博 士 論 文

Visual Quality Evaluation of Urban Landscape Based on Image Analysis in Shenyang, China

中国瀋陽市の都市景観における画像分析を用いた視覚的印象評価に関する研究

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Visual Quality Evaluation of Urban Landscape Based on Image Analysis in Shenyang, China

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Preface

This study constructed an urban landscape visual quality evaluation method based on Image analysis method. Taking Shenyang, China, as an example, the visual quality for urban landscape was evaluated at three levels: macro, meso and micro. It explains the correlation between the visual quality of urban landscape and public visual perception characteristics from different perspectives. The study proposes effective strategies on optimizing the urban landscape environment, And provide reliable theoretical references for the urban landscape and planning.

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ABSTRACT

The study focused on the urban landscape visual quality evaluation of Shenyang, China. The visual quality evaluation model of Shenyang urban landscape was constructed at the macro, meso and micro levels. It was supposed to provide theoretical reference for the development of Shenyang urban landscape.

In chapter one, the background and significance of the research was described. During the urbanization process of china, the built-up areas of the urban have expanded rapidly. The overall environment of urbanization changed from spatial increment period to stock period during the urbanization rate growing slowly. But the visual quality of the environment was declining in some cities. There were some destructive constructions, which causes visual landscape pollution. It was supposed to further improve the quality of urban human settlements landscapes by evaluation of urban visual quality more scientific.

In chapter two, the concept of visual quality was introduced. The trend of visual quality evaluation were summarized. Meanwhile, theory and application of urban landscape visual quality evaluation was expounded. The four paradigms of landscape visual evaluation were summarized. The visual landscape control methods in some developed countries were combed. The progress in applied research were analyzed.

In chapter three, the main research methods of visual quality of urban landscapes were introduced. It included field questionnaire survey, Baidu street view image acquisition (BSV), scenic beauty evaluation(SBE), semantic differential method (SD), semantic segmentation technology based on deep learning (deeplabv3+), balanced incomplete block design-law of comparative judgment(BIB-LCJ), etc.

In chapter four, the visual quality of the Shenyang urban core area streetscape was evaluated from macro level. The study used Baidu map api to extract bsv images and then built a semantic segmentation network deeplabv3+ by computer deep learning and training, applying the method to semantically segment 634 sample collection points with a total of 5072 streetscape photos in the core area of Shenyang. The results of the semantic segmentation were organized into 5 indices and they indicated the public perception. In addition, 150 topical samples were chose from the acquired bsv panoramic images, based on SBE method, they were evaluated their streetscape

visual quality by combining VR panorama. Then the landscape quality of the 150 topical samples and their related characteristics were conducted correlation and regression analysis by using SPSS software in order to construct a model of urban streetscape evaluation. Finally, on the basis of the evaluation model, the visual quality of each street in the core area of Shenyang was calculated by combining the characteristic indices of other sample collection points and drew a map of the visual quality of the streets in the core area of Shenyang.

The chapter five, at the macro level of the city, the visual quality of the waterfront park was evaluated. Urban waterfront park are an important area of urban living environment. In this chapter, we obtained photographs of landscape from Hunhe river waterfront linear park and the South Canal waterfront park, the visual quality of the waterfront park was evaluated the basis of the SBE method and SD method. The principal components of the landscape characteristics were extracted, 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 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 park, and the results can be applied to the planning, construction, and management of waterfront parks.

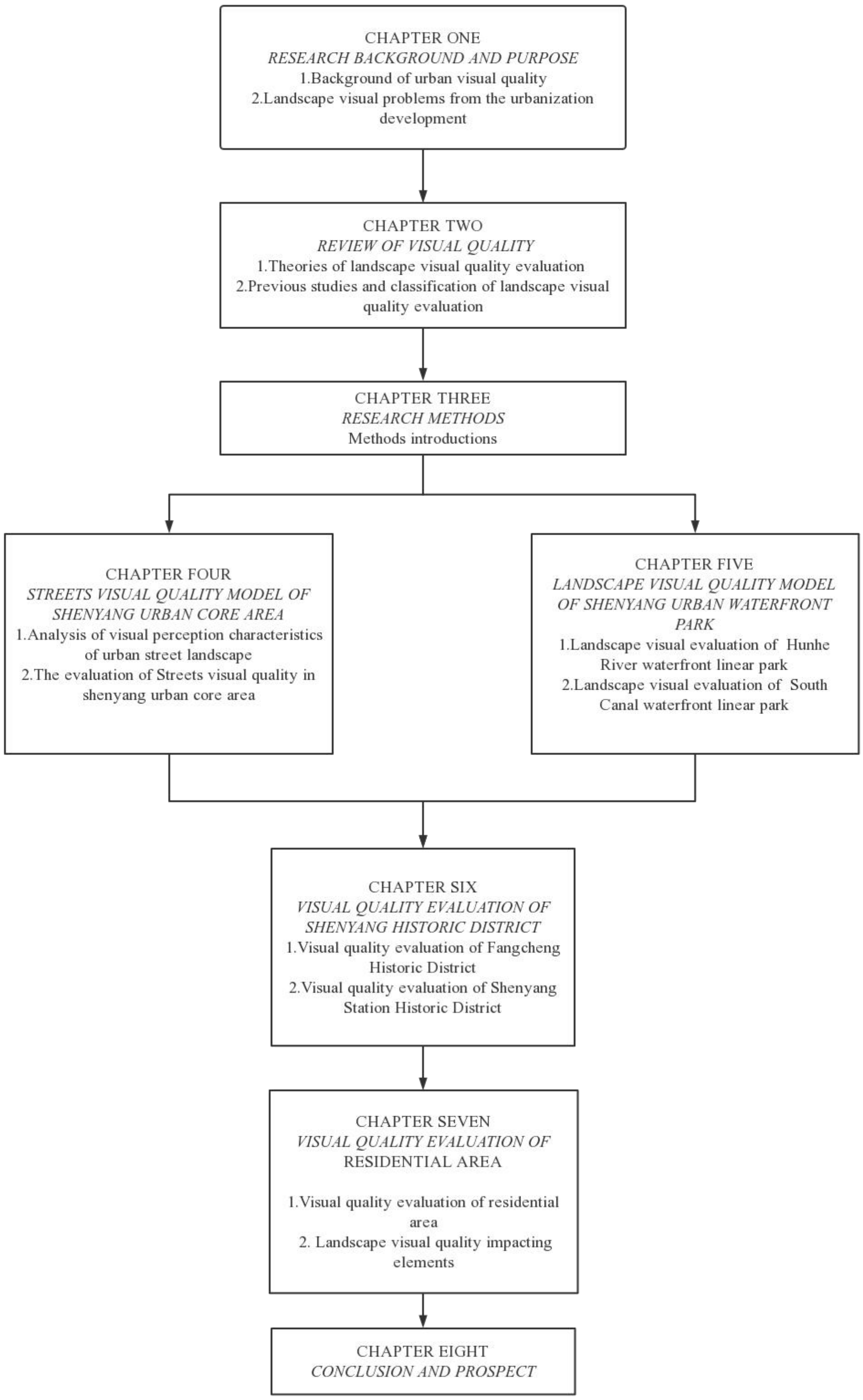
The chapter six, the landscape visual quality of Shenyang historical and cultural district were evaluated at the meso level. Shenyang Fangcheng historical and cultural district, Shenyang Imperial Palace and Shenyang station historical and cultural district were chose for the research site, they obtained sample landscape photos by three ways: On-site photography, VR, and BMSV, then using the SBE method to evaluate the LVQ. We applied the method of On-site photography to obtain 82 sample photos for SBE analysis in the Shenyang Fangcheng historical district, the result showed that the LVQ of the historic street was good because the historical buildings in the street improved the overall LVQ of the street; the residential street was bad due to the old buildings and messy street environment reduced the overall LVQ of the street. In the research of Shenyang Imperial Palace, the panoramic image data of 18 nodes in Shenyang Imperial Palace were obtained through the VR cloud on the Quanjingke website. They were stored in the computer and connected with the VR device and using this method for SBE analysis. The results showed that the LVQ was better in the south and central of Middle area, the northern of Middle area was bad. The main influence factors of LVQ were the Green Space Factor, building color and building maintenance. In the research of Shenyang station historical and cultural district, BLV image data was used to obtained sample and a total 49 nodes were collected sample 360° panoramic photos for SBE analysis. The results indicated that the high-quality nodes were focus on the Shengli South Street and Nanjing North Street, which were dominated by historic functions; the low quality nodes were mostly concentrated in Minzhu road and its nearby areas which was mainly residential functions. In the Shenyang station historical and cultural district, the historical atmosphere and high GSF can effectively improve the LVQ, however, higher pedestrian and vehicular flow will reduce the LVQ. In the Shenyang historical and cultural district, building, color and vegetation are the main influences factors on the LVQ, the LVQ could be improved by effective control of building and color as well as enhancing the Green Space Factor.

In chapter seven,the residential areas were took as the research object to explore the landscape visual quality at the micro level. The value of aesthetic Law of Comparative Judgment (LCJ value) was obtained by BIB-LCJ method. The LCJ values of three types landscape spaces in four residential areas were analyzed and the landscape elements impacting the visual landscape quality of residential areas were obtained. According to the LVQ comparison. In residential areas, LVQ of Longhu was good, LVQ of Vanke was normal, LVQ of Jindi was bad. In landscape space, road space > field space > green space. The study found that the green space and field space have high improvement potential. Meanwhile, the landscape elements impacting landscape space were analyzed, The optimization strategy of the landscape elements for residential areas was proposed.

In chapter eight, the conclusions of the each chapters were Summarized.

孙 冬 博士論文の構成

Visual Quality Evaluation of Urban Landscape Based on Image Analysis in Shenyang, China



CONTENTS

Chapter 3. Research Methods

Chapter 4. Streets Visual Quality Model of Shenyang Urban Core Area

Chapter 6. Visual Quality of Shenyang Historic District

Chapter 7. Visual Quality of Residetial Area

Chapter 8. Conclusion

CONTENTS OF FIGURES

CONTENTS OF TABLES

Chapter 1

RESEARCH BACKGROUND AND PURPOSE

CHAPTER ONE: RESEARCH BACKGROUND AND PURPOSE

1.1 Research background

In 2020, the urbanization rates of major developed countries in the world were all higher than 70%, among them, the United States was 82.9%; Japan and Germany were respectively 91.9% and 77.5% .As the same time, the urbanization rate of China was 62.5%[1]. The overall environment of urbanization changes from spatial "increment period" to "stock period" during the urbanization rate generally growing slowly down [2](Fig 1-1).

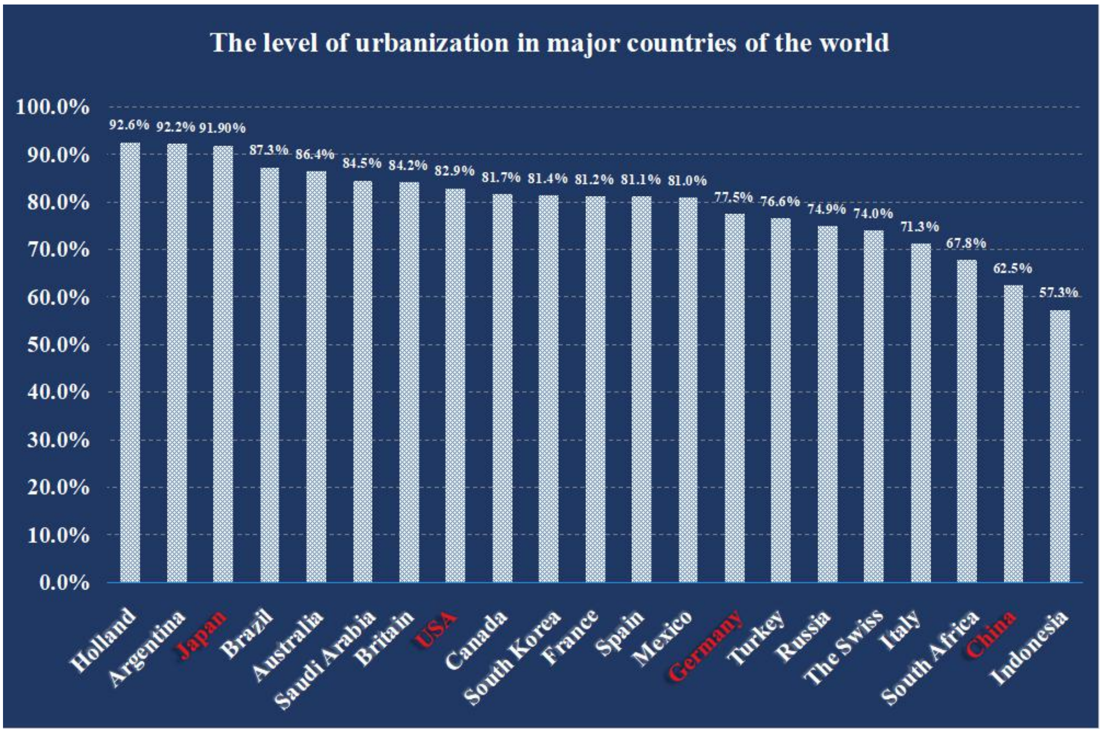


Fig 1-1 The level of urbanization in major countries of the world

The quality of urban environment has gained more attention. People are beginning to focus on protecting the urban environment and trying to remedy the environmental problems which caused by industrialization and urbanization. The urban regeneration is a main method to solve those problems in the "stock period ".

In the process of urban regeneration, as an important part of urban environment, the urban landscape not only improves the social lifestyle, enhances the urban vitality and identity, makes the public physical and mental pleasure , develops sense of citizenship , but also increases urban attraction[3][4]. With the Sustainable Development Goals proposed, the aesthetic significance of urban landscape is based on environmental and ecological order. It reflects the vitality beauty and formal beauty.

As visual quality is the most important landscape feature that directly affects people's perception, its merits and demerits directly affect human judgment and psychology of the environment. Therefore, the landscape aesthetic value is mainly expressed in the landscape visual quality[5][6]. The landscape impacts are "development-induced changes in the structure, character and nature of the landscape" in environmental impact factors. Landscape visual perception is a subset of landscape impacts[7]. The landscape visual quality evaluation is a part of landscape impact evaluation. "The correct evaluation of urban landscape is the basis for correct design "[8] (Fig 1-2).

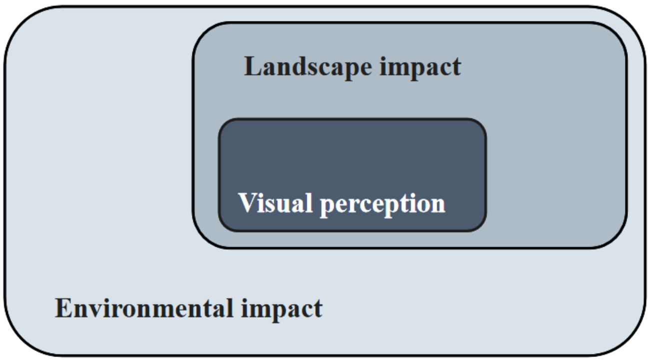


Fig 1-2 Environmental, landscape, visual impact structure map

Fig 1-3 Landscape visual pollution (The source of photos from Baidu Street Views)

In the process of urban regeneration, in order to solve the problems of visual pollution and quality deteriorate of the landscape, Europe and the United States were the earlier than other countries in paying attention to protect landscape resources. They emphasized the importance of visual resources and visual evaluation through legislation and other forms[3]. (Fig 1-3).

In the 1960s, Western countries have already established standardized procedures for visual environment quality evaluation by using methods, such as psychological and behavioral preferences. In 1969, the National Environmental Policy Act (NEPA) was enacted in the United States, which was the first country institutionalize environmental evaluation in the world. The “sustainability” and “livability”were important indicators in the evaluation and construction of Urban Human Settlements environment in the UK and the USA[9][10]. In 1972, environment evaluation was incorporated into public utilities in Japan. The government established uniform regulations. The Japanese Environmental Impact Assessment Act was enacted in June 1997 and was implemented in 1999[11].

In 2002, some environmental assessment regulations and *The Law of the People's Republic of China on Environmental Impact Assessment* [12][13]were promulgated in China. But China lacks some laws, rules and regulations for constructing of visual landscapes on urban environments.

There are some urban landscape visual problems such as homogenization and fragmentation in China [14]. Due to the visual environment evaluation of urban landscape is not as widely developed as Environmental Impact Assessment (EIA) [15]and Strategic Environmental Assessment (SEA)[16][17]18], the research of relevant norms and methods for visual quality evaluation of urban landscape will fill in the literary gaps of this relatively unexplored field. Therefore, the study of the visual environment evaluation system for urban landscape systems is particularly important .It is a core element in evaluating the visual quality of Urban Human Settlements environment.

Traditional evaluation based on field survey with a small scope and low levels of refinement[19]. Lacking of landscape aesthetics has led to a decline in the overall urban environment and landscape visual quality. However, with the development of digital and sensor technologies, such as urban streetscape images, urban points of interest, VR panoramic images, personal social platform travel check-in and other multi-source urban data collection, large size and scale urban landscape environment research become to be possible. City-awareness (computing) has become an important urban research hotspot by continuously acquiring, integrating and analyzing multiple heterogeneous big data in cities to solve the problems what the cities faced. At the same time, the combination of deep- learning and computer vision provides technical support for the urban visual environment evaluation on a large spatial scale[20].

Combining streetscape images with deep learning allows for a broader representation and analysis of the physical urban environment [21].Artificial intelligence technology can effectively identify streetscape image features[22].Semantic image segmentation based on deep learning, such as SegNet and DeepLab V3, has been applied for the automatic recognition of urban elements from massive amounts of streetscape images[23][24].

1.2 Purpose and significance of the study

1.2.1 Purpose of the study

In the current urban planning, urban construction and urban renewal, the economic benefits and technical issues were focused on. People paid attention to ecological quality and neglected efforts to protect the visual environment. The landscape visual environment is increasingly valued as a part of the living environment. Purpose of the research will enhance the attention of the public and managers through theoretical summary and practical application. The relevant laws and regulations will be improved in order to protect the visual resources of the urban landscape. Meanwhile, a framework of visual environmental impact evaluation guidelines for urban landscape to improve the visual environmental impact evaluation system will be found preliminarily.

1.2.2 Significance of the study

(1) The significance of the urban landscape visual quality for urban planning and environmental management

Landscape visual environmental quality evaluation is an important part of urban planning and environmental management[3]. Since the study of urban landscape has been carried out, landscape theory has been mostly applied to tourist attractions, landscape design, historic and cultural districts and urban planning [25][26]. Targeted laws and regulations are enacted to govern the relevant areas.

Establishing a landscape visual environment evaluation system is very important. The urban landscape visual environment can be truly protected through the development of scientific and effective management and rational urban planning. Therefore, it is essential to carry out research on models and methods for evaluating the urban landscapes visual environment.

(2) Beneficial to improve the existing urban environmental landscape evaluation system

The urban landscape has generally been damaged under the influence of rapid urbanization. There are already some legal regulations around the world. For example, in 2004，*the Landscape Act*, *the Law Concerning the Revision of the Law for the Implementation of the Landscape Law* and *the Law Concerning the Partial Revision of the Urban Green Space Preservation Law* (collectively referred to as the "Landscape, Greening & Outdoor Advertisement ") were introduced in Japan [27][28]. *The Urban Civility Act* of 1967 and *the Town & Country Planning Act* of 1968, which continued to the present in British .France introduced *Law on Landscape* and *the Territorial Development and Planning Directive Act* in 1993. The latest version of China's *Legislative Law of* *the People's Republic of China* gave each locality legislative power [29].Then each locality published urban landscape regulations. For example, the Cityscape Planning of Shenyang and the Cityscape Planning of Zhejiang Province, etc. Although the quality of urban landscape such as tourist scenic areas and historic and cultural districts is being emphasized, there is no landscape visual quality evaluation criteria for urban functions and public spaces. Specially, the urban landscape evaluation system isn't established. Based on all of the above, this paper conducts a study on the evaluation of the visual environment of urban landscape by studying public space in the city at three levels: macro, meso and micro levels. It is a useful addition to the evaluation of urban environments. Filling the gap in the theory and method of urban landscape visual evaluation can further improve the urban visual quality evaluation system to support the urban regeneration.

(3) Beneficial to urban regeneration and city construction

Urban regeneration, such as urban landscape management and old urban areas, has always been the focus of the government's work [30]. Undergoing large-scale renovation of the old city, blindly expanding the scale of the city, widening and renovating the city roads, the city is obsessed with high-rise buildings. The government ignores the characteristics and natural environment of the city in urban regeneration. In the rapid construction of the city to form a "thousand cities in one" phenomenon at the same time [31]. The visual evaluation includes the visual performance (quality) and visual impact of the project landscape.

The landscape visual evaluation in urban regeneration can work both in built-up urban areas and proposed projects. In terms of built-up urban areas, existing landscape visual problems in the city were identified by conducting a landscape visual evaluation of existing urban areas. Targeted scientific recommendations based on the current situation and characteristics of the city will help urban regeneration successfully. By evaluating the visual quality of the landscape for the proposed project can provide constructive advice in implementation possibilities and results of the proposed project targeted. It identifies shortcomings and optimizes the project before carried out.

(4) New technology of multi-source data provides a new method for the urban landscape visual quality evaluation

Most of the environmental information was obtained by some methods such as field survey, questionnaire and on-site photo capture in terms of data acquisition in the past. With the rapid development of digital technology today, combining multiple sources of data has been a new avenue of research for visual landscape evaluation, as evidenced by several studies. The new data acquisition methods such as Google, Tencent, Baidu street view, VR panoramic and POI data , mixed with GIS are introduced to establish a visual quality research method based on multi-source data. Technologies for landscape visual evaluation, computer virtual technologies such as VR panorama, AR, EEG test and eye-tracking technology are applied in the study of landscape visual environment quality. Semantic Segmentation based on Convolutional Neural Networks (CNN) is also used to recognize various landscape elements, including sky, buildings and greenery in the street view images. Computerized deep learning allow for the quantification of landscape elements. Compared with the traditional human subjective semantic difference (SD) method, the evaluation method is faster and more objective in transforming people's "indeterminate" subjective perceptions into objective quantitative data (Fig 1-4).

Fig 1-4 Examples of new technologies

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Chapter 2

REVIEW OF VISUAL QUALITY

CHAPTER TWO: REVIEW OF VISUAL QUALITY

2.1 Background

The definition was given in the European Landscape Convention published in 2000: “Landscape”means an area, as perceived by people, whose characters are the result of the action and interaction of natural and /or human factors[1][2][3]. The convention explicitly emphasized that 87% of sensory perception of the observer and the landscape were vision elements, which played a dominant role [4][5]. Some scholars believe that the beauty of the landscape can be judged by evaluating the components of the landscape space[6][7].

2.2 Research Progress

The core of aesthetic value lies in people's judgment of beauty [8].It is a process that known as the judgment of visual quality [9][10][11]. Landscape starts from human perception which trying to argue that people's aesthetic perception of a particular landscape is different from other landscapes [12][13]. The studies of visual landscapes integrate the intersection of landscape architecture, ecology, psychology, geography and other disciplines. There are many scholars acquire achievements in this area , although landscape aesthetics is strongly subjective and cannot be analyzed quantitatively[4].

In 1960s, scholars from various countries reflected the aesthetic value of landscape in the process of urban planning and construction, including regional landscape evaluation [14][15], forest landscape evaluation [16], classification system and method of various landscapes [17][18]. These have been used in landscape planning management and urban construction. In 1970s, theories and models which proposed by scholars have also made important contributions to the development of landscape quality evaluation, including "evocation" theory, "lookout-shelter" theory [19], public preference model and component proxy model, etc.

In 1980s, the rise of visual simulation technology accelerated the study of visual landscapes. More and more computer technologies were applied to the research. At the same time, theories have been proposed including the "emotional/arousal response model" [20], the "landscape information processing model" [21][22], the evaluation of the visual environment of the landscape [23][24], five models (ecological model, formal aesthetic model, psychophysical model, psychological and phenomenal model) [4][25]and two landscape evaluation methods (public preference model and component surrogate model) by Crofts R S.[26]. Since 2000, ecology combined with aesthetics gradually. The rapid development of visualization technology has provided technical support for landscape visual evaluation studies.

2.3 Four major paradigms on landscape visual evaluation

The visual landscape evaluation is divided into four major paradigms of thought, including the expert paradigm, the psychophysical paradigm, cognitive paradigm and the empirical paradigm[27][28]. Although the research methods of the four paradigms are complementary, they are also different.

2.3.1 Expert paradigm

The expert paradigm evaluates the landscape quality by landscape experts[29]. It focuses on the formal beauty of the landscape, so this approach is the main tool in the practice of landscape management.

2.3.2 Psychophysical paradigm

The psychophysical paradigm recognizes a correlation or stimulus-response relationship between landscape attributions and the observer's evaluation [30][31]. It establishes a quantitative relationship between the public's aesthetic attitudes and objective measurements of the components that make up the landscape for evaluating the landscape visual quality.

2.3.3 Cognitive paradigm

The cognitive paradigm emphasizes the significance of landscape in terms of human cognitive and emotional responses. They try to explain the aesthetic process of landscape in terms of human evolutionary processes and functional needs. The high quality landscapes are cognitively interacted with people and exchange information.

2.3.4 Empirical paradigm

The empirical paradigm more emphasis on the personal experiences and feelings about the landscape in the landscape aesthetic evaluation. It is used to determine whether a landscape is good or bad by obtaining the subjective experience of people through surveys and psychological tests. It is difficult to establish a scientific descriptive model.It cannot be called a systematic approach to landscape evaluation.

2.4 Study of visual landscape control methods in various countries and regions

2.4.1 Publication and application of visual landscape regulations

The decline of visual landscape quality and the protection of tourism resources have prompted scholars in various countries to focus their research on the evaluation of landscape visual resources[32]. The construction of landscape visual environment is regulated through the enactment of laws[33]. For example:

The Wildlands Act (1964), *the Wild and Scenic Rivers Act* (1968), *the National Environmental Policy Act* (1969), *the Coastal Management Act* (1972) and *the National Forest Management Act* [4] (1975) in American. These initiatives have promoted the quantification of various aesthetic values in the landscape.

The enactment of the *Countryside Act* (1968) in British. *The Federal Nature Conservation Act* of 1976 and *the Federal Building Code of 1987* in German. In 1984, Italy introduced *the Galasso Law*.

In 2004, Japan released *the Landscape Law* and other "Landscape Three Green Laws"[34][35], which clarify the scope of landscape planning. The landscape law established guidelines for the formation of good landscapes in landscape planning areas and established guidelines for identifying "important landscape buildings" or "important landscape trees".

China enacted *the Interim Regulations on the Administration of Scenic Areas* (1985) [4], *the Regulations of the People's Republic of China on the Administration of Urban Greening* (1989) and *the Code of Planning for Scenic Areas* (1999).

2.4.2 Natural elements control methods

2.4.2.1 USA- Visual Management System

The Visual Management System was developed in the United States in 1970 [36][37][38]. This system reduced the visual impact of human activities on the landscape by controlling various indicators[39]. This system was later refined to focus on public information and ecosystem to emphasize the character of the landscape. Seven levels of aesthetics based on the Scenic Attractiveness Class and landscape visibility was developed as targets for inclusion in the forest management framework. The new landscape management system combines multiple elements for integrated planning [40][41][42][43][44].

2.4.2.2 Japan - Mountain Visual Control

In 2002, Japan controlled the construction around the mountain in order to see the mountain

Mount Fuji from all angles. The height of the surrounding buildings was controlled through the enactment of the mountain control method to protect the visibility of Mountain Fuji by combing the landscape corridors.

2.4.2.3 Hong Kong, China - Overlook ridge line control

In 2002, Hong Kong passed a law to strictly control and guided the urban landscape[45]. The visibility of the ridge line landscape on both sides of Victoria Harbour was protected and analyzed by landscape visual evaluation regulations. It ensured the protection of the ridge line in the urban design process and allows unobstructed to view the ridge line from a distance.

2.4.3 Artificial elements control methods

2.4.3.1 France - Spindle control

Paris, France used "spindle control" to control the visible relationship of buildings and building masses, emphasizing static visual integrity[39]. The control cubes were constructed according to the landscape protection objects and overlook points, controlling the height of the elements within the context [46]. The coordination among landscape elements was constituted by effectively controlling the visual characteristics of the elements in the urban landscape.

2.4.3.2 British- Strategic Overlook Landscape

In 1938, the British controlled buildings height around open spaces, attractions and historic buildings through Strategic View, Viewing Corridor, Wilder Setting Consultation Area and Background Consultation Area [47][48]. It ensured that citizens can enjoy city views from all parts of the city.

2.4.3.3 Hangzhou, China - Spatial Visual Information System

Hangzhou developed and applied a "spatial visual information system" to protect the natural landscape of West Lake by visual landscape and buildings height control. The surrounding buildings height and skyline were controlled after analyzing the visual effect from the perspective of West Lake[45].

2.5 Advances in applied research on landscape visual quality

Landscape visual quality evaluation was first applied to natural forest landscapes, in 1990, Gobster, P. H. examined the forest landscape through the ecological aesthetic perspective [49][50][51]. Combining aesthetic value with ecological value allowed for better analysis of human aesthetic perception of the landscape. With the impact of urbanization, the study of landscape visual has shifted from undeveloped natural areas to urban and rural areas. Currently, the evaluation of landscape visual environment mainly includes natural ecological landscape and urban landscape.

2.5.1 The natural landscape visual environment quality evaluation

Forest landscapes have unique biological, ecological, hydrological, social and aesthetic properties [52]. The human visual aesthetic is nature-oriented and usually has a stronger interest in the forest landscape [53]. Yu Kongjian found that the quality of forest landscape in forest parks was closely related to the quality of recreation and ecological quality of parks[54][55];Through the psychophysical method, Chen Xinfeng et al. objectively reflected quantitative indicators that influenced the magnitude of the aesthetic value score of forest landscapes [56]; wang et al. explored a comparative analysis method suitable for visual landscape quality through a comparative analysis of forest park landscapes [57]; Chen Y et al. evaluated urban forest landscapes [58]; Zhou NX et al. explored the relationship between the aesthetic quality of forest landscapes and landscape pattern indices [59].

The key point of the plants landscape visual environmental quality evaluation is evaluating the ornamental characteristics of plants. Weng Shufei et al. applied the SBE (Scenic Beauty Evaluation) method to analyze and evaluate the plant configuration of Guangzhou parks [60]. Yang Haijun evaluated the visual effects of grassland landscape by SD (Semantic Differential) method [11]; Zhou Chunling used the SBE method to explore the beauty degree of the green landscape environment in Beijing settlement areas and came up with the influencing elements of the beauty degree of the settlement plant landscape [62];Misgav, A. studied the public's visual preferences for vegetation [63]. The research objects of water landscape mainly included wetland and evaluation of river landscape. Yao Yumin et al. evaluated the visual quality of urban waterfront landscapes using a combination of public perception and expert evaluation [64]. Hu et al. explored public and students preferences for unmanaged streamside vegetation landscapes in urban streams [21]. Zhu Runyu evaluated the visual environment of urban waterfront landscapes by using hierarchical analysis and comprehensive scoring methods [65]. Liu Qian analyzed the overview of urban waterfront landscape and the current situation of each landscape element, focusing on visual characteristics, creation methods and psychological feelings [66]. Sun Liang et al. analyzed the visual quality of urban waterfront parks through eye movements [67].

2.5.2 The urban landscape visual environment quality evaluation

The main research objects of urban landscape visual environment quality evaluation include urban roads, urban parks, etc.

Qin Qing used a combination of system theory and empirical analysis to discuss the visual quality evaluation of urban road landscape, taking Chang'an Road in Xi'an as an example [68]. Shao Yohan and Liu Bingyi analyzed and evaluated the landscape aesthetics of urban streets, ultimately arriving at the key factors that influence the aesthetics of the streets [69]. Sarah Garre studied the different effects of different road network structures on streetscape quality through quantitative indicators [70]. Luo Xi evaluated the visual environment of the landscape of historic districts by landscape pictures and a comprehensive index of visual landscape pollution [71]. Hwang et al. argued that appropriately pruned and moderately wild urban green space landscapes were preferred [21]. Li et al. studied residents' esthetic attitudes toward natural vegetation in urban parks. The study of Qi Tong, Wang Yajuan et al. showed that natural and artificial landscapes positive or negative effected on landscape quality from the perspective of visual landscape [72].

2.6 Prospects for Landscape Visual Assessment Research

Currently, theoretical studies on landscape visual quality are mainly focused on the expert paradigm and psychophysical paradigm. Scholars should pay attention to the complementary nature of each field and evaluate the characteristics of the landscape as a whole comprehensively in the evaluation process. The evaluation process combines expert and public opinion to accommodate future landscape development.

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Chapter 3

Research Methods

CHAPTER THREE: RESEARCH METHODS

3.1 Multi source data collection for landscape

With the development of technology, Multi source data collection for landscape are diversified. In the 1970s and 1980s, landscape perception studies mainly used traditional data collection methods, including field survey method, perspective hand-drawing and photographic method[1][2]. At the beginning of the 21st century, the visualization tools such as Geographic Information System (GIS), Virtual Reality (VR), Augmented Reality (AR), Remote Sensing and Visual Models had rapidly developed as a part of landscape perception and visual quality[3][4][5].

3.1.1 Field Survey

Field survey is also called field interview or field research. First visit and inspect the field. Then enter the field to conduct an early research, according to the results of field observation to adjust the research plan and research procedures. Finally, according to the adjusted research plan and research procedures to conduct field survey, filling out the field survey form and recording the research content.

Field survey is the researcher in the field through observation to obtain direct, vivid perceptual awareness and reliable first-hand information[5].

3.1.2 Photographic Method

Photographic is an important method for obtaining information about the urban landscape data, which can record most of the details in the research site. It is convenient for repeating research and data processing after leaving the field. However, the progress of the study not only will be affected if the photographic methods are not rigorous and the content is non-representative, but also wasting the energy, manpower and time. Therefore, scientific sampling methods are especially critical.

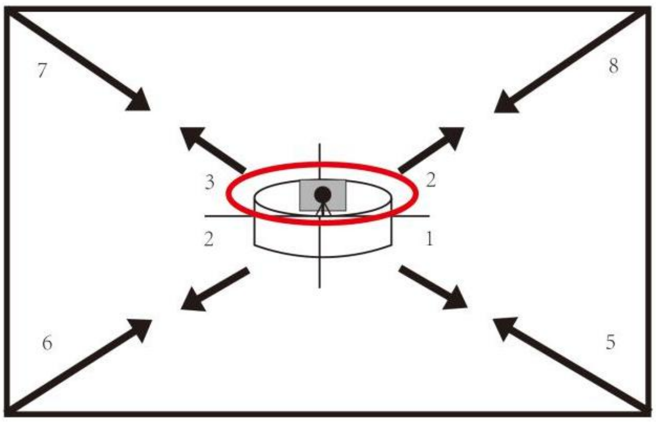

Fig 3-1 Sample picture of photographing method

Landscape image acquisition needs to be taken as a small sample for landscape image acquisition. Sampling is taken with the center of the small sample as the base point, one photograph is taken from the center point toward the four corners and one photograph from the four corners towards the center(Fig3-1)[6][7].

3.1.3 Cityscape Big Data

3.1.3.1 Baidu Street View Image

In the background of increasingly mature data acquisition technology, the use of street view images to build environment quality evaluation of public space is feasible. Street View Image has the characteristics of wide coverage, objective, realistic and convenient acquisition. Frequently used Streetscape image data sources include Baidu, Tencent and Google . Baidu Streetscape Map can provide 360°panoramic static images, so it can be directly obtained.

3.1.3.2 VR Panorama

In recent years, virtual reality technology has emerged in the domestic Landscape gardening community[1]. Studies have been shown the virtual reality technology is applicable to landscape architecture planning and design. VR (Virtual Reality) technology is more common in landscape studies. Due to the immersive, interactive and conceptual nature of VR technology[8][9][10][11], it is generally accepted that VR panorama technology has a higher value in conveying information than traditional media in landscape visual quality evaluation[12][13].

3.1.3.3 Other Urban data

(1) Urban POI data

POI data is often called Point of Interest, which is derived from the Digital Line Graphic (DLG) map. It contains four attributes: name, address, coordinates and category. POI data carries spatial and attribute information of geographic entities which relevant to people's lives. The spatial distribution of different functional urban entities in the city can be visualized[14].

(2)Weibo data

Weibo is a social service platform which has emerged as a convenient way to share and exchange information in recent years. There is a large amount of check-in data in Weibo data. Users who publish these check-in data can serve as real-world sensors. It can be used to perceive the traditional landscape of city for research[15].

(3)Point Cloud data

Point cloud data is a collection of vectors in a 3D coordinate system, which contains geometric position. Some of the point cloud data have color information.

In the current research, point cloud data is applied in studies related to green space factor, quantitative scene assessment methods, landscape beauty preference of open space forms and landscape beauty evaluation.

3.2 Landscape visual quality evaluation

3.2.1 Test Method

3.2.1.1 Field questionnaire

This method requires the observers to use the actual landscape as a medium in the field landscape evaluation. It takes the observers to the field to feel the reality of the landscape[16].

3.2.1.2 Laboratory questionnaire

The laboratory questionnaire is a method for quantitative evaluation in the laboratory using 2D/3D images. The 2D images landscape quality evaluation means that making slides from acquired 2D images. The experts are invited to evaluate the photos in the same environment. 3D, VR images during the evaluation, the experimenter will explain and show all samples. The observers will wear VR equipment to watch panoramic images, experience VR virtual environment and evaluate them. The data will be recorded by professionals.

3.2.1.3 Network questionnaire

Network questionnaires are used to obtain visual landscape evaluation, which has proven to be reliable. This requires digital data presented by digital photos or digital visualization. People all around the world have the opportunity to participate in surveys through the Internet[16][17][18]. It is a great way to achieve a large sample for the survey, which cost lower and easier to adjust the lack of questionnaire design in time. Meanwhile, network questionnaires can be released and recycled through website and e-mail. The data is directly recorded by database to facilitate screening and analysis.

3.2.2 Scenic Beauty Estimation method

3.2.2.1 Related concepts of SBE method

Scenic Beauty Estimation method, proposed by Daniel and Boster, is the most commonly used evaluation method in the psychophysical paradigm[19][20][21][22][23][24][25].

3.2.2.2 Basic procedures of SBE method

(1) Preparation phase

Before using the SBE(Scenic Beauty Evaluation) method to evaluate the urban landscape, it is necessary to make preparations, including :

①The investigation and selection of landscape sample photo collection sites, full-angle photography of the determined sampling points;

②Evaluation of photo selection. Photo selection can fully reflect the landscape information around the sampling point as much as possible；

③Selection of observers.

(2) Evaluation phase

In the evaluation process, slides are used for judging in the room, the specific methods of operation can refer to the standardized methods provided by Daniel and Boster.

①Observers are asked to pay more attention to the landscape conveyed by photos rather than its quality.

②A pre-demonstration is performed before the slides are played, let the observers understand the evaluation and establish the scoring criteria.

③Playing slide formally. The playing interval of each photo is 5-10s, in order to make the observers give the scores for the beauty value independently.

(2)Analysis phase

The scores given by the observers are calculated. The statistical analysis of the model is established to obtain the beauty value.

$$Z_{ij} = \frac{\left(R_{ij} - \overline{R_j}\right)}{S_j} \tag{1}$$

$$SBE_i = \Sigma Z_{ij} / N_i \tag{2}$$

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.

3.2.2.3 Analysis of advantages

First of all, compared with real field evaluation, it can save massive research expenditure by using photo samples as the evaluation media. It has higher control over the evaluation objects. The evaluation process of SBE method is carried out indoor, which has high practicability and operability. In addition, compared with the expert evaluation model widely used in the actual evaluation process, the psychophysical model can better eliminate the adverse effects of subjectivity.

3.2.2.4 Application in landscape evaluation

In the evaluation of a single landscape type, the SBE method was applied in an early period. At the beginning, it was used to evaluate the beauty value of forest landscape to play the comprehensive benefits of forest resources. Subsequently, the SBE method extends from forest landscape evaluation to plant landscape evaluation. It is common to use this method to evaluate the plant landscape and garden stone landscape of urban parks, residential areas, road, waterfront parks . Comparing with the single landscape type, the SBE method has also been widely used in the evaluation of the overall landscape, mainly including park landscape, square, traffic linear landscape and rural landscape. The steps and methods of evaluation are the same as single type. Finally, the evaluation results are analyzed. In addition, in the process of landscape evaluation, the SBE method is also used in combination with other evaluation methods. For example, Li Yujia combined the SBE method with the AHP method (Analytic Hierarchy Process)and also used SD (Semantic Difference) method to evaluate.

3.2.3 BIB-LCJ method

3.2.3.1 Basic Procedures of BIB-LCJ method

The Balanced Incomplete Block design-Law of Comparative Judgment（BIB-LCJ) method was pioneered by Professor Yu Kongjian in 1988[26].It was combined the mathematical model of Balanced Incomplete Block (BIB) with the Comparative Judgment method (LCJ). It compared and ranked the photos of selected landscape samples to obtain the public's aesthetic attitude toward the beauty of the landscape.

First, the landscape sample photos are selected as the evaluation media. Second, the selected landscape sample photos are randomly numbered. The BIB mathematical model is selected according to the number of photos that are compatible with them. The number of samples in each group in the BIB mathematical model is usually 5-7. Finally, referring to the BIB group table (Fig 2a,b), the sample photos are divided into 5 or 7 groups according to the BIB design table. The subjects are asked to rank each group of photos. The experiment is repeated several times[27].

