博 士 論 文

Research on Spatial Perception and Physical Features of Urban Streets based on Street View Big Data and Computer Vision Technology

街路景観のビッグデータとコンピューター視覚技術に基づく都市街路の空間知覚と物理的特徴に関する研究

北九州市立大学大学院国際環境工学研究科

2023 年 3 月

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Doctoral Thesis

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MARCH 2023

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Preface

Based on streetscape big data and computer vision technology,the streets of typical coastal cities Qingdao and Fukuoka were selected as the site to explained the correlation between physical features and the perceptual features of urban coastal streets to evaluation of the quality of street space.Combining the existing evaluation indexes