Sense of seclusion             | 2.367        | 2.867        | 3.867        | 3.333         | 3.108      |
| Vitality                       | 3.200        | 2.867        | 3.733        | 3.900         | 3.425      |
| Sense of safety                | 2.833        | 3.533        | 2.733        | 3.600         | 3.175      |
| Comfort                        | 3.500        | 3.100        | 3.700        | 3.800         | 3.525      |
| Interestingness                | 3.567        | 2.300        | 3.000        | 2.600         | 2.867      |

#### Table F2. Hunnan citizen park.

| Landscape characteristics       | Sample No.13 | Sample No.14 | Sample No.16 | Sample No.20 | Sample No.22 | Sample No.23 | Mean value |
|--------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|
| Sense of space                 | 4.067        | 4.200        | 2.567        | 3.867        | 2.500        | 2.167        | 3.228      |
| Landscape layering             | 1.833        | 3.367        | 3.433        | 2.100        | 2.400        | 2.233        | 2.561      |
| Unity                          | 3.233        | 3.267        | 3.933        | 2.400        | 3.100        | 2.933        | 3.144      |
| Conspicuousness                | 2.900        | 2.633        | 3.533        | 2.433        | 2.800        | 3.133        | 2.906      |
| Intactness                     | 3.233        | 3.167        | 3.700        | 2.400        | 2.967        | 2.800        | 3.044      |
| Harmony                        | 2.567        | 3.400        | 3.933        | 1.833        | 2.900        | 2.600        | 2.872      |
| Degree of spatial variation    | 1.533        | 2.967        | 3.467        | 1.833        | 2.533        | 2.367        | 2.450      |
| Sense of rhythm                | 1.900        | 3.267        | 3.567        | 2.467        | 2.167        | 2.300        | 2.611      |
| Sense of order                 | 2.667        | 3.400        | 3.567        | 2.100        | 3.000        | 2.567        | 2.883      |
| Ecology                        | 3.900        | 2.833        | 3.400        | 2.467        | 2.633        | 2.900        | 3.022      |
| Approach                       | 2.467        | 3.033        | 4.167        | 2.233        | 3.100        | 2.533        | 2.922      |
| Element richness               | 1.467        | 3.367        | 3.267        | 1.933        | 2.667        | 2.167        | 2.478      |
| Tidiness                       | 2.533        | 3.800        | 3.233        | 2.400        | 2.900        | 2.400        | 2.878      |
| Density                        | 2.467        | 2.600        | 3.833        | 1.600        | 3.267        | 3.200        | 2.828      |
| Attractiveness                 | 1.600        | 2.967        | 3.767        | 1.533        | 2.467        | 2.233        | 2.428      |
| Mystery                        | 1.900        | 2.933        | 3.967        | 1.667        | 2.533        | 2.500        | 2.583      |
| Uniqueness                     | 1.367        | 2.800        | 3.100        | 1.533        | 2.167        | 2.433        | 2.233      |
| Sense of seclusion             | 2.933        | 2.567        | 3.633        | 2.633        | 3.200        | 3.000        | 2.994      |
| Vitality                       | 2.433        | 2.900        | 3.733        | 1.600        | 2.700        | 2.833        | 2.700      |
| Sense of safety                | 2.867        | 3.033        | 3.633        | 2.733        | 3.300        | 2.333        | 2.983      |
| Comfort                        | 2.200        | 3.333        | 4.067        | 1.967        | 2.933        | 2.767        | 2.878      |
| Interestingness                | 1.567        | 2.733        | 3.300        | 1.467        | 2.300        | 2.467        | 2.306      |
### Table F3. Wulihe park.