I	II	III
1 2 3 4 5	1 6 11 16 21	1 7 13 20 24
6 7 8 9 10	2 7 12 17 22	2 8 14 16 25
11 12 13 14 15	3 8 13 18 23	3 9 15 17 21
16 17 18 19 20	4 9 14 19 24	4 10 11 12 22
21 22 23 24 25	5 10 15 20 25	5 6 12 19 23
IV	**V**	**VI**
1 8 15 19 22	1 9 12 18 25	1 10 14 17 23
2 9 11 20 23	2 10 13 19 21	2 6 15 18 24
3 10 12 16 24	3 6 14 20 22	3 7 11 19 25
4 6 13 17 25	4 7 15 16 23	4 8 12 20 21
5 7 14 18 21	5 8 11 17 24	5 9 13 16 22

(a) 5 groups

I	II	III	IV
1 2 3 4 5 6 7	1 8 15 22 29 36 43	1 9 18 24 35 40 48	1 10 21 26 34 37 46
8 9 10 11 12 13 14	2 9 16 23 30 37 44	2 10 19 25 29 41 49	2 11 15 27 35 38 47
15 16 17 18 19 20 21	3 10 17 24 31 33 45	3 11 20 26 30 42 43	3 12 16 28 29 39 48
22 23 24 25 26 27 28	4 11 18 25 32 39 46	4 12 21 27 31 36 44	4 13 17 22 30 40 49
29 30 31 32 33 34 35	5 12 19 26 33 40 47	5 13 15 28 32 37 45	5 14 18 23 31 41 43
36 37 38 39 40 41 42	6 13 20 27 34 41 48	6 14 16 22 33 38 46	6 8 19 24 32 42 44
43 44 45 46 47 48 49	7 14 21 28 35 42 49	7 8 17 23 34 39 47	7 9 20 25 33 36 45
V	**VI**	**VII**	**VIII**
1 11 17 28 33 41 44	1 12 20 23 32 38 49	1 13 16 25 31 42 47	1 14 19 27 30 39 45
2 12 18 22 34 42 45	2 13 21 24 33 39 43	2 14 17 26 32 36 48	2 8 20 28 31 40 46
3 13 19 23 35 36 46	3 14 15 25 34 40 44	3 8 18 27 33 37 49	3 9 21 22 32 41 47
4 14 20 24 29 37 47	4 8 16 26 35 41 45	4 9 19 28 34 38 43	4 10 15 23 33 42 48
5 8 21 25 30 38 48	5 9 17 27 29 42 46	5 10 20 22 35 39 44	5 11 16 24 34 36 49
6 9 15 26 31 39 49	6 10 18 28 30 36 47	6 11 21 23 29 40 45	6 12 17 25 35 37 43
7 10 16 27 32 40 43	7 11 19 22 31 37 48	7 12 15 24 30 41 46	7 13 18 26 29 38 44

(b) 7 groups

Note: The Roman numerals I.....VI in the table are the order of the repeated experiments (Sequence recombination). Numbers 1-25 are photo numbers.

Fig 3-2 BIB group table (Source: "Tables of Commonly Used Mathematical Statistics" prepared by the Institute of Numerical Sciences, Chinese Academy of Sciences)

3.2.3.2 Application in landscape evaluation

The application of BIB-LCJ method is mostly concentrated in plant landscape, few applications in waterfront and wetland landscape. For example, Lai King-yi (2018)[28], Jin Aifang (2018) [29]and Song Jian-jun(2020) [30]evaluated the beauty degree of single-plant flower border, landscape plant landscape and waterfront green space plant landscape respectively; Chen

Guodong (2020) [31]evaluated the quality of wetland park ecological environment, etc. Fewer studies used a combination of multiple evaluation methods in the landscape evaluation process. The SD method was often used by researchers in combination with the BIB-LCJ method. Because the BIB-LCJ method was based on the hierarchical ranking of landscape samples to project conclusions, which was subjective ranking. Zhang Jinsong (2018) [32]and Wang Yanxiang (2018) [33]combined the BIB-LCJ method with the SD method, they used a combination of qualitative and quantitative methods to evaluate the landscape quality.

3.2.3.3 Comparative Analysis of SBE, LCJ and BIB-LCJ

(1) Analysis of the disadvantages of SBE and LCJ method

The SBE method mostly uses slide as the medium for judging the measurement, develops the beauty scale by scoring them one by one. Although the SBE method can evaluate a large number of landscape samples, it lacks comparison among the landscape samples, which makes the scale less reliable [34][35]. The LCJ method generally uses pairwise comparison method or ranking queue method to judge, through two-by-two comparison between landscape samples or mutual comparison between multiple landscape samples [27], resulting in the selected probability scale or ranking scale. The LCJ method provides a comparative evaluation between each landscape sample, but only be applied to the comparative evaluation of small samples landscape(less than 20)[35]. If the LCJ method is applied to the comparative evaluation of a large number of landscape samples, not only the workload is huge, but also the reliability of the results cannot be guaranteed.

(2) Analysis of the advantages of BIB-LCJ method

Compared with the SBE method and LCJ method, the BIB-LCJ method uses the BIB experimental design model to compare the ranking of the beauty among each landscape sample by the LCJ method. It both takes into account the comparison between each landscape sample and satisfies the need for a large number of landscape samples. Therefore, the BIB-LCJ method is more reliable, which reflect the landscape beauty degree more realistically.

3.2.4 ASG Comprehensive analysis method

The ASG integrated method is a collective name of Analytic Hierarchy Process (AHP) method, SBE method and GIS (Geographic Information System). Firstly, AHP method hierarchical analysis is used to determine the weights of the evaluation indexes, SBE method is used to obtain the subjective aesthetic preferences and overall perceptions of the viewers. Secondly, GIS method is used to obtain data such as the elevation of the site. Finally, the evaluation results are synthesized and the subjective preference matrix is constructed by using the Importance-performance Analysis (IPA)[36][37].

Other methods for evaluating the quality of the landscape visual environment include Analytic Hierarchy Process (AHP) method, Post occupancy Evaluation (POE) method, geographic information system (GIS) method, Polynomial Chaos Expansions (PCE) method and the importance-performance analysis (IPA) method.

3.3 The landscape characteristics analysis methods

3.3.1 SD method

3.3.1.1 Introduction of SD method

As a method of measuring psychological feelings on a linguistic scale, SD (Semantic Difference) method proposed by C.E. Osgood in 1975. The purpose was to achieve quantitative representation of the research object concept and the structure of the experimental object[38]. The SD method originated from psychological experiments. It was a mature psychological experimental method, which had been gradually expanded to the fields of architecture and planning with the development of psychology.

3.3.1.2 Basic Procedures of SD method

(1) Preparation phase

The preparation phase of SD method includes: ①Identification of adjective pairs. They are the psychological and physical quantities that people produce as an intuitive perception of the landscape environment. ②Evaluation scale setting. The evaluation scale is generally set using a five-level Likert scale or a seven-level scale.

(2)Testing phase

The evaluation data is collected mainly through questionnaires in two forms: direct survey on field and indirect survey through photo evaluation.

The direct survey is a questionnaire administered to subjects in the field. The indirect survey is through the sampling of photos or videos of the field landscape, then showing them to subjects for questionnaire.

(3) Statistics Phase

After the questionnaires are completed, the researchers need to perform statistics all the questionnaires, calculate the mean score values for each sample characteristic and draw a detailed SD analysis table. Finally, the data is imported into SPSS for statistical analysis.

3.3.1.3 Application of evaluation in the landscape

In specific applications, SD method was first used in psychological research. After the 1990s, it was gradually expanded to architecture, landscape, gardening and urban space. The SD method was applied to the landscaping of urban living space to investigate the perceptual evaluation of different people. Zhu Jiefang (2012)[38] used the SD method to analyze several street spaces in

Shanghai and Taizhou. Xiao Qing et al. (2017)[39] took Fengyang Gulou Square as the research object and conducted environmental evaluation by applying the SD method..

3.3.2 Semantic segmentation method

3.3.2.1 Concept of Semantic segmentation method

Semantic segmentation method is a part of computer vision technology. Semantic segmentation method can divide objects of different categories and locations in the image into their own independent sub-regions along their boundaries. It generates the corresponding color annotated image for observation and differentiation[40] (Fig 3-3).

Semantic segmentation method is mainly implemented by extracting image features (color features, texture features, geometric features, etc.)[41].

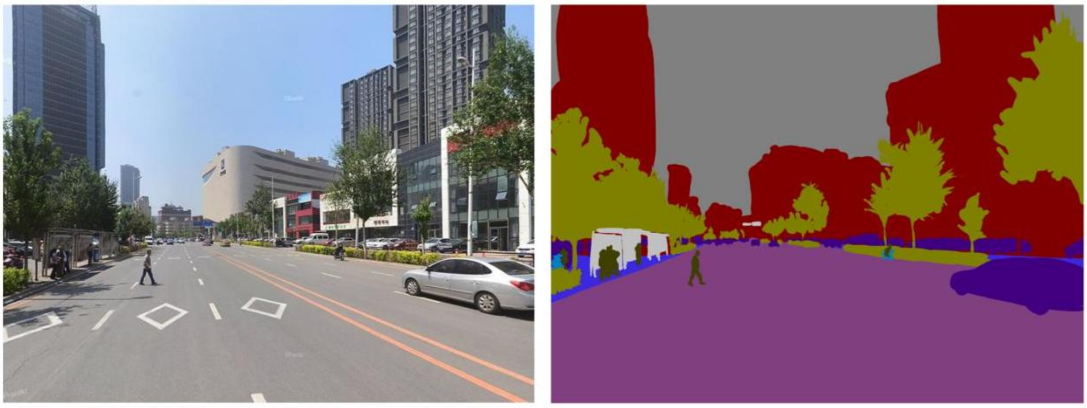

Fig 3-3 A color segmentation result

3.3.2.2 Full Convolutional Network (FCN) based semantic segmentation

Google team has proposed Deeplab 3V models in order to solve the problem that full convolutional neural network loses part of the detail information, resulting in less detailed output results[42]. DeeplabV1 [43] uses FCN for image segmentation, which adopts null convolution to expand the Receptive Field of the network [42][44][45] and adds a void space pyramid pooling ASPP module[46]. It uses the Multi_Grid strategy to capture multi-scale feature information[47].

3.3.2.3 Application in landscape evaluation

The online streetscape images provide an ideal data source for semantic segmentation technology based on convolutional neural network deep learning. (Gong et al., 2018; Wu et al., 2020; F. Zhang et al., 2018; Zhang et al., 2019a)[48][49][50][51] used streetscape images to analyze and evaluate the streetscape characteristics of city, the characteristic indicators were used to describe the urban street space. Based on street view images, Wu et al. used Segnet semantic segmentation technology to quantify the visual appearance characteristics of streets in Shenzhen, China.

3.3.3 Comparative Analysis of Semantic Segmentation and SD Method

When the SD method is used to consider landscape characteristics, the evaluation results of the observers are usually collected through questionnaires, field interviews and landscape visualization. However, if the research object is large, widely distributed and dispersed, these methods need significant cost and time. It is difficult to achieve large-scale and large-scale rapid popularization evaluation. It is difficult to understand the characteristics of the design area and the potential needs of the local public for planners. In contrast, the fast recognition ability of landscape elements of machine learning semantic segmentation has application advantages. Artificial intelligence uses the powerful performance of computers and the ability to calculate and process data. The large scale urban research based on expert analysis, public feedback and scene information data can be carried out.

3.4 Summary

In this chapter, first, Method of acquiring multivariate data for urban landscape is introduced, including Field research method, Photography Method, Cityscape Big Data, VR Panorama and Urban POI data. Second, Evaluation method of urban landscape visual landscape quality is explained, including Evaluation of data collection methods ,Scenic Beauty Estimation and Relevant Concepts of BIB-LCJ method. Finally, it is the research data, we introduce the Urban landscape characterization methods, including Introduction of SD method and Concept of Semantic segmentation method. A comparative analysis of these two characterization methods is also presented.

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Chapter 4

STREETS VISUAL QUALITY MODEL OF SHENYANG URBAN CORE AREA

STREETS VISUAL QUALITY MODEL OF SHENYANG URBAN CORE AREA

4.1 Introduction

Urban streets reflect the quality of urban public space and the urban characteristics, it's important to create a comfortable and satisfying urban landscape. The urban street has the function of field, it can provide field for residents to do activities, socialize and entertainment [1][2]. The space of urban street is the most widely distributed and the most varied public space, its landscape visual quality(LVQ) has important influence for daily life and well-being of residents [3][4]. Recently years, with the development rapidly and regenerate of the human settlement environment, the urban streetscape is built many times and it complicates the urban streetscape in street appearance, human settlement environment and perceived complexity [5][6][7]. The urban streetscape characteristics and visual quality directly impact the interactive behavior of residents in the city [8]. The streets with good visual quality not only provide a visual aesthetic experience for people [9][10], but also has positive impact in physical activity, public health [11-13] and social connectedness [14-15]. Therefore, the evaluation of the streets visual quality is order to provide a way to understand the function and performance of urban streets.

Nevertheless, it isn't a new problem that to build a high quality urban street space. Some scholars have used methods such as face-to-face interviews, questionnaires and field survey to analyze the relationship between public visual preferences and built environment [16]. There are deep understanding in the relationship between the visual quality, the spatial perception and the design elements [17-18]. Nowadays, most scholars are restricted to conduct small scale studies because the field survey and the questionnaire consume a lot of cost and time [19-20].

In recent years, due to the development of multivariate data acquisition and computer image recognition technology, they bring new research potential to the research of streetscape visual quality; Crowdsourcing map services and Geotagged image such as Baidu street view (BSV) and Google street view (GSV), they provide new method of data acquisition which High resolution panoramic images of streets and communities are provided to researchers free of charge. Tong Long et.al [21] used GSV to research the streetscape greening and public preference. A large number of street panoramic images are used and combining deep learning algorithm, they provide information analysis methods for the study of streetscape perception. The method is outstanding in some ways which classification and mapping of street canyons in urban environment, automatic extraction of semantic information, visual element classification and Image scene features, it has been widely followed and successfully practiced in many fields [22-28].

4.2 Study framework

In this chapter, the visual quality of the Shenyang urban core area streetscape was evaluated at a macro level. The study used Baidu Map API to extract BSV images and then built a semantic segmentation network DeepLabv3+ by computer deep learning and training, applying the method to semantically segment 634 sample collection points with a total of 5072 streetscape images in the core area of Shenyang. The results of the semantic segmentation were organized into 5 indices and they indicated the public visual perception. In addition, 150 typical samples were chosen from the acquired BSV panoramic images, based on SBE method, they were used to evaluate their streetscape visual quality by combining VR panorama. Then the landscape quality of the 150 typical samples and their related indices were conducted correlation and regression analysis by using SPSS software in order to construct a model of urban streetscape evaluation. Finally, on the basis of the evaluation model, the visual quality of each street in the core area of Shenyang was calculated by combining the characteristic indices of other sample collection points and drew a map of the visual quality of the streets in the core area of Shenyang（Fig 4-1）.

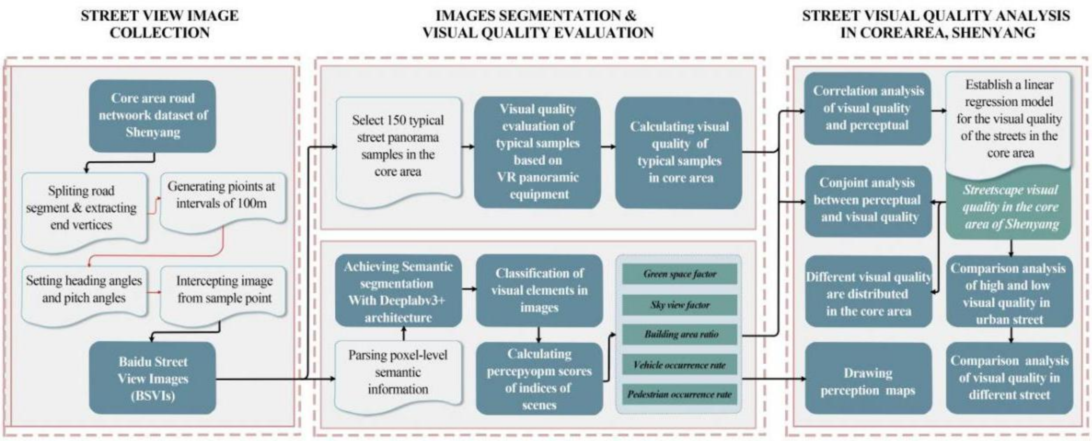


Fig 4-1 Analytical framework

4.3 Study methods

4.3.1 Study area

In this chapter, 20 landscape of arterial roads were chosen as research objects from the core area of Shenyang (within the first ring road). The urban core area is located in center of Shenyang, it ranged from the East first ring expressway in the east to Shengli North Street in the West and from Wenhua road in the south to railroad lines of Shenyang north railway station in the north (Fig 4-2). It was about 7.3km long and 4.5km wide, with a total area of about 32.4km^2. The total length of the 20 arterial roads is about 63.4km.

Fig 4-2 Urban core area of Shenyang

4.3.2 Baidu street view images collection

In order to comprehensively showed the landscape characteristics of the streets spaces in the urban core of Shenyang, the study collected the BSV images at each 100m along the road network, there were 634 sample collection points and they were evenly arranged on the 20 arterial roads (Fig 4-3). The total length of the arterial roads was 63.4km. The BSV images were collected by using the Baidu Maps API in an HTTP URL form (Baidu, 2015). The sending of the URL parameters need to use the standard HTTP defined by Baidu Maps API, it allowed users to obtain a static image from any direction and viewing angle which any point was available in BSV (Table 4-1). But there were disadvantages about applying BSV, most of researches used URL codes which with a reference direction toward the North Pole, e.g. 0° (true north) to measure in the collection process. However, their street angle had certain angles with true north, so the BSV images cannot accurately reflect the perceived views of the streets. Therefore, in order to ensure the accuracy of the data, the front and rear views were needed to ensure always parallel with the street heading by calculating topological features of street networks. The pitches (up/down angles of the camera relative to the horizon) passed to the Baidu Maps API were set to 0, it conforms to the perception local residents (Fig 4-4) [29].

Fig 4-3 BSV Street view images collection point

Table 4-1 Required parameters for Baidu map street view imagery (Source: Baidu)

Parameters	Description	Value
ak	Developer key, obtained by request	32 Character
width	Image width , Unit is statue, Range[10,960]	960
height	Image height, Unit is statue, Range[10,720]	720
location	The location of street	Latitude and longitude of

	view sampling point	collection points
Coordinate type	Coordinate type of street view	wgs8411
heading	Facing angle, indicating the angle with north. Range[0,360]	Parallel/perpendicular to road direction
pitch	Pitch angle, the angle of the low head of the street camera, Range[0,90]	0
fov	Visual Angle, Range[10,360]	45

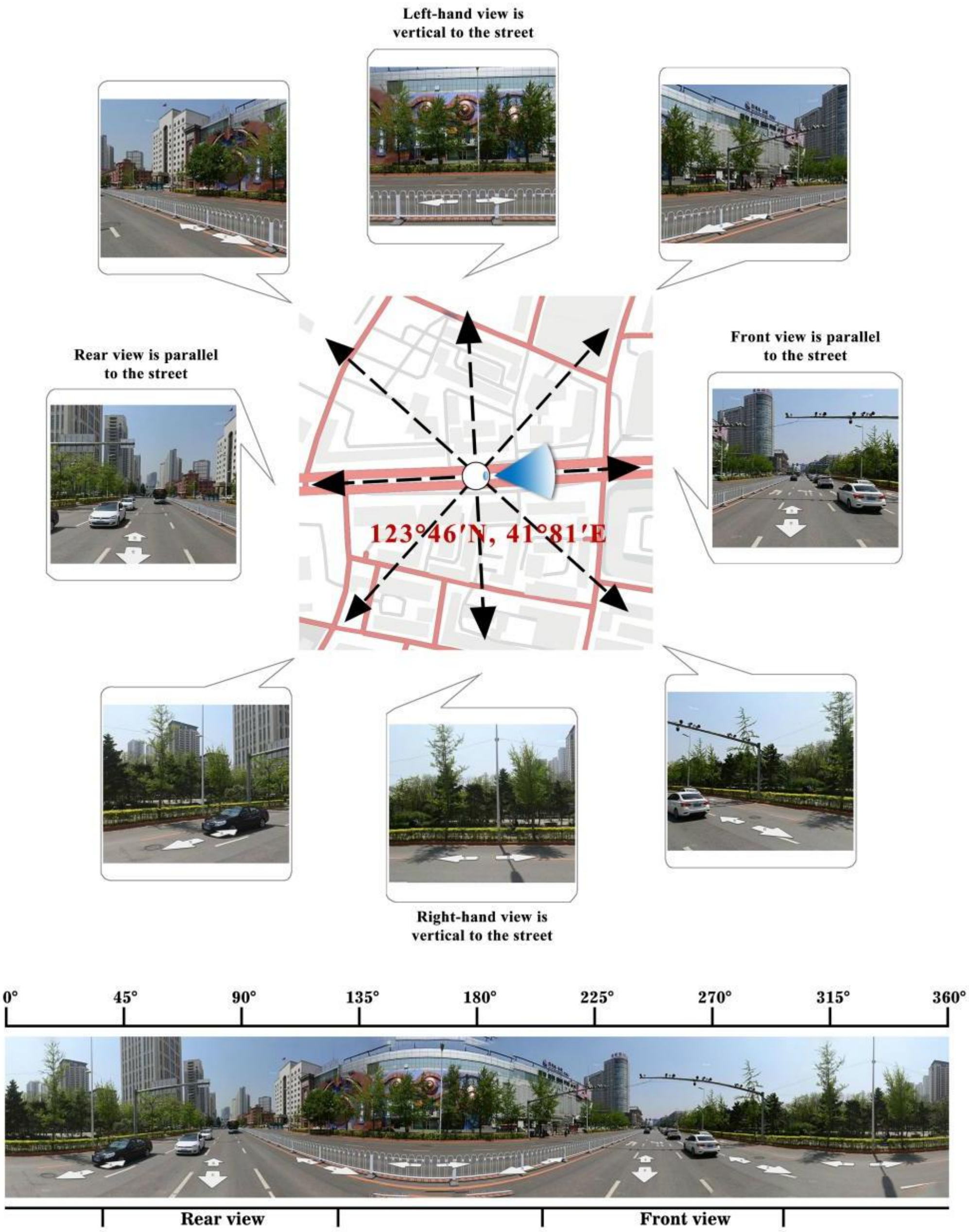


Fig 4-4 Intercept BSV images in panoramic vision box from different angles

The BSV data collection was conducted in May to September 2018. Due to the urban streetscape changes follow with seasons so that if the date of the image is not considered, it will cause the public visual aesthetic preferences for the urban streetscape being influenced from the vegetation proportion in the streetscape as well as it also leads to a wrong calculation of the street greenness index by semantic segmentation. The Baidu Street View metadata application programming interface (API) surveys information on shooting time and dates of collected images, based on the above analysis the images were used which taken in the summer 2018. Some images form roads that inaccessible to pedestrians were excluded such as high-ways and elevated bridges. According to these criteria, we collected 8 streetscape images in per sample collection point, a total of 5072 streetscape images were collected.

4.3.3 Semantic segmentation

In order to analyze the visual perception which based on BSV images, the physical characteristics parameters in per streetscape image were needed to identify. Semantic segmentation was an advanced method that uses pixels to classify images into multiple labels such as buildings, sky, greenery, vehicles, pedestrians (Fig 4-5). DeeplabV3+ was presented by the Google team in 2015 that was a fully trainable architecture for semantic segmentation, it could almost entirely predict the visual elements of the static scene. To fuse multi-scale information, the encoder-decoder which commonly used for semantic segmentation was introduced and combined with an encoder that can be controlled at will to extract resolution of characteristics, balancing accuracy and time consumption through hole convolution. This method had been frequently used in some previous studies of street image and semantic segmentation due to its more efficient performance in terms of memory footprint time, ability to segment small road scenes with high accuracy and utilization of smaller training sets [30] [31]. Therefore, DeepLabv3+ is used for pixel semantic segmentation of BSV images in this chapter as well as we used Matlab to summarize the percentage of streetscape physical parameters in every streetscape image and according via formula1, to calculate the average of each sample collection point to represent the average parameter of the position.

$$P_i = \frac{\sum_{i=1}^{8} V_i}{8} \{i \in (1,2,\cdots,n\}$$

where P_i is the average proportion of every visual element and V_i denotes the proportion of visual elements in one direction image.

Fig 4-5 Semantic segmentation labels

4.3.4 Definition and calculation of five streetscape character indices

This study reorganized and defined five characteristic indices of street visual perception based on semantic segmentation of BSV image visual elements and they were used to indicate the visual perception scores of the streetscape. The following was a specific explanation of these concepts and sketches of the five characteristic indices representing the perception of streetscapes were shown in Fig 4-6.

(1) Green space factor

The concept of greenness was first proposed by the Japanese scholar to express the proportion of green color in the range of human vision [32]. It was more accurate and intuitive than indicators such as green area ratio and green coverage ratio, it had long been recognized as an essential element in cityscape design [33]. Green space had multiple benefits in inspiring the publics' visual esthetic appreciation of streetscapes as well as increasing outdoor staying time, it relieved stress and negative psychological symptoms in psychological and physical [34]. In previous researches, some scholars had calculated common indices using BSV panoramas such as canopy cover rate, the green view index and greenery, they were described to the characterize distribution of greenery in street space which aimed to raise a proactive awareness of urban vegetation improvement [35] [36] [37]. In this study, Greenness was defined as the proportion of green spatial vegetation pixels in the overall pixels.

$$G_i = \frac{1}{n}\sum_{i=1}^{n} Tn\,\{i \in (1,2,\cdots,n)\}$$

T_n denoted the proportion of tree pixels; the sum indicates the total number of tree pixels in each image.

(2) Sky view factor

Openness was the degree of sky visibility and determines the amount of perceived lightness [38]. It indicates the proportion of the sky which was visible from a point on a horizontal surface [39] [40]. The street width, the height of building facade and building layout, they all had a direct impact on openness in the urban streets, a wide and set-back structure leaded to higher proportion of the sky. In addition, the presence of dense high-rise buildings will obstruct sky visibility because they form deep street canyon so the openness was affected [41]. We defined the sky openness was the ratio of visible sky pixels to the overall pixels.

$$S_i = \frac{1}{n}\sum_{i=1}^{n} Sn \{i \in (1,2,\cdots,n)\}$$

S_n denoted the proportion of sky pixels; the sum indicates the total number of sky pixels in each image.

(3) Building area ratio

Building area ratio denoted constraints of the built environment on the pedestrian spatial perception [42]. In the urban environment, outdoor building was the most prominent elements that forms the basic structure of the street space, it separated the exterior and the interior of the buildings. A well-enclosed street spaces produced the impression of high security for people. Nevertheless, the higher degree of enclosure obstructs the sightline and affected the overall perception of the streetscape [43]. Scholars had proposed the section height-to-width ratio to calculate the degree of the sense of visual enclosure [44]. In this study, we defined building area ratio as the proportion of building pixels in the overall pixels.

$$B_i = \frac{1}{n}\sum_{i=1}^{n} Bn \{i \in (1,2,\cdots,n)\}$$

B_n denoted the proportion of building pixels and the summation denoted the total number of building pixels in each image. This equation represented the extent to which the street canyon was visually surrounded by the street wall and corresponding horizontal elements.

(4) vehicle occurrence rate

vehicle occurrence rate indicates the proportion of vehicle attendance in the road space. The presence of vehicles on the street was unavoidable, as one of the most variable factors in the streetscape, it was influenced by the number of vehicles driving, parking, driving high and low peak periods. In generally the low vehicle occurrence rate facilitates the overall evaluation and viewing of the streetscape by the observers, however, the high vehicle occurrence rate reduced the observers' overall perception of the streetscape and result in a poor visual impression. In the research, we defined it as the proportion of vehicle pixels in the overall road pixels.

$$V_i = \frac{\frac{1}{n}\sum_{i=1}^{n} C_i}{\frac{1}{n}\sum_{i=1}^{n} R_n + \frac{1}{n}\sum_{i=1}^{n} PA_n + \frac{1}{n}\sum_{i=1}^{n} F_n + \frac{1}{n}\sum_{i=1}^{n} C_n + \frac{1}{n}\sum_{i=1}^{n} PE_n + \frac{1}{n}\sum_{i=1}^{n} BI_n}$$

$\{i \in (1,2,\cdots,n)\}$

C_i denoted the proportion of vehicles pixels, R_n denoted the proportion of roads pixels, PA_n denoted the proportion occupied by pavement, F_n denoted the proportion of fences pixels, C_n denoted the proportion of vehicle pixels, PE_n denoted the proportion of pedestrian pixels Summation denoted the total number of building pixels in each image and BI_n denoted the proportion occupied by bicycle pixels. The equation represented the effect of vehicle elements on human visual perception in urban street space.

(5) pedestrian occurrence rate

Pedestrian occurrence rate was the impact extent to the streetscape by the number of pedestrians. Kevin Lynch (1960) thought that pedestrian was the most dynamic element of the streetscape including organization in pedestrian flow, quantity, and dress code, it had an impact on the observer's landscape evaluation. Crowd gathering and pedestrian quantity directly affected the observes' evaluation of the visual quality that the streetscape in commercial and historic areas, however, few scholars had included pedestrians as a factor in the evaluation of streetscape visual perception. Therefore, pedestrian occurrence rate was introduced into the street visual perception characteristic index in this study and it was defined as the proportion of pedestrian pixels in the overall road pixels.

$$V_i = \frac{\frac{1}{n}\sum_{i=1}^{n} PE_i}{\frac{1}{n}\sum_{i=1}^{n} R_n + \frac{1}{n}\sum_{i=1}^{n} PA_n + \frac{1}{n}\sum_{i=1}^{n} F_n + \frac{1}{n}\sum_{i=1}^{n} C_n + \frac{1}{n}\sum_{i=1}^{n} PE_n + \frac{1}{n}\sum_{i=1}^{n} BI_n}$$

$\{i \in (1,2,\cdots,n)\}$

PE_i denoted the proportion of pedestrian pixels, R_n denotes the proportion of road pixels, PA_n denoted the proportion occupied by sidewalks, F_n denoted the proportion of fence pixels, C_n denoted the proportion of vehicle pixels, PE_n denoted the proportion of pedestrian pixels Summation denotes the total number of building pixels in each image and BI_n denoted the proportion occupied by bicycle pixels. The equation represented the influence of pedestrian elements on visual perception in urban street space.

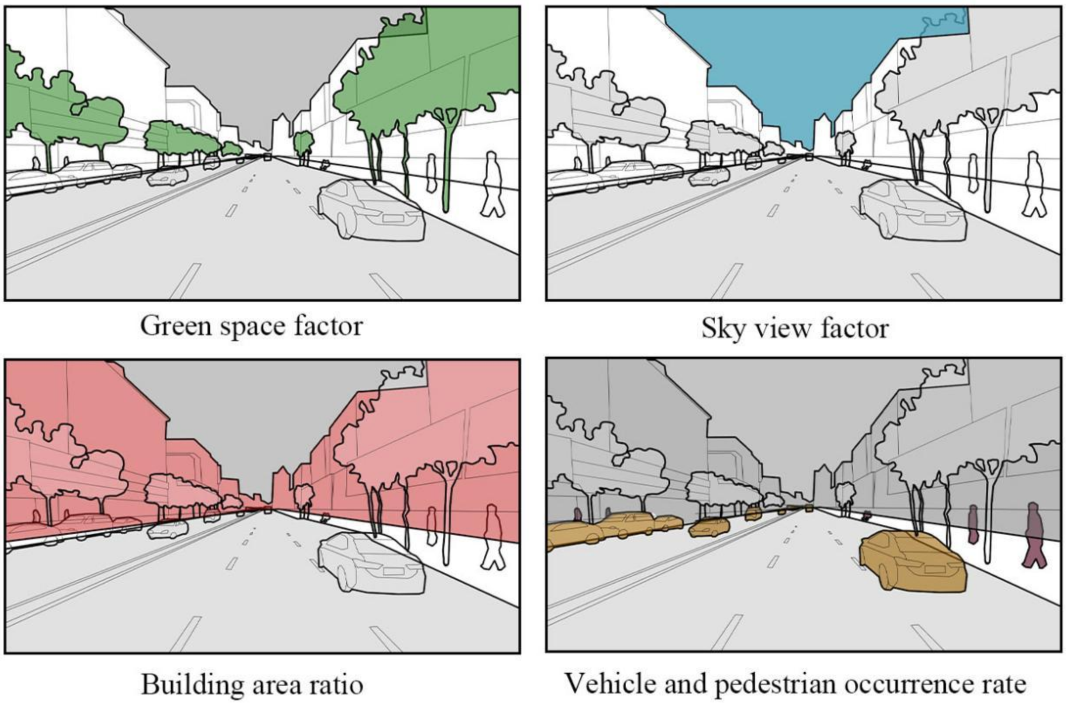


Fig 4-6 Sketch of five aspects representing streetscape perception

4.3.5 Evaluation of visual quality in urban street landscape

In order to evaluate and analyze the quality of urban streetscape, we chose a typical sample collection point that the most representative and reflect the information of the surrounding landscape in each street. A total of 150 panoramic images were used to evaluate the visual quality of urban streetscape to provide a Data Foundation for establishing a visual quality model of the streetscape in the urban core area of Shenyang (Fig 4-7).

The experimental method in this study was different with the traditional powerpoint test, it used a Virtual reality headset to replace multimedia in order to show a more comprehensive and realistic scenario for observes (Fig 4-8). Before the experiment, experimenters explained the assessment knowledge, equipment use and scoring requirements of the experiment and then all panoramic images of the typical photos were taken rapidly to establish an evaluation criterion for observes. Researchers connected the Virtual reality headset with an ipad or computer device, projected 150 BSVs typical samples that chose into VR and randomly played, there were 50 observes to evaluate visual quality of streetscape. Scoring criteria was a seven-point scale ranging from 1 (very dislike) to 7 (very like), the testers informed the researchers of the scoring by dictation and the researches performed the questionnaire to fill in the questionnaire truthfully. In order to ensure the reliability of the experimental results, the selection of testers should not be limited to the specialty; The playing time of each panoramic image was 15 seconds. A total of 150 questionnaires were obtained and they were valid by checking. Finally, transform individual observer's ratings to standard(z) scores, these dates were used to get the final standardized SBE value of each topical sample.

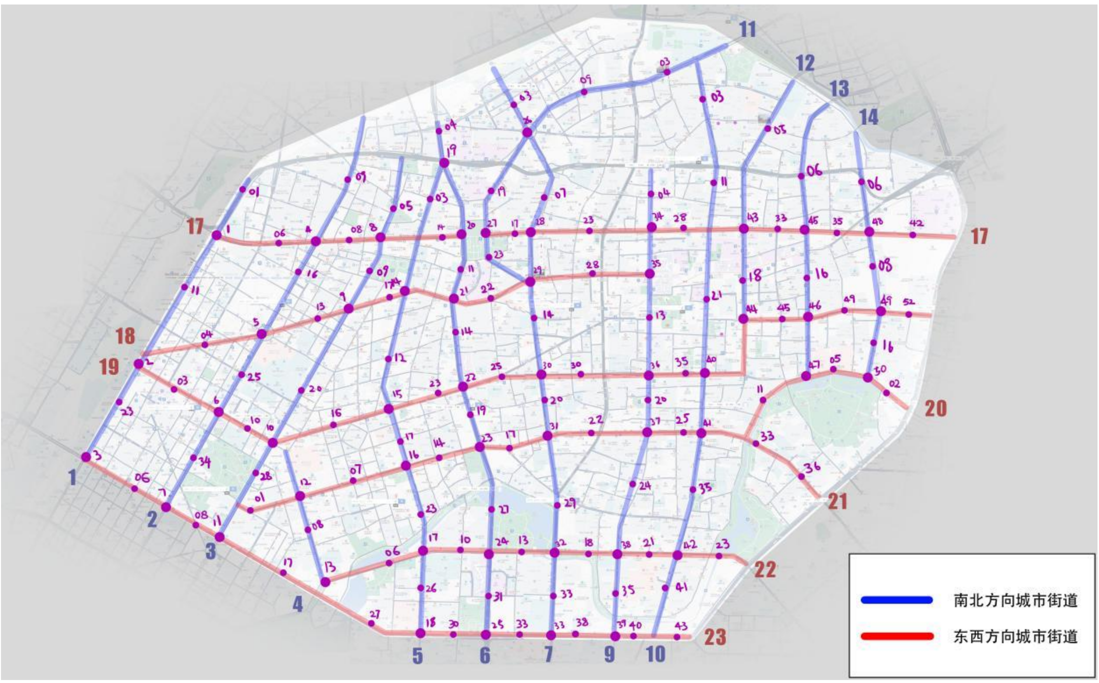


Fig 4-7 Urban streetscape 150 typical sample collection

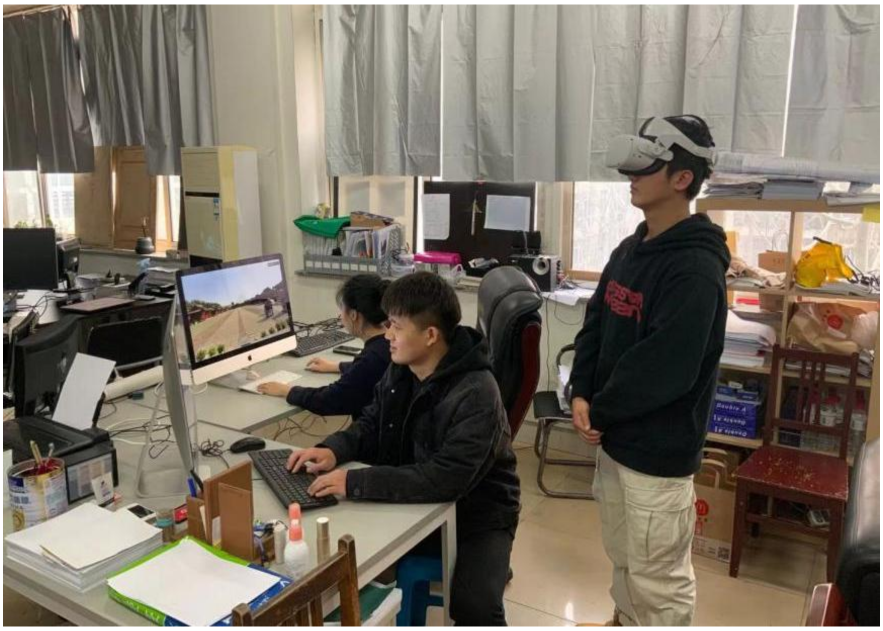


Fig 4-8 Visual quality evaluation with VR

4.3.6 Statistical analysis

The data of the visual quality and landscape characteristics of the 150 typical samples were subjected to analysis by using SPSS 17.0 software, confirmed the degree of correlation and eliminated landscape characteristics that are not significantly correlated. Then a regression analysis with landscape quality as the dependent variable and relevant landscape characteristics as the independent variables is implemented to establish a visual quality evaluation model of urban streetscape.

4.4 Results

4.4.1 Analysis of visual perception characteristics of urban street landscape

(1) Comparison of visual perception characteristics of different types of streets

The study uses DeepLabv3+ semantic segmentation network on MATLAB platform to perform semantic segmentation on 634 sampling points with a total of 5072 streetscape photos. The semantic segmentation results are organized into five metrics to represent the public's visual perception. The visual perceptual characteristics scores of each sampling point were counted using EXCEL (Table4- 2).

Table 4-2Comparison of the perceptual characteristics of different types of streets1

perception characteristics	NS average	WE average	CR average	Average of 634 samples	Standard deviation
Green space factor	0.162	0.1996	0.1138	0.1730	0.1264
Sky view factor	0.1486	0.139	0.1992	0.1488	0.0666
Building area ratio	0.2359	0.2261	0.2165	0.2306	0.1015
vehicle occurrence rate	0.2047	0.1867	0.2005	0.1971	0.1022
pedestrian occurrence rate	0.0202	0.0193	0.0176	0.0197	0.0178

By comparing the mean values of the five visual perception characteristics of the overall sample: building area ratio (0.2306) > vehicle occurrence rate (0.1971) > green space factor (0.1730) > sky view factor (0.1488) > pedestrian occurrence rate (0.0197). It can be found that the floor area in the regional street space tended occupy a larger proportion of the pedestrian's view. In contrast, the small standard deviation values of pedestrian occurrence rate (0.0178) and sky view factor (0.0666) indicated that the sky openness was relatively similar for all streets with no significant differences. A comparison of the standard deviations of the five visual perception characteristics revealed that the highest standard deviation (0.1264) was found for green space factor. It indicated that the green space factor had huge difference in the sampling points, different types of streets and different street functions all contributed to the difference in street green space factor.

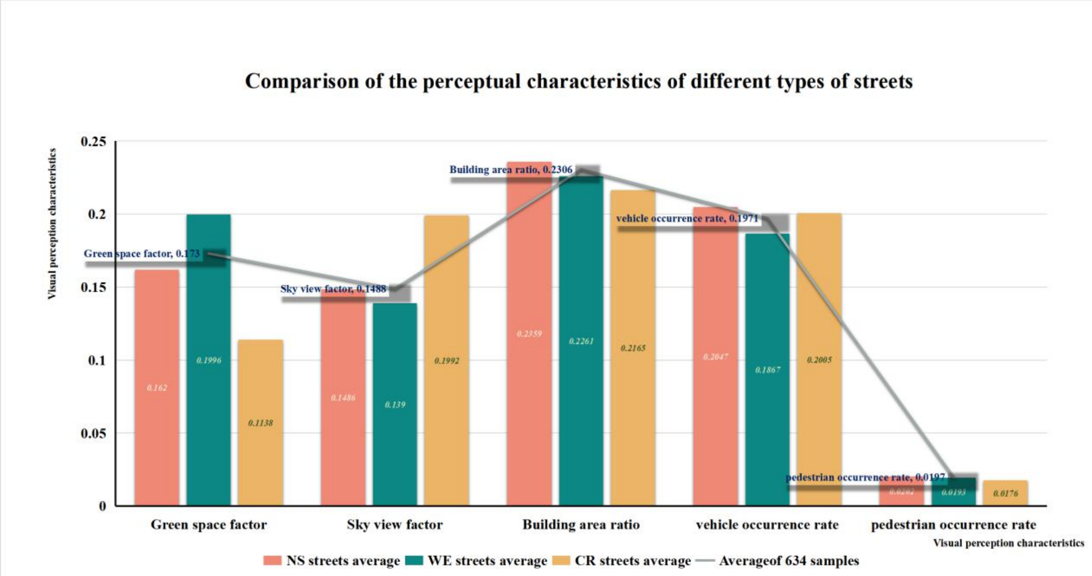


Fig 4-9 Urban streetscape 150 typical sample collection

Among the north-south streets, a comparison of the mean values of each characteristic of the three types of streets with the mean value of the overall sample reveals (Fig 4-9) that the green space factor (0.1620 < 0.1730) and sky view factor (0.1486 < 0.1488) were lower than the mean value of the overall sample. Residential visual perception characteristics: building area ratio (0.2359>0.2306), vehicle occurrence rate (0.2047>0.1971) and pedestrian occurrence rate (0.0202>0.0197) were higher than the mean of the overall sample. In the east-west streets, except for green space factor (0.1996>0.1730), the other visual perception characteristics: sky view factor (0.1390<0.1488), building area ratio (0.2261<0.2306), vehicle occurrence rate (0.1867<0.1971) and pedestrian occurrence rate (0.0193<0.0197) were lower than the overall sample mean. Among the intersections, green space factor (0.1138<0.1730), building area ratio (0.2165<0.2306) and pedestrian occurrence rate (0.0176<0.0197) were lower than the overall sample mean, while two characteristics, pedestrian occurrence rate (0.1992>0.1488) and vehicle occurrence rate (0.2005>0.1971) were higher than the overall sample mean. The above results indicated that there are some differences between different types of street types in terms of visual perception characteristics.

According to the comparison of the different visual perception characteristics of the three types of streets, it was found that the mean value of the east-west streets was higher (0.1996) in terms of green space factor. This was because that the north-south roads in Shenyang were generally wider than the east-west roads, the high percentage of sky and ground in the field of view results in generally lower visual perception scores for green space factor in the street space. As a result, east-west streets had relatively high green space factor. In terms of sky view factor, road intersections generally had high visual perception scores.

In addition, the dense vegetation covered of east-west streets mean a higher degree of shading of the sky, it often resulting in lower sky openness [46]. Among the five visual perceptual characteristics, building area ratio had the highest index in all three types of street space. This was often related to the planning of urban streets. Urban design guidelines were often limited to the relationship between street width and the height of adjacent buildings. The density of the building masses affected the closure of the street space as much as the height of the plants. This results showed low sky openness between north-south and east-west streets in an urban environment. The sample with the highest value of building area ratio (0.522) was located in the north-south street of the urban commercial street.

In major commercial streets, street enclosures were often formed using building facades of varying heights. In residential roads, where building massing was relatively lower in the street enclosure, the arrangement of trees often plays a dominant role. The building objects in view tended to be more dispersed and lower at road intersections, with a more open field of view. There were more vehicles in the road, the dense traffic naturally created a higher vehicle occurrence rate. The results of the study found that sampling locations with low pedestrian incidence tended to be near intersections, freeways, and express arterials, rather than urban arterials and side streets. This was in agreement with the study of Xiang et al (2021) [47]. Because the road was wider at road intersections and the vehicle rate was higher, the incidence of pedestrians at intersections was weakened to a certain extent.

(2) Results of the spatial distribution of five visual perceptual characteristics

In this work, we used Deeplabv3+ to calculate the scores of the five visual perceptual features for 634 sampling points, (Table 4-3). Then applying the method of Jenks Natural Breaks to identify the classification interval and group the similar values, in order to produce significant differences between the groupings of each characteristic. The research aimed at grading and grouping the characteristic value of each sample collection point to obtain the hierarchy of influences which could conform to its characteristics and utilized the Arc GIS software to visualization for the data results.

Table 4-3 Comparison of average values of visual perceptual characteristics by street

GSF	No.	SVF	No.	BAR	No.	VOR	No.	POR	No.
0.381	20	0.244	6	0.307	12	0.27	4	0.039	10

0.339	22	0.182	13	0.29	18	0.266	10	0.038	9
0.232	4	0.167	23	0.282	21	0.244	13	0.026	4
0.21	3	0.165	9	0.277	13	0.24	23	0.024	19
0.184	1	0.165	22	0.273	10	0.239	7	0.023	18
0.183	5	0.164	7	0.26	23	0.224	9	0.023	21
0.182	14	0.157	2	0.255	19	0.211	18	0.023	23
0.178	19	0.156	17	0.248	9	0.204	3	0.021	7
0.169	11	0.149	12	0.243	7	0.204	22	0.02	13
0.162	10	0.146	11	0.238	1	0.199	14	0.019	22
0.162	23	0.146	18	0.235	17	0.195	20	0.016	3
0.155	6	0.143	3	0.23	2	0.191	6	0.016	5
0.152	7	0.138	10	0.228	5	0.184	21	0.016	20
0.148	17	0.136	14	0.227	14	0.171	2	0.014	12
0.136	21	0.134	20	0.212	11	0.17	12	0.013	14
0.131	9	0.131	1	0.199	.	0.165	19	0.012	1
0.121	18	0.127	4	0.194	4	0.164	5	0.012	11
0.118	2	0.112	5	0.147	6	0.156	1	0.011	2

0.107	13	0.111	19	0.103	20	0.153	11	0.008	17
0.064	12	0.107	21	0.102	22	0.127	17	0.006	6

GSF: Green space factor; SVF: Sky view factor; BAR: Building area ratio; VOR: Vehicle occurrence rate; POR: Pedestrian occurrence rate; No: Corresponding street number

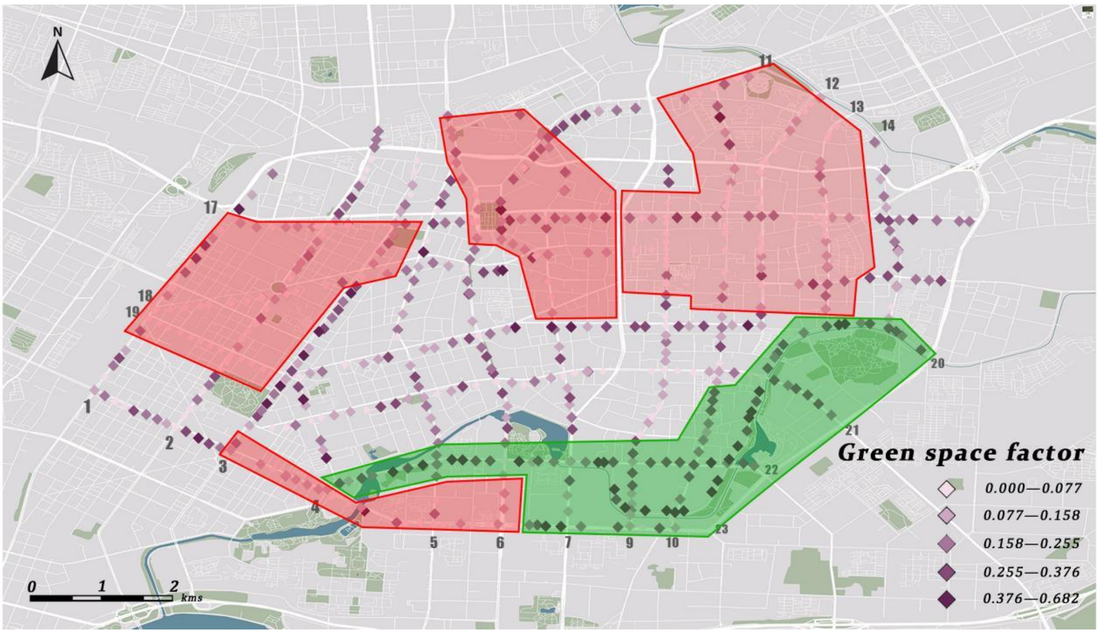
1) The spatial distribution of green space factor

The Green Space Factor was a psychological perception index which the greenery quality of urban street spaces. People had different psychological feeling in each range of GVF. In this section, the GVF of the street in the core area were divided into five levels that 0%-7.7%, 7.7%-15.8%, 15.8%-25.5%, 25.5%-37.6% and 37.9%-68.2%. In the research according to the five levels, all sample collection points were classed three intervals that low value interval (0%-15.8%), middle value interval (15.8%-25.5%) and high value interval (25.5%-68.2%). The social surveys result of publishing by Ministry of land and transportation of Japan showed that the environment with high GVF was peace as well as it could promote the surrounding commercial atmosphere and gather people. The official document recognizes for the first time that the GVF higher than 25% can give the public a better feeling of greenery, so it became a goal of greenery construction which the GVF was higher than 25% in many cities.

Table 4-4 Interval distribution of green view factor.

Perception characteristic	Mean value of 634 samples	high value interval	middle value interval	low value interval
Green space factor	0.173	25.8%	21.1%	53.2%

According to the calculation result of the street spaces GVF in Shenyang Core Area(Table 4-4), it was the overall mean value of GVF was 0.173. In the core area, there were 164 sample collection points in the high value interval, accounting for about 25.8% of the total; 133 sample collection points were in the middle value interval, accounting for about 20.9% of the total; 337 sample collection points were in the low value interval, accounting for about 53.2% of the total. In conclusion, the GVF of the Shenyang core area was in the lower than middle level. It showed a model of GVF that low center and high periphery (Figure 4-10). In the core area, the GVF of the southeast area was higher and the northeast area was lower, the distribution of the GVF had significant difference in some streets.



Green space factor

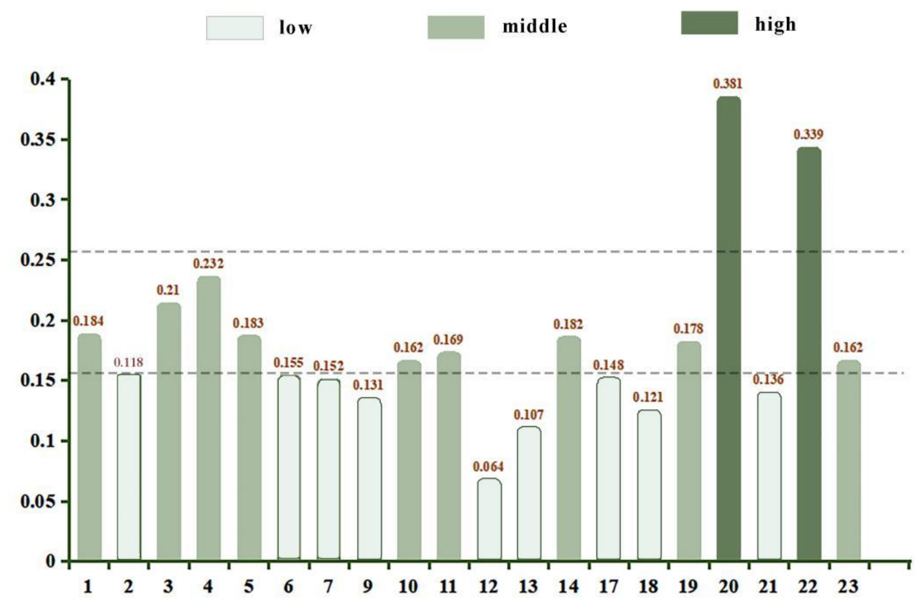


Fig 4-10 The overall spatial distribution of green space factor

According to analysis the street view images to confirm road characteristic. From Figure 4-10, it can be concluded that Street 20 Dongbinhe Road, Street 22 Wenyi Road and Street 4 Guangrong Road show high levels of street greenery. Among them, the waterfront park along the South Canal is positioned as a countryside recreation for cultural appreciation and scenic tours. The low intensity of artificial development in the district and the emphasis on greening along the streets had contributed to the high overall green space factor of 20th street as well as 22nd street. No. 4 Street Guangrong Street, as the main street connecting Zhongshan Park and Nanhu Park, it had a relatively narrow street surface. Dense street trees were planted along both sides of the street, creating a high green space factor in its streets.

With the exception of these three streets which had a higher green space factor, Dongshuncheng Road at 12th Street had the lowest overall green space factor and its streets were wider. Dongshuncheng Road intersects with Shenyang's most prosperous Middle Street, which was surrounded by a dense cluster of high-rise buildings. The street 12 had the lowest greenery because multiple reasons such as sparse green vegetation. Similar to Dongshuncheng Road, Street 13 Xiaoshizi Street and Street 2 Nanjing North Street also had wider roads. These two streets were dense residential buildings, pavement trees planted sparser, the lack of pavement between the carriageway green belt. Therefore, the score of green space factor was relatively low.

Urban street greenery, which trees, shrubs, lawns and other forms of vegetation in the street was an important design element in the urban landscape as well as it was the skeleton of the urban landscape. The quality of the greenery environment had the most direct impact on people's mental comfort. Some scholars' researches indicated the greenery of urban streets plays an important role in enhancing the attractiveness and walkability of streets [48]. Moreover, vegetation can improve people's aesthetic evaluation of the urban landscape [49].

2) Spatial distribution of sky view factor

The Sky View Factor reflects the openness and the perceiving light intensity of the street, it impacts the people's visual perception and sense of pleasure. In this section, the SVF of the street in the core area were divided into five levels that 0%-9.1%, 9.1%-13.4%, 13.4%-18.5%, 18.5%-25.7% and 25.7%-41.9%. In the research according to the five levels, the SVF was classed three intervals that low value interval (0%-13.4%), middle value interval (13.4%-18.5%) and high value interval (18.5%-41.9%).

Table 4-5 Interval distribution of sky view factor

Perception characteristic	Mean value of 634 samples	high value interval	Middle value interval	Low value interval
Sky view factor	0.148	27.3%	22.6%	50.1%

According to the calculation result of the street SVF in Shenyang Core Area(Table 4-5), the overall mean value of SVF was 0.148. In the core area, there were 173 sample collection points in the high value interval, accounting for about 27.3% of the total; 143 sample collection points were in the middle value interval, accounting for about 22.6% of the total; 318 sample collection points were in the low value interval, accounting for about 50.1% of the total. In conclusion, the SVF of the Shenyang core area was in the middle level. The presence of fewer buildings in the area allowed more sky area to be preserved, streets with high sky view factor in Shenyang's urban core were located in Youth Street and the Fangcheng area of the Shenyang Imperial Place. Due to the establishment of more buildings and the presence of more high-rise buildings, the skies of commercial and old building streets were blocked. Thus, the sky view factor was less low.

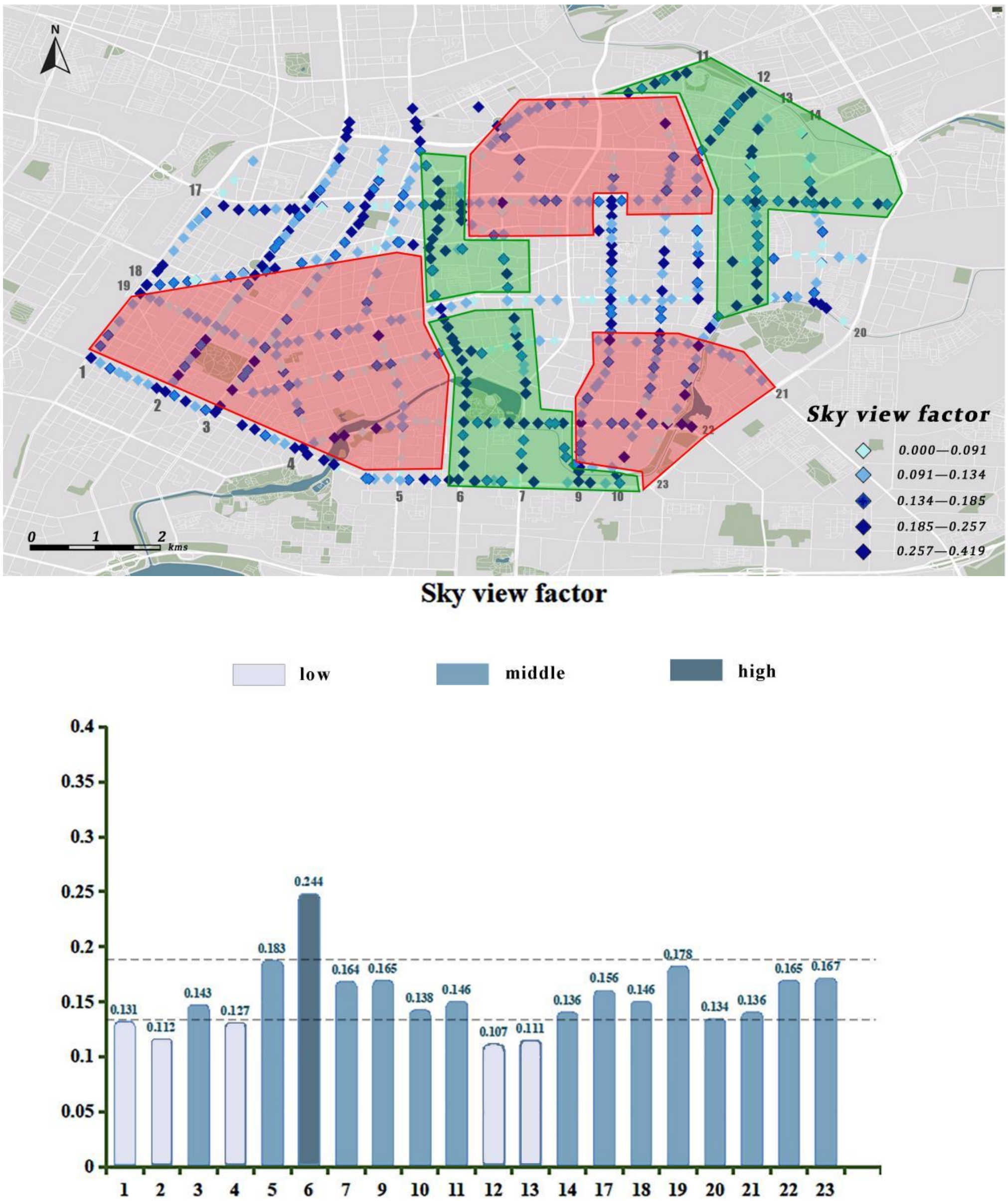


Fig 4-11 Spatial distribution of sky view factor

From Figure 4-11, it can be seen that the sky view factor of the longitudinal streets was overall higher than that of the transverse streets, with a higher degree of sky view factor in the 6th and 13th streets. Street 6 is Youth Street, where the street trees on both sides of the road were neatly arranged and lowly shaded by buildings. On the left side of the street are large buildings and on the right side of the street was adjacent to Youth Park and City Hall Square. There were no more buildings on one side of the street, giving the street a low degree of enclosure. The street retains an appropriate amount of sky, creating an open street space and a comfortable spatial experience. Street 13 was Xaoshisha Road, which had a large number of residential buildings set up on both sides of the street. Although the street interface was relatively cluttered and crowded, the low building height allowed for a clear view of the street space. The large sky area over the street enhances the sky view factor of the street space.

The sky was less open on 21st Street Buzzing Road, 19th Street China Road and 5th Street. The Renao road in the 21st street was in the middle of a group of residential buildings, the buildings on both sides of the street were not only old but also of different heights. The staggered building heights divided the sky over the street, not only reducing the sky view factor but also cluttering the skyline, greatly reducing the visual quality of the street itself. The China Road in Street 19 was a commercial street section, with a large number of commercial complexes set up on both sides of the street. The street itself was narrower making the height and width of the street relatively large, forming a narrow street canyon with a subsequent decrease in sky view factor. Super high-rise buildings were set up on both sides of street 5. There were more of them, which greatly block the permeability of the street and obstruct pedestrian sightlines. The street trees planted on both sides of the street were also flourishing. Although it improved the visibility and vitality of the street, the overgrown vegetation occupies part of the street space and had a negative effect on the sky view factor. The plants reduced the area of sky over the street.

The research and application value of SVF on the visual environment quality of urban space had been widely recognized, it also had an important role in improving local climate. The study by Lv Fei et al [50]. Indicated that the residential SVF has important positive impact on public's emotional health.

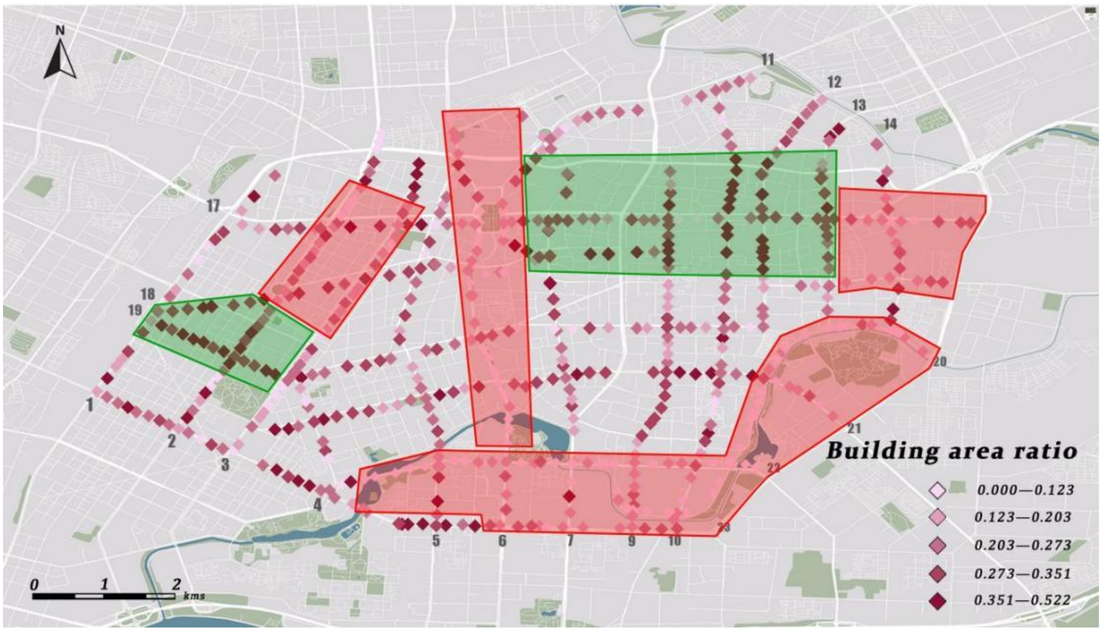
3) Spatial distribution of building area ratio

Building Area Ratio was defined as the enclosure degree of the street by building interface on both sides of the street. Although the street with high BAR could bring the sense of safe to people, it caused the pedestrian sighting was blocked and reduces the perception of street space. In this section, the BAR of the street in the core area were divided into five levels that 0%-12.3%, 12.3%-20.3%, 20.3%-27.3%, 27.3%-35.1% and 35.1%-52.2%. In the research according to the five levels, the BAR was classed three intervals that low value interval (0%-20.3%), middle value interval(20.3%-27.3%) and high value interval(27.3%-52.2%).

Table 4-6 Interval distribution of building area ratio

Perception characteristic	Mean value of 634 samples	High value interval	Middle value interval	Low value interval
Building area ratio	0.230	33.1%	26.2%	40.7%

According to the calculation result of the street BAR and the distribution of the intervals in Shenyang Core Area （Table 4-6）, the overall mean value of BAR was 0.230. In the core area, there were 210 sample collection points in the high value interval, accounting for about 33.1% of the total; 166 sample collection points were in the middle value interval, accounting for about 26.2% of the total; 258 sample collection points were in the low value interval, accounting for about 40.7% of the total. Overall, the street building area ratio in the core area of Shenyang was at a medium level, where the locations with relatively high building area are mainly located in the core commercial area and the historical cultural protection zone. The overall distribution showed a higher distribution in the northeast-southwest and a lower distribution in the northwest-southeast.



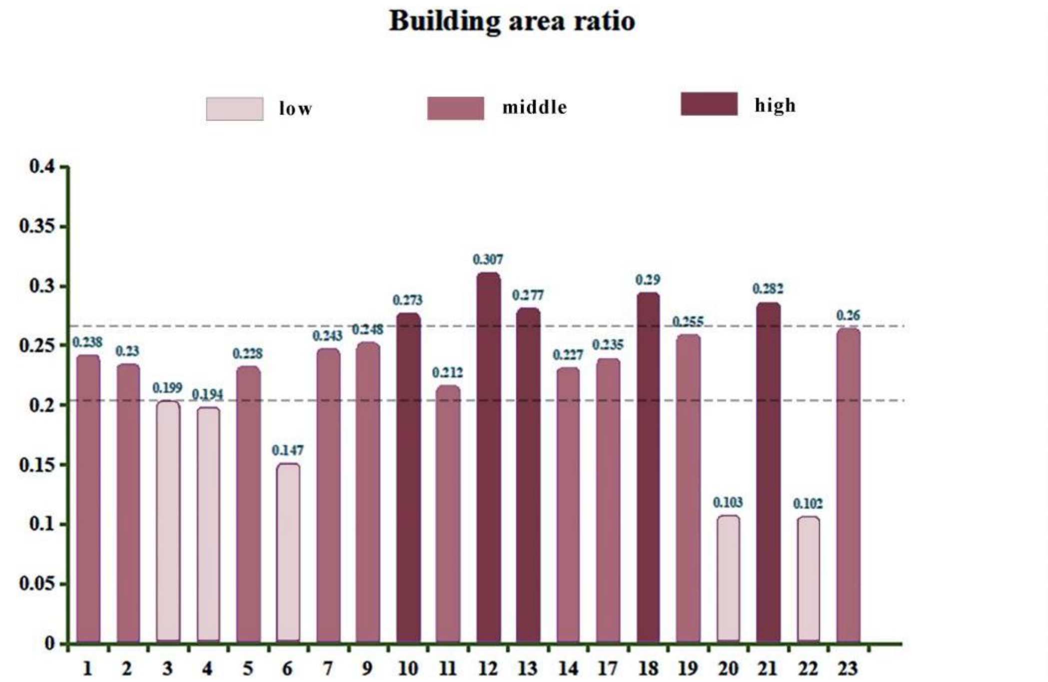


Fig 4-12 Spatial distribution of building area ratio

Both Dezeng Road in 12th Street and Renao Road in 21st Street had the same street characteristics (Fig 4-12). A large number of buildings were set up on both sides of the street, with high building heights and a continuous street interface. The building type of No. 12 is more complex and had a higher building area ratio. The street was a mixed commercial and residential street, where the street interface was not only continuous, but also due to the commercial stores, their commercial signboards and decoration even created a secondary contour interface, further increasing the floor area of the street. A large number of historic and cultural buildings were preserved in the Zhongshan Road section of No. 18 Street to protect the cultural identity of the section. Although the building critical ratio was high in all three sections, the architectural style and the architectural arrangement of the buildings of the street 12 and the street 21 were confusing, making the street as a whole form a more architectural interface. On the contrary, the architectural style was unified and the street interface was flat and uniform in the 18th street, while the architectural shape with historical characteristics brought a unique street culture to the street as a whole.

The building criticality in 22nd street, 20th street, and 6th street is relatively low. 22nd Street and as 20th Street have something in common. Both were adjacent to city parks or squares. Street 22 was Wenyi Road, which was adjacent to Youth Park, Zaojiao Garden, Wanliutang Park and Luxun Children's Park.The street 20 was a combination of Xiaoheyan Road and Dongbinhe Road, which was adjacent to Wanliutang Park and Wanquan Park. Both streets had fewer urban structures on both sides of the street and are open with permeable street views. At the same time, a large number of street trees were planted on both sides of the street, the street trees were neatly arranged and flourishing. Although the above reasons make its street building area relatively low, the overall visual quality of the street had been improved. Although there were a large number of commercial buildings and commercial complexes in some sections, the buildings were arranged in a concentrated manner in the 6th street Youth Street, the street is wide and spacious and open, and the height and width of the street was relatively low, which leaded to a relatively small floor area in this street. However, the street architecture was very modern and unified in architectural style so that the street interface is harmonious and complete, which enhances the visual quality of the street.

The above results showed that streets adjacent to city parks and city squares had low street building area ratio. Due to the low critical ratio of the building, the street space was open, the street had a clear line of sight and a comfortable spatial feeling. On the other hand, the streets with more residential buildings in the urban core. The building area of the street was relatively high and the street as a whole was closed and narrow. It created a more depressing space atmosphere. It can be seen that the building area ratio negatively affects the degree of openness of the street space.

The numerical magnitude of the BAR was the same as the degree of the street space closure [51]. A complete and continuous building facade can create a more orderly and full of vitality the streetscape (park et al, 2019). A reasonable Bar can build a good sense of enclosure and give the impression of a high degree of safety [52], so more opportunities that promote interaction between sports activities and residents were provided [53].

4) Spatial distribution of vehicle and pedestrian occurrence rate

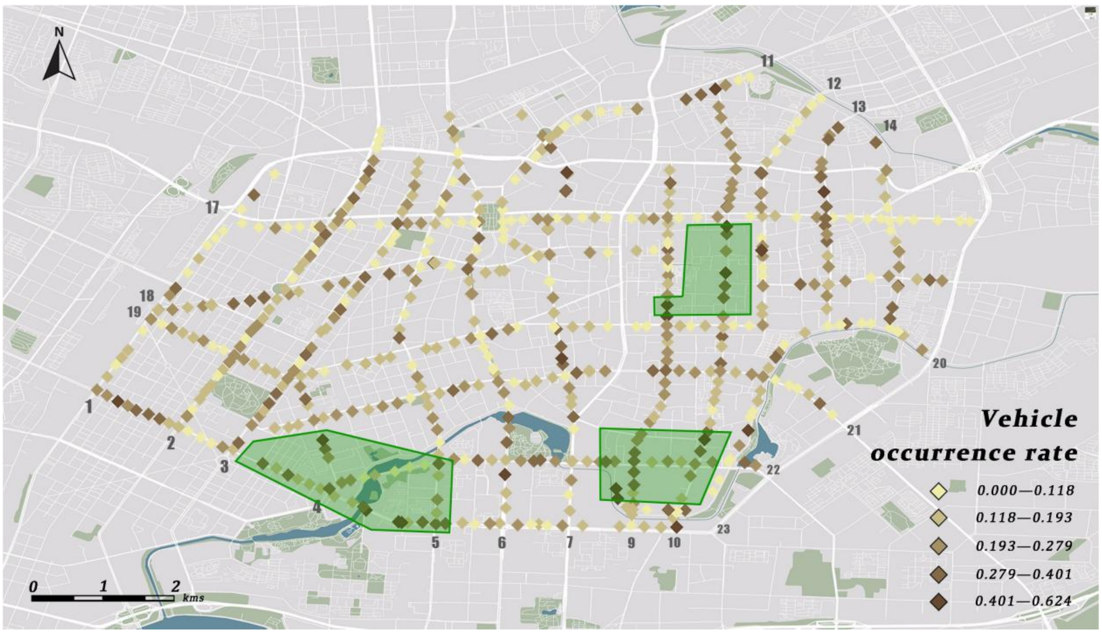
Vehicle and pedestrian were the major moving elements so the vehicle occurrence rate and the pedestrian occurrence rate had important impact on the visual perception of urban streets, the usage of urban streets can be shown by them. In the research according to the Jenks Natural Breaks, the VOR was classed three intervals that low value interval (0%-19.3%), middle value interval (19.3%-27.9%) and high value interval (27.9%-62.4%). the POR was classed to low value interval (0%-2.4%), middle value interval (2.4%-4%) and high value interval (4%-15%).

Table 4-7 Interval distribution of vehicle and pedestrian occurrence rate

Perception characteristic	Mean value of 634 samples	High value interval	Middle value interval	Low value interval

Vehicle occurrence rate	0.197	19.2%	26.2%	54.6%
Pedestrian occurrence rate	0.0196	11.5%	17.7%	70.8%

According to the calculation result of the street VOR and POR(Table 4-7), they indicated that the overall mean value of VOR was 0.230. In the core area, there were 122 sample collection points in the high value interval, accounting for about 19.2% of the total; 166 sample collection points were in the middle value interval, accounting for about 26.2% of the total; 346 sample collection points were in the low value interval, accounting for about 54.6% of the total. The VOR of the Shenyang core area was at the lower level. In mean value of the POR, the overall mean value was 0.0196. In the core area, there were 73 sample collection points in the high value interval, accounting for about 11.5% of the total; 112 sample collection points were in the middle value interval, accounting for about 17.7% of the total; 449 sample collection points were in the low value interval, accounting for about 70.8% of the total. The POR of the Shenyang core area was at the lower level. In the core area of Shenyang, the streets with high vehicle occurrence rate are mainly located near commercial streets as well as historical and cultural districts. The area had increased traffic due to excessive pedestrian traffic. For the streets around the core, the incidence of vehicles was low.



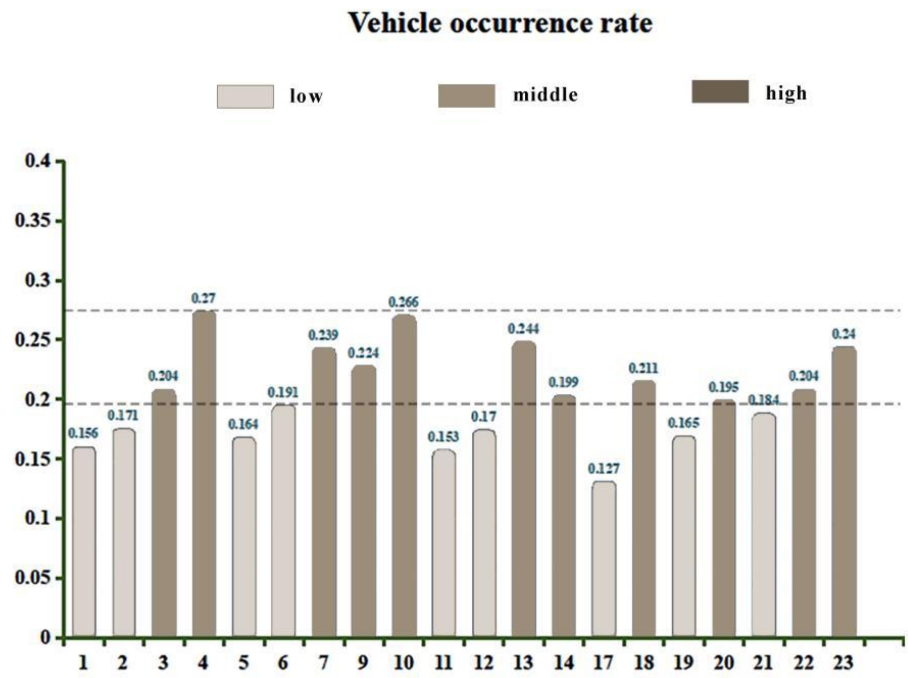


Fig 4-13 Spatial distribution of visual perceptual features of vehicle occurrence rate

As shown in Figure 4-13, street 4 has the highest vehicle occurrence rate, indicating that it had the highest traffic volume. Street 4 intersects with Daxi Road and Heping North Street at the north end, Wenyi Road and Jiaxing Road at the south end. The number of intersecting roads on Street No. 4 was high, so the roadway has a high incidence of vehicles. Guangrong Street is a mixed commercial and residential street. Due to the large number of stores on both sides of the street resulting in a large flow of customers, while the street was narrow, traffic not only to avoid pedestrians had problem of traffic congestion. The above points caused to the high vehicle occurrence rate on this street. Street 17 was located in the northern part of the core area of Shenyang and belonged to the edge streets in the core area. The street was a mixed commercial and residential street, which had mainly traffic functions. Although there were more stores in street 17, it was not a commercial complex. It cannot attract and gather a large number of people as well. The openness of the street promotes the flow of traffic, so the incidence of vehicles on this street was low.

As can be seen in Figure 4-14, the streets with the highest pedestrian occurrence rate were Street 10, Street 9 and Street 4, which was more consistent with the streets with higher vehicle occurrence rate mentioned above. Both streets were located in the square city area of the Shenyang Imperial Palace, which attracted more people as a famous tourist attraction, thus impacted on the commercial streets near the Shenyang Imperial Palace and increased its pedestrian occurrence rate. In addition, Zhonghua Road in Street 18 and Zhonghua Road in Street 19 have a high pedestrian occurrence rate as historical and cultural districts. Except for the historic districts and commercial streets next to large commercial complexes, all other streets in the core area of Shenyang had a pedestrian occurrence rate, with the lowest on the city main roads. In general, the pedestrian occurrence rate was higher in the historic districts and commercial districts in the core area of Shenyang. The pedestrian occurrence rate on streets such as main traffic roads was low.

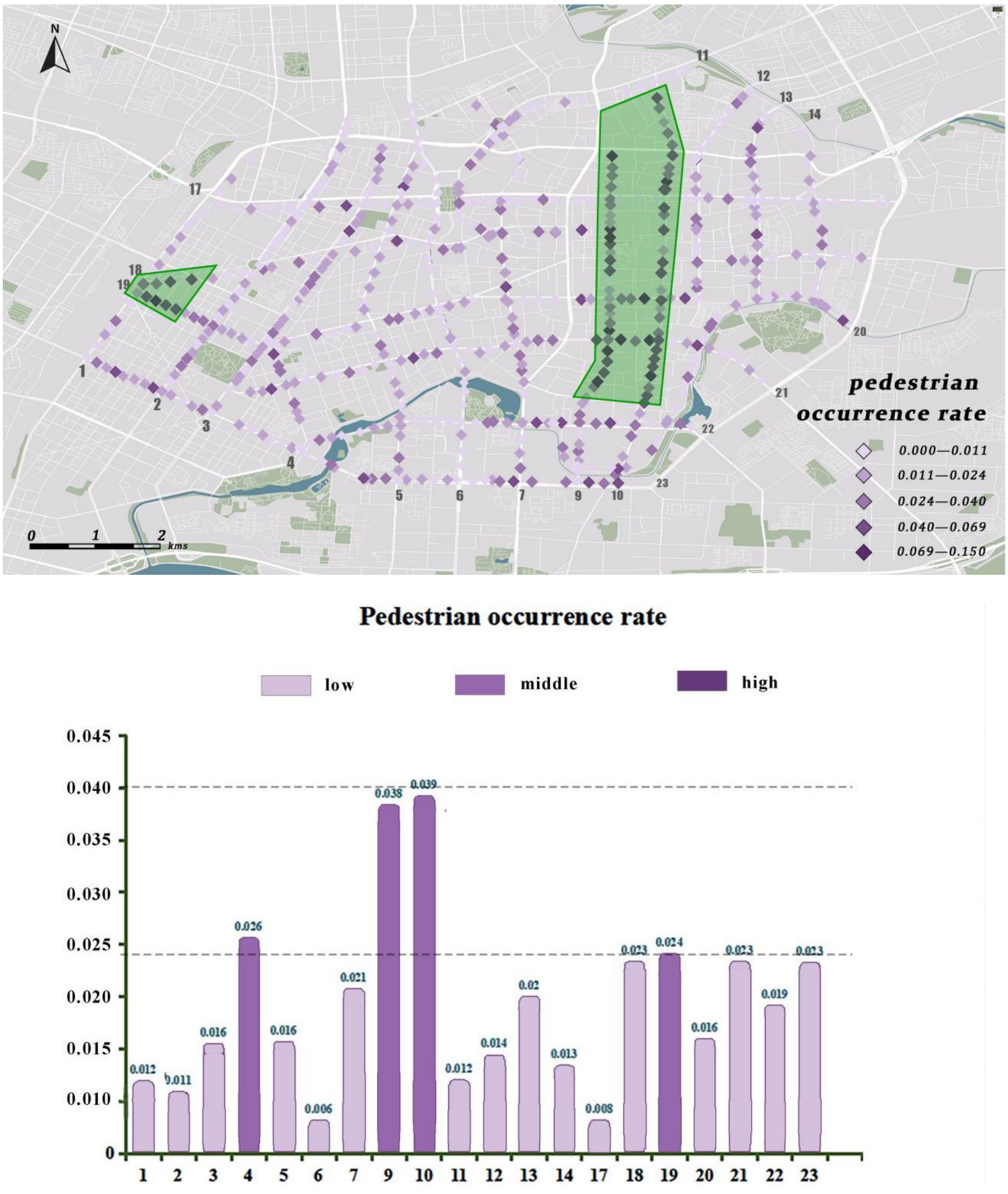


Fig 4-14 Spatial distribution of visual perceptual features of pedestrian occurrence rate

(3) Analysis of visual dominant characteristic in the core area of Shenyang

The landscape character differs in different parts of each street, especially in the longer road such as urban arterial roads. In order to analysis the dominant landscape vision characteristics on the Street internal scale, we classified each sample point based on the visual perceptual characteristics extracted from BSVs. According to existing research [15] [17] we chose three static visual perceptual characteristics in the urban street space such as green space factor, sky view factor and building area ratio. In order to standardize the classification rule, we used information entropy [40] to measure the proportional relationship between these visual perceptual characteristics. The calculation formula of information entropy was as follows:

$$L = -\sum_{k=1}^{4} p_k \log p_k$$

where Pk is the proportion of sky, tree, building, and other elements. The distribution of L can be converted to a heavy-tailed distribution by taking:

$$L_r = \frac{1}{L}$$

The distribution of streetscape categories in the core area of Shenyang was detailed in Figure 17 and Table 4-8.