| Landscape characteristics | Sample No.25 | Sample No.26 | Sample No.29 | Sample No.30 | Sample No.32 | Sample No.35 | Mean value |
|---------------------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|
| Sense of space            | 2.233        | 3.267        | 2.733        | 3.100        | 2.933        | 3.667        | 2.989      |
| landscape layering        | 3.233        | 3.167        | 2.900        | 2.567        | 2.500        | 3.367        | 2.956      |
| Unity                     | 4.100        | 3.433        | 3.033        | 3.467        | 3.333        | 3.000        | 3.594      |
| Conspicuousness           | 3.933        | 3.700        | 2.733        | 3.567        | 2.767        | 2.800        | 3.250      |
| Intactness                | 3.933        | 3.767        | 3.167        | 3.767        | 3.033        | 3.367        | 3.506      |
| Harmony                   | 3.967        | 3.433        | 2.967        | 3.533        | 3.200        | 3.400        | 3.417      |
| Degree of spatial variation| 3.200        | 2.900        | 2.933        | 2.400        | 2.233        | 3.400        | 2.844      |
| Sense of rhythm           | 2.867        | 3.100        | 2.700        | 2.600        | 2.200        | 2.933        | 2.733      |
| Sense of order            | 3.133        | 3.233        | 3.367        | 3.467        | 3.333        | 3.333        | 3.311      |
| Ecology                   | 4.633        | 3.867        | 3.000        | 3.000        | 2.667        | 2.433        | 3.267      |
| Approach                  | 3.967        | 3.633        | 3.200        | 3.433        | 3.400        | 3.600        | 3.539      |
| Element richness          | 2.967        | 2.867        | 3.033        | 2.467        | 2.600        | 3.900        | 2.972      |
| Tidiness                  | 3.967        | 3.900        | 3.667        | 4.033        | 3.267        | 3.567        | 3.733      |
| Density                   | 4.300        | 3.800        | 3.067        | 3.333        | 2.967        | 2.700        | 3.361      |
| Attractiveness            | 4.200        | 3.333        | 2.733        | 2.867        | 2.633        | 3.567        | 3.222      |
| Mystery                   | 4.067        | 3.400        | 2.500        | 2.900        | 2.900        | 3.467        | 3.206      |
| Uniqueness                | 3.600        | 2.733        | 2.233        | 2.767        | 2.200        | 3.000        | 2.756      |
| Sense of seclusion        | 4.333        | 3.600        | 2.600        | 3.133        | 3.133        | 2.433        | 3.206      |
| Vitality                  | 4.167        | 3.800        | 3.100        | 3.367        | 3.100        | 3.200        | 3.456      |
| Sense of safety           | 3.600        | 3.667        | 3.367        | 3.467        | 3.400        | 2.900        | 3.400      |
| Comfort                   | 4.300        | 3.600        | 2.933        | 3.267        | 3.300        | 3.467        | 3.478      |
| Interestingness           | 3.800        | 2.867        | 2.267        | 2.767        | 2.433        | 3.500        | 2.939      |

### Table F4. Changbai park.

| Landscape characteristics | Sample No.38 | Sample No.39 | Sample No.43 | Sample No.45 | Sample No.48 | Mean value |
|---------------------------|--------------|--------------|--------------|--------------|--------------|------------|
| Sense of space            | 3.667        | 2.967        | 4.500        | 3.333        | 2.600        | 3.453      |
| landscape layering        | 3.367        | 3.167        | 2.933        | 2.900        | 2.600        | 2.993      |
| Unity                     | 3.267        | 3.700        | 3.033        | 2.567        | 2.600        | 3.033      |
| Conspicuousness           | 3.000        | 3.467        | 3.067        | 3.567        | 2.800        | 3.180      |
| Intactness                | 3.200        | 3.300        | 2.767        | 3.400        | 2.500        | 3.033      |
| Harmony                   | 3.433        | 3.733        | 2.833        | 2.633        | 2.467        | 3.020      |
| Degree of spatial variation| 3.300        | 3.033        | 2.800        | 2.433        | 2.433        | 2.800      |
| Sense of rhythm           | 3.033        | 2.400        | 3.033        | 2.900        | 2.433        | 2.760      |
| Sense of order            | 3.600        | 2.467        | 2.833        | 2.900        | 2.167        | 2.793      |
| Ecology                   | 2.567        | 3.700        | 2.533        | 3.100        | 3.200        | 3.020      |
| Approach                  | 3.400        | 3.567        | 2.800        | 3.600        | 2.833        | 3.240      |
| Element richness          | 3.300        | 3.233        | 2.787        | 3.167        | 2.533        | 3.000      |
| Tidiness                  | 3.467        | 2.867        | 3.200        | 3.033        | 2.200        | 2.953      |
| Density                   | 3.033        | 3.533        | 2.100        | 2.800        | 2.633        | 2.820      |
| Attractiveness            | 3.153        | 3.400        | 2.367        | 3.367        | 2.300        | 2.913      |
| Mystery                   | 3.300        | 3.433        | 2.333        | 3.267        | 2.367        | 2.940      |
| Uniqueness                | 3.167        | 3.300        | 2.467        | 2.967        | 2.300        | 2.840      |
| Sense of seclusion        | 3.067        | 3.567        | 2.567        | 2.767        | 2.667        | 2.927      |
| Vitality                  | 3.133        | 3.667        | 2.300        | 3.533        | 2.433        | 3.013      |
| Sense of safety           | 2.967        | 3.067        | 2.333        | 3.400        | 2.533        | 2.860      |
| Comfort                   | 3.500        | 3.433        | 2.433        | 3.533        | 2.267        | 3.033      |
| Interestingness           | 3.069        | 3.200        | 2.500        | 3.233        | 2.300        | 2.860      |
Appendix G