1) Street dominated by a single characteristic

Dominance of a single visual perceptual characteristics were defined as the proportion of a single characteristic was at least twice as large as the proportion of the second largest characteristic in the GVF, SVF and BAR. Three class were generated based on this rule: Green space factor (G), Sky view factor(S) and Building area ratio (B).

$$P_{r1} \geq 2 \times P_{r2}$$

where Pr_1= the proportion of the largest feature; Pr_2= the proportion of the second largest.

2) Street dominated by two characteristic

Two-characteristic-dominated classes were defined as the proportions of the two largest characteristics among the three being relatively close, in that the larger one is less than twice that of the smaller one. They were both much larger than the proportion of the smallest characteristic in that the second largest proportion was at least twice that of the smallest proportion. Three classes were generated based on this rule: Green space factor/Sky view factor (GS), Green space factor/Building area ratio(GB) and Sky view factor/Building area ratio(SB);

$$P_{r1} < 2 \times P_{r2} \ and \ P_{r2} \geq 2 \times P_{r3}$$

where Pr3 = the proportion of the smallest visual perceptual characteristics.

3) Streets with mixed characteristics

This class was defined as the proportion of the three visual perceptual characteristics was close and the difference between the three characteristic proportions was less than twice that of the latter, one class was generated based on this rule: Green space factor/ Sky view factor/ Building area ratio(GSB)

Table 4-8 Percentages of grids for sever streetscape classes

G	S	B	GS	GB	SB	GSB
21.1%	6.4%	38.8%	6.7%	12.6%	13.5%	0.6%

Note: G: dominant by green space factor; S: dominant by sky view factor; B: dominant by builingarea ratio; GS: dominant by G/S; GB: dominant by G/B; SB: dominant by S/B; GSB: dominant by G/S/B.

The results show(Table 4-8), the calculation of the proportion of the seven types of visually dominant features showed that B(0.388)> G(0.211)> SB(0.135)>GB(0.126)> GS(0.0670)> S(0.064)> GSB(0.006). The most significant feature of the street space in the core area of Shenyang was the building area ratio (0.388). The visual dominant types associated with it: GB (0.126), SB (0.135), GSB (0.006) account for 65.5% of the overall visual ratio. The urban core of Shenyang contained the main commercial areas of the city with dense and tall building clusters on both sides of the streets. The core area had several historic areas, cultural areas (Shenyang Fangcheng Imperial Palace, Historic District of Shenyang Station, etc.) and several residential areas. The most prominent visual feature of the street space in the core area was building area ratio because the large number of historic buildings and residential buildings. Green space factor was the second ranked visual dominant feature (0.2113). The visual dominant types associated with it: GS (0.067), GB (0.126), GSB (0.006) accounted for 41% of the overall visual types. The southern part of the core area ran through the Shenyang South Canal, and several waterfront linear parks were distributed. The surrounding streets were richly planted with vegetation. The core area had several green spaces inside, including Zhongshan Park and City Hall Square. That was the reason of the second visual dominant feature was green space factor in the core area.

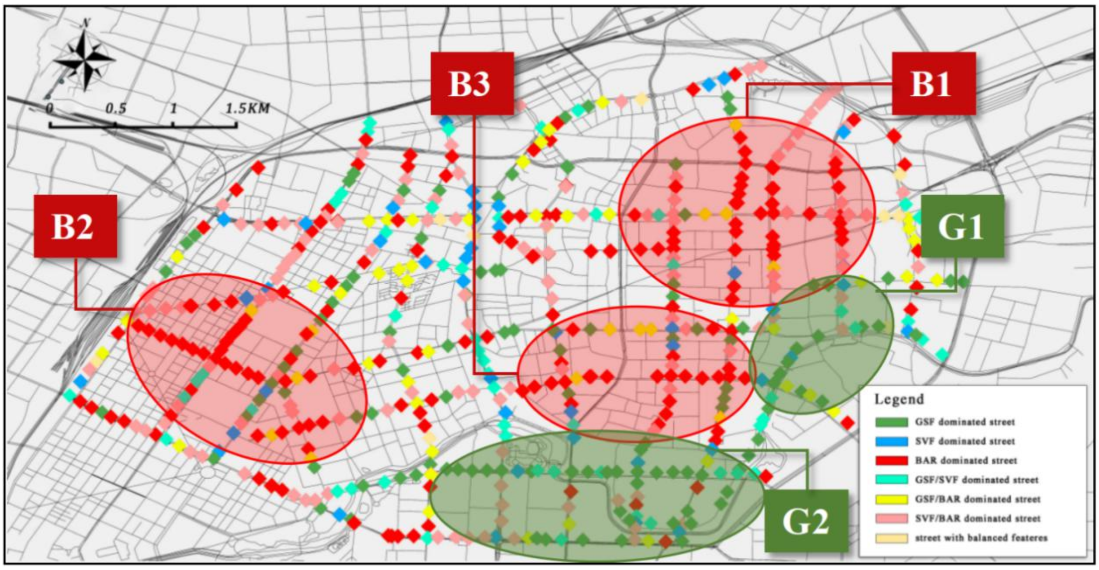


Fig 4-15 Spatial distribution of BAR and GSF dominated street

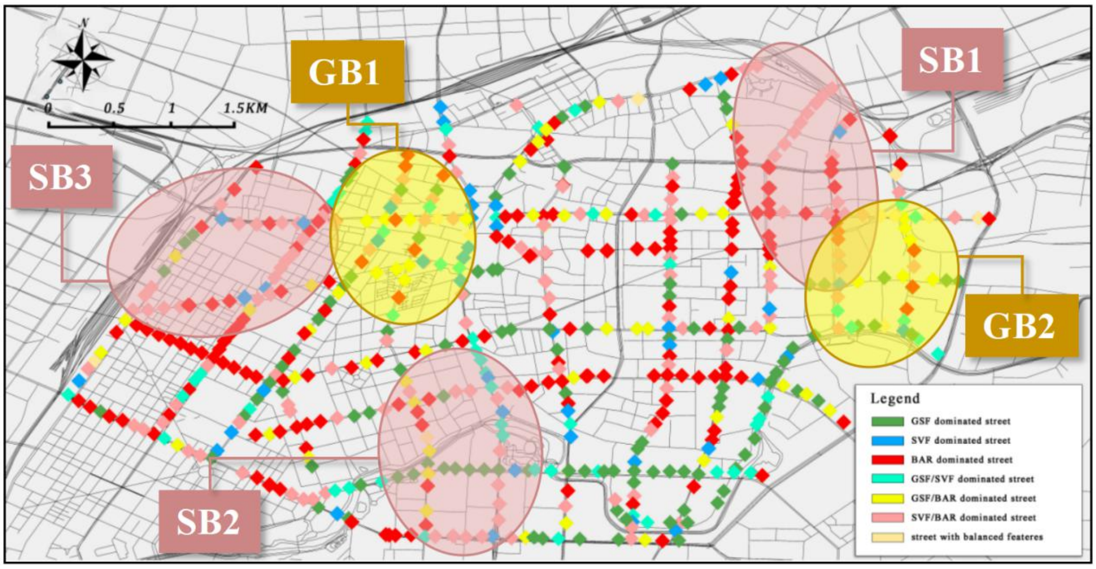


Fig 4-16 Spatial distribution of GSF/BAR and SVF/BAR dominated street

By observing the spatial distribution of seven visually dominant features in the core area of Shenyang (Figure 4-15,4-16): The building area ratio of the largest proportion of visual dominant features (0.388) was mainly distributed in three areas, including B1 commercial area, B2 commercial area and B3 residential area. Three areas had the characteristics of narrow street surface, dense and high buildings on both sides. The green space factor (0.2113), the second most dominant visual characteristic, was mainly distributed in the G1 residential and recreational area, which was close to the South Canal Park and rich in greenery in the surrounding streets. The G2 area buildings were tall, but the building density was low and the roads had a high proportion of street trees and green belt on both sides. The third visually dominant feature SB (0.135) was mainly distributed in three areas (SB1, SB2, SB3) which located in the southeast, south, and west of the core area, respectively. Three areas had wide roads with low-intensity high-rise office buildings on both sides of the street. GB (0.126) was the fourth dominant visual characteristic.GB1 and GB2 are mainly located in the area with a mixture of commercial and residential buildings. Both areas had equally dense buildings on both sides of the road. Green facilities were well built in the street space. The dual dominant visual characteristics of green space factor and building area ratio in this area were formed.

4.4.2 Urban street landscape visual quality evaluation model

To further investigate the effects of five visual perceptual features on the street visual quality, 150 typical sampling points were selected for SBE scoring of their BSV panoramic images from 634 sampling points. The typical sample of streets was selected to reflect as fully as possible the spatial information of the streets in the street segment, The visual quality results of 150 typical samples in streets were as follows Table 4. We used SPSS 25.0 to analyze the correlations between the visual quality of 150 typical samples and their scores on five visual perceptual features (Table 4-9).

Table 4-9 Ranking order of landscape quality for 150 street samples and road classifications

Photo Number	Road Type	Standard Value	Photo Number	Road Type	Standard Value	Photo Number	Road Type	Standard Value
0631	NS	1.442	0126	CR	0.175	1910	WE	-0.275
0729	NS	1.394	0111	NS	0.156	0922	CR	-0.287
2340	WE	1.346	0225	NS	0.156	0932	CR	-0.291
1714	WE	1.326	0605	CR	0.152	1708	WE	-0.306
0328	NS	1.175	0118	CR	0.142	0723	CR	-0.320
0320	NS	1.114	0325	CR	0.136	1407	CR	-0.329
2206	WE	1.072	2338	WE	0.118	0512	NS	-0.330
1123	NS	1.059	0524	CR	0.108	0710	CR	-0.331
0212	CR	0.970	1923	WE	0.097	1930	WE	-0.360
0609	CR	0.931	2101	WE	0.097	1319	CR	-0.361
0629	CR	0.928	1818	CR	0.091	1041	NS	-0.368
2342	WE	0.920	0601	NS	0.083	1221	CR	-0.372
0221	CR	0.844	0410	CR	0.077	0404	CR	-0.376
0613	CR	0.833	1742	WE	0.075	2327	WE	-0.396

1723	WE	0.764	1804	WE	0.067	0720	NS	-0.396
0307	CR	0.754	2117	WE	0.049	1218	NS	-0.404
0913	NS	0.747	0209	NS	0.045	1010	NS	-0.411
0730	CR	0.617	0917	CR	0.044	1951	WE	-0.413
0627	NS	0.585	0517	NS	0.031	1316	NS	-0.424
1122	CR	0.562	0938	CR	0.028	0920	NS	-0.431
2133	WE	0.547	1925	WE	0.022	1916	WE	-0.436
1119	NS	0.545	0611	NS	0.011	0334	CR	-0.455
2222	WE	0.500	1322	CR	-0.010	1205	NS	-0.510
1103	NS	0.490	0234	NS	-0.017	2122	WE	-0.519
0614	NS	0.484	0924	NS	-0.017	1814	WE	-0.530
0305	NS	0.482	1815	CR	-0.022	1903	WE	-0.538
0123	NS	0.444	0101	NS	-0.040	2005	WE	-0.552
1717	WE	0.426	2136	WE	-0.040	2125	WE	-0.562
0734	CR	0.423	1949	WE	-0.044	1208	CR	-0.565
2213	WE	0.409	1408	NS	-0.047	1937	CR	-0.566
2330	WE	0.406	1003	NS	-0.050	2002	WE	-0.567
0618	CR	0.402	0714	NS	-0.051	1412	CR	-0.586
0228	CR	0.391	0408	NS	-0.062	1735	WE	-0.592
0633	CR	0.380	1945	WE	-0.073	0905	CR	-0.592
0216	NS	0.376	0309	NS	-0.082	2328	CR	-0.597
0503	NS	0.336	1306	NS	-0.088	2317	WE	-0.611
0910	CR	0.330	1817	WE	-0.105	0718	CR	-0.638
1035	NS	0.300	2114	WE	-0.118	0237	CR	-0.689
2218	WE	0.298	0707	NS	-0.135	1030	CR	-0.745
2210	WE	0.275	1115	CR	-0.140	1734	CR	-0.785
1828	WE	0.259	0518	CR	-0.157	1935	WE	-0.801
1728	WE	0.240	2223	WE	-0.188	0935	NS	-0.802
2334	WE	0.231	2306	WE	-0.190	1733	WE	-0.804
1110	NS	0.213	1706	WE	-0.195	1406	NS	-0.810
0515	CR	0.209	0528	NS	-0.201	0713	CR	-0.878
0703	NS	0.203	1039	CR	-0.214	1413	CR	-0.888
0733	NS	0.197	2011	WE	-0.215	1417	NS	-0.971
0523	NS	0.196	1701	CR	-0.256	0904	NS	-1.113
0619	NS	0.189	1822	WE	-0.264	1021	NS	-1.124

2107	WE	0.184	2308	WE	-0.267	0623	CR	-1.406

Note: NS: north-south street; WE: east-west street; CR: intersection

Table 4-10 Correlation analysis of five visual perceptual features with visual quality

VISUAL PERCEPTION CHARACTERISTIC	PEARSON CORRELATION	SIG.(2-TAILED)	NUMBER OF CASES
Green space factor	.324**	.000	150
Sky view factor	.035	.669	150
Building area ratio	-.359**	.000	150
Vehicle occurrence rate	-.182*	.026	150
Pedestrian occurrence rate	-.212**	.009	150

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

It is clear from Table 10 that the green space factor showed a highly positive correlation with the SBE value (significance level a=0.01). Streets with high visual quality scores tended to have higher green space factor, which was consistent with the findings of previous conclusions. Urban greenery can create a pleasant mood and have a positive impact on people's psychological perception. In comparison, building area ratio, vehicle occurrence rate and pedestrian occurrence rate were negatively correlated with SBE values. Traffic volume and pedestrian flow are high in streets with low visual quality, while dense buildings obstruct the view of people. For example, in the northern section of 9th Street, Zhengyang Street had a lower green space factor, narrower sky view and higher floor area. This means that the streets were less green. The taller buildings made the overall street feel more enclosed, which leaded to a relatively poor visual experience. Specifically, green space factor of street had the highest importance for improving the street visual quality (0.324), with negative relative importance for building area ratio (-0.359), vehicle occurrence rate (-0.182) and pedestrian occurrence rate (-0.212). This was in line with classical urban design theory. Although the sky view factor (0.035) did not show the correlation of SBE values, the reason may be that the sky view factor of main roads in the core area of Shenyang was more similar. The canopy of street trees had a shading relationship to the sky. The high positive effect of street greenery offsets the relatively low positive effect of sky views. This resulted in a relatively low weighting of the contribution of sky view factor in the overall analysis.

The street visual quality was used as the dependent variable and the four retained visual perceptual characteristics. Green space factor, building area ratio, vehicle occurrence rate and pedestrian occurrence rate as independent variables. A linear regression model was built (Table

4-11).

Table 4-11 Regression coefficient

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	.379	.224		1.690	.093
	green space factor	.736	.509	.148	1.446	.150
	building area ratio	-1.315	.658	-.244	-2.000	0.47
	vehicle occurrence rate	-.939	.516	-.139	-1.822	.070
	pedestrian occurrence rate	-2.949	2.684	-.089	-1.099	.274

Dependent variable：standardized value   R Square=0.169   Adjusted R Square=0.146

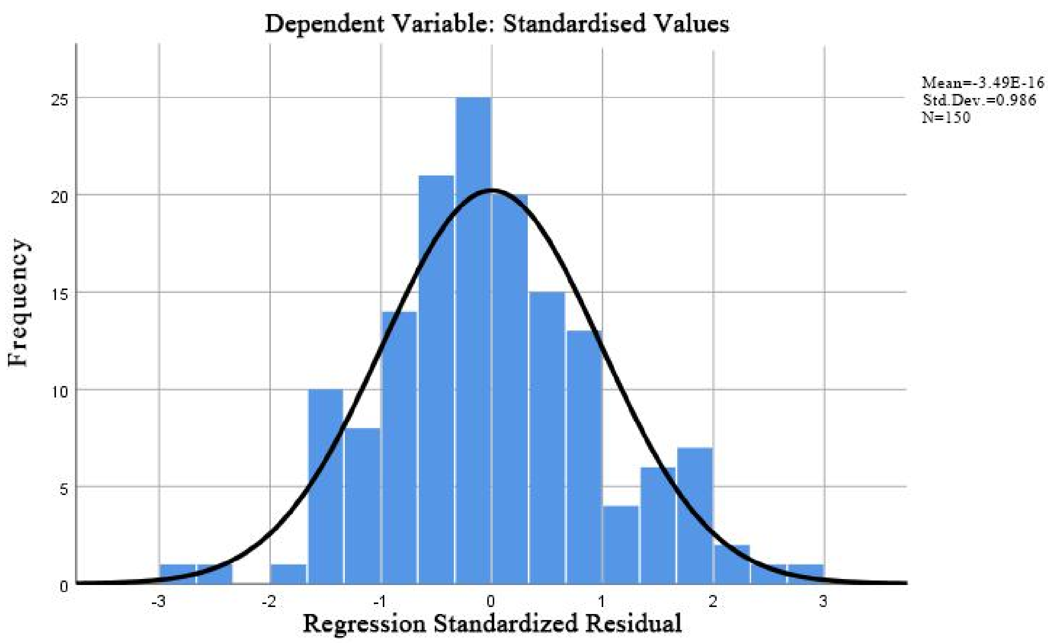


Fig 4-17 Regression standardized residual

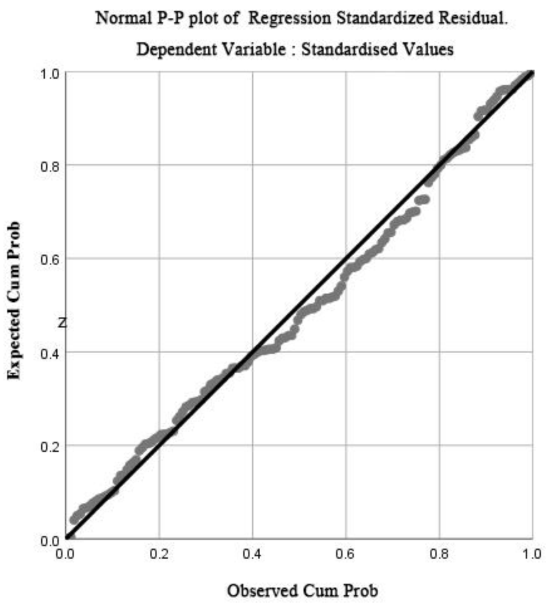


Fig 4-18 Normal P-P plot of regression standardized residual

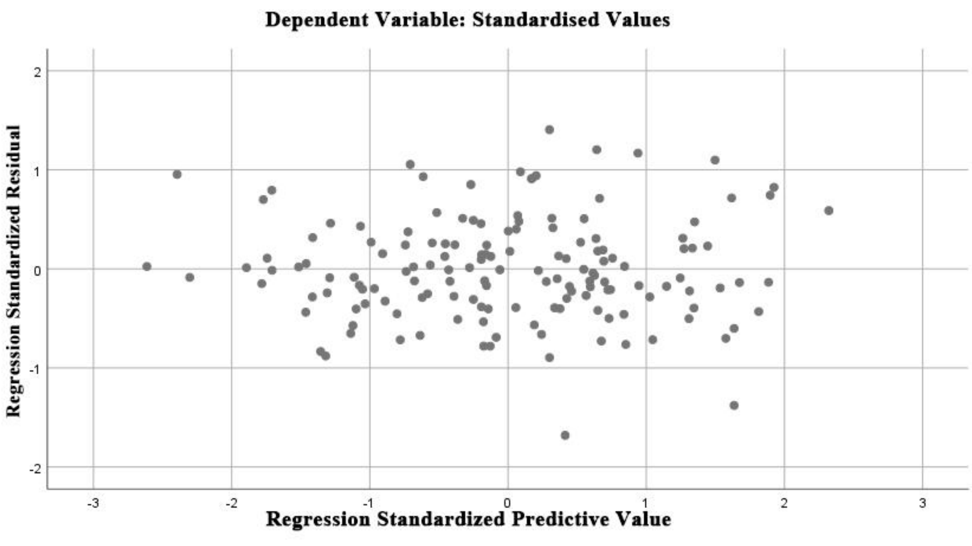


Fig 4-19 Scatterplot

The histogram sample of the standardized residual samples (Fig 4-17) visualizes that the standardized residuals approximately obey a normal distribution with mean (Mean) of 0 and standard deviation (Std. Dev) of 1. It also follows from the normal probability sample (Fig 4-18) that the scattered samples are basically scattered around the first quadrant on the diagonal. This can be judged that the residuals basically obey a normal distribution and satisfy the applicable range of multiple linear regression. The scatter plot of scenic beauty evaluation and their normalized residuals (Fig 4-19) showed that the vast majority of the predictions fall randomly within a range of plus or minus 2 around the vertical. There was no significant relationship between the predictions and normalized residual values. So the model should satisfy the assumptions of consistency of linearity and variance with a good fit.

Y：$0.736X_1-1.315X_2-0.939X_3-2.949X_4+0.379$

In the model, X_1 was the green view factor, X_2 was the building area ratio, X_3 is the vehicle occurrence rate, and X_4 was the pedestrians occurrence rate. Using the visual quality evaluation model of the streets in the core area of Shenyang. The visual perceptual features of 634 sampling points calculated by semantic segmentation were substituted into the Shenyang core area street visual quality evaluation model. It was possible to calculate the overall urban street visual quality in the core area of Shenyang.

4.4.3 The urban street visual quality evaluation in the core area of Shenyang

Taking into account the traffic function, the current analysis of the visual quality of the core area of Shenyang focuses only on the main streets of the city. All bridges, tunnels and elevated roads were temporarily excluded. Specific evaluation criteria for these traffic guidance roads will be given in future studies (Table 4-12). We used the colors from light blue (low quality) to dark blue (high quality) to represent the calculation results by calculating the visual quality of the landscape for the 634 street sampling points in the core area (Fig 4-20).

Fig 4-20 Spatial distribution of street visual quality in the core area of Shenyang

Table 4-12 Spatial distribution of streetscape visual quality in the urban core of Shenyang

Street number	Maximum value sampling point number	Visual quality value	Minimum value sampling point number	Visual quality value	Visual quality average
20	2024	0.748	2007	-0.156	0.294
22	2204	0.799	2201	-0.386	0.247
6	0620	0.507	0630	-0.396	0.102
11	1121	0.458	1117	-0.383	0.046
17	1739	0.404	1712	-0.345	0.035
3	0328	0.430	0303	-0.403	0.032
1	0108	0.479	0103	-0.440	0.020
5	0507	0.602	0527	-0.472	0.013
14	1417	0.366	1415	-0.450	-0.011
2	0231	0.418	0229	-0.409	-0.029
4	0410	0.294	0406	-0.380	-0.034
19	1927	0.438	1902	-0.563	-0.050
7	0729	0.335	0727	-0.427	-0.115
21	2131	0.355	2125	-0.584	-0.134
23	2310	0.473	2326	-0.576	-0.135
9	0936	0.236	0909	-0.679	-0.174
12	1220	0.198	1212	-0.426	-0.178
18	1823	0.433	1829	-0.576	-0.179
13	1322	0.405	1303	-0.553	-0.196
10	1005	0.342	1016	-0.856	-0.226

We derived the average visual quality of each street by calculating the average visual quality of all sampled points for that street at the street level. The visual quality scores at the street level were shown in Table 4-11, it was easy to conclude that there is a more significant spatial distribution difference in the street visual quality in the core area of Shenyang.

The analysis of the results of the landscape visual quality of the overall sample of the Shenyang core area showed (Table 4-12) that the average value of the landscape visual quality of 8 of the 20 main streets in the Shenyang core area was positive (20th, 22nd, 6th, 11th, 17th, 3rd, 1st, 5th), the remaining 12 streets had negative mean values for the landscape visual quality (14th, 2nd, 4th, 19th, 7th, 21st, 23rd, 9th, 12th, 18th, 13th, 10th).Thus, it can be seen that the 20th street had the best landscape visual quality (0.294) and the 10th street had the lowest landscape visual quality

(-0.226). The overall landscape visual quality for each street was approximately the same as the landscape visual quality for the sample within the street. The top 7 streets (20, 22, 6, 11, 17, 3, 1) were classified as high quality streets and the bottom 7 streets (21, 23, 9, 12, 18, 13, 10) were classified as low quality streets. Comparing high quality streets and low quality streets had the following differences.

Fig 4-21 Street visual quality in urban core of Shenyang

(1) High-visual quality streets

The road was open, the buildings along the street were low, the sky is open (22, 20, 06, 17). The streets had wide width and high road continuity, high neatness, good accessibility, high level of greening on both sides, small spacing between trees and lush plants (20, 22, 6, 11). The middle of the road with a wider road surface was either equipped with a railing (01, 03, 11) or a green belt to divide the road. The middle of the road with a wider road surface was either equipped with a railing (01, 03, 11) or a green belt to divide the road. Trees and greenery were planted to separate the motor vehicle lane from the bicycle lane, in the bicycle lane from the sidewalk as well. This enhanced road safety (17, 11).The predominantly red and off-white historic building heritage park extended north-south within the historic district and positively influences the surrounding landscape (01).The architecture of the commercial area had a modern feel (06, 03). Part of the construction section of the commercial area to remediate and repair the road façade. The construction section affects the surrounding visual environment but was rich in greenery. It had good overall visual quality (06). The residential area was full of life. The street volume was small and easy to manage. The streets with mainly residential functions were planted with trees with large canopies to form shade to block car exhaust and noise, creating a quiet and livable environment (03, 22).

The 20th street had the best landscape visual quality (0.294), with the highest landscape visual quality (0.748) in the 2024 sample in the comparison of the mean visual quality of all streets. The sample was located in the spacious and clean southern section of Dongbinhe Road in Shenyang's urban core. The east side of the road was a waterfront park with a relatively open view of the sky. The west side had relatively low and scattered residential buildings. Street trees on both sides of the street were relatively dense, plants are planted in a regular and orderly manner, forming a strong natural atmosphere. The best landscape visual quality for this sample was achieved with the combination of natural landscape elements and artificial landscape elements.

NO.20

NO.22

NO.06

Fig 4-22 Panoramic pictures of high-visual quality streets

(2) Low-visual quality streets

Old neighborhoods with dense buildings in disrepair, old facades, dirty road environments and low greening levels (23, 09, 10, 13). There are dilapidated and unmanaged buildings in some areas with sparse surrounding vegetation (23, 09). New construction in the area where the old and new settlements alternate crowded the green space, resulting in the occupation of the original road. A large number of store plaques of different colors, styles and sizes exist along the residential area. The trees on both sides of the road had large canopies, blocking the view of business and poor visual effects (09, 10). The roads in the residential area were narrow. The movement of people and vehicles is disorderly (09). The wall enclosure forms an enclosed space with low sky visibility (19). Some of the street sides were parked by motor vehicles, which intensified the sense of disorder in the spatial environment and negatively affects the landscape visual quality (13). The commercial area was thinly greening, with widely spaced street trees, sparse foliage and small crown size (12). The road width was wide with tall buildings, broken traffic signs, no plant decoration along the street and too open space (12).

In the comparison of their average value of visual quality of all streets, the 10th street had the lowest average value of landscape visual quality (-0.226), where the lowest value 1016 sample (-0.856) was located in the core commercial area of Shenyang. The sampling site was located at the intersection of Chaoyang Street and Middle Street as a typical commercial street. The road with a large number of people and vehicles mix was narrow, making the street space very chaotic order. The surrounding dense cluster of high-rise buildings encroaches on the sidewalk while blocking the sky, exacerbating the sense of closure of the overall street space. The streets were not planted with vegetation resulting in heavy artificiality and low overall street visual quality.

NO.18

NO.13

NO.10

Fig 4-23 Panoramic pictures of low-visual quality streets

4.4.4 Conjoint analysis of streets visual quality in Shenyang core areas based on visual perception characteristics

By conjoint analysis the streets visual quality in the core area of Shenyang with its four related visual perception characteristics, in order to reveal the influence of different visual perception characteristics on the streets visual quality and make a detailed, complete evaluation of the street environment to further determine the optimization strategies for different streets. (Table 4-13).

Table 4-13 Comparison analysis between of visual quality and perceptual characteristics

Street number	Visual quality average	Green space factor	Building area ratio	Vehicle occurrence rate	Pedestrian occurrence rate
20	0.294	0.381	0.103	0.195	0.016
22	0.247	0.339	0.102	0.204	0.019
6	0.102	0.155	0.147	0.191	0.006
11	0.046	0.169	0.212	0.153	0.012
17	0.035	0.148	0.235	0.127	0.008
3	0.032	0.210	0.199	0.204	0.016
1	0.020	0.184	0.238	0.156	0.012
5	0.013	0.183	0.228	0.164	0.016
14	-0.011	0.182	0.227	0.199	0.013
2	-0.029	0.118	0.230	0.171	0.011
4	-0.034	0.232	0.194	0.270	0.026
19	-0.050	0.178	0.255	0.165	0.024
7	-0.115	0.152	0.243	0.239	0.021
21	-0.134	0.136	0.282	0.184	0.023
23	-0.135	0.162	0.260	0.240	0.023
9	-0.174	0.131	0.248	0.224	0.038
12	-0.178	0.064	0.307	0.170	0.014
18	-0.179	0.121	0.290	0.211	0.023
13	-0.196	0.107	0.277	0.244	0.020
10	-0.226	0.162	0.273	0.266	0.039

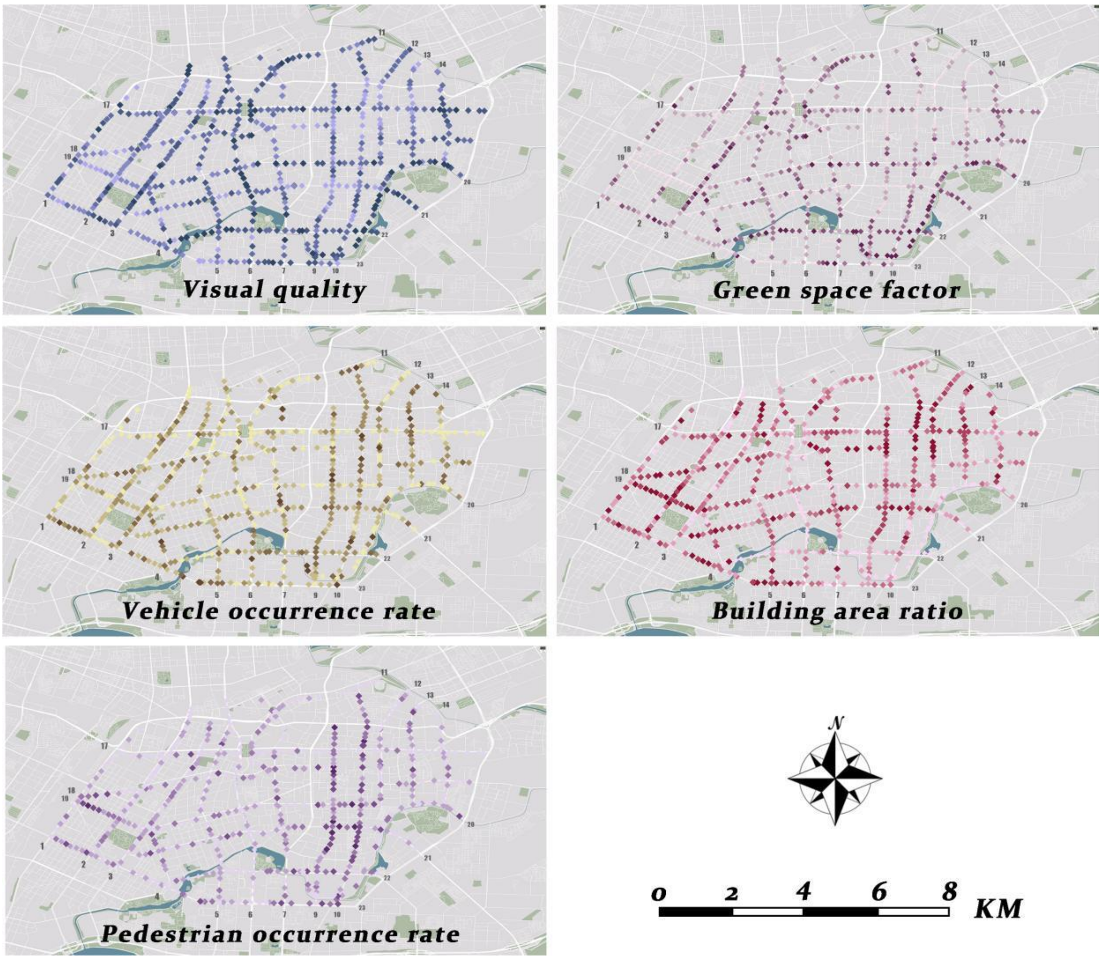


Fig 4-24 Streets Visual quality in the Shenyang core area with its four related characteristics

A conjoint analysis of the streets visual quality in the core area of Shenyang with its four related visual perception characteristics (green space factor, building area ratio, vehicle occurrence rate and pedestrian occurrence rate) can be found.No.20, No.22 and No.6 street obtained the high visual quality, the comparison shows that.No.20 and No.22 street had the high green space factor and low building area ratio, they were near the southern of the core area and close to the open water and green space parks, the surrounding road space had more intensive planting, the road environment was beautiful and highly green. At the same time, the variety of green facilities created a high green coverage ratio, the residential area on the west side of Dongbinhe Road at No.20, South Canal Waterfront Park on the east side, the low residential buildings on the west side, It was largely obscured by boarder trees, which created a relatively low Building area ratio.No.22 was Wenyi Road, its road space also had dense planting, while the narrower road makes the perception of the street green space factor overall high.No.6 was Qingnian Street, it was one of the main north-south roads in Shenyang and the main line of the Golden Corridor project, as a famous landscape demonstration road, its overall green space factor was high, the southern section had a scenic Qingnian park, the east and west of the northern section is full of high-rise building.

No.10 obtained the lowest visual quality among the core area of Shenyang, it consisted of the northern section of Dabei Street, the middle section of Chaoyang Street and the southern section of Danan Street. Comparing the four visual perception characteristics, it can be found that the overall green space factor of the street is the lowest. But the building area ratio, pedestrian occurrence rate and vehicles occurrence rate were high. The middle section of Chaoyang Street was located at the core commercial district of Shenyang, this area had dense commercial building clusters. The road was narrow, crowded and mixed with pedestrians and vehicles, the planting was very sparse, the streetscape was heavily artificialized and lacks a sense of nature. Multifaceted common factors contributed to the lower visual quality of No.10. The green space factor of No.13 and No.18 overall low, the street space was sparsely planted, the surrounding residential building had many floors, Mixed commercial and residential road result in a high pedestrian occurrence rate and vehicles occurrence rate.

In general, the southeast side of the area where was near the Nanyun River and along the line of waterfront park obtained the high streetscape visual quality. We also found that there was a difference in visual quality, even in the same street. For example, in the No. 3, the southern section of Heping South street had a high visual quality compared with the northern section of Heping North street. The reason was the north and south parts of the street had different functions, the area around the northern section had more residential neighborhoods and the building facade was more dilapidated. The southern section was mainly for resting and viewing, its street green coverage ratio was high, the vegetation configurations were varied, creating a large difference in the street visual quality at both ends of the same street. In general, the mean values of visual quality in the south of the Shenyang core area was higher than the north. The visual quality of the Outside Street within the area was higher than the Interior streets.

From BSV images, we can clearly know that the more vegetation in the street space, the smaller building volume there were.No.10, No.13 and No.18 obtain the lowest visual quality, their street space have dense high-rise buildings, while the vegetation along the roadside was very sparse. No.18 was Zhongshan Road, although it had many trees planted, the overall public visual perception of the street was affected by the narrow street.

4.5 Discussion

4.5.1 Streetscape visual quality

In this study, green and open views can increase the beauty of the city [52], Wide street spaces not only had good openness, but also the higher road grades had more green space factor and management levels, brought people a stronger sense of safety [53]. The single greening layers and less greening on the facade created a poor streetscape visual quality. As studies had shown, the more greening structure layer, the more Greening ornamental and the more positive emotions it evoked [54]. Road green belts are laid out with grassland, flowers, shrubs and other plant elements [55], this study found that closure diminishes the spatial quality, which was consistent with Tang and Long's study, they found that openness can increase the attractiveness of the streetscape and improves the comfort of public activities. The construction of narrow road can improve the landscape permeability along the street and reduces the closure, by reducing the wall enclosures and appropriately increasing small plazas on the street cover the construction fence, reduced the negative impact on visual quality. The old building facades can be shaded by adding facade greenery while repairing them in a time.

4.5.2 The relationship between visual perceptual characteristics and visual quality

By analyzing the correlation between the five visual perceptual characteristics and the corresponding visual quality, urban street greening had long been considered an important landscape design element in urban environments. People often had a better psychological feeling when they were in a pace with a high degree of greenery, the places with a high green space factor, there space atmosphere were more natural and easy to create a friendly and relaxed atmosphere. The vegetation increased people's aesthetic evaluation of the urban landscape [57-58]. Van Herzele and De Vries' study showed that urban greening can bring a sense of pleasure and happiness, promoting people's emotional and psychological. In addition, the functions of urban street greening, including purifying the air [59] alleviating the urban heat island effect [60] and reducing the noise pollution, all of them can effectively improve the pedestrian walking experience in the street. A street space with many vegetation and a good green landscape layer can often create a comfortable and quiet street experience. Based on the analysis of the green space factor of the Shenyang core area, its green space factor (0.173) was far less than Yoji Aoki (1991) pointed out that when the visible proportion of greenery was greater than 30%, it proved to be a more popular urban streetscape. Increase the green space factor of the space by optimizing the street trees, ground greening along the street, vertical greening and street corner green space. In addition, in the practice of urban design and transformation, attention shedould be paid to the density and height of green plants on both sides of the street and the relationship with the scale of the street, considering the overall aesthetics and hierarchy. When the canopy of street trees covers too much, it is easy to form a large area to block the sky, creating a darker space and affecting people's visual perception, so the canopy amplitude of street trees should be controlled and management and maintenance should be strengthened in time.

Building area ratio, vehicle occurrence rate and pedestrian occurrence rate showed negative correlations with SBE values in this study. Previous studies had shown that building area ratio can affect the perception of visual quality of street space more intuitively and profoundly than other visual perception features. Studies had shown that the higher enclosures created by higher building area ratio reduced the visual perception of pedestrians in the street space. The interface aesthetics of the street frontage of its urban street buildings also had an important impact on the perception of the street [61]. To enhance residents' aesthetic perception of the street, it was necessary to increase the openness of specific areas. Demolition of some dangerous houses thus improving the sky view ratio of the area. It allowed for a higher sky view factor and created a better visual experience.

The number of lanes, motorized and non-motorized vehicles and the dynamics of street users affect the order of the street. The street as a traffic space was psychologically burdensome [62]. It reduced the public's aesthetic perception of the street. In the urban spaces, in most cases people and vehicles move forward in confusion. The vehicle appeared to slow down with stalling in the case of narrow space. Crowded roads had a serious impact on people's walking experience in the streets. Therefore, the road planning of city streets should be as clear as possible, dividing pavement, non-motorized lanes and motorized lanes to create a well-ordered traffic road environment. In addition, according to the actual situation, urban planner should use of railings, height difference, pavement color texture to improve the overall image of the city street pavement. Pedestrian detours can be effectively reduced by optimizing street access, reducing the number of roadway intersections and adjusting roadway fencing to improve pedestrian conditions. The addition of street features and micro-landscape elements can enhance both the vibrancy of the street and the pedestrian experience. Furthermore, aesthetic preference and visual appeal can be enhanced through the addition of distinctive streetscapes and compelling visual elements [63].

4.5.3 Streetscape visual quality in core area of Shenyang

The high-quality streets in Shenyang core area generally had humanized streetscape such as good greenness and reasonable building area ratio, however, the low-quality streetscape always lack these key elements and rational relationship between the key elements. In addition, the overall results of this assessment, in agreement with results from Shenyang residents' perceptions of street perception. No.20 and 22 were streets along the South Canal waterfront, various cultural and art venues, landscape sculptures and residential buildings were distributed in the streets, there was beautiful street environment. Their street quality was higher than others because other streets lacked attention to human visual perception under the functionalism planning developments of the past decades.NO.20 street was the highest SBE street in visual quality map, it also agree with the general consensus of the locals.

In the future urban planning of Shenyang, for the design of urban street greening, there were differences in the requirements of street greening for different functions of streets, such as in the core old town with mainly residential buildings, there should be plant large trees to make up a continuous shade trees to block the noise and exhaust fumes from the carriageway to the residential area and then created Private and quiet living space. Increasing the proportion of green space by building small-scale and vertical greening to improve public's psychological feeling and enhance the aesthetics of community streets. There should be create an open green landscape by reducing plant canopy width and increasing planting spacing to avoid blocking the human sighting of businesses along the streets. In terms of building area ratio, large building facades in street space reduce public preference, which was consistent with the attention recovery of architectural scenes theory [64-65]. Therefore, the design of building facade on both sides of the streets should be reduce its functionality and poorly designed aesthetic buildings, to avoid building architectures that are not in line with public aesthetics, minimize the use of fences which easily blocked the view, climbing plants should be used to beautify the street facades of buildings. In addition, due to the different functions of the streets and spaces, it is necessary to control the building interface on both sides of the street to avoid the situation which the closed wall completely isolates the view for the public. Under the conditions, it was possible to improve people's visual aesthetic feeling by setting up functional places for people to interact and communicate as well as corresponding greening facilities. The maintenance of pavement and public facilities in the urban street space can directly reflect the degree of management of this block and then directly affecting the visual quality of urban streets in Shenyang.

4.6 Limitations

Although this study has its merits, there are several aspects which still worth discussing in the future. First, the assessment results in this study are mainly perception-based visual quality, without considering aspects such as sound, odor, and noise, many issues have not discussed in this study, for example, human emotion and sense of community are not included.

Second, landmarks and other famous buildings as important visual endpoints in the urban environment have a very important effect on the street visual quality. Due to the lock of building audit data, especially the location of unique landmarks and the number of buildings with non-rectangular profiles, the visual perception characteristics which defined by building area ratio, it may show deviations that do not correspond to the real situation, therefore, having more accurate image segmentation semantic data will help produce more accurate data results.

Third, physical characteristics of the built environment, such as cross-sectional proportions, the continuity in street, ornamentation and materials, visual importance and the sensory effects on human scale streetscape perception.

4.7 Summary

As a prospective empirical study, this chapter uses BSV streetscape images and semantic segmentation Calculation to affect the visual perception characteristics of the public aesthetic evaluation, explains the association between the scenic beauty estimation of urban street and public visual perception characteristics from different perspectives. It provides an effective strategy for the regeneration of urban streetscapes.

The main visual perception characteristics and their spatial distribution of streets in the urban core of Shenyang had been obtained. In the core area of Shenyang, distribution status of green space factor showed a low level in the center and a high level in the periphery. In addition, the green space factor of streets in the downtown at a low level. The study found that the building area ratio of the core area was high, the core commercial area and historic district had the highest building area ratio.

In addition, this chapter evaluated the visual quality of streetscape based on the SBE method. In order to construct a model to evaluate the streetscape visual quality in the core area of Shenyang, the correlation and regression analysis were used to analyze the relationship between the streetscape visual quality and visual perception characteristic. The results showed that the green space factor was a positive indicator, which impacted the public's aesthetic evaluation of urban streets. The building area ratio, vehicle occurrence rate and pedestrian occurrence rate had a negative effect on visual aesthetic.

Meanwhile, urban streets with lower LVQ were identified as the key areas for urban renewal according to the results of the streetscape visual quality in the core area of Shenyang. Urban planner can optimize greening plant design of street to effectively enhance the street green space factor and reduce the building area ratio; controlling the height and volume of new buildings to avoid excessive building area ratio. In the commercial streets or historic district, the one-way street of vehicle planning design was needed to reasonably adopt to reduce traffic congestion and effectively reduce the vehicle occurrence rate for the purpose of efficiently improving the overall visual quality of core area in Shenyang.

In addition, this study extends the deep learning-driven research paradigm, reveals the visual perceptual characteristics which influence the urban streets visual quality. We uses semantic information from a large number of BSV streetscape images to construct an analysis framework for visual characteristics.

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Chapter 5

LANDSCAPE VISUAL QUALITY MODEL OF SHENYANG URBAN WATERFRONT PARK

CHAPTER FIVE: LANDSCAPE VISUAL QUALITY MODEL OF SHENYANG URBAN WATERFRONT PARK

5.1 The Hunhe river

5.1.1 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 [1][2][3][4][5], which was an important space for the public to leisure, entertainment, fitness and communication [6][7][8][9], and it has a unique and important significance to the urban environment [10][11] 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 [12][13]. 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 [14][15][16]; the spatial continuity of various landscape elements [17]; the conservation of ecosystems[18], and the following user requirements[19].

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 [20], has hydrophilic and green recreation space [21][22], reflects spatial order with linear landscape characteristics, which can change the scenery with the visitors walking reflects the landscape continuity of park [23], it can purify air [24], improve the viability of aquatic ecosystems [25][26]and upgrade ecological environmental quality and social culture[27]. 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 [28][29][30]; the establishment of waterfront plant landscape evaluation system has made the reaction to the aesthetic public aesthetic preferences [31].[32]; some methods, such as big data and mobile phone location data have applied to analyze the vitality of the waterfront open space [33]. The comprehensive evaluation of urban waterfront landscape by the POE method has could realize the public participation. The AHP method has been applied to construct urban river landscape evaluation model [34][35], waterfront landscape evaluation and suitability analysis [36][37][38]. The GIS technology has determined the stability of watershed environment [39][40], and Scenic Beauty Estimation (SBE) Method has been applied to quantitatively analyze the waterfront landscape [41][42][43][44].

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[45][46][47] (Andrew Lothian 1999, Daniel T. C. 2001, Gonzalo de la Fuente de Val et al. 2006). Some various methods have been developed, among which the most accurate and rigorous method has been the evaluation of a psychophysical model [48][49][50][51][52][53](Daniel Terry C. and Boster Ron S. 1976, Roger S.Ulrich 1986, Ervin H. Zube 1987, S.Kaplan, R.Kaplan 1989, A.TerrencePurcellaRichard JLambb 1998, Daniel T. C. 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 [54][55][56][57][58](Daniel T. C. 2001, Hands D. E. and Brown R. D. 2002, Meitner M. J. 2004, Clay G. R.and Smidt R. K. 2004, Arriaza M. et al 2004, Acar C. et al 2006). Based on SBE method, it was found that the ecology, diversity, vividness and maintainability [59][60][61][62]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 [63]. Visual quality assessment has developed to multi-sensory experience, multi-scale and multi-angle simulation, and Ease of user evaluation [64]. In order to explore the influence of forest landscape [65][66], landscape spatial pattern [67], park landscape [68][69], vegetable landscape [70][71], rural landscape [72] 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 [73]. 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 [74][75]. 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.

5.1.2 Methods

5.1.2.1 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 riversides, 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, Wulihe Park, Changbai Park and Changqing Park, each park includes a waterfront trail and a greenbelt trail.

Fig 5-1 Distribution of the waterfront linear parks on both sides of the Hunhe river

Distribution map of the waterfront linear parks (Fig 5-1) 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 wrail 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.

Changbai Park is located in the westernmost part of Hunhe Park. The coastline is 1.9 kilometers long, average width of the park is 235 meters. Several observation platforms were connected by wooden walkways with a length of two kilometers, and visitors can enjoy the magnificent view of the park. The main vegetation on the greenbelt path is Canadian poplar, accounting for 85% of the total deciduous trees in the park. In addition, there are several activity fields in the greenbelt trail.

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 acquatic 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.

5.1.2.2 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 . It has been applied frequently in previous studies[76] [77]. 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) (Fig 5-2) 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 horizonta 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 (Fig 5-3). 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.

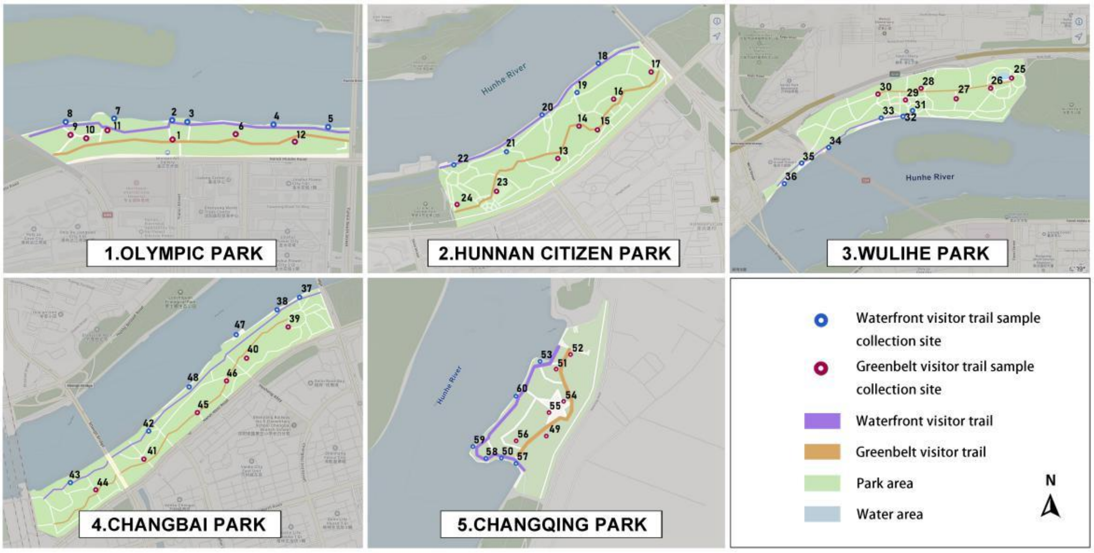


Fig 5-2 Samples points and trails distribution of each park


Photo 17


Photo 18


Photo 19


Photo 20 (SD)


Photo 21


Photo 22 (SD)


Photo 23 (SD)


Photo 24


Photo 25 (SD)


Photo 26 (SD)


Photo 27


Photo 28


Photo 29 (SD)


Photo 30 (SD)


Photo 31


Photo 32 (SD)


Photo 33


Photo 34


Photo 35 (SD)


Photo 36


Photo 37


Photo 38 (SD)


Photo 39 (SD)


Photo 40


Photo 41


Photo 42


Photo 43 (SD)


Photo 44


Photo 45 (SD)


Photo 46


Photo 47


Photo 48 (SD)

Fig 5-3 The 60 photos of SBE method(25 photos of SD method)

5.1.2.3 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 [78]. Students were widely used as respondents in relevant studies because of their efficient work [79][80][81][82]. Meanwhile, the LVQ preference of different major students had similarity [83]. 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 [84]. 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 seconds. This presentation aimed at helping observers to create their own criteria before the evaluation process. In the evaluation, each sample photo was shown 15 seconds apart, on a seven-point scale ranging from 1 (very dislike) to 7 (very like) . 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. 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).

$$Z_{ij} = \frac{(R_{ij} - \overline{R_j})}{s_j} \qquad (1)$$

$$SBE_i = \sum Z_{ij}/N_j \qquad (2)$$

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 j .

$\overline{R}_j$= 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 5-1). 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 minutes, 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. After checking the evaluation results, 30 evaluation tables were obtained, all of which were valid.

Table 5-1 Characteristics of landscape and adjective groups in SD method

Evaluated item	Adjectives in pair
Sense of space	Cramped&wide
Landscape layering	Single-layer&muti-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-secluded
Vitality	Unvital&vital
Sense of safety	Dangerous&safe
Element richness	Scenic components are single&scenic components are rich
Interestingness	Boring&interesting

5.1.2.4 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 variablesmay 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.

5.1.3 Result and analysis

5.1.3.1 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 [85][86].

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 Canas I [87].

5.1.3.2 Evaluation of SBE

By sorting the landscape quality of the 60 samples photos (Table 5-2), 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 5-3) 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 5-2 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	0.639	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

By comparing the landscape quality mean values of the waterfront trails with the greenbelt trails in Table 5-2, 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.

Table 5-3 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 trail mean value	Greenbelt trail mean value
Olympic Park	7	0	0.238	0.315	0.199
Wulihe Park	4	1	0.179	0.058	0.220

Changqing Park	5	2	0.124	0.168	0.093
Changbai Park	3	8	-0.176	-0.099	-0.283
Hunan Citizen Park	1	9	-0.371	-0.366	-0.372

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 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 cramped 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).

5.1.3.3 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 .

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 (2.733 < 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 5-4), 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.

Table 5-4 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	2.633	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 5-5 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
Lntactness	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 5-6 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	3.394
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 5-7 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	3.533	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	2.767	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	3.133	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

Table 5-8 Changqing 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
Conspicuousness	3.167	4.100	3.033	3.667	3.492
Intactness	3.467	3.800	3.100	3.800	3.542
Harmony	3.233	4.133	3.167	3.867	3.600
Degree of spatial variation	2.700	3.733	2.133	3.233	2.950
Sense of rhythm	3.067	3.267	2.267	3.400	3.000
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 5-9 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 green belt 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	3.212	3.314	3.269	0.463
Conspicuousness	4.100	55	2.430	20	3.148	3.212	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	4.333	25	2.367	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

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 5-9), 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.

5.1.3.4 Landscape visual quality model

SPSS 25.0 was used to analyze correlation between visual quality and landscape characteristics of 25 sample photos. Table 5-9 indicated that the sense of space p-value was bigger than the significance level (significance level of a=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).

Table 5-10 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	0.461*	0.020
Approach	0.717**	0.000
Element richness	0.486*	0.014
Tidiness	0.671**	0.000
Density	0.745**	0.000
Attractiveness	0.834**	0.000
Mystery	0.826**	0.000
Uniqueness	0.724**	0.000

Sense of seclusion	0.597**	0.002
Vitality	0.881**	0.000
Sense of safety	0.403*	0.046
Comfort	0.798**	0.000
Interestingness	0.759**	0.000

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

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

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 5-11 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 5-11 showed that the regression analysis was statistically significant because R square was 0.999 . However, 16 characteristics in Table 5-6 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 ($p < 0.05$). The variables had a high correlation and it were independent of each other, which could be used for principal component analysis.

Table 5-11 Backward regression coefficient

		Unstandardized coefficients		Standardized coefficients			Collinearity statistics	
Model		B	Std. Error	Beta	T	Sig.	Tolerance	VIF
4	(Constant)	-1.89	0.251		-7.516	0		
	landscape layering	-0.288	0.128	-0.302	-2.242	0.066	0.02	49.801
	Unity	0.236	0.078	0.213	3.032	0.023	0.074	13.584

	Intactness	-0.625	0.119	-0.514	-5.253	0.002	0.038	26.356
	Harmony	0.649	0.095	0.694	6.823	0	0.035	28.433
	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	0.508	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

Note: Dependent variable: standardized value R Square=0.999 F=152.419

The total variance explained (Table 5-12) 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 were noted as f1,f2 and f3, they could represent the 18 landscape characteristics to analyze the visual quality of the waterfront linear parks.

Table 5-12 Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	11.788	65.488	65.488	11.788	65.488	65.488
2	2.514	13.964	79.452	2.514	13.964	79.452
3	1.135	6.307	85.76	1.135	6.307	85.76
4	0.767	4.261	90.02			
5	0.539	2.994	93.015			
6	0.378	2.102	95.117			
7	0.208	1.157	96.274			

8	0.195	1.086	97.36			
9	0.124	0.687	98.047			
10	0.11	0.613	98.66			
11	0.084	0.465	99.125			
12	0.053	0.295	99.42			
13	0.042	0.236	99.656			
14	0.026	0.146	99.802			
15	0.013	0.071	99.873			
16	0.011	0.063	99.936			
17	0.006	0.034	99.97			
18	0.005	0.03	100			

Note: Extraction method: principal component analysis.

By Table 5-13, 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.

Table 5-13 Rotated component matrix

			Component	
		1	2	3
X1	Landscape layering	0.896	-0.031	0.263
X2	Unity	0.402	0.666	0.428
X3	Intactness	0.482	0.626	0.42
X4	Harmony	0.698	0.459	0.424
X5	Degree of spatial variation	0.911	0.009	0.254
X6	Sense of rhythm	0.86	-0.134	0.139
X7	Sense of order	0.559	0.106	0.646
X8	Ecology	-0.132	0.909	0.047
X9	Approach	0.584	0.306	0.646
X10	Tidiness	0.519	0.152	0.702

X11	Attractiveness	0.831	0.365	0.363
X12	Mystery	0.797	0.438	0.349
X13	Uniqueness	0.856	0.362	0.117
X14	Sense of seclusion	0.082	0.926	0.115
X15	Vitality	0.544	0.674	0.385
X16	Sense of safety	0.033	0.196	0.886
X17	Comfort	0.658	0.482	0.508
X18	Interestingness	0.872	0.303	0.205

Note: Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 5 iterations.

Analytical expressions for each principal component was as follows.

F1=0.233stdx1+0.234stdx2+0.246stdx3+0.273stdx4+0.240stdx5+0.195stdx6+0.228stdx7+0.093stdx8+0.259stdx9+0.233stdx10+0.282stdx11+0.282stdx12+0.253stdx13+0.134stdx14+0.260stdx15+0.155stdx16+0.279stdx17+0.262stdx18 (1)

F2=-0.295stdx1+0.238stdx2+0.197stdx3+0.030stdx4-0.283stdx5-0.338stdx6-0.094stdx7+0.532stdx8-0.004stdx9-0.052stdx10-0.066stdx11-0.018stdx12-0.088stdx13+0.491stdx14+0.192stdx15+0.137 stdx16+0.059stdx17-0.123stdx18 (2)

F3=-0.087stdx1+0.018stdx2-0.012stdx3-0.024stdx4-0.106stdx5-0.156stdx6+0.302stdx7 0.192stdx8+0.249stdx9+0.347stdx10-0.091stdx11-0.110stdx12-0.299stdx13-0.207stdx14-0.066stdx15+0.663stdx16+0.055stdx17-0.212stdx18 (3)

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 follows.

Stdx1=(x1-2.997)/0.537

Stdx2=(x2-3.269)/0.463

Stdx3=(x3-3.276)/0.422

Stdx4=(x4-3.259)/0.548

Stdx5=(x5-2.832)/0.558

Stdx6=(x6-2.829)/0.487

Stdx7=(x7-3.117)/0.474

Stdx8=(x8-3.145)/0.587

Stdx9=(x9-3.273)/0.508

Stdx10=(x10-3.335)/0.563

Stdx11=(x11-2.971)/0.684

Stdx12=(x12-2.983)/0.622

Stdx13=(x13-2.655)/0.592

Stdx14=(x14-3.081)/0.472

Stdx15=(x15-3.147)/0.579

Stdx16=(x16-3.088)/0.448

Stdx17=(x17-3.208)/0.567

Stdx18=(x18-2.755)/0.603

A linear regression model was created with visual quality as the dependent variable and f1, f2, f3 as the independent variables. The regression standardized residual (Fig 5-4) showed that the standardized residual approximate followed a normal distribution with a mean of 0 and a variance of 1. It was also noted that the points of Fig 5-5 were basically scattered on the diagonal of the first quadrant, which meaning the residuals basically obey normal distribution and indicated that the model assumptions were satisfied for these data. The scatterplot (Fig 5-6) showed that the standardized residuals scatterplot against predicted values should be a random pattern centred, they around the line of zero standard residual value. In the standardized residuals, the scatter fluctuations range is not vary with the change of the standardized predicted values. From the above analysis, 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 5-9 and yielded the linear regression equation.

Y=0.134 f1+0.064 f2-0.064 f3-0.024 (4)

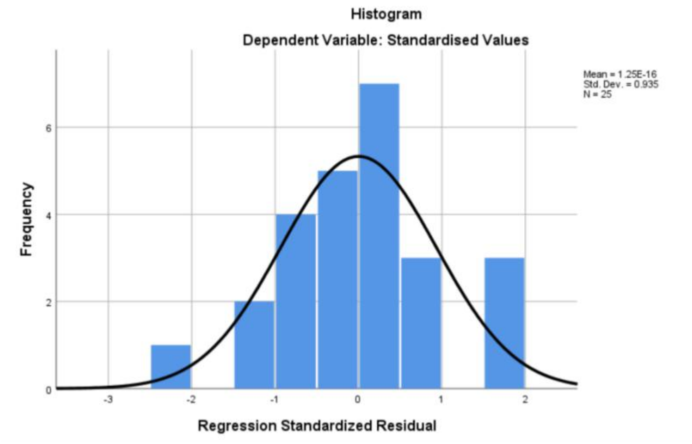


Fig 5-4 Regression standardized residual

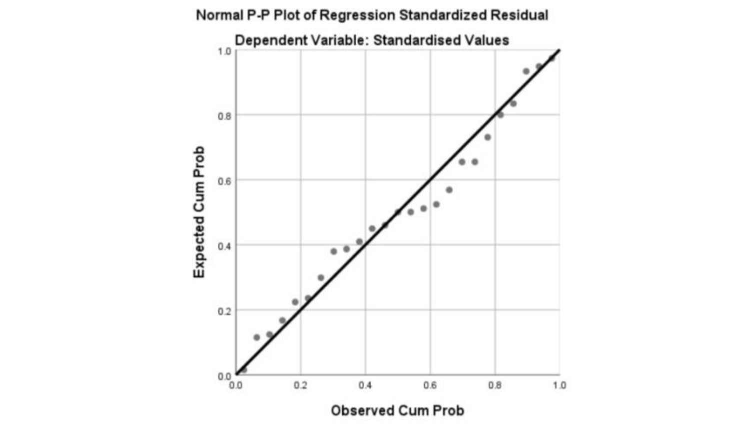


Fig 5-5 Normal P-P plot of regression standardized residual

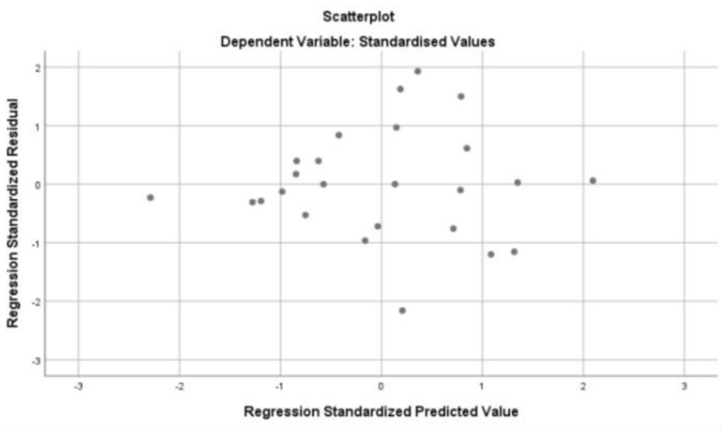


Fig 5-6 Scatterplot

Table 5-14 Regression coefficient

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std.Error	Beta			Tolerance	VIF
(Constant)	-0.024	0.051		-0.471	0.642		
F1	0.13	0.015	0.853	8.501	0	1	1
F2	0.064	0.033	0.194	1.933	0.067	1	1
F3	-0.064	0.049	-0.129	-1.289	0.211	1	1

Dependent variable: standardized value R Square=0.789 Adjusted R Square=0.759

The standardized Beta coefficient (Table 5-9) 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:

$$Y=0.031x1+0.097x2+0.108x3+0.07x4+0.035x5+0.028x6+0.010x7+0.099x8+0.033x9+0.009x10+0.05x11+0.06x12+0.078x13+0.134x14+0.086x15-0.031x16+0.064x17+0.066x18-3.224$$

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.

5.1.4 Discussion

5.1.4.1 Landscape elements

The study confirmed that the water had a significant impact on landscape aesthetic preferences [88][89][90]. 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 [91]. Wide and clear water could positively enhance public perception of the visual quality of the waterfront landscape [92], in agreement with results from Bulut and Yilmaz, Dramstad et al. and Howley's demonstrated that water had an important effect on it. R.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[93]. 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 [94]. 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 also emphasized the positive influence of waterfront plants on the landscape quality of waterfront in his research [95]. The construction of high-rise buildings was inevitable for the development of the urban waterfront areas[96] . 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 [97]. Other research based on perception suggests: plant community was a important factor affecting the landscape aesthetic value [98] and abundant plant species and reasonable proportion of trees, shrubs and herbs could effectively improve the visual quality of the greenbelt trails [99]. The importance of ecology was fully supported by the literature of landscape perceptions and evaluations [100], 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 [101]. But the man-made structures might be a negative impact on the visual quality of the landscape [102]. 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, rockscapes, 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 [103], Bulut and Yilmaz [104] emphasized its negative impact on visual quality.

5.1.4.2 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.

5.1.4.3 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 [105][106] is consistent with this paper. Meanwhile, Wherrett Joanna Ruth , RonghuaWang et al andA.T. Purcell [107] had determined that there was a negative correlation between artificial elements and visual quality. Jun Yang et al, C. Y. Jim et al also deemed that artificial elements such as buildings and roads could affect the publics 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" [108][109]. 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 [110]. 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" [111]. 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.

5.1.5 Summary

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 effective measures to control the landscape impact of the high rise buildings around the parks and reducing its visual pollution, giving full play to the linear advantages of the waterfront linear park,strengthening the landscape of Important visual space node,enhancing the interactivity between the open space and people, and improving the landscape layers.

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.

5.2 The South Canal

5.2.1 Methods

5.2.1.1 Study area

In this study, three parks along the South Canal, namely Nanhu Park, Qiannian Park and Wanliutang Park, were selected as the study area in Shenyang, China. Nanhu Park is located in the western part of the South Canal, Qiannian Park is located in the central part of the South Canal, as well as Wanliutang Park is located in the eastern part of the South Canal(Fig 5-7).

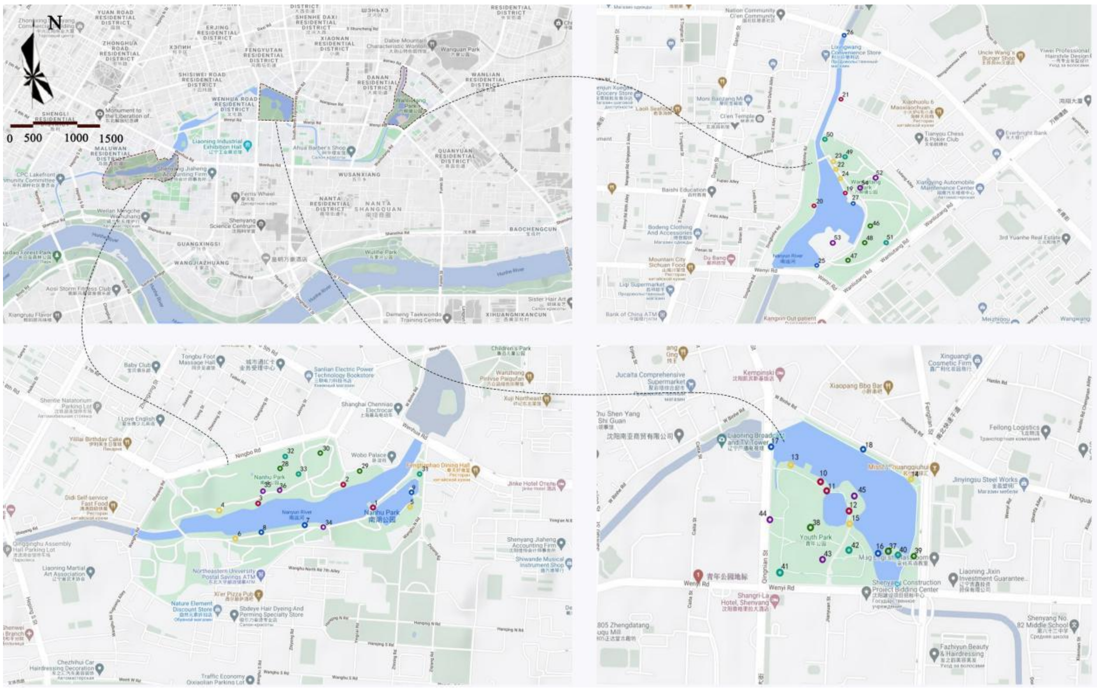


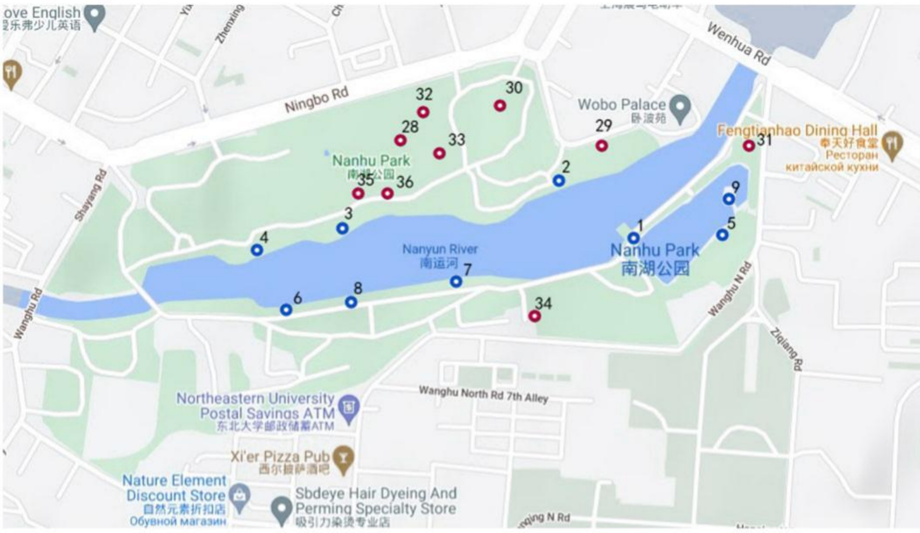
Fig 5-7 Distribution of the waterfront parks on both sides of the South Canal

The South Canal is an important part of Shenyang's water system around the city, stretching 14.5 kilometers. Including water, greenery, parks, roads, street and other functions into one, formed the clear river, lush greenery, continuous attractions, unobstructed road, beautiful scenery of city ecological corridor, not only functions significantly in regulating climate, purify air, reduce noise, amenity and improve ecological environment and other functions, at the same time also has the effect such as flood control, drainage, sewage treatment,river diversion. Nanhu Park covers an area of 52 hectares, including 12 hectares of water, with green land, flowers, trees, water, Bridges.The Qingnian park covers an area of 29 hectares, of which 14 hectares of water, and each small scenic spot with its own characteristics is built here.Wanliutang Park covers an area of 31 hectares and is famous for the variety and large number of willows.

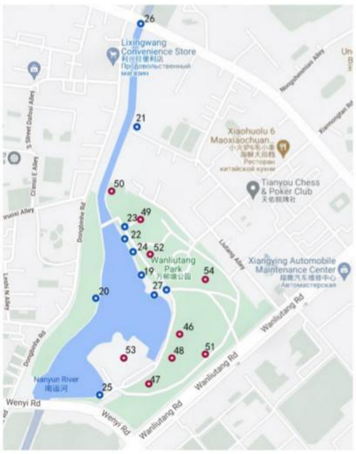
5.2.1.2 Sample selection and acquisition

The landscape nodes of the three parks in the South Canal include two types, namely waterfront nodes and non-waterfront nodes. In this study, these two types of landscape are divided into six spatial types, namely waterfront activity site landscape, waterfront road landscape, open space landscape and non-waterfront activity site landscape, non-waterfront road landscape and non-waterfront open space landscape.

In this study, six typical node Spaces were selected in each park, there where three sampling points that best represent the spatial characteristics of each space to collect photos,total of 54 sampling points (Fig 5-8).



Nanhu Park



Wanliutang Park

Qingnian Park

Fig 5-8 Samples points of each park

The photos were taken from May 20 to May 27, 2021, from 10:00 am to 15:00 PM on a clear day. Use camera to shoot at a height of about 1.6 meters without flash. Eight photos were taken at each sampling point, and one of the eight photos was selected as a typical sample photo at the sampling point.

A total of 54 typical sample photos were taken as the evaluation object. In this study, teachers and students majoring in landscape architecture in Shenyang Jianzhu University were used as research observers to score visual preference of park landscape (Fig 5-9). Sixty students participated in the test, and 56 of the test results were valid.

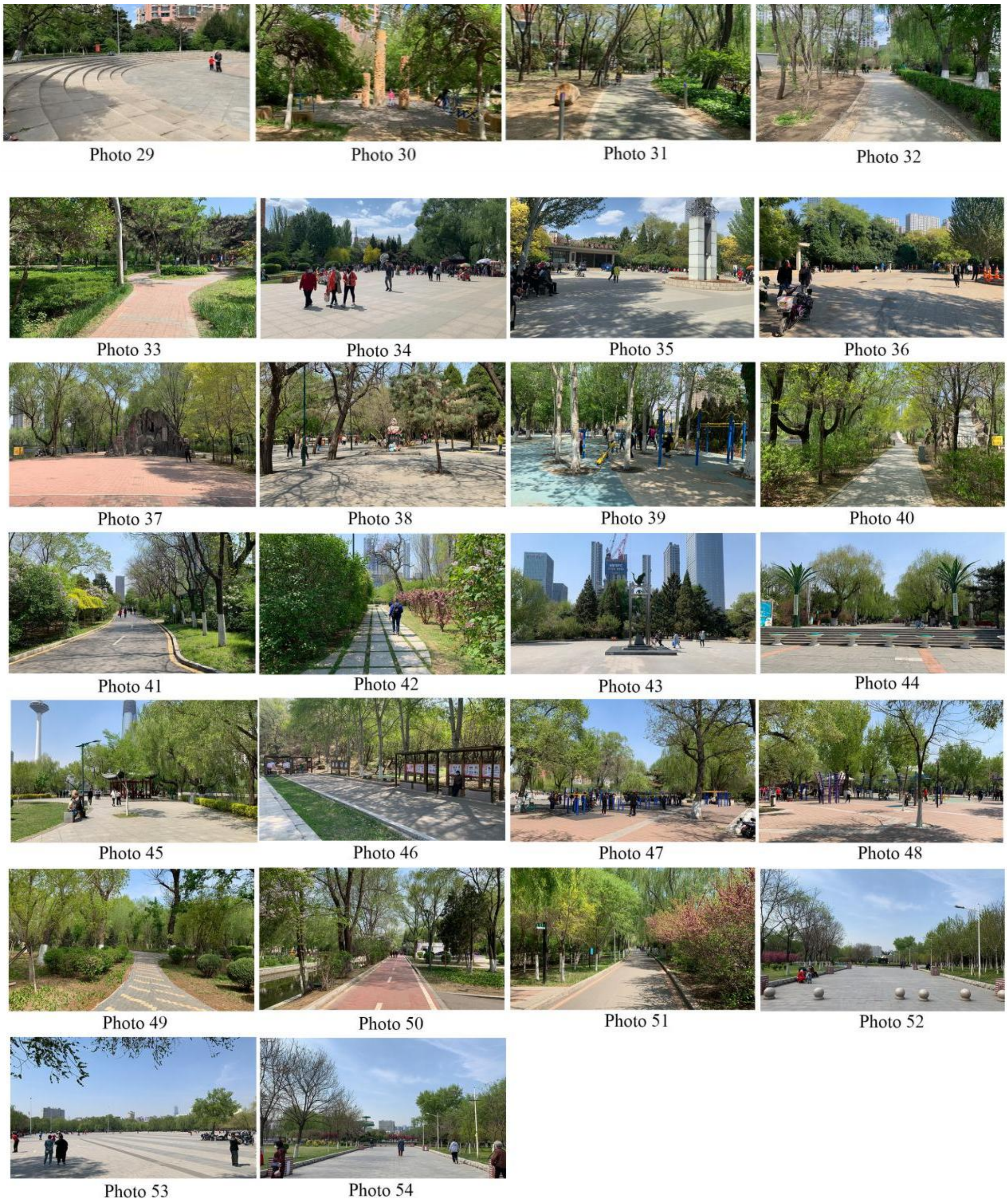


Fig 5-9 The 54 photos of SBE method

The photos of each waterfront park were randomly sorted into a questionnaire applet, and the observer scanned the QR code for online scoring. Observers were asked to rate the visual quality of each image on a scale of 1 to 7. Finally, the collected data were sorted into Excel spreadsheets, which were then converted into SPSS15.0 software to calculate the standardized visual quality score of each photo.

5.2.2 Result and analysis

5.2.2.1 SBE result

The results of the dare vision quality evaluation of the three parks in Table 5-15 show that 25 of the 54 samples have positive SBE values, while the remaining 29 samples have negative SBE values.Among them, the sample quality of Qingnian Park is 10 positive and 8 negative, the sample quality of Nanhu Park is 7 positive and 11 negative, the sample quality of Wanliutang Park is 8 positive and 10 negative (Table 5-15).

Table 5-15 Ranking order of landscape quality for the 54 samples

Sample No.	Trail type	Standardized value	Sample No.	Trail type	Standardized value	Sample No.	Trail type	Standardized value
14	WR	0.948	6	WR	0.123	44	NO	-0.302
5	WR	0.777	50	NR	0.091	24	WR	-0.314
18	WO	0.741	40	NR	0.084	37	NA	-0.350
4	WR	0.687	15	WR	0.039	29	NA	-0.369
51	NR	0.662	49	NR	0.024	22	WR	-0.404
17	WO	0.654	23	WR	0.004	33	NR	-0.405
8	WO	0.633	25	WO	0.001	46	NA	-0.419
7	WO	0.627	27	WO	-0.027	31	NR	-0.453
9	WO	0.620	2	WA	-0.032	38	NA	-0.465
42	NR	0.586	3	WA	-0.036	34	NO	-0.475
26	WO	0.546	54	NO	-0.043	47	NA	-0.505
16	WO	0.503	1	WA	-0.101	48	NA	-0.534
12	WA	0.471	52	NO	-0.168	20	WA	-0.537
41	NR	0.398	43	NO	-0.168	11	WA	-0.550
21	WA	0.358	45	NO	-0.194	32	NR	-0.578
13	WR	0.312	10	WA	-0.203	35	NO	-0.650
19	WA	0.220	30	NA	-0.235	36	NO	-0.662
28	NA	0.777	53	NO	-0.243	39	NA	-0.894

Note: 1-9,28-36 locates in Nanhu Park; 10-18,37-45 locates in Qingnian Park; 19-27,46-54 locates in Wanliutang Park; W stands for waterfront nodes ; N stands for non-waterfront nodes; A stands for activity sites; R stands for road; O stands for open space

Table 5-16 Quantity distribution of high and low quality samples

	Positive value samples quantities	Negative value samples quantities	Total mean value	Waterfront nodes mean value	Non-waterfront nodes mean value
Nanhu Park	4、5、6、7、8、9、28	1、2、3、29、30、31、32、33、34、35、36	-0.02	0.37	-0.40
Qingnian Park	12、13、14、15、16、17、18、40、41、42	10、11、37、38、39、43、44、45	0.42	0.32	-0.15
Wanliutang Park	19、21、23、25、26、49、50、51	20、22、24、27、46、47、48、52、53、54	-0.07	-0.02	-0.13

(1)According to the comparative analysis of landscape quality of waterfront landscape nodes and non-waterfront landscape nodes in each park (Fig 5-10):

Fig 5-10 The south canal visual quality map

For the Qingnian park, it has the most high-quality samples and the least low-quality samples among all parks. Open sky and water, colorful pavement, rich variety, lush, ordered of plants make the tour area full of natural sense, space more hierarchical sense. The reason for the improvement of the overall quality of the park is that the spring flowering plants produce brightly colored flowers which enrich the overall color increase the vitality of the space and the harmony between the plants and the site.

In Nanhu park, the waterfront landscape nodes the quality is outstanding, the open sky and the water, Lush greenery with abundant change and beautiful essay gives a person the feeling of high quality. However, in the non-waterfront node, the landscape quality of Nanhu Park is the lowest among the three parks, with disorderly plants, single color and old pavement.

In Wanliutang park, the overall landscape quality is the worst.At waterfront nodes, messy plants,turbid water, the water surface is covered by waterside plants, and the land is exposed seriously, the river form and revetment form are simple, with poorly hydrophilic, few trees, low green coverage rate, single plant species, and the beautiful natural characteristics of the river disappear and lack of spatial change. At non-waterfront nodes, old, dirty and monochromatic paved surfaces the landscape node lacks plant enclosure.

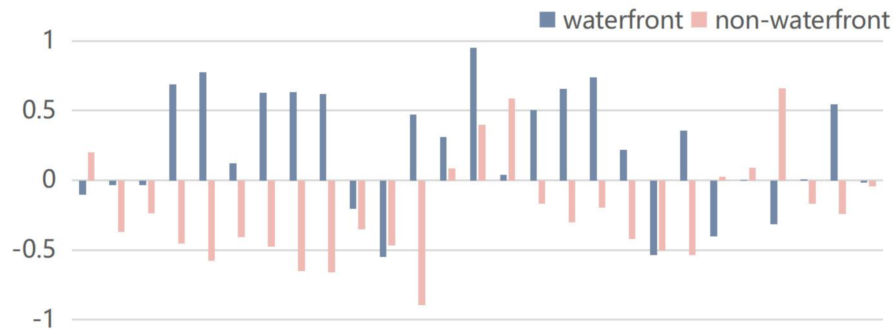


Fig 5-11 SBE comparison between waterfront and non-waterfront

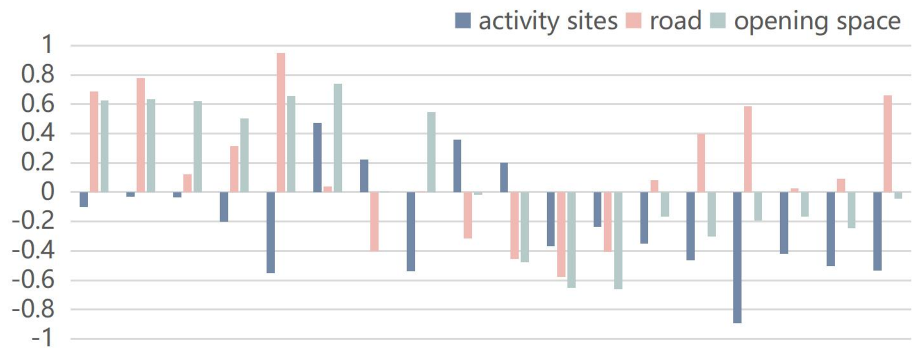


Fig 5-12 SBE comparison of activity sites, road and open space

(2)According to the comparative analysis of waterfront space quality of each park: SBE Nanhu Park waterfront space(0.37)>SBE Qingnian Park waterfront space(0.32)> SBE Wanliutang Park waterfront space(-0.02).

In the waterfront space of Nanhu Park, the vegetation configuration is mainly the multi-layer plant landscape of trees, shrubs and grass, with straight trunks and regular forms, forming strong sense of layering, rich tree shape, colorful(6,9),the water is broad and clear, the pavement style is beautiful, the color is unified, the ground is clean, the surrounding buildings are harmonious with the waterfront landscape, the architecture and furniture type were diverse, include the cultural building,the landscape bridge, the hydrophilic platform, etc(5,7), the sky is open and the view is wide(4,8).

In the waterfront space of Wanliutang Park, there were intensive planting(21,26) and an abundance of plant species(23)in some spaces, however, in other spaces, native vegetation on both sides of the river bank was scarce, landscape types was fewer, and the vegetation is chaotic and single(22,24),water area is small, view narrow, water pollution is serious and the water color was gray green, and water reflection blurred(20,27).