The standardized factors were stdxi (i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18). The order of the factors were: landscape layering, unity, intactness, harmony, degree of spatial variation, sense of rhythm, sense of order, ecology, approach, tidiness, attractiveness, mystery, uniqueness, sense of seclusion, vitality, sense of safety, comfort, interestingness. The formula of standardization factor was the original variable minus the mean values and divided by the standard deviation, which was calculated as table G2.

Table F5. Changing park.

| Landscape characteristics | Sample No. 50 | Sample No. 55 | Sample No. 58 | Sample No. 59 | Mean value |
|---------------------------|--------------|--------------|--------------|--------------|------------|
| Sense of space            | 3.600        | 4.233        | 3.200        | 4.167        | 3.800      |
| landscape layering        | 3.000        | 3.700        | 2.467        | 3.533        | 3.175      |
| Unity                     | 3.300        | 4.267        | 2.800        | 3.367        | 3.433      |
| Intactness                | 3.167        | 4.100        | 3.033        | 3.667        | 3.492      |
| Harmony                   | 3.467        | 3.800        | 3.100        | 3.800        | 3.542      |
| Degree of spatial variation| 3.233        | 4.133        | 3.167        | 3.867        | 3.600      |
| Sense of rhythm           | 3.067        | 3.733        | 2.133        | 3.233        | 2.950      |
| Sense of order            | 3.000        | 4.133        | 2.867        | 3.433        | 3.358      |
| Ecology                   | 3.667        | 3.067        | 3.200        | 3.300        | 3.308      |
| Approach                  | 2.567        | 3.967        | 2.867        | 2.967        | 3.092      |
| Element richness          | 2.733        | 3.400        | 2.300        | 3.133        | 2.892      |
| Tidiness                  | 3.133        | 4.233        | 3.133        | 3.167        | 3.417      |
| Density                   | 3.400        | 3.500        | 2.500        | 3.067        | 3.117      |
| Attractiveness            | 2.767        | 4.133        | 2.467        | 3.300        | 3.167      |
| Mystery                   | 2.767        | 3.900        | 2.233        | 3.233        | 3.033      |
| Uniqueness                | 2.633        | 3.867        | 2.033        | 3.200        | 2.933      |
| Sense of seclusion        | 3.400        | 2.967        | 2.967        | 3.433        | 3.192      |
| Vitality                  | 3.500        | 3.533        | 2.600        | 3.333        | 3.242      |
| Sense of safety           | 2.167        | 3.733        | 3.167        | 2.833        | 2.975      |
| Comfort                   | 2.933        | 3.700        | 2.767        | 3.400        | 3.200      |
| Interestingness           | 2.533        | 3.833        | 2.167        | 3.100        | 2.908      |

Table G1. Analytical expressions of each principal component.

Table G2. The formula of standardization factor.

| Sdx1 = x1 - 2.997 | Sdx7 = x7 - 3.117 | Sdx13 = x13 - 2.655 |
|-------------------|-------------------|---------------------|
| Sdx2 = x2 - 3.269 | Sdx8 = x8 - 3.145 | Sdx14 = x14 - 3.081 |
| Sdx3 = x3 - 3.276 | Sdx9 = x9 - 3.273 | Sdx15 = x15 - 3.147 |
| Sdx4 = x4 - 3.259 | Sdx10 = x10 - 3.335 | Sdx16 = x16 - 3.088 |
| Sdx5 = x5 - 2.832 | Sdx11 = x11 - 2.971 | Sdx17 = x17 - 3.208 |
| Sdx6 = x6 - 2.829 | Sdx12 = x12 - 2.983 | Sdx18 = x18 - 2.755 |
ORCID iDs

Dong Sun @ https://orcid.org/0000-0003-0151-6896
Weijun Gao @ https://orcid.org/0000-0003-0299-3686

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