(3)According to the comparative analysis of the non-waterfront space quality of each park: SBE Wanliutang Park non-waterfront space (-0.13)>SBE Qingnian Park non-waterfront space(-0.15)> SBE Nanhu Park non-waterfront space (-0.4).

In the non-waterfront space of Wanliutang Park, the vegetation was colorful ,laying and color contrast beautiful in some spaces(50,51). In other spaces, plants are sparse and cluttered, with dull colors(46,53). And the pavement monotonous, formed by red bricks and stone(47,48,54).

In the non-waterfront space of Nanhu Park, the vegetation coverage rate is low, and the field is uncovered. The plant monochromatic and depressed, monotonous outline, lack of sense of hierarchy, and the artificial elements were significant, moreover, the vegetation vitality is weak(29,31,36),the pavement is damaged, the field is dirty and messy, and the sculpture feel incongruous. The style and color of some buildings outside the district are not consistent with the landscape of the park(30,32,35).

5.2.2.2 Landscape factor analysis

As can be seen from the average score of landscape quality, waterfront space is generally higher than non-waterfront space except for road space in Wanliutang Park. After comparing the positive and negative landscapes of the three parks in the South Canal, it is found that the landscape elements have the following differences:

(1) Vegetation: Among the samples that scored positive, there were weeping willows, spring flowering plants, spring foliage plants, etc., with obvious beautiful landscape color contrast(4, 42, 50, 51). Erect trees, canopied trees and dense shrubs, showing good vitality(5, 6, 13, 14, 28, 41). There are open and tidy lawns, which has greatly improved the openness(4, 9, 16, 21). There are willow slender branches, forming a sense of beauty. For landscape samples with negative SBE, vegetation distribution is sparse and land is bare(22, 24, 31, 32). Trees grow in disorder, plants grow in disorder, lack of hierarchy(30, 38, 39, 47, 48). The vegetation is monochromatic, mostly gray, and lacks spring foliage and flowers(36, 37, 38, 44).

(2) Water:Landscape quality score is positive in the landscape sample of wide water, clear river(5, 12, 13, 14, 19, 21), trees and beautiful buildings along the shore are reflected in the water(16, 17, 18, 25, 26). There are recreational facilities in the water, colorful rowboat(4, 6, 7, 8, 9). On the contrary, the landscape samples with negative landscape quality score had smaller water surface area and polluted water quality(3, 11, 20).The lack of vegetation around the water leaves the bare earth bare(10, 22, 24).

(3) Artificial buildings in the park:Examples that scored positive for landscape quality included elaborate buildings, pavilions and Bridges(12, 19, 21), which are surrounded by lush trees and beautiful flowers, and are in harmony with their surroundings in type and color. Exquisite buildings, pavilions and Bridges were among the landscape samples that scored positive for landscape quality. In the landscape samples with negative landscape quality, pavilions and structures are rough and simple, which are not harmonious with the surrounding landscape(1, 30, 35), ugly sculptures(30, 35), and buildings block the trees and sky in the view(1, 2, 30, 35).

(4) Sidewalk or square ground in a park. In the positive landscape, exquisite pavement texture, colorful pavement color(12, 14, 41, 49), as well as grass Mosaic stone road(42), winding path is very quiet, make people feel peaceful(28, 50, 51). The landscape samples with negative score were paved with single texture and asphalt pavement(31, 32, 33, 37, 38, 44), most of the roads were not surrounded by plants on one or both sides, resulting in bare land(31, 32). The activity site also wide and surrounded by plants, and the plants were not well arranged. Most of them only had trees with few leaves and lacked spring leaf plants and shrubs(34, 36, 47, 53).

(5) Artificial structures outside the park. In the samples with positive landscape quality score, most of the architectural colors are cold colors, which are very harmonious with the color of sky and water and improve the visual quality of the landscape(8, 17, 18), while in the samples with negative score, the architectural colors are abrupt warm colors(2, 27), which are not harmonious with the natural landscape in the park. At the same time, in the samples with positive landscape quality score, the buildings are generally far away from the park, which serves as the distant scenery of the park, enabling people to appreciate the ecological beauty of the park and the beauty of modern architectural technology when looking across the river, which is conducive to improving the overall experience of landscape beauty(16, 17, 25). However, in some landscape samples of negative group parks, high-rise buildings are close to each other, which makes people feel oppressive and reduces the sense of layering of landscape, leading to closed sight(27, 43). In the positive samples, the architectural complexes can often form a beautiful skyline, with the height and height of buildings scattered at random and obvious contour rhythm, while in the negative samples(As shown in samples 7, 8, 16 and 17), the landmark buildings are too prominent or the building volume is too large, or the partial building contour lacks the echo relationship with

the contour line of plant community(As shown in samples 2, 27, 43 and 45).

5.2.3 Discussion

The fact proved that, vegetation is an important factor in the park landscape. Graceful and colorful vegetation can add beauty to the whole landscape, with rich plant species, Multi-layer, distribution in the form of trees, shrubs and grass, neat plant communities, obvious seasonal changes in leaves and flowers, which can greatly improve the overall landscape beauty. The water body can endue the landscape with spirit, and its wide and clear surface can significantly improve the quality of the landscape. Especially, the combination of water and surrounding neat and lush plants can give people a feeling of beauty.

At the same time, in urban parks, the artificial buildings opposite the wide waterfront in harmony with the environment will also improve the landscape quality. The landscape has well-designed pavilions and bridges and other buildings that harmonize with the surrounding colors and forms to enrich the landscape. Winding roads paved with different materials and patterns and their appropriate width in the landscape can have a variety of positive effects. The lack of vegetation surrounding asphalt roads or their apparently hard surfaces can have a negative impact. In addition, man-made structures outside the park landscape had a significant impact on the results of the study.The closer the building is to the park, the greater the negative impact on the park landscape. Therefore, distant buildings that are in harmony with the landscape of the park will have a positive impact on the overall landscape.

5.2.4 Summary

This chapter evaluated the landscape visual quality and the landscape characteristic factors in Shenyang urban waterfront park . The evaluation model of the landscape visual quality was established and the landscape elements were analyzed. It was found that the LVQ of green space in Shenyang waterfront parks was poor, indicating that non-waterfront spaces were neglected in the design and construction of waterfront parks. The mainly problem with the visual quality of Shenyang waterfront park is the non-waterfront space had a single landscape element, poor lawn quality and lacked of landscape maintenance, the pavement was serious damaged and had more weeds. The results of the principal component analysis show that the public prefer landscapes with formal and natural features, and that artificial features conflict with the public's preferences.

Therefore, Shenyang waterfront park should strengthen the 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.)

The final regression model showed that sense of seclusion, ecology, intactness, uniqueness, unity and vitality were the top six contributing landscape characteristics. In the optimization of Shenyang Waterfront Park, the original natural ecological berm should be preserved. It required the planting of ecological and vibrant plants, reasonable combination with plants. The colorful and well-organized vegetation communities should be created, the unique landmark nodes should be increased in the park. Vegetation is the basis of the park landscape diversity, he not only full of vitality, impact on people's aesthetic, at the same time, he also played an important role to the overall ecological park, therefore, the city park should further strengthen the green management, keep the vitality of vegetation, use the seasonal characteristics of plants, more make the park have more rich color change in different season.The landscape aesthetic characteristics of urban parks are not only related to the acreage of scenic spots, landscape elements and their combination, but also closely related to the location and positioning of urban parks and the urbanization construction of the region where the park is located, enriching the types of landscape elements and creating a degree of color contrast enhances the landscape quality of the entire city park is very important. Water also occupy an important place in park landscape quality evaluation, clear the broad waters can be a positive impact, on the contrary, the turbid water experience brings negative effect.When water body is coordinated with water plants or distant buildings outside the garden, it will bring better positive effects and improve landscape quality. Therefore, water body protection and management should be strengthened, water quality should be improved, and water plants and create a good hydrophilic site by using waterside plants and revetments.

Meanwhile, the style of park paving and man-made structure will also affect the overall landscape quality, the width of the road should not be too wide, choose exquisite paving style, suitable for planting rich plants on both sides of the road, create exquisite path. The form, color and skyline of the exterior buildings need to be controlled as much as possible to make them harmonious with the landscape of the park.

This chapter proposes the renewal strategy for urban waterfront parks, which is helpful to construction and management of urban waterfront parks.

5.3 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.

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Chapter 6

VISUAL QUALITY EVALUATION OF SHENYANG HISTORIC DISTRICT

CHAPTER SIX: VISUAL QUALITY EVALUATION OF SHENYANG HISTORIC DIATRICT

6.1 Background

Historic district is a fusion of historic and culture with modern life. It not only inherits the connotations of historic and culture, but also has many functions, such as tourism, residential and commercial. The historic buildings have made the street space become a place to exchange traditional culture, allowing the city to retain and perpetuate its historical and cultural connotations. Its historical nature makes it an irreplaceable presence. However, the rapid development of urbanization has also brought about many problems, the most obvious problem is the standardization of cities and buildings led to the urban environment characteristics gradual receding and disappearance, the city looks the same. Architectural and urban cultures appear increasingly similar and characteristics of crisis [1]. Nowadays, more and more historical and cultural streets are pursuing their commercial value, leading to their street pattern disappeared, intensifying the mix of urban streets. The lack of urban character and the problem of disorderly development have become the main problems of urban development. The research object in this chapter is the urban meso scale, two historic districts were selected in Shenyang, Liaoning Province: the Shenyang FangCheng historic district (containing Shenyang Imperial Palace) and the Shenyang Railway Station historic district. The research aims are: (1) to investigate the streetscape visual quality in Shenyang's historic districts; (2) to analysis the problems which occur in historic district landscapes; (3) to explore the influencing factors of historic district landscapes; (4) to provide suggestions for historic district landscapes.

6.2 Shenyang Fangcheng Historic and Cultural District

6.2.1 Research base

According to the Regulations of the Shenyang on the protection of historical and cultural cities, which was implemented in January 2009, the historic district scope of Shenyang Fangcheng was:Shenyang Imperial Palace as the centre, Shenyang Road and Middle Street Road as the auxiliary line, east from East Shuncheng Street, west to West Shuncheng Street, south to South Shuncheng Road, north to North Shuncheng Road, through the section intersecting with Middle Street Road and Shenyang Road to radiate to both sides, forming a historic district with "well" type. The Fangcheng is about 1.3 Km wide from east to west and 1.3 Km long from north to south, covering an area of about 1.7 Km². The historic district of Shenyang Fangcheng defined in this paper included not only the historical and cultural streets, but also the commercial streets such as Middle Street Road and the residential streets within Fangcheng. The research base includes the historical and cultural, commercial center, characteristic style, residential life and other urban functions, brings together historical and cultural buildings and landscapes from the Qing Dynasty, the Republic of China, as well as multiple periods from the Qing Dynasty (1636) to 385 years ago, It incorporates history traces and regional cultural characteristics from different eras, it has high historical value (Fig 6-1).

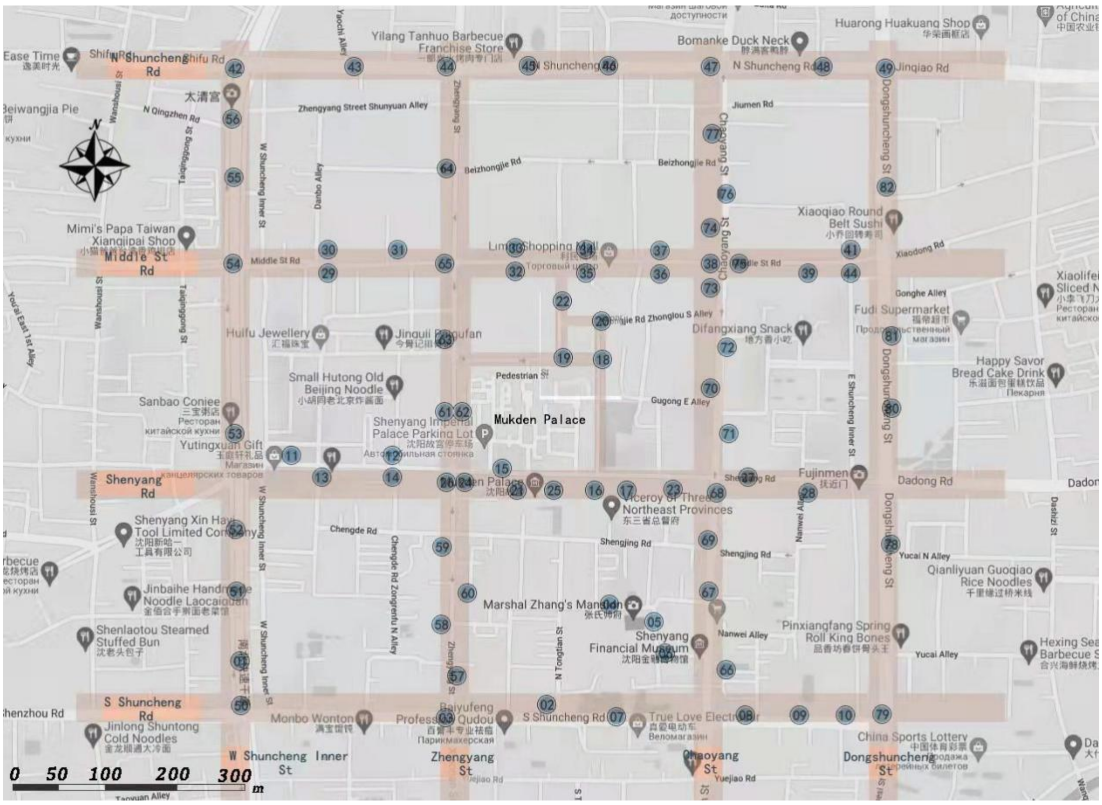

Fig 6-1 Sample points and streets distribution of Shenyang Fangcheng

6.2.2 Research Methodology and Sample Collection

Eight major urban streets in Fangcheng were selected for the study and divided into 24 sections, setting up 82 sampling points, each point location was shot from 4 angles according to the sample point location set for each street. Among the photographs taken at each sample point, selecting a typical sample photograph which best reflected the landscape information of the sample point. 82 typical sample photographs were used for LVQ (Fig 6-2). These samples were all taken on a sunny morning (9:00-11:30) or afternoon (1:30-4:00) in April 2021.To ensure the consistency of technical specifications for photo shooting, the camera used SONY RM3, shot maintain eye level, The height was about 1.6 meters and no flash was used.

In this research, 152 graduate students from landscape architecture and design studies major were invited to Investigate as observer, using the SBE method to judge the landscape visual quality of the streets. Judgement is using 7 levels of judging criteria in the following order: 1 (very much dislike) - 7 (very much like). A total of 152 questionnaires were collected, 16 invalid questionnaires were excluded after screening, 136 valid questionnaires were retained, the evaluation data were entered into EXCEL for standardization.


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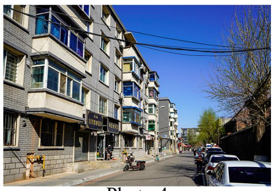
Photo 2


Photo 3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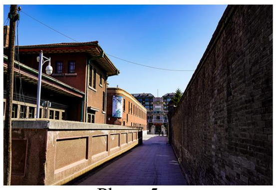
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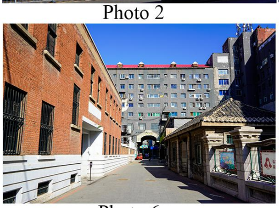
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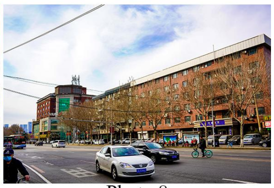
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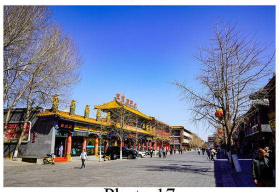
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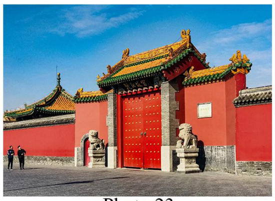
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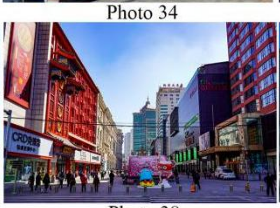
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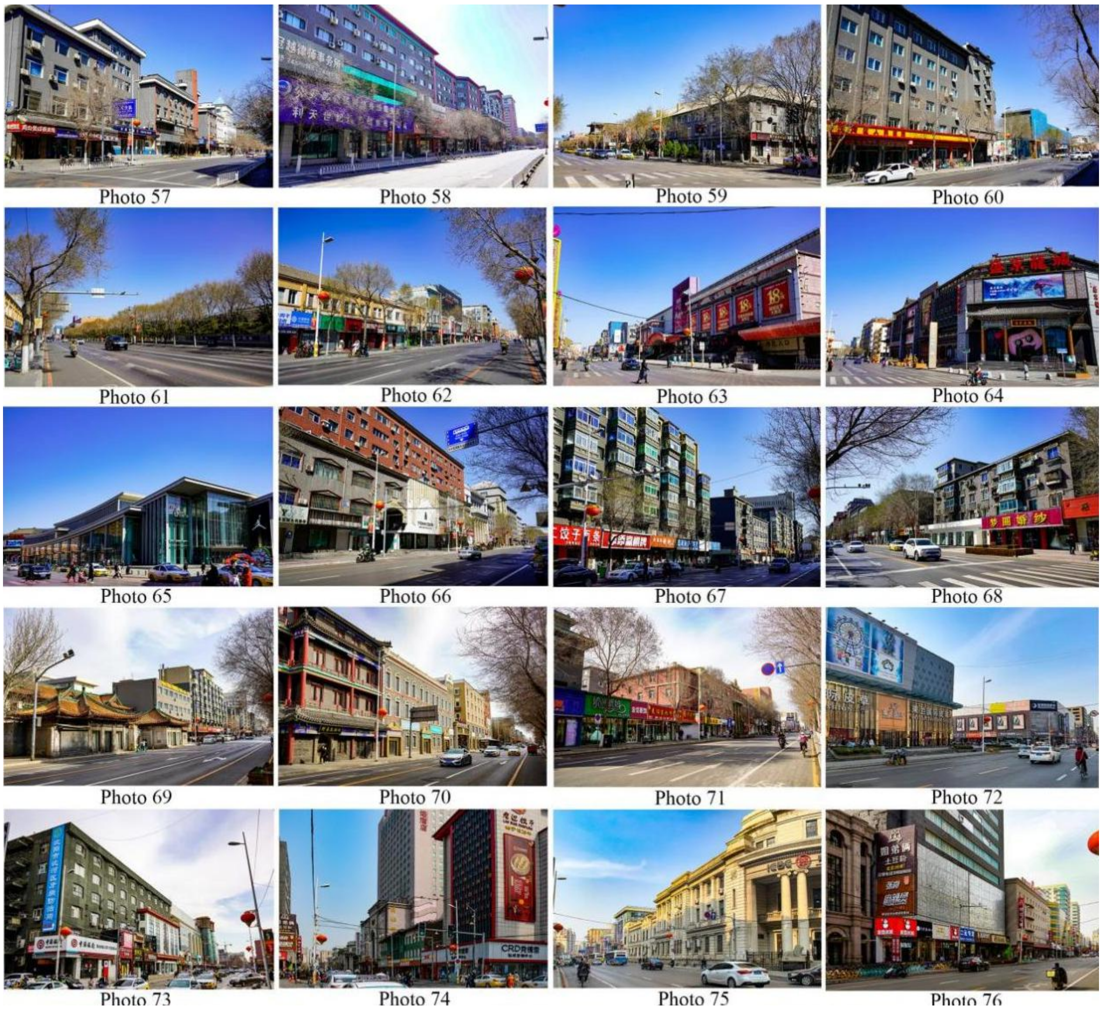


Fig 6-2 The 82 photos of SBE method

6.2.3 Result Analysis

Based on the POI data of Baidu Map and combined with the building types within the sample point photos for neighborhood classification, the 24 studied road sections were divided into three categories: the historic streets, the commercial streets and the resident streets.

6.2.3.1 Comparative analysis of street LVQ

Table 6-1 Ranking order of landscape quality for the 82 samples and streets classification

Sample NO.	Street type	Standardized value	Sample NO.	Street type	Standardized value	Sample NO.	Street type	Standardized value
39	C	1.210	64	H	0.079	10	R	-0.256
75	C	1.014	37	C	0.055	57	R	-0.268
23	H	0.983	74	C	0.052	8	R	-0.270
18	H	0.815	36	C	0.052	66	R	-0.283
25	H	0.689	34	C	0.020	29	C	-0.286

27	H	0.624	40	C	0.017	77	C	-0.291
5	H	0.575	17	H	0.014	80	H	-0.300
70	H	0.552	19	C	0.002	51	R	-0.328
35	C	0.511	6	H	-0.014	55	R	-0.345
32	C	0.497	7	H	-0.030	50	R	-0.346
65	C	0.488	1	R	-0.052	73	C	-0.356
69	R	0.470	53	H	-0.059	54	C	-0.367
21	H	0.446	9	R	-0.061	49	R	-0.378
14	H	0.441	15	H	-0.086	82	C	-0.379
38	C	0.416	22	H	-0.104	30	C	-0.381
13	H	0.415	3	R	-0.108	63	C	-0.384
45	H	0.372	42	R	-0.131	62	C	-0.389
12	H	0.292	28	H	-0.139	67	R	-0.392
56	R	0.291	59	R	-0.169	2	R	-0.410
26	H	0.290	78	R	-0.180	76	C	-0.411
24	H	0.285	47	C	-0.180	58	R	-0.428
33	C	0.281	61	H	-0.203	52	R	-0.443
72	C	0.263	4	R	-0.207	44	R	-0.461
11	H	0.244	41	C	-0.213	71	C	-0.489
16	H	0.192	79	R	-0.216	60	R	-0.563
46	H	0.179	20	C	-0.229	48	R	-0.570
81	R	0.135	31	C	-0.236	68	R	-0.688
			43	R	-0.237			

Note: H stands for history street; C stands for commercial street; R stands for residential street.

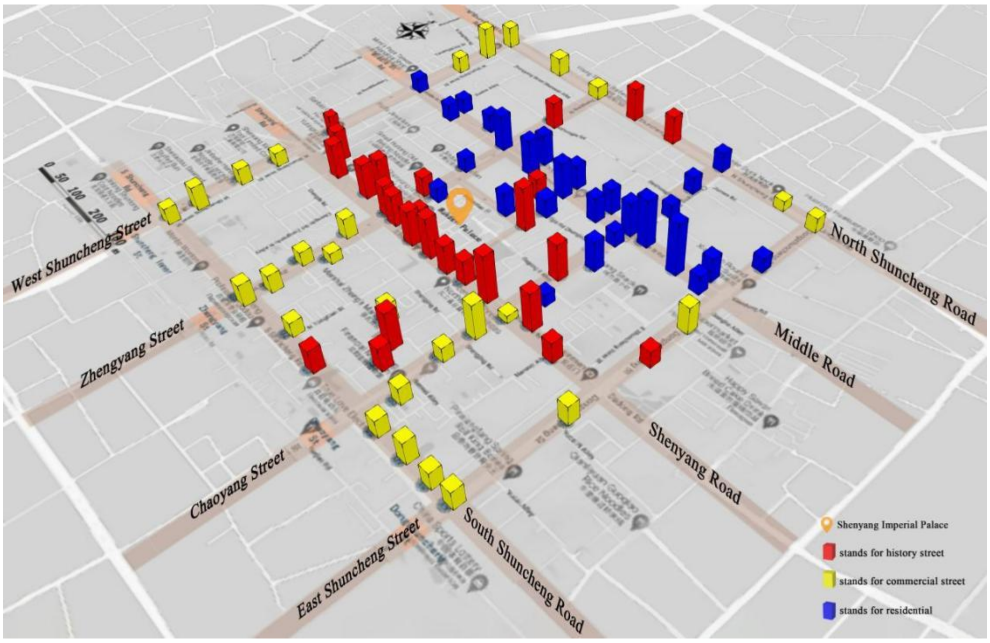


Fig 6-3 The streetscape visual quality map of Shenyang Fangcheng

Through the SBE analysis of 82 sample photos (Table 6-1), the top 27 samples were selected as high quality samples and the latter 27 samples were selected as low quality samples. By analyzing the number of high quality samples and low quality samples distributed in each street (Table 6-2) and the average landscape quality score ,it could be seen that the landscape quality of the three types of streets as order as follows:SBE Historical and Cultural Streets> SBE Commercial Streets> SBE Living Streets as well as the streetscape visual quality map of Shenyang Fangcheng was built (Fig 6-3). the landscape quality of 8 streets in Fangcheng is as order as follows: SBE Shenyang Road (0.287)> SBE Middle Street (0.149)> SBE Chaoyang Road (-0.047)> SBE South Shuncheng Road (-0.083)> SBE North Shuncheng Road (-0.176)> SBE East Shuncheng Road (-0.188)> SBE Zhengyang Street (-0.204)> SBE West shuncheng Road (-0.228) (Fig 6-4).

Table 6-2 Quantity distribution of high and low quality samples and comparison in different streets.

Street type	High-quality samples quantities	Low- quality samples quantities	Total mean value
History Street	16	1	0.252
Commercial Street	8	10	0.010
Residential Street	3	16	-0.246

Among the high-quality samples, there were 16 samples of historical and cultural streets , 8 samples of commercial streets and 3 samples of living streets. Among the low-quality samples, 16 samples of living streets were of low quality, there were 10 samples of commercial streets and 1 sample of historical and cultural streets (Fig 6-5).

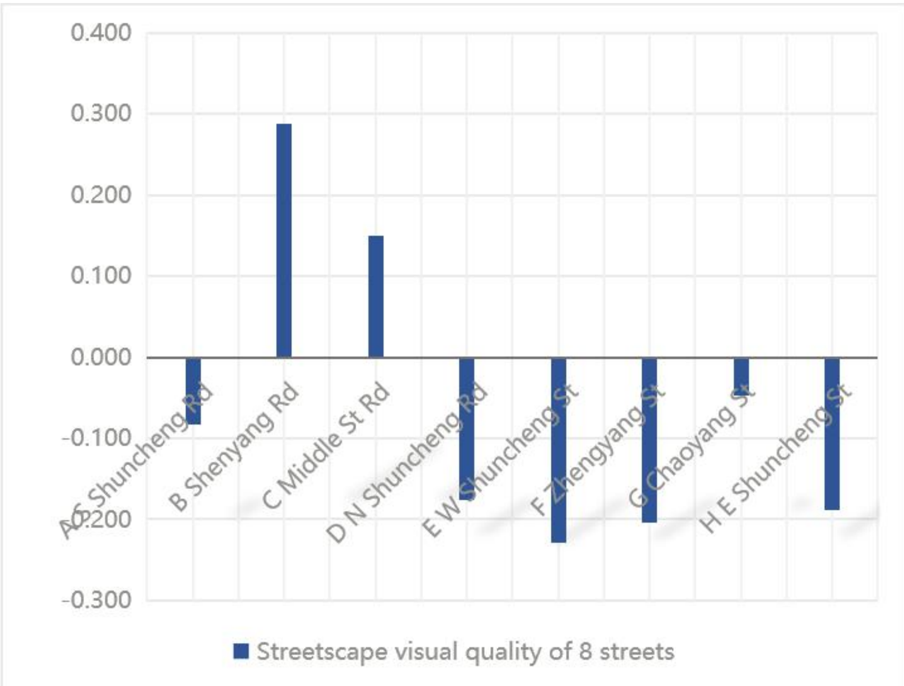


Fig 6-4 SBE comparison of 8 streets

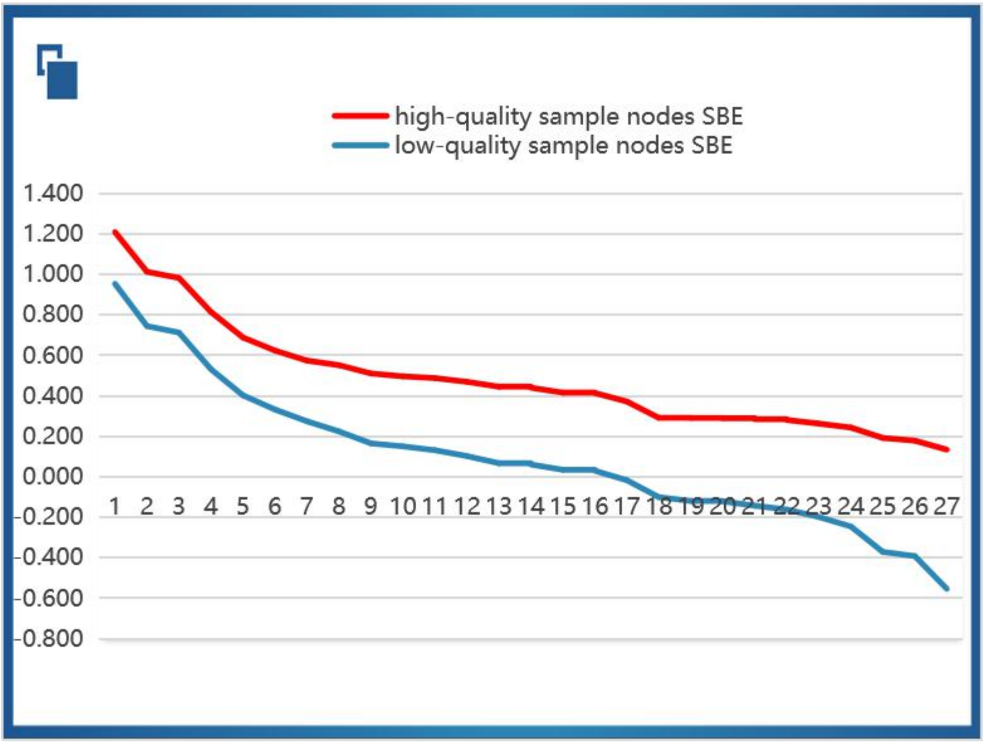


Fig 6-5 SBE distribution of high-quality and low quality samples

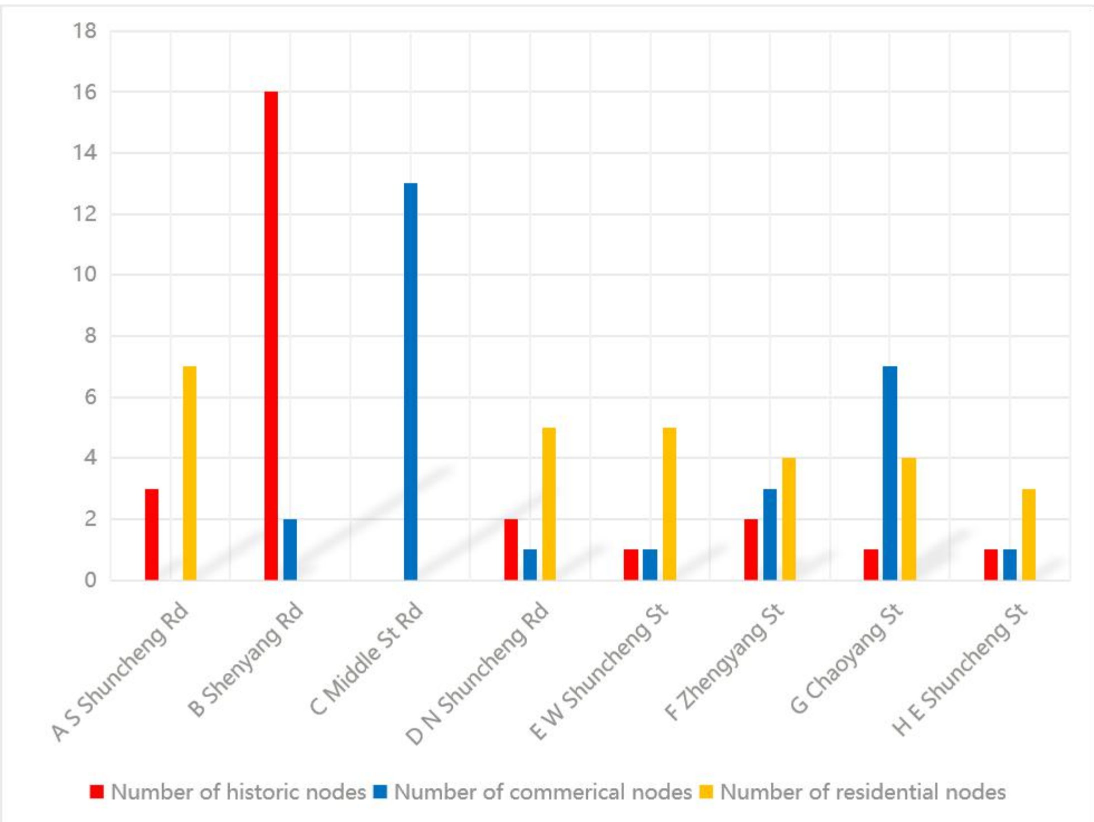


Fig 6-6 Distribution of various types of sample collection points in the street

By comparing landscape quality average scores shown in each street (Fig 6-6), it was found that the landscape quality of historical and cultural streets was the best prominent (0.252). The historical and cultural streets in the research base were mainly distributed in Shenyang Road, the east and west sides of Shenyang Road were cultural district, a large number of antique buildings was distributed in this section; the middle section of Shenyang Road was the entrance to the Shenyang Imperial Palace, where some of the Shenyang Imperial Palace´s historic buildings and the entrance to the palace gate were located here. A large number of Chinese architecture preserved in Shenyang Road, Its buildings were well protected and restored, the building clusters on both sides of the street was perfection; on the east and west sides of the street located plenty of antique buildings, Its architectural form was harmonious, the colors and building forms of the historic buildings preserved the historic and cultural characteristics of Shenyang Road, following the urban fabric and continuing the history and culture of city; the entrance plaza in the middle of the street, with open space and regular plant arrangement, the paving materials and colors had contrast with the colors of the Shenyang Imperial Palace buildings, they shown the unique style of the Shenyang Imperial Palace ´s historic buildings. Streets in good condition, wide and clean roads to meet traffic demand and maintain traffic flow; street trees were planted in a regular manner, enriched the spatial hierarchy of the street and enhanced its vitality.

Among the historical and cultural streets, B1 section obtained the most prominent (0.348), which was located at the west side of Shenyang Road (Table 6-3). Most of the section was Chinese antique buildings, while some of the buildings in this section was European architecture, the two styles architecture portfolio was harmonious, with the help of architectural color and building layout for mutual integration, although the style was different, existed a certain sense of history; The road was neat and tidy, the traffic flow was relatively loose. The road sections did not cause congestion and made an open space pattern; The building colors were harmonious, culturally distinctive and full of order.

No. 23 obtained the highest landscape quality among the historic and cultural streets, it was the Palace Gate of the Shenyang Imperial Palace, which was the ancient building, its preservation was well, the sample was a complete representation of the magnificent atmosphere for the Qing Dynasty palace; the space was open, the red of the Shenyang Imperial Palace harmonizing with the gray of the square, together creating a sense of majesty of ancient Chinese royal architecture. The sample perfectly shown the historical and cultural characteristics of the research base, giving people a immersion sense.

The pedestrian commercial streets landscape quality was better（0.010）.The commercial streets were mainly located at the middle street in Fangcheng, as well as the northern part of Zhengyang Street and the central part of Chaoyang Street. Large commercial complexes and diversity of urban buildings were on both sides of the street with modern streetscape. Building clusters were broadly divided into two categories. One type was the commercial complex of antique architecture which continued the Fangcheng´s historical and cultural characteristics of Fangcheng, its building types were divided into Chinese architecture and Western architecture. The buildings on the both sides of the street were orderly. However, the contrasting colors and styles of the two types of buildings created a visual contradiction and impacted on the commercial street. The other type was the modern commercial complex with glass as the main material, its buildings main color was blue, due to the Permeable building materials, it greatly enhanced the modern sense of the street, however, the large permeable building walls created a confusing street interface. The excessive building volume on both sides of the street made the street space narrow. The subway entranced and some structured occupy a large amount of street area, caused the street congestion and excessive people flow. These questions maked the commercial street presenting a crowded scene. The commercial street had a variety of colors, different building styles had different architectural color schemes, however, the chaotic building complex had caused color confusion; the lack of plants in commercial streets reduced the landscape vitality of the street.

Among the commercial streets, the No.C3 obtained the best streetscape visual quality(0.358), which was located at the east side of Middle Street. In this section, the architectural style consisted of Western architecture and modern commercial complexes, double eave roof pavilion at the center of the street added a historical sense to the modern landscape of commercial pedestrian street, it harmonized with the historical characteristics of Fangcheng. No.H3 obtained the lowest landscape visual quality among commercial streets (-0.379), it was located at the north of East Shuncheng Road, some of buildings in this section were old even dirty on the surface, the color in this street interface was chaotic, the narrow street and the tall buildings formed a narrow street canyon , which reduced the sky area above the street and closed the street space, created a depressing atmosphere.

No.39 obtained the highest quality of commercial streets, which was the Shenyang Commercial City, the building adopted Western style architecture, the mainly color of the building was white, the advertising plaques was blue, it formed a plain architectural color system; It had a larger road scale and less pedestrian flow, it created a quieter spatial experience; the color of the street was harmonious, the landscape furniture facilities of the street were arranged orderly, which formed a street space full of order. The residential streetscape obtained the lowest quality (-0.246). The lowest visual quality of streetscape was found in No. 71 among commercial streets (-0.489), due to the conflict styles and colors of the stores decoration and plaques along the street, made the streetscape was confusing, although the streets were lined with neatly planted street trees, the fading leaves trees made it no vitality and created a dilapidated atmosphere.

Residential streets were mainly located at the boundaries around Fangcheng (East Shuncheng Road, South Shuncheng Road, West Shuncheng Road, North Shuncheng Road), Some of the residential streets were mixed with commercial, the buildings were cluttered and architectural style lacked of color uniformity; most of the buildings were too old and poorly maintained, some streets had a haphazard distribution of cable facilities, which greatly affected the streetscape experience; the residential streets had a poor cultural sense, disconnected from the cultural characteristics of the inner Fangcheng, seriously destroying the urban development texture; Its street space was narrow, the traffic flow was too excessive, causing the space blockage and streetscape crowded and dilapidated; most of the buildings on both sides of the residential streets had commercial buildings on the 1st to 3rd floors, with advertisements and plaques of different sizes and styles, even existed commercial plaques more prominent, which disrupted the consistency of the street building interface made people pay more attention to the secondary streetscape outline than the building facade to a certain extent; The building color was obsolescence and single, too many high-rise buildings caused visual oppression; due to the residential street space was narrow, traffic flow can not be clearly separated from the pedestrian flow, it made traffic jams and crowding.

NO.D3 of the living streets obtained the lowest streetscape quality(-0.474), which located at the east of North Shuncheng Road. This road was a mixed residential and commercial street, due to the non-uniformity of the building form caused the visual conflict of the street facade, some architectural scale was too large, which was more abrupt in the streetscape; the large advertisements and plaques on both sides of the street were too prominent, their design style, size and color were disorganized, resulted in a confusing street interface, which reduced the overall streetscape visual quality; street trees on both sides of the street were sparsely planted, it had a disorganized appearance and not pruned, which made the street overall vitality decline; some commercial bodies were too large and had unique architectural forms which conflicted with the surrounding environment, although the building itself had character, it destroyed the integrity of the street.

NO.68 of the residential streets obtained the lowest landscape quality(-0.688), which located at the south of Chaoyang Street, the buildings on the one side of the street were old buildings which had commercial stores on the first floor, it was decorated in a very big difference, its color contradicted with the color of residential buildings, it caused color confusion in street interface. The excessive pedestrian flow on the street created a spatial congestion visual experience for the public. Howere, NO.68 of the residential streets obtained the highest landscape quality(0.470), which also located at the south of Chaoyang Street, but the Chinese antique buildings appeared in this sample, the low traffic flow and open space enhanced the streetscape visual quality.

Table 6-3 Ranking order of landscape quality for the 24 streets and streets classification

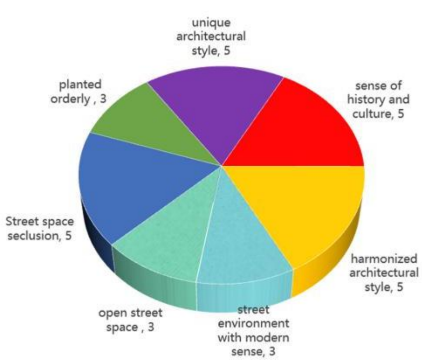
Street NO.	Street type	Standardized value	Street NO.	Street type	Standardized value
A1	R	-0.190	E1	R	-0.372
A2	H+R	0.081	E2	H+C	-0.213
A3	R	-0.195	E3	R	-0.027
B1	H	0.348	F1	R	-0.357
B2	H	0.275	F2	H+C	-0.326
B3	H	0.243	F3	H+C	0.283
C1	C	-0.301	G1	R	-0.223
C2	C	0.236	G2	H+C	-0.007
C3	C	0.358	G3	C	0.091
D1	R	-0.277	H1	R	-0.198
D2	H+C	0.124	H2	H+R	-0.083
D3	R	-0.474	H3	C	-0.379

Note: H stands for history street; C stands for commercial street; R stands for residential street.

6.2.3.2 Analysis of street samples characteristics visual quality

High quality sample of urban streets, street environment with a strong sense of history and culture (18, 21, 23, 25, 26); harmonized architectural style and neat architectural interface (11, 13, 27, 39, 70); street environment and architecture with a modern sense (32, 33, 72)； open street space with wide views (16, 24, 81); Street space seclusion (05, 09); densely planted with orderly arranged street trees (14, 45, 46); unique architectural style (12, 35, 38, 56, 65, 75)(Fig 6-7).

Low quality sample of urban streets, the buildings were old and lack of maintenance and repair (02, 08, 44, 62, 67); the street interface clutter caused the visual perception confusion (49, 54, 73, 76); narrow street spaces, obstructed views, and fewer streetscape components led to a lack of landscape(29, 57, 58, 60, 66); advertising and commercial plaques on both sides of the street disrupted the street interface integrity (48, 51, 52, 55, 68, 71); Confusing building colors and not harmonious street colors (30, 50, 63); street congestion caused by excessive flow of pedestrian and traffic (10, 77, 80, 82).



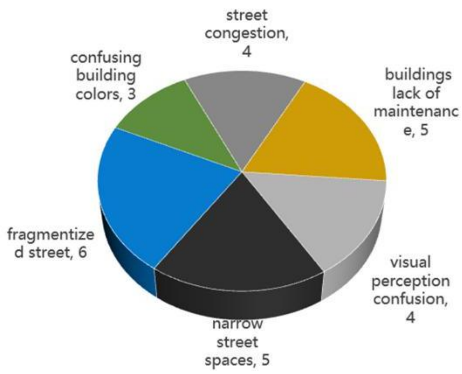


Fig 6-7 Samples quantity of landscape quality influenced by the landscape characteristics

6.3 Shenyang Imperial Palace

6.3.1 Research site

Shenyang Imperial Palace is built in 1625, the early Qing Dynasty Palace. Shenyang Imperial Palace covers an area of 63,272 square meters, north to Zhonglou South Lane Street, south to Shengjing Street, west to Zhengyang Street and east to Shengjing Garden. According to the architectural layout and construction sequence, Shenyang Imperial Palace can be divided into three parts: East, Middle and West Districts. The east district includes the Dazheng Hall and the Ten Wang Pavilion. It was built during the Nurhaci period. It was the place where the emperor held the ceremony and the office of the Eight Banners Minister worked. The middle district was built during the reign of Emperor Taizong of the Qing Dynasty. It was the place where the emperor carried out political activities and the empress lived. The west district was the place where the Qing emperor read, watched and stored the Si Ku Quan Shu during his eastern tour of Shengjing. Shenyang Imperial Palace inherits the tradition of Chinese architecture and integrates Han nationality, Manchu and Mongolian architecture and landscape arts, which has high historical value(Fig6-8).

6.3.2 Research method and sample collection

In this study, the panoramic image data of 18 nodes in Shenyang Imperial Palace were obtained through the VR cloud on the Quanjingke website. They were stored in the computer and connected with the VR device(Fig 6-8). Before the test, the experimenters explained the scoring instructions and introduced the scoring content to each tester. In addition, this study divided Shenyang Imperial Palace into five districts. The VR panorama of 18 nodes were chosen as the research object. 30 graduate students from landscape architecture and design majors were selected to investigate. We used the SBE method to evaluate the LVQ of the Imperial Palace.

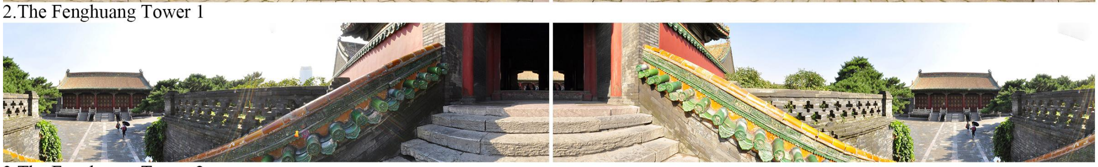
Fig 6-8 Sample points and functional areas distribution of Shenyang Imperial Palace

Fig 6-9 Landscape visual quality evaluation using VR equipment

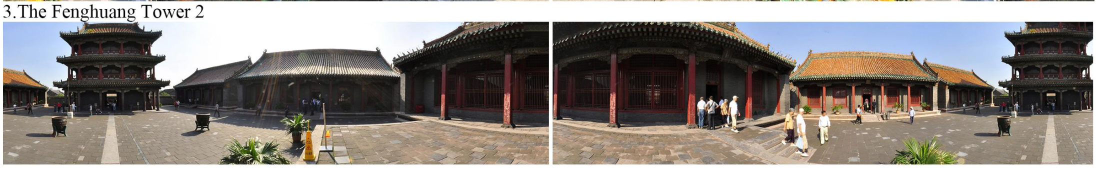
The judgment adopted the 7-level evaluation standard, as follows: 1 (very dislike) -7(very like). The observers evaluated the SBE of 18 panoramic image data by VR equipment in turn. The scores were informed to the experimenters by oral presentation and recorded(Fig 6-9). A total of 30 questionnaires were collected. They were 26 valid questionnaires. The evaluation data were input into EXCEL for standardization to obtain the SBE values (Fig 6-10).

1.The Shengyang Palace-Dazheng palace 1

2.The Fenghuang Tower 1

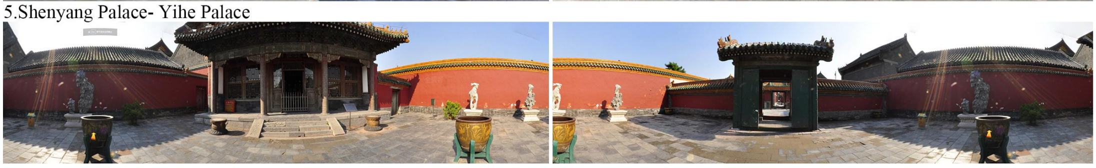


3.The Fenghuang Tower 2



4.Inside the Imperial Palace

5.Shenyang Palace- Yihe Palace



6.The Opera Stage

7.Wensu Pavilion

8.Shiwang Pavilion

9.Shenyang Palace-Qingning Palace 1

10. Shenyang Palace-Qingning Palace 2

11. The Dong qi jian Tower

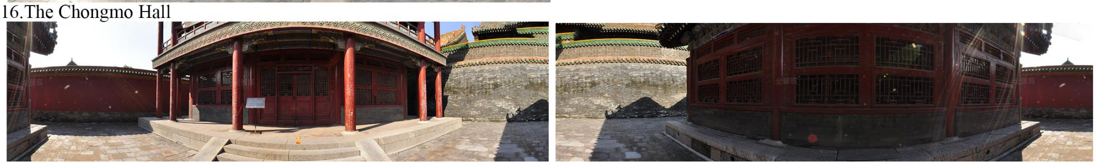
12.The Fenghuang Tower 3

13.The Dongsuo

14.The Diguang Hall

15.The shenyang Palace-Dazheng Palace 2

16.The Chongmo Hall



17.The Baoji Palace

18. Shenyang palace-Hall of Veneration of Governance

Fig 6-10 Panoramic image of the landscape areas shown on the VR web page

6.3.3 Analysis of Shenyang Imperial Palace LVQ

The Shenyang Imperial Palace area was divided into five landscape areas (as shown), analysis of the SBE value of each landscape area(Table 4), the following ordering could be seen: the south of Middle Road > the central of Middle Road > West Road > East Road > the north of Middle Road (Fig 6-11).

The LVQ was better in the south and central of Middle Road, they contained a large number of plant landscapes, the green space factor of the space was high; the northern part of Middle Road contained a large number of landscape area, which was an important landscape area of Shenyang Imperial Palace, however, due to the low green space factor in this landscape area, poor building maintenance, the mainly color of the buildings in the area was gray, which caused single color, the above reasons led to the low LVQ of the landscape area.

Table 6-4 Distribution of nodes within the landscape area and SBE of the landscape areas

Area Name	Node Distribution	Mean value	Area Name	Node Distribution	Mean value
West Road	Wensu Pavilion	0.287	The Central of Middle Road	The Diguang Hall	0.433
	The Opera Stage			The Fenghuang Tower1	
	The Yuannei Palace			The Fenghuang Tower3	
The North of Middle Road	The Fenghuang Tower2	-0.702		The Dongsuo	
	Shenyang Palace1			Shenyang Palace-Yihe Palace	
	Shenyang Palace2		East Road	The Shenyang Palace-Dazheng Palace2	0.124
	The Dong qi jian Tower			Shiwang Pavilion	
	The Chongmo Hall			The Shenyang Palace-Dazheng	

				Palace1	
	The Baoji Palace		The South of Middle Road	Shenyang Palace-Hall of Veneration of Governance	0.939

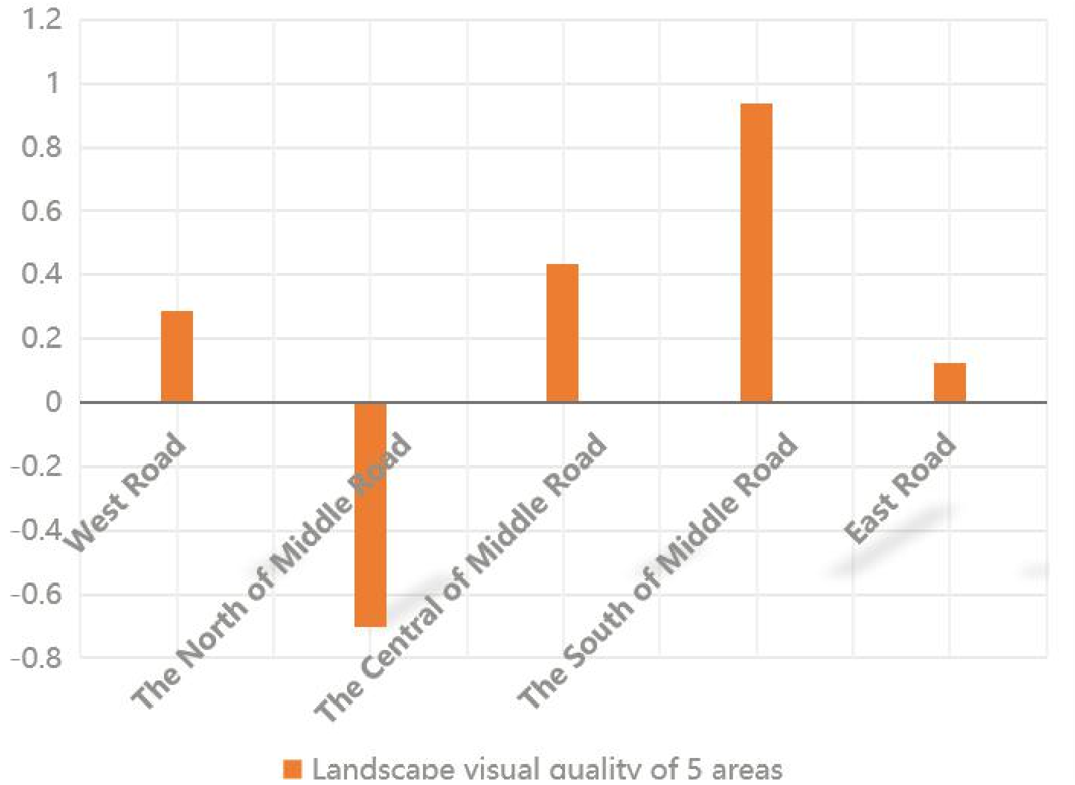


Fig 6-11 SBE of 5 landscape areas

6.3.4 Analysis of Shenyang Imperial Palace nodes LVQ

Vegetation: In the positive value group, there was a high green space factor within each node.In terms of vegetation configuration, the overall landscape was dominated by trees. Although there were no colorful flowers for embellishment, the trees have straight trunks ,upright shapes and the planting of trees was symmetrically distributed according to the axis within the nodes, which shown the strong order of the royal garden(12), large neatly laid lawns in some node landscapes shown the good vitality in the space (7); In negative value group, cluttered plants in some nodes, although flowerbeds and placement stones were set, the plants in the flowerbeds were cluttered and contradicted with surrounding environment, which reduced the LVQ(17), Some nodes had plants, but the vegetation percentage was too small, the green space factor of the node landscape was not improved(3,8), most of the negative nodes had no vegetation layout, resulting in a single node landscape without vitality, while making the node within the dull color without contrast (4, 6).

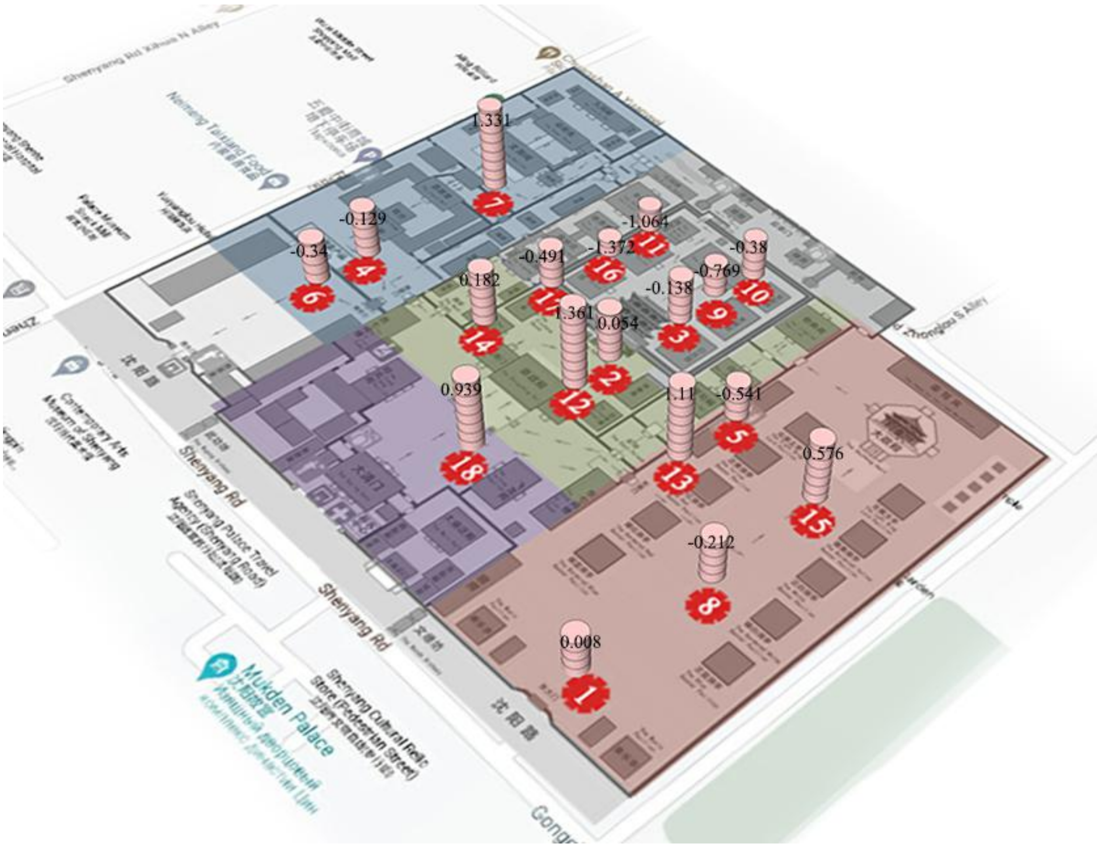


Fig 6-12 Visual quality map of the Shenyang Imperial Palace landscape area

Architecture: In the positive value group, individual buildings in some nodes were exquisite, the overall arrangement of the building clusters was orderly. Building, vegetation, rockery and other gardening elements were organically organized together, forming a harmonious and complementary landscape space, integrating architectural beauty with natural beauty in general(15, 18), the building color scheme of Palace architecture color theme used red, yellow, green and gray. Yellow glazed tiles increased in area, yellow and green squatting beasts intervaled appear on both sides of the roof ridge, it shown the exquisite palace of the Qing Dynasty, inherited the historical culture (2, 14); In the negative nodes, the historic buildings were poorly maintained, the walls and wooden doors were cracked (11), the node space was narrow and the buildings occupied excessive, which created a lack of landscape elements in the space and caused the node space landscape monotonous and boring (16, 9). Most of the building colors were gray, while the paving in the nodes also used the same color scheme, created a single color for the overall space and contradicted with the colors of other palaces to make the space inharmonious (10).

Rockery: as one of the important elements of the Royal Garden, there were a large number of different styles of rockery in the Shenyang Imperial Palace. In the higher scoring nodes, the unique rockery shape created an abstract natural landscape together with the surrounding vegetation and buildings, although the scale was small, the natural landscape was integrated into the building clusters, which increased the sense of nature and achieved the effect from nature and above nature (13); there were no other landscape elements around to match with the rockery in the space, which not only created landscape monotony, but also made the rockery destructive to the surrounding landscape. Although more rockery were set up, there were no connection between them and they cannot form a harmonious landscape scene (5).

Pavement: overall, the pavement of Shenyang Imperial Palace was neat and orderly, pavement materials and colors were uniform, in the nodes which SBE was positive, the pavement also followed the overall central axis, it emphasized the rigorous and unified royal garden style, which made the overall node space full of order (1). However, In the negative nodes, the site pavement was slightly flawed, some pavements were damaged but not repaired in time, some were repaired but differed from other pavements, which destroyed the integrity of the space (10).(Please refer to Table 6-5)

Table 6-5 landscape quality for the 18 nodes

Node name	Node No.	Standardized value	Node name	Node No.	Standardized value
The Fenghuang Tower3	12	1.361	The Fenghuang Tower2	3	-0.138
Wensu Pavilion	7	1.331	Shiwang Pavilion	8	-0.212
The Dongsuo	13	1.110	The Opera Stage	6	-0.340
Shenyang Palace-Hall of Veneration of Governance	18	0.939	Shenyang Palace2	10	-0.380
The Shenyang Palace-Dazheng Palace2	15	0.576	The Baoji Palace	17	-0.491
The Diguang Hall	14	0.182	Shenyang Palace-Yihe Palace	5	-0.541
The Fenghuang Tower1	2	0.054	Shenyang Palace1	9	-0.769
The Shenyang Palace-Dazheng Palace1	1	0.008	The Dong qi jian Tower	11	-1.064
The Yuannei Palace	4	-0.129	The Chongmo Hall	16	-1.372

6.4 Historic and Cultural District of Shenyang Station

6.4.1 Research site

Shenyang Station Historic and Cultural District is centered on Shenyang Station. It has three arterial roads distributed on the cast side which Zhonghua Road, Zhongshan Road and Minzhu Road. And it extends many nodes such as South Ten and North Seven in the north-south direction. It covers an area of about 1.44 square kilometers. Among them, Zhongshan Road has lots of historic buildings. The buildings of Zhongshan Square are distributed wrap-aroundly, they a large number of them are mainly historic and cultural buildings. The overall environment of Zhonghua Road is worse than Zhongshan Road and the least construction activities are carried out around Minzhu Road. More buildings with historic styles were built in the block. Their architectural forms are preserved well and scattered all over the block. Due to the western architectural styles were popular at that time, the buildings in this historic and cultural district also contained the intense of European style. The architectural heritage of the district was mainly built in the first half of the 20th century. It is important for the historical information study of architecture, economy and humanities in Northeast China in this period.

Fig 6-13 Node space type distribution diagram

6.4.2 Research method and sample collection

Six streets in the block (Shengli South Street, Zhongshan Road, Zhonghua Road, Democracy Road, Nanjing South Street, and Nanjing North Street) were selected for the study objects and 49 nodes were selected to evaluate the street LVQ(Fig 6-13). In this study, BLV image data was used to obtained sample and each node was collected sample 360°panoramic photos. Then, the panoramic photos of 49 nodes were randomly arranged to make a powerpoint and played the powerpoint by projector. The observers evaluated the LVQ of sample photos by playing powerpoint (Fig 6-14).

In this study, 162 graduate students from landscape and design majors were selected for the survey and the SBE method was used to evaluate the LVQ of the studied streets. Judgments were made using a seven-paint scale ranging from: 1 (very dislike) — 7 (very like). A total of 151 questionnaires were collected. There were 127 valid questionnaires. The evaluation data were entered into EXCEL for standardization to derive the SBE values.

5.Shengli South Street

7.Shengli South Street

12.Minzhu Road

15.Intersection of Minzhu road and Nanjing South Street

17.Zhongshan Road

18.Zhongshan Road

20.Zhongshan Road

21.Zhongshan Road

31.Nanjing South Street

32.Nanjing South Street

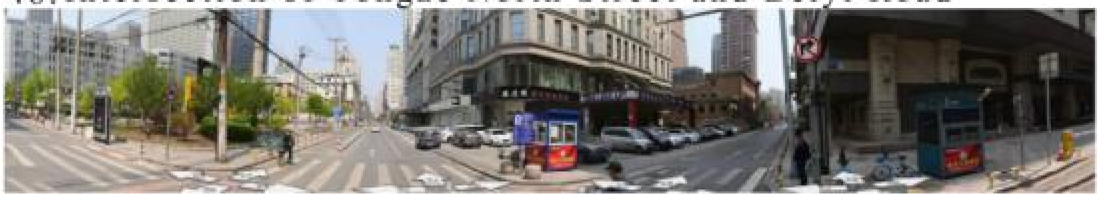
37.Nanjing North Street

40. Minzu North Street

46. Beiyi Road

47. Intersection of Tianjing North Street and Beiyi Road

48.Intersection of Tongze North Street and Beiyi Road



49.Intersection of Tongze North Street and Beier Road

Fig 6-14 Panoramic images of typical nodes for LVQ evaluation

6.4.3 Comparative analysis of visual landscape quality of street blocks

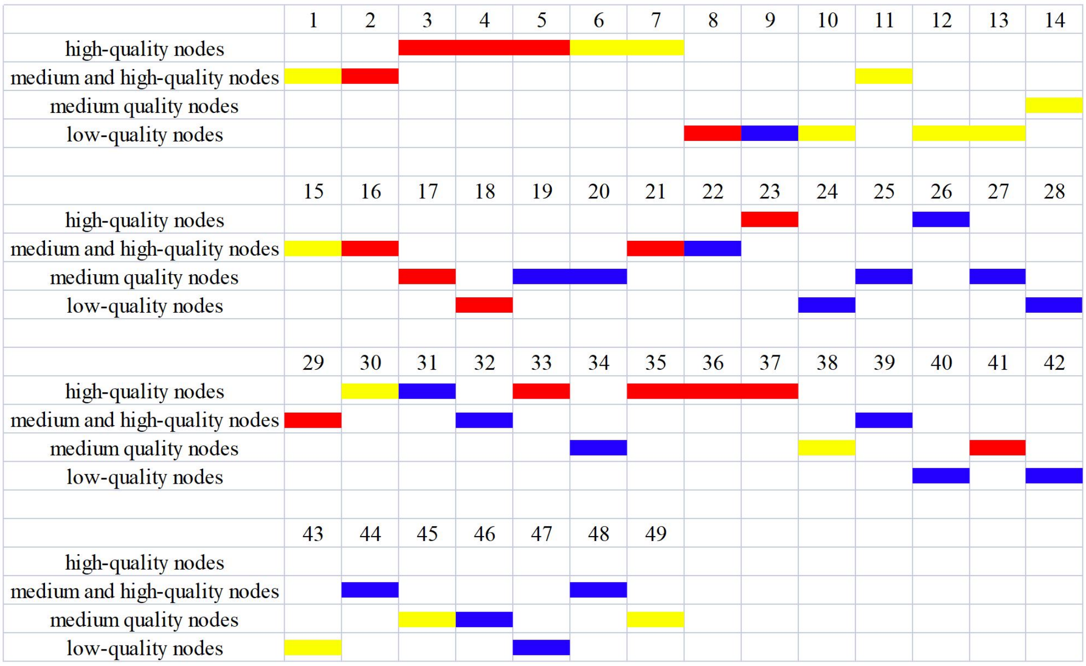


Fig 6-15 Node level diagram

According to the LVQ analysis of 49 node photos (Table 6-6), the top 13 nodes were classified as high-quality nodes, the ranking 14-25 nodes were classified as second high-quality level nodes, the 26-37 nodes were classified as the middling quality level nodes and the bottom 12 nodes were classified as low-quality level nodes. Among the high-quality nodes, eight nodes were historic types, which were nodes 37, 4, 36, 23, 33, 5, 35 and 3 respectively; three nodes were residential types, which were nodes 30, 6 and 7 respectively and two nodes were commercial types, which were nodes 31 and 26 respectively. Among the second high quality level nodes, four nodes were historic types, which were nodes 21, 2, 16 and 29 respectively; three nodes were residential types, which were nodes 15, 11 and 1 respectively and five nodes were commercial types, which were nodes 32, 44, 39, 22 and 48. Among the middling quality level nodes, two nodes were historic types, which were nodes 41 and 17 respectively; four nodes were residential types, which were nodes 45, 14, 38 and 39 respectively and six nodes were commercial types, which were nodes 46, 34, 19, 25, 27 and 20. In the low-quality nodes, two nodes were historical types, which were nodes 8 and 18 respectively; four nodes were residential types, which were nodes 40, 28, 24, 9, 42 and

47 respectively and six nodes were commercial types, which were nodes 40, 28, 24, 9, 42 and 47(Fig 6-15).

Table 6-6 Ranking Order of Landscape Quality for the 49 Samples and Street Classification

Sample NO.	Space type	SBE value	Sample NO.	Space type	SBE value	Sample NO.	Space type	SBE value	Sample NO.	Space type	SBE value
37	H	1.928	15	R	0.477	41	H	-0.108	40	C	-0.600
4	H	1.208	32	C	0.299	46	C	-0.121	10	R	-0.639
36	H	1.148	44	C	0.245	34	C	-0.149	13	R	-0.702
31	C	0.981	21	H	0.193	17	H	-0.215	28	C	-0.710
30	R	0.967	11	R	0.192	19	C	-0.245	12	R	-0.764
23	H	0.954	1	R	0.169	45	R	-0.248	24	C	-0.767
6	R	0.936	39	C	0.158	14	R	-0.333	8	H	-0.865
7	R	0.819	2	H	0.103	25	C	-0.398	9	C	-0.942
26	C	0.795	22	C	0.078	27	C	-0.477	43	R	-0.943
33	H	0.770	16	H	0.036	38	R	-0.483	42	C	-1.200
5	H	0.698	29	H	-0.012	49	R	-0.492	18	H	-1.213
35	H	0.693	48	C	-0.075	20	C	-0.570	47	C	-1.224
3	H	0.651									

Note: H stands for history street; C stands for commercial street; R stands for residential.

Fig 6-16 SBE value of high-quality node

The historic and cultural characteristics were the most outstanding in the high-quality nodes.

They were distributed in Nanjing North Street and Shengli South Street, there preserved many historic buildings. The building had coordinated color and a strong sense of history. The roads were wide and clean and the traffic was flowing smoothly. The planting forms of street trees were regular and orderly. They had a rich sense of layering. Among them, node 37 had the highest LVQ. The node was located in Zhongshan Square. There were open space and the streetscape had historical atmosphere by matching historic landscape facilities with the surrounding buildings and plants. The LVQ of node 4 was worse than node 37. It was located in the center of the street of the Shenyang railway station. The street space was open. The building style was unified. The buildings had historical style and the building color was harmonious with surrounding environment. But the street greenery on both sides was slightly inferior to 37.

There was a balance between the historic, commercial and residential functions in the second high quality level nodes(Fig 6-17). Nanjing South Street was a representative street with good LVQ. Large commercial complexes were set up on both sides of the street. The streetscape style was relatively modern. The buildings on both sides of the streets had unique forms and rich colors. Their materials and the overall style of street were unified. The residential function of node 15 was more outstanding. This point was located in the junction of Minzhu road and Nanjing South Street. It was an important traffic node. The node had harmonious and unified landscape color, open road space and typical modern commercial functions. The residential buildings were modern style and they created a wavy skyline. The commercial function of node 32 was better. The streetscape was enriched by planting street trees. A harmonizes street environment was created by combining street trees with commercial building facades. The historic function of node 21 was good. The historic building style improved the LVQ of the whole space.

Fig 6-17 SBE value of medium and high quality node

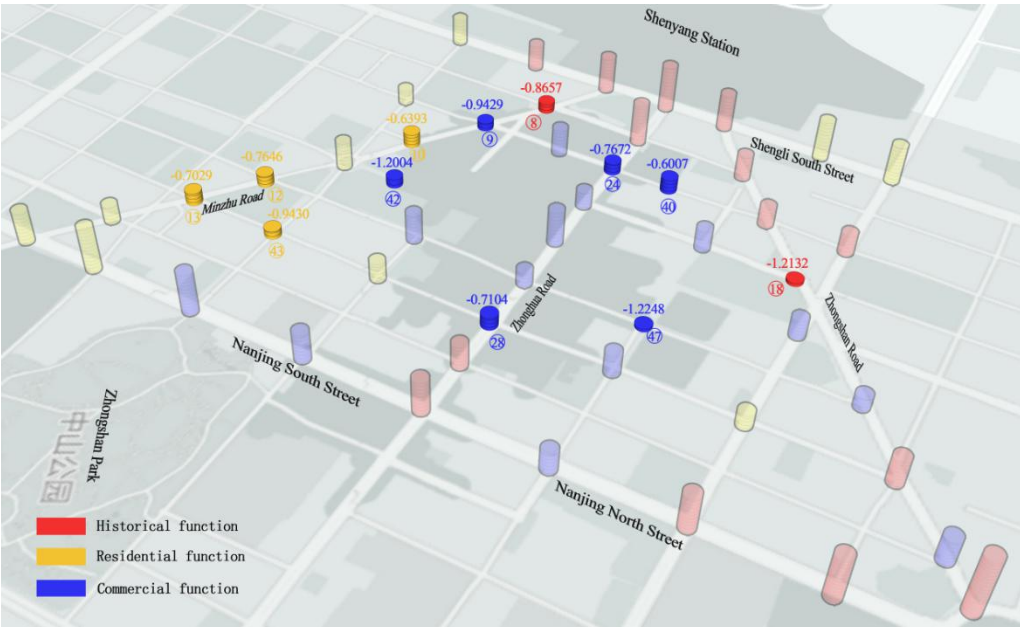


Fig 6-18 SBE value of medium quality node

The middling quality level nodes were mainly residential function. They were most located in Minzhu Road and their landscape quality were poor.(Fig 6-18). There was a large population flow and narrow space in the street. They reduced the street LVQ. The original streetscape was destroyed, which causing the sense of cultural was more and more weak. Among them, the LVQ of nodes 20 and 49 were the worst. The node 20 was mainly commercial. Although some plants were planted on both sides of the streets, large area lawns were full of uncovered soil. It reduced the street LVQ. In addition, the heavy traffic of the street caused the overall LVQ of the street poor. The node 49 was residential function with low LVQ. Because the node building were old and it lacked of maintenance as well as the node had few plants and single color.

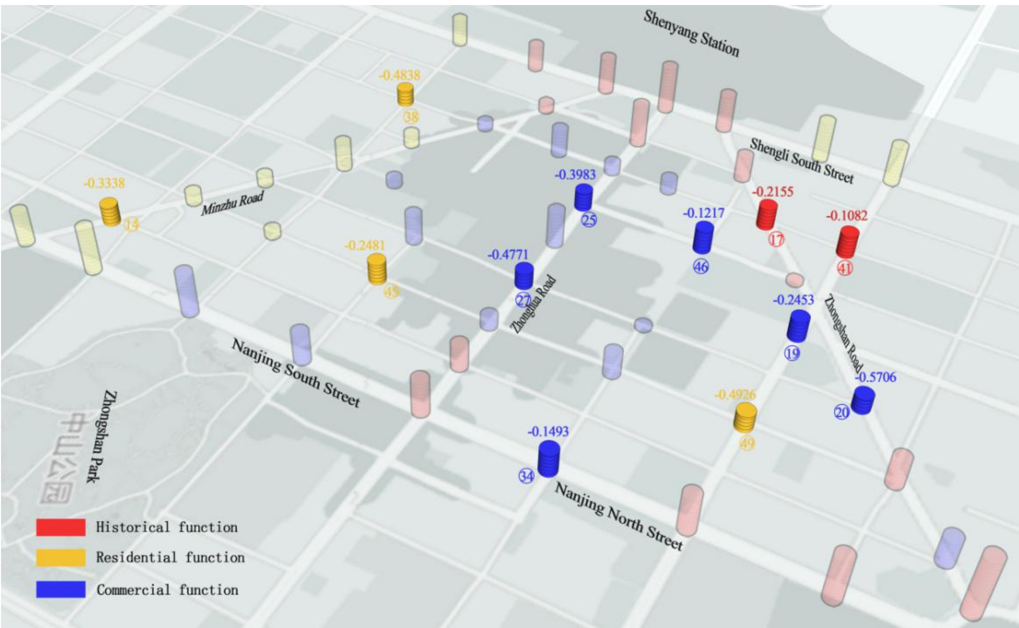


Fig 6-19 SBE value of low quality node

Low quality nodes were mainly residential and commercial functions. The buildings distributed on the Minzhu road and the Minzu South Street were messy (Fig 6-19). Building complexes were old and their combination was disharmonious. The building colors were gray and there were more high-rise buildings blocking the view. Among them, the LVQ of commercial node 47 was the worst as a result of its narrow street space, busy traffic caused the street space confusion. Some buildings had conflict with the overall street environment because their too broken. The unreasonable location of parking leaded to road congestion and the lack of plant landscape. The above points were the reasons for the low LVQ of the node.

Table 6-7 The Distribution Number of Each Quality Node in Six Streets and The Average LVQ of streets

	High-quality samples in the number of each street	Medium-high quality samples in the number of each street	Medium quality samples in the number of each street	Low quality samples in the number of each street	grand average
Nanjing North Street	3	0	1	0	0.905
Nanjing South Street	3	1	0	0	0.754
Shengli South Street	5	2	0	0	0.655
Zhongshan Street	0	3	3	1	0.277
Zhonghua Street	2	1	2	2	-0.087
Minzhu Street	0	2	1	5	-0.447

By analyzing the distribution number of different quality nodes in each streets and the mean value LVQ scores of each street (Table 6-7): SBE Nanjing North Street (0.9052) > SBE Nanjing South Street(0.7546) > SBE Shengli South Street (0.6554) > SBE Zhongshan Road (0.2766) > SBE Zhonghua Road (-0.0879) > SBE Minzhu Road (-0.4475)(Fig 6-20). Nanjing North Street was dominated by historic functions. It had a large proportion of historic buildings. In addition, the historic buildings were maintained well and the color was harmony and beauty. Its representative landscape was located in the node 36. The style and color of the historic buildings were full of historical sense. They created a special historic streetscape. The space was open and the skyline was varied. The Nanjing South Street was mainly commercial functions, the appearance of commercial stores was well integrated with the neighborhood landscape. It has open space, modern style buildings and wide roads. Its traffic order was good. Its representative landscape was node 31, the greenery on both sides was large. The buildings were uniform in color and it had abundant skyline landscape. Shengli South Street and Zhongshan Road were mainly historic functions. The architectural forms which here on both sides of the street were harmonious, the architectural color retained the historic characteristics of this region. The street as a whole followed to the urban fabric and continued the urban history and culture. But the scare of high-rise buildings was too large, it was abrupt in the streets cape, this made the overall LVQ of the streets in middle score. The representative landscape with positive effect was node 5, instead, it was node 18. Its architectural style and color were inharmonious and narrow spatial vision, resulted in low LVQ. Zhonghua Road focused on historic and commercial functions. Narrow streets and sparse street greenery reduced LVQ. The overload of pedestrian and vehicular traffic made the congestion, less greenery reduced the vitality of the streetscape, making the commercial street a crowded appearance and making the overall LVQ of streets lower. The representative landscape was node 17, which was dominated by historic functions and located at the edge of the historic landscape, lacking of greenery on both sides of the street, made its LVQ low. The main function of Minzhu road was residential. The buildings in the street were cluttered. Most buildings were too old and poorly maintained. The street billboards were messy and the road pavement was untidy, which made the overall LVQ of the street was lowest. Its representative landscape was node 12.

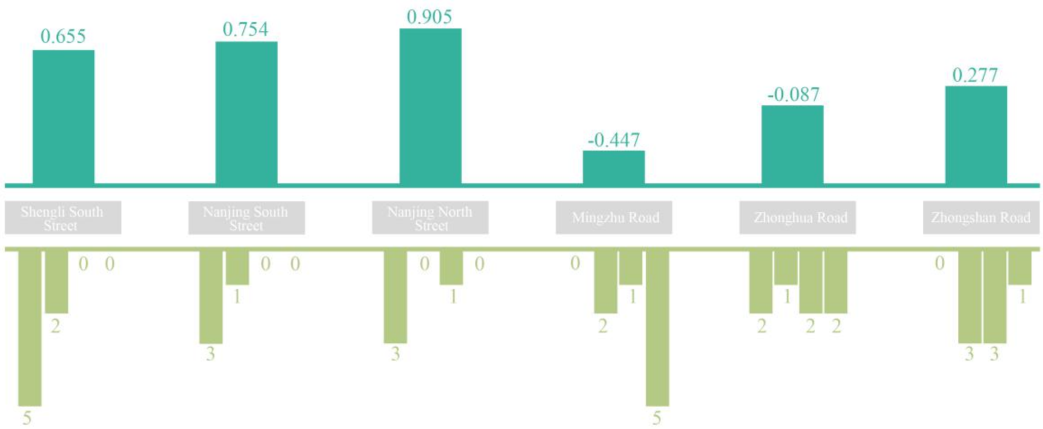


Fig 6-20 Comparative analysis of streets

Fig 6-21 Block analysis diagram

By analyzing the distribution number of high quality nodes, medium-high quality nodes, medium quality nodes and low quality nodes in each block (Fig 6-21), it can be shown that high quality nodes were concentrated in block 1 and block 2, they were Shengli South Street and Nanjing North Street, which were dominated by historic functions. Medium and low quality nodes were mostly concentrated in block 3. It was Zhonghua Road and its right block. It mainly focused on commercial functions. Low quality nodes were mostly concentrated in block 4, which located at Minzhu road and its nearby areas. It was mainly residential functions. Therefore, it was speculated that the overall LVQ of the historic district was the highest in the historic block of Shenyang station, the overall LVQ of the commercial district was low and the overall LVQ of the residential district was the lowest. It was because compared with blocks 3 and 4, blocks 1 and 2 had a stronger historic heritage, a higher vegetation coverage, road openness and varied skyline. Moreover, because blocks 3 and 4 were mainly commercial and residential functions, traffic flow, pedestrian flow, cleaning degree and other factors also indirectly affect the LVQ of the street.

6.5 Discussion

The landscape evaluation of the built environment of street space is a subjective cognitive evaluation.The variables that control the quality of the built environment landscape include components of the street, spatial scale, street color, architectural style, green vegetation, signage system, etc.[2][3]. In addition to the components of the street can affect the street landscape quality, the user's perception of the space will also have a direct impact on the street landscape quality. Therefore, the study of the visual quality of streetscapes must link the physical elements to the subjective perception of people.[4]. In the process of modern urban development and design, some of the historic districts do not continue the original historical and cultural characteristics of the streets, but incorporate too much modern landscape. At the same time, most of the buildings in the historic streets are too dilapidated, which seriously affects the quality of the streetscape. These reasons have led to the present low quality and cluttered landscape of the historic district.

This study confirms that architecture, as one of the constituent elements of the street space landscape, has a large impact on the streetscape quality of the historic district. Architecture is an important part of the neighborhood environment. The history, architectural style, building color and location of the buildings determine the form and appearance of the city [5]. When the street architecture style is jumpy or fragmented, it will destroy the visual unity; Meanwhile, the uniform dull style will reduce the capacity of visual elements and will affect the good visual preference [6]. The quality of the streetscape can be improved if the historic buildings are properly preserved and innovated [7]. Therefore, in the landscape design of the streets in the historic district, especially for the building facades, a clear style direction needs to be determined for the whole district. For historic streets, it is necessary to preserve the original historical and cultural characteristics of the street. While ensuring that the original historicity is not lost, the design approach of urban modernization is incorporated. It preserves the cultural heritage of the historic streets and continues the urban texture of the development of the times. After the unified style, the partial streets atmosphere is created by combining the street culture.

The physical properties of a building can affect the sense of enclosure of a space. The sense of enclosure in an urban environment can be generated by complete blocks of buildings [8]. I It can be inferred from the different results derived from a large number of studies that the height of the continuous group of buildings on the street and the height of the buildings at the far end of the street will affect the sense of space to some extent. The majority showed a preference for open landscapes. This result is consistent with other studies [9]. An open streetscape will have a positive psychological impact and an open visual experience for the public and it blends in with its surroundings in a harmonious way by adjusting the height of the building. At the same time in the linear street design, both ends of the street try to avoid large flyovers, arches, rockeries and plaques to block the permeable line of sight. If landscape barriers or divisions are required, sparse planting or construction can be used to ensure openness of the street space and permeability of the view.

Street color is an important consideration affecting the landscape quality of the urban street, which directly affects the appearance of the city [10]. Color has two different time scales in the process of architectural and urban transformation. First, while the role of color in short-term use is primarily based on functional and attractive purposes, color also has a long-term social and economic logic. Second, it remains a feature of aesthetic use value to preserve the historical and cultural characteristics of the city in long-term use [11].

With the development of urban space, the social structure triggers changes in color aesthetics, the ecological environment influences the context of urban color. Ultimately, the spatial pattern of the city shows different characteristics synthesized in the color space pattern. Color influences human perception and behavior in complex environmental spaces. The combination of colors influences whether the emotional experience is pleasant or not. The degree of color harmony is an important factor in influencing preferences of crowd and behavior. A uniform and non-monotonous streetscape attracts more public attention. A haphazard color distribution will destroy the integrity of the street; a single color scheme will reduce the interest of the streetscape and the landscape quality of the street. In addition to the colors of the buildings in the street that affect the overall landscape quality of the street, the advertising signs within the street are also an important influencing factor. There should be a unified visual guide for advertising signs. The basic style, outline, size, color scheme, height and lighting of advertising signs should be figuratively defined so that the whole block is consistent in style, colorful in content.

Studies have shown that the green space factor has an important role in creating the overall street atmosphere [12]. When the percentage of visible greenery is greater than 30%, it proves to be a more popular urban streetscape [13].The shading or removal of street trees in urban streets can result in a lack of greenery in the street, thus reducing the visual quality of the street. Increasing plant density and diversity, selecting plant species with greater green coverage, shortening the distance to green spaces and buildings, ultimately urban streets add to the aesthetic quality [14].

The design of street landscape creates a harmonious space to create a street space that meets people's needs by combining landscape elements such as architecture, landscape elements and street facilities, it does not destroy the original cultural atmosphere in the space but also enriches the landscape level of the space.

For the historic area of the Forbidden City, the historic architecture and plant configuration have an important impact on the visual quality of its landscape [15]. They are the basic elements that constitute the classical Chinese garden. The green space factor and planting configurations are important to historic districts. Improved the green space factor and refined planting configurations will enhance the visual quality of the landscape in historic areas. The historic buildings are rich and vivid in color, with strong contrasts between colors [16]. The rich colors and strong color contrasts give the historic area space a historical character and continue the historical lineage.

The study result indicated that the residential district LVQ was the worst and it had the most potential. The residential district had some problem as follow:

1. There was cluttered building layout. As a result of the facade and color of the buildings which in the residential district, meanwhile there were differences in building styles, they caused an inharmonious environment in the district.

2. The commercial buildings facades weren't unified with the overall street, so the street integrity was destroyed.

3. Cluttered color caused overall color confusion in the the residential district, it made the streetscape become more fragmented.

4. As a result of the streets were narrow and the buildings on both sides of the street were large, the street canyons were created by them as well as there was depressing atmosphere.

5. The traffic flow and pedestrian volume were high in the residential district, however, the narrow streets cannot effectively dredge traffic and then the traffic efficiency of the street was reduced.

According to the above current problems of the residential district, we propose the following landscape improvement strategies for the residential district:

During the streetscape design of the residential district, firstly we need to determine the style characteristics of the overall street, then make local changes in order to show the difference between them, finally use the subtle changes to reflect the layers of the street atmosphere; the design of plaques and advertising signs of the commercial buildings on both sides of the street should be unified, their style, size, height and color need to be specific required to ensure a consistent style in the district and integrity of block landscape; related studies show that there is a high preference efficiency when street aspect ratio between 1.0 and 1.4, after the street width is identified, the height requirements of the buildings which along the street need to be combined with the proportional requirements of 1.0-1.4, in this way a comfortable street space can be created; for the problem of traffic congestion which caused by the high traffic flow and pedestrian volume, we need to Traffic optimization at the city level.

6.6 Summary

Historic district not only continued the cultural connotation of a city, but also is an important area for urban regeneration. This chapter acquired landscape sample photos by three ways: field photography, VR and BSV. It applied the SBE method to evaluate the visual quality of Shenyang Fangcheng historic district (including Shenyang Imperial Palace) and Shenyang Station historic district. The study found the existing visual quality problems in Shenyang historic district, analyzed the impact of landscape elements on it and proposed improvement strategies.

In the Shenyang Fangcheng historic district, the LVQ of the historic and commercial streets was high.They were mainly concentrated in Shenyang Road and Middle Street. The rest of the streets in Fangcheng had poor LVQ. They were mostly residential streets, which reduced the overall LVQ in the Fangcheng historic district. In Shenyang Station historic district, the high quality nodes focused on historic functions. The medium quality nodes and low quality nodes were dominated by commercial functions and residential functions, they were mainly concentrated in Minzhu Road. In the Shenyang Imperial Palace, the highest LVQ was in the southern part of the Minzhu Road. The northern part of Minzhu Road had the lowest LVQ, where contained a large number of viewpoints, it was an important part of Shenyang Imperial Palace

The main problems of the Shenyang historic district were as follows: (1) The streets green space factor was extremely low and most streets were not planted with street trees on both sides. Although some streets had vegetation planted on both sides, the street green space factor did not meet the standard. In some of the historic districts, the building area ratio were high . No plants were grown, resulted in a single landscape and lacked vitality in the area. (2) The building style was messy and poorly maintained. A lot of building walls were cracked, meanwhile the style and form of the buildings in the street had greatly difference. They resulting in a confusing street interface. (3) As a result of chaotic color of the buildings, the streets were created an inharmonious environment, most of the building colors were single and gray which caused a gloomy visual environment. (4) Traffic congestion was serious, crowded and chaotic street created a depressing street atmosphere.

The improvement strategies: (1)Reasonably increase the planting on both sides of the streets to enhance the overall green space rate of the area and increase the vitality of the landscape. (2) Maintenance and repair of the old buildings, the style and color of commercial signboards need to be unified. (3) Add pedestrian street in historic district, set up pedestrian-vehicle segregated roads and motor vehicle roads.

This chapter aims to be able to improve the landscape visual quality in historic district of Shenyang.

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Chapter 7

VISUAL QUALITY OF RESIDETIAL AREA

CHAPTER SEVEN: VISUAL QUALITY EVALUATION OF RESIDENTIAL AREA

7.1 Abstract

At present, urban renewal has gradually become an important method of urban development. At the same time, with the rapid development of economy and the improvement of public living standards, the public's demand for living environment gradually changes from material demand to spiritual demand. However, the public's visual aesthetics and subjective feelings are often easily ignored in the living environment. This study used residential areas as research subjects to explore the landscape visual quality at the micro level of the city. The value of aesthetic law of comparative judgment (LCJ value) was obtained by BIB-LCJ method. The LCJ values of different residential areas and each landscape space were analyzed, the landscape elements affecting the landscape visual quality(LVQ) of residential areas were obtained. The results showed that the main elements affecting residential areas include plants, pavement, landscape facilities and water. However, the landscape elements concerned by the landscape space of the residential area are different. Therefore, this study put forward different methods and suggestions for the landscape design and transformation of residential areas.

7.2 Study on the visual quality of urban residential area landscape

7.2.1 Overview of the field

This paper focused on the completed residential areas in Hunnan District, Shenyang to explore the landscape elements that affecting the visual quality of residential areas. Considering that volume ratio, greenfield ratio and building type made differences in the landscape quality of settlements, residential areas with volume ratios of 1.5-2.5 and greenfield ratios of 20%-35% were chosen as the subjects. The research chose 4 typical residential areas (Vanke the Paradiso, Emerala Legend, Vanke New Landmark and Jindi Chang qing wan) which based on the size of the residential area, with different volume ratio, different greenfield ratio, different building types and covered as many landscape elements as possible. The information of the residential areas was shown in the table7-1.

Table7-1 Residential area information

	Build time	Building Types	Landscape Styles	Land Area	Volume Ratio	Greenfield ratio
Vanke Jinyu Lanwan	2009	High Level	Thai style	226000m^2	2.5	21%
Longhu Tianpu	2020	Multi-story, High-rise	New Chinese style	64000m^2	2.0	29%
Vanke Xinli Cheng	2007	High Level	Modern	52,659m^2	2.2	35%
Jindi Chang qing wan	2008	High-rise,Multi-story	European-style	224000m^2	1.7	27%

7.2.2 Materials and methods

7.2.2.1 Sample acquisition and selection

The landscape elements of the residential areas are mainly concentrated in the green space, road space and field space. The photos were taken in clear weather. During the morning (9:00-11:30) and afternoon (1:30-4:00) in June 2021 in order to display the landscape elements as comprehensively as possible. The photographers and shooting tools were kept the same. The camera was kept horizontal at a height of about 1.6m without using a flash. The location of each sampling point was also measured using a GPS signal receiver. A total of 482 photographs were taken in the four settlements. The photos of each settlement were selected by considering the angle, exposure, clarity and other possible interference factors. Based on the spatial types of residential areas, eight experts selected 49 representative landscape sample photos that fully reflect the green space, road space and field space out of 482 photos (Fig 7-1). Among them, 12 were for Vanke Xinli Cheng (4 road space samples, 4 green space samples, 4 field space samples), 12 were for Vanke Jinyu Lanwan (4 road space samples, 4 green space samples, 4 field space samples), 12 were for Longhu Tianpu (4 road space samples, 4 green space samples, 4 field space samples), 13 were for Jindi Changqing wan (4 road space samples, 5 green space samples, 4 field space samples) (Fig 7-2).

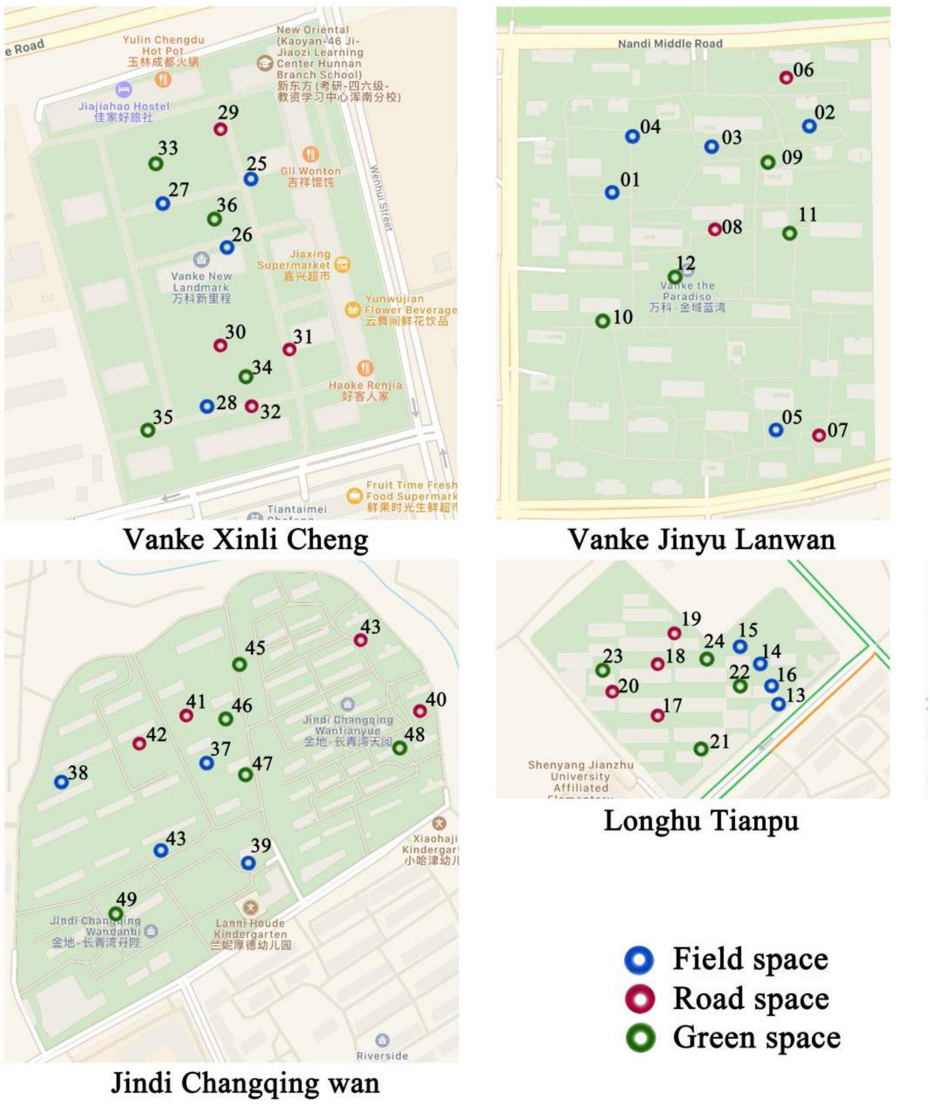

Fig 7-1 Collection point of each residential area

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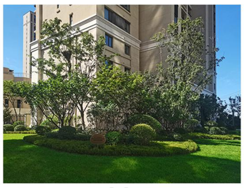
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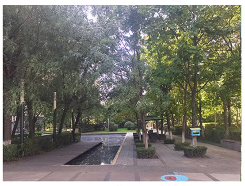
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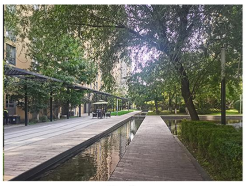
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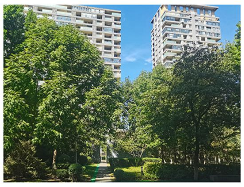
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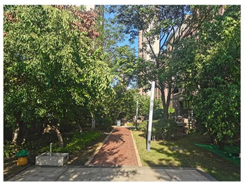
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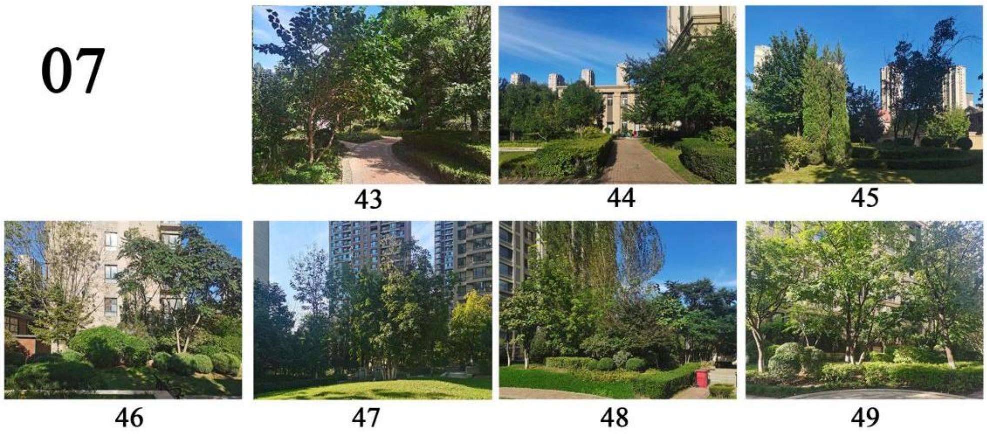

Fig 7-2 The 49 photos and numbers of BIB-LCJ method

7.2.2.2 Evaluators, questionnaire design and study process

138 college students participated in the questionnaire survey, including 43 in landscape, 57 in architecture and 38 in design. The questionnaire includes the following parts: (1) Name, age, gender and profession of the evaluator; (2) Introduction of the connotation and judging method of the visual quality evaluation of the landscape; (3) Grading evaluation table of the photos.

The BIB-LCJ method was used in this study. Eight different partitions were used with reference to the balanced incomplete block design (Fig 7-3). The 49 samples in each partition were divided into 7 groups, each group containing 7 photographs. A slide show was used to present each group of photos to the observer offline, each group of sample photos was shown for 2 minutes. A 7-level scale was used, from" very like" to" very dislike" in the order of 1, 2, 3, 4, 5, 6 and 7. The observers were required to begin their evaluations by selecting a favorite photo among the seven photos of each group and placing the number in the Level 1 column. Then selected the least favorite photo and put the number in the 7-level column. Finally, the most favorite and least favorite photos were used as a reference to rank the remaining photos.

I	II	III
01 02 03 04 05 06 07	01 08 15 22 29 36 43	01 09 18 24 35 40 48
08 09 10 11 12 13 14	02 09 16 23 30 37 44	02 10 19 25 29 41 49
15 16 17 18 19 20 21	03 10 17 24 31 33 45	03 11 20 26 30 42 43
22 23 24 25 26 27 28	04 11 18 25 32 39 46	04 12 21 27 31 36 44
29 30 31 32 33 34 35	05 12 19 26 33 40 47	05 13 15 28 32 37 45
36 37 38 39 40 41 42	06 13 20 27 34 41 48	06 14 16 22 33 38 46
43 44 45 46 47 48 49	07 14 21 28 35 42 49	07 08 17 23 34 39 47

IV	V	VI
01 10 21 26 34 37 46	01 11 17 28 33 41 44	01 12 20 23 32 38 49
02 11 15 27 35 38 47	02 12 18 22 34 42 45	02 13 21 24 33 39 43
03 12 16 28 29 39 48	03 13 19 23 35 36 46	03 14 15 25 34 40 44
04 13 17 22 30 40 49	04 14 20 24 29 37 47	04 08 16 26 35 41 45
05 14 18 23 31 41 43	05 08 21 25 30 38 48	05 09 17 27 29 42 46
06 08 19 24 32 42 44	06 09 15 26 31 39 49	06 10 18 28 30 36 47
07 09 20 25 33 36 45	07 10 16 27 32 40 43	07 11 19 22 31 37 48

VII	VIII
01 13 16 25 31 42 47	01 14 19 27 30 39 45
02 14 17 26 32 36 48	02 08 20 28 31 40 46
03 08 18 27 33 37 49	03 09 21 22 32 41 47
04 09 19 28 34 38 43	04 10 15 23 33 42 48
05 10 20 22 35 39 44	05 11 16 24 34 36 49
06 11 21 23 29 40 45	06 12 17 25 35 37 43
07 12 15 24 30 41 46	07 13 18 26 29 38 44

Note: The Roman numerals I.....VIII in the table are the order of the repeated experiments (Sequence recombination). Numbers 1-49 are photo numbers.

Fig 7-3 Balanced incomplete block design

Source: "Tables of Commonly Used Mathematical Statistics" prepared by the Institute of Numerical Sciences, Chinese Academy of Sciences

7.2.2.3 Data processing

A total of 138 questionnaires were returned in this study, with a 100% return rate. 10 invalid questionnaires were deleted, 128 valid questionnaires were applied. The data was entered into an Excel spreadsheet to produce the evaluator's ranking of each sample photo. The evaluator's ranking of each photo was summed to obtain the rank sum (M) for each sample. The mean rank (MR) and selection score (MC) were found. The specific formula was as follows:

$$MR = \frac{M}{n}$$

$$Mc = G - MR$$

$$Mc' = Mc + 0.5$$

$$P = \frac{Mc'}{G}$$

In the above equation: N was the total number of evaluations; G was the total number of grades; Mc was the modified selection score; P was the selection score percentage for each sample. The value of aesthetic law of comparative judgment (LCJ value) for each sample was finally derived by the PZO transformation table. The level 1 represents the highest rating and level 7 represents the worst rating. The higher the LCJ value of the final data conclusion by the formula, the samples ranking more near the top.

7.2.3 Result and analysis

7.2.3.1 Landscape quality analysis of different residential areas

LCJ values for each sample were obtained (Table 7-2). The LCJ value of residential area and the LCJ average value of different landscape spaces were counted (Table 7-3).it could be concluded that overall landscape quality of the 4 residential areas ranked as follows: Longhu Tianpu (0.260) > Vanke Jinyu Lanwan (0.026) > Vanke Xinli cheng (-0.100) >Jindi Chang qing wan(-0.168).

Table 7-2 LCJ values and landscape types of 49 samples

Sample number	LCJ value	Landscape space type	Sample number	LCJ value	Landscape space type	Sample number	LCJ value	Landscape space type
1	-0.031	F	18	0.619	R	35	-0.689	G
2	-0.059	F	19	0.390	R	36	-0.118	G
3	0.511	F	20	0.275	R	37	-0.307	F
4	0.289	F	21	0.540	G	38	-0.292	F

5	0.229	R	22	0.036	G	39	0.231	F
6	-0.384	R	23	-0.014	G	40	-0.281	F
7	0.393	R	24	0.623	G	41	0.492	R
8	0.022	R	25	-0.200	F	42	-0.064	R
9	-0.078	G	26	0.109	F	43	-0.084	R
10	-0.246	G	27	-0.316	F	44	-0.090	R
11	-0.336	G	28	-0.417	F	45	-0.275	G
12	-0.003	G	29	0.084	R	46	-0.333	G
13	-0.336	F	30	0.319	R	47	-0.226	G
14	0.006	F	31	0.381	R	48	-0.457	G
15	0.174	F	32	0.036	R	49	-0.495	G
16	0.630	F	33	-0.517	G			
17	0.180	R	34	0.132	G			

Note: 1-12 locates in Vanke Jinyu Lanwan: 13-24 locates in Longhu Tianpu: 25-36 locates in Vanke Xinli cheng: 37-49 locates in Jindi Changqing Wan: F stands for field space: R stands for road space: G stands for green space.

Table 7-3 Landscape quality analysis of different residential areas

	Total average score	Average score of field space	Average score of road space	Average score of green space

Vanke Jinyu Lanwan	0.026	0.178	0.065	-0.166
Longhu Tianpu	0.260	0.118	0.366	0.296
Vanke Xinli Cheng	-0.100	-0.206	0.205	-0.298
Jindi Chang qing wan	-0.168	-0.162	0.063	-0.357
Total value		-0.072	0.700	-0.525

The LCJ value of Longhu Tianpu residential area was the highest. The landscape visual quality(LVQ) of road space, green space and field space were outstanding. The LCJ values for the landscape spaces are ordered as: road space, green space and field space. In the road space, the color of pavement was mainly gray, and the form was simple. In terms of color, the matching of buildings, walls and road pavement was natural and harmonious. The plants on both sides of the road had rich layers. The road space had strong permeability and good openness. In green space, plant communities form open space, semi open space and closed space through the combination of trees, shrubs and lawns. Rich spatial levels can meet the different needs of users. The green view index of green space was high, which made the residential area beautiful and vitality. The landscape of green space was more lively and full of vitality through the combination of water, plants and landscape stones. The lines of buildings were hard and straight, but the lines of plants were soft, so lush plants can weaken the hard lines of buildings. The pavement, landscape facilities and surrounding plants were the main landscape elements of the field space. The plants in the field space were mainly composed of grassland, shrubs and a small part of trees, they formed an open space. Waterscape formed a harmonious relationship with plants and facilities, which improved the landscape quality of the field.

In Jinyu Lanwan residential area, the LCJ value of field space was the highest, and the green space was bad. In the field space, the different colors, styles and patterns of pavement were used to increase the artistic appeal. Abundant landscape facilities and landmark landscape had activated the atmosphere of the field space. The pavement style and plants match were different in the road space. It was mainly reflected in the classification of roads. The main road was asphalt pavement, mainly composed of shrubs and tall trees. The pavement of pedestrian road consisted of two colors. The color of pavement was contrast with plants and buildings and there was high plant density on both sides of the road. The landscape path was mainly stepping stone, and the surrounding plants were composed of tall trees and shrubs. In the green space, there were many tall trees, which leaded to high plant density and closed space, low shrubs increased the layering of green space, and lawns were the basis of plant community. But the lawns in residential area were exposed obviously.

In Xinlicheng residential area, the LVQ of road space was good and the LVQ of field space and green space were bad. In the road space, the color of the main road pavement was coordinated with the buildings, and the plants around the road were abundant. One side of the road was the waterscape, surrounding plants, roads and water form a good landscape. The field space was inclined to natural plant landscape. Exuberant plant communities lack clipping, it leaded to the field dim and shorts vitality. In the field space, the pavement was inconsistent with the structure. Around the activity site, the plants were mainly lush trees, and the field space was closed. Lacking of shrubs in green space made the landscape rigid and unattractive.

In Changqing residential area, the landscape quality of road space was good and the landscape quality of green space was bad. There were many pavement styles in road space. The pavement was consistent with the architectural style. There was diversity of plant types on both sides of the road. The space with more trees was closed, with more shrubs and lawns was open. There were abundant activity facilities in the site space, but the pavement and facilities were damaged. The plant communities around the site had a high density, forming the closed space. In the green space, the plant community was mainly composed of trees, shrubs and lawns. But the plant density in some areas was unreasonable, which made the plants in the green space confused and out of order.

Through the comparison of the four settlements, the advantages and disadvantages of each landscape space in the residential area were compared. By improving the poor landscape space, the landscape visual quality of the whole residential area can be advanced. It was found that Longhu residential area had the good LVQ. The plants in the residential area were rich in layers, the pavement was simple, the landscape facilities and landmarks landscape were abundant. The Vanke residential area was normal. In Wanke Jinyulanwan, there were abundant landmark landscape and high openness in the field space. However, the LVQ of road and green space was normal, which had high plant density. In the field space and green space of Vanke xinlicheng, the plants were too luxuriant, which led to the reduction of openness, the landscape facilities and landmark landscape were not harmonious with the surrounding landscape. The Jindi residential area was bad. The density of plants was high, the management of pavement and facilities was poor.

7.2.3.2 Landscape quality analysis of different spatial types

As can be seen from Table 7-3, among the 49 samples, there were 23 positive samples and 26 negative samples. It was found that among the three landscape spaces, the positive samples were the most in road space and the negative samples were the most in green space. Among the three landscape spaces, the road space had the most positive samples and the green space had the most negative samples. The top 4 samples were classified as high-quality samples, and the bottom 4 samples were classified as low quality samples (Table 7-4). Comparing the LVQ of each landscape space, we can find that there were many differences in the landscape.

Table 7-4 Sample table of high and low landscape quality in different landscape spaces

	Field space		Road space		Green space	
	Number	LCJ value	Number	LCJ value	Number	LCJ value
Top four in sample ranking	16	0.630	18	0.619	24	0.623
	3	0.511	41	0.492	21	0.540
	4	0.289	7	0.393	34	0.132
	39	0.231	19	0.390	22	0.036
The last four samples	37	-0.307	42	-0.064	48	-0.457
	27	-0.316	43	-0.084	49	-0.495
	13	-0.336	44	-0.090	33	-0.517
	28	-0.417	6	-0.384	35	-0.689

The total LCJ value of the field space was negative (-0.072). Among them, the LCJ values of Longhu residential area and Jinyulanwan residential area was positive, the LCJ values of Xinlicheng residential area and Changqingwan residential area were negative. The field space of the residence with positive LCJ value was mostly open space, the field was mainly regular, the field was rich in the style of activity facilities and landscape furniture. The plant occupancy was relatively small.

In the field space of high-quality samples, the relationship between waterscape, landscape facilities and plant communities was harmonious. Plants and structures were reflected in the water, making the landscape lively and interesting. The trimmed shrubs were linear and smooth. Several trees were added in the middle to enrich the layering of the landscape (16). In the field space, the plants of high-quality samples were mainly lawn, with shrubs and trees planted in the surroundings. It increased the openness of the field (03, 04). In some landscape samples, the trees in the background were tall and their crowns were in good shape. Combined with the foreground and middle landscape plants, they reflected strong vitality. The plant density was high, but it did not impact the opening width of the field (39). In the field spaces of low quality landscape, the high number of trees were grown vigorous around the perimeter, space was more enclosed (27, 28, 13). The trees in some of the sites were messy, poorly layered and not very vigorous. Structures and pavements were damaged, their colors were inconsistent.

The LCJ value of road space was the most prominent (0.700). The LCJ values of road space in four residential areas were positive. Among them, the LCJ value of Longhu residential area was the highest. It is followed by Xinlicheng residential area, Jinyulanwan residential area and Jindichangqingwan residential area. In the road space of Longhu residential area, the roads were mainly regular straight lines. The color and style of pavement were simple and consistent with the architectural style of residential area. Plant communities on both sides of the road were composed of more low plants and fewer trees. The structures, water and other elements around the road enriched the landscape of the road space. In Jinyu Lanwan and changqingwan residential areas, the paving style of the road was diverse. The paving color was mainly warm, using a variety of color patchwork synthesis. The vegetation area on both sides of the road was large, with high plant density, lush growth and lack of vitality.

In the road space, the high-quality samples contrasted with the low quality samples. The road with high landscape quality was cleaner, and the road pavement style made it simple and beautiful. The plants on both sides of the road were mainly short shrubs and lawns. They had beautiful shape, rich species and strong layering, (18, 19). The path was naturally integrated with the surrounding plant community (07). Roads with low LVQ included asphalt roads and brick roads. The roads were wide and the surrounding plants were dense (06, 08). The texture and color of pavement were harmonious with the surrounding plants, impacting LVQ of the road space (42, 43, 44).

The total LCJ value of green space was the worst (-0.525). Among the four residences only the Longhu residential area has positive landscape quality of green space, while the rest have negative values. The plant community in the Longhu residential area was low in density and dominated by diverse shrubs. Among them, the species and number of trees were low, the sense of space and neatness were attractive. In residences with negative LCJ values, there were many plant species, mainly shrubs and trees, with a high number of plants, high density and cluttered plant space. The plant community has a high green space factor, a strong seclusion, a lack of space and the problem of bare ground surface.

Comparing high-quality samples with low quality samples in green space, it was found that the LVQ decreased when the plant density was particularly high. The samples with high plant density, there were many and disordered plants. The space was relatively closed. The combination of plants with water features and rock placement in the higher landscape quality samples made the views more pleasant (21,34). In green space, some gaps needed to be left between plants, artificial pruning shrubs and straight trees of different heights could highlight the layering of plants. Plants in the low landscape quality sample were dominated by shrubs and trees, with a strong sense of enclosure and inaccessibility. High density plants lacked permeability and had problems such as bare ground (48,35,33,49).

7.2.4 Discussion

By comparing the LCJ values of the three landscape spaces, the result indicated road space (0.700) > field space (- 0.072) > green space (- 0.525). It can be seen that the green space had the greatest potential for landscape quality improvement, and the most important landscape elements were plants and water. Diversity of plant types can enhance the richness and layering of plant communities. The landscape quality of residential green space had been improved. The composition, color and species diversity of plants were the main factors of the landscape visual quality, the view had been put forward by other researchers. The green space combined natural plants and artificial plants was more popular with the public, and the artificially shrubs were indispensable. Tugrul Polat emphasized the lack of shrub plants in plant composition had a negative impact on visual quality [1]. The density of plant community impacts the landscape quality of green space. Too high or too low landscape density will lead to people's disgust, it is the best way that the vegetation coverage was controlled in an appropriate range. Water in green space was the important element impacting landscape quality. Some studies found that water had the significant impact on landscape preference [2][3]. At the same time, the combination of water and plants significantly improved the landscape quality.

The field space of residential area had some promotion potential. The landscape elements impacting the field space mainly include pavement, structures, landscape facilities, plants and water. Landscape facilities such as scenic wall, scenic stone and pavilion are landmark landscapes in the field space. They increased the richness of the landscape and had a positive impact on the field space. The style and color of pavement, landscape facilities and structures impact the landscape quality of the field space in the residential area [4]. In conclusion, artificial elements had a positive impact on landscape quality. These research conclusions were contrary with the views of Wang et al. and Purcell's. They deemed that artificial elements had the negative correlation with visual quality [5][6]. The public prefer artificial plants. Lawns and shrubs had the main impact on the landscape quality. The main characteristics of artificial lawn were light green, clean, tidy and open [7]. Some researches emphasized people prefer clean and tidy rather than wild landscape in residential field space [8]. In addition, Regular waterscape can improve the landscape quality of field space.

7.2.5 Summary

In this chapter, the BIB-LCJ method was used to evaluate LVQ of four residential areas in Shenyang at a micro level. The poor landscape quality of green space and site space in residential areas reduced the overall landscape quality of residential areas, indicating that they had greater potential for improvement. The results of the analysis showed that the main influencing factors in green space were the morphology and disposition of plant communities. The public preferred a neat and orderly style of plant community, while the public rated the natural style plant community lower. In the site space, the main influencing factors were landscape structures and landscape facilities. The public preferred open and regular sites with rich artificial elements in the landscape. Pruning shrubs and trees, creating a combination of natural and artificial plant communities. We can enhance open and permeable sites , add regular and rich structures or landscape vignettes. Maintaining a clean and neat lawn, designing uniform and regular paving style and color can enhance the landscape quality of the site space in Shenyang Hunnan residential area. Meanwhile, we analyzed the landscape quality of residential areas and provided some target-oriented suggestions.

(1) Plant

Plants are the main impact factors in each landscape spaces types of residential areas. Plant communities can show the landscape layering in landscape space. It is necessary that pay attention to the density of plant communities. If the plant density was too high or too low, it will affect the landscape quality of residential areas. In residential areas, the public prefer artificial plant communities. We should pay attention to the construction of artificial lawn and shrubs, enrich understory plants and reduce field exposure. Monotonous colors will cause public aesthetic fatigue, abundant colors landscape can be created through flowers and colorful plants.

(2) Landscape Facilities

Landscape facilities have the positive impact on the landscape quality of residential areas. Landscape facilities and the surrounding environment can create a harmonious atmosphere. The color of landscape facilities contrast with architecture and pavement. Landscape facilities with practical functions could create cultural atmosphere and sense of belonging in the residential area. Landscape facilities need to be consistent with other landscape elements of the residential area to meet the public demand. It can improve the landscape quality and enhance the interaction between people and the landscape.

(3) Pavement

The texture and style of pavement mainly impacted the visual quality of landscape in residential areas. We should pay attention to the material, the texture, style and color of pavement. The pavement of roads and fields did not exist independently. They shall be coordinated with landscape facilities and buildings. It were important that the management and regular inspection and replacement of field pavement.

(4) Landmark landscape

landscape stones, landscape walls and pavilions were the main landmark landscapes in the residential landscape. Proper construction of pavilions, bridges and other buildings or add landscape stones, landscape walls and water in the landscape spaces, they can contrast with other landscape elements in color and enhance color richness. Meanwhile, it also improved the LVQ of residential area.

(5)Water

In residential waterscape design, living atmosphere and open space needs to be concerned. Regular water injection and pumping could avoids the water turbidity. In addition, aquatic animals and plants can enhance the beauty of the landscape and improve the water quality.

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Chapter 8

CONCLUSION

CHAPTER EIGHT: CONCLUSION

8.1 Conclusion

Urban visual landscape is an important part of urban environment.Landscape visual quality evaluation is a part of landscape impact assessment,the current evaluation of urban landscape is the basis of urban landscape design. At present, the relevant laws and norms of urban landscape visual environment evaluation has not yet formed a system. Through multi-sourcing data approach, this study studies the landscape visual quality of the city at three different levels: macroscopic, mesoscopic and microscopic.

The main works and results can be summarized as follows:

In chapter one, RESEARCH BACKGROUND, PURPOSE AND SIGNIFICANCE OF VISUAL QUALITY EVALUATION OF URBAN LANDSCAPE have been presented in the research. The importance of urban regeneration is shown through an analysis of urbanization rates in major countries around the world. Finally, by analyzing the legal regulations on landscape visual environment in China, Japan, France and UK, the importance of legal regulations on landscape visual environmental protection is emphasized. Meanwhile the urban landscape visual quality evaluation has an important position in the landscape visual environment.

In chapter two, REVIEW OF VISUAL QUALITY have been presented. An overview of the stages of development of visual landscape evaluation is provided. Include the theories proposed by various scholars, the establishment of four major schools of thought (expert, psychophysical, cognitive, and empirical) and the rise of various research technologies. Two kinds of visual landscape control methods in each Nation were compared, including natural elements control method, Manual element control method. The combing of previous studies has divided the landscape visual environment quality evaluation into three categories, including natural landscape visual environment quality evaluation, ecological landscape visual environment quality evaluation, visual environment quality evaluation of urban and rural landscape. Finally, the future perspectives of landscape visual evaluation are presented.

In chapter three, RESEARCH METHODS have been presented. First, Method of acquiring multivariate data for urban landscape is introduced, including Field research method, Photography Method, Cityscape Big Data, VR Panorama and Urban POI data. Second, Evaluation method of urban landscape visual landscape quality is explained, Scenic Beauty Estimation and Relevant Concepts of BIB-LCJ method. Finally, the Urban landscape characterization methods were introduced, including Introduction of SD method and Concept of Semantic segmentation method.

In chapter four, STREET LANDSCAPE CHARACTERISTIC AND VISUAL QUALITY MODEL OF SHENYANG URBAN CORE AREA have been presented. The main visual perception characteristics and their spatial distribution of streets in the urban core of Shenyang had been obtained by using BSV images and semantic segmentation technique at the macro level. In the core area of Shenyang, distribution status of green space factor showed a low level in the center and a high level in the periphery. In addition, the green space factor of streets in the downtown at a low level. The study found that the building area ratio of the core area was high, the core commercial area and historic district had the highest building area ratio.

In addition, this chapter evaluated the visual quality of streetscape based on the SBE method. In order to construct a model to evaluate the streetscape visual quality in the core area of Shenyang, the correlation and regression analysis were used to analyze the relationship between the streetscape visual quality and visual perception characteristic. The results showed that the green space factor was a positive indicator, which impacted the public's aesthetic evaluation of urban streets. The building area ratio, vehicle occurrence rate and pedestrian occurrence rate had a negative effect on visual aesthetic.

Meanwhile, urban streets with lower LVQ were identified as the key areas for urban renewal according to the results of the streetscape visual quality in the core area of Shenyang. Urban planner can optimize greening plant design of street to effectively enhance the street green space factor and reduce the building area ratio; controlling the height and volume of new buildings to avoid excessive building area ratio. In the commercial streets or historic district, the one-way street of vehicle planning design was needed to reasonably adopt to reduce traffic congestion and effectively reduce the vehicle occurrence rate for the purpose of efficiently improving the overall visual quality of core area in Shenyang.

In chapter five, LANDSCAPE VISUAL QUALITY MODEL OF SHENYANG URBAN WATERFRONT PARK have been presented, Chapter 5 evaluated the visual quality of the landscape of Shenyang urban waterfront park and extracted the landscape characteristic factors. The evaluation model of the landscape visual quality was established and the landscape elements were analyzed.It was found that the LVQ of green space in Shenyang waterfront parks was poor, indicating that non-waterfront spaces were neglected in the design and construction of waterfront parks. The biggest problem with the visual quality of Shenyang waterfront park is the non-waterfront space had a single landscape element, poor lawn quality and lacked of landscape maintenance, the pavement was serious damaged and had more weeds. The results of the principal component analysis show that people prefer landscapes with formal and natural features, and that artificial features conflict with people's preferences.

Therefore, Shenyang waterfront park should strengthen the 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.). The final regression model showed that sense of seclusion, ecology, intactness, uniqueness, unity and vitality were the top six contributing landscape characteristics. In the optimization of Shenyang Waterfront Park, the original natural ecological berm should be preserved. It required the planting of ecological and vibrant plants, reasonable combination with plants. The colorful and well-organized vegetation communities should be created, the unique landmark nodes should be increased in the park. This chapter proposes the renewal strategy for urban waterfront parks, which is helpful to construction and management of urban waterfront parks.

In chapter six, VISUAL QUALITY OF SHENYANG HISTORIC DISTRICT (FANGCHENG HISTORIC DISTRICT, SHENYANG IMPERIAL PALACE & SHENYANG STATION HISTORIC DISTRICT) have been presented. Historic district not only continued the cultural connotation of a city, but also is an important area for urban regeneration. This chapter acquired landscape sample photos by three ways: field photography, VR and BSV. It applied the SBE method to evaluate the visual quality of Shenyang Fangcheng historic district (including Shenyang Imperial Palace) and Shenyang Station historic district. The study found the existing visual quality problems in Shenyang historic district, analyzed the impact of landscape elements on it and proposed improvement strategies.

In the Shenyang Fangcheng historic district, the LVQ of the historic and commercial streets was high.They were mainly concentrated in Shenyang Road and Middle Street. The rest of the streets in Fangcheng had poor LVQ. They were mostly residential streets, which reduced the overall LVQ in the Fangcheng historic district. In Shenyang Station historic district, the high quality nodes focused on historic functions. The medium quality nodes and low quality nodes were dominated by commercial functions and residential functions, they were mainly concentrated in Minzhu Road. In the Shenyang Imperial Palace, the highest LVQ was in the southern part of the Minzhu Road. The northern part of Minzhu Road had the lowest LVQ, where contained a large number of viewpoints, it was an important part of Shenyang Imperial Palace

The main problems of the Shenyang historic district were as follows: (1) The streets green space factor was extremely low and most streets were not planted with street trees on both sides. Although some streets had vegetation planted on both sides, the street green space factor did not meet the standard. In some of the historic districts, the building area ratio were high . No plants were grown, resulted in a single landscape and lacked vitality in the area. (2) The building style was messy and poorly maintained. A lot of building walls were cracked, meanwhile the style and form of the buildings in the street had greatly difference. They resulting in a confusing street interface. (3) As a result of chaotic color of the buildings, the streets were created an inharmonious environment, most of the building colors were single and gray which caused a gloomy visual environment. (4) Traffic congestion was serious, crowded and chaotic street created a depressing street atmosphere.

The improvement strategies: (1)Reasonably increase the planting on both sides of the streets to enhance the overall green space rate of the area and increase the vitality of the landscape. (2) Maintenance and repair of the old buildings, the style and color of commercial signboards need to be unified. (3) Add pedestrian street in historic district, set up pedestrian-vehicle segregated roads and motor vehicle roads.

This chapter aims to be able to improve the landscape visual quality in historic district of Shenyang.

In chapter seven, VISUAL QUALITY OF RESIDENTIAL AREAS have been presented. the BIB-LCJ method was used to evaluate LVQ of four residential areas in Shenyang at a micro level. The poor landscape quality of green space and site space in residential areas reduced the overall landscape quality of residential areas, indicating that they had greater potential for improvement. The results of the analysis showed that the main influencing factors in green space were the morphology and disposition of plant communities. The public preferred a neat and orderly style of plant community, while the public rated the natural style plant community lower. In the site space, the main influencing factors were landscape structures and landscape facilities. The public preferred open and regular sites with rich artificial elements in the landscape. Pruning shrubs and trees, creating a combination of natural and artificial plant communities. We can enhance open and permeable sites , add regular and rich structures or landscape vignettes. Maintaining a clean and neat lawn, designing uniform and regular paving style and color can enhance the landscape quality of the site space in Shenyang Hunnan residential area. By summarizing the advantages and shortages of each space in the four residential areas, the study put forward some optimization strategies from landscape elements such as plants, pavements, landscape facilities and water. It provided some research basis for the future research. The conclusions helped the designers to make targeted and optimized design in residential areas.

In chapter eight, CONCLUSION AND PROSPECT have been presented. This study conducted the LVQ of urban streets, historic districts and residential areas,which used a image analysis method to quantitatively research at the macro level, the meso level and the micro level for Shenyang,China.In order to identify problems of the urban landscape visual quality and propose corresponding urban regeneration approaches.The contribution of the research is utilizing scientific theories and methods that combined qualitative and quantitative to urban regeneration design in the new period of urban data and new analytical techniques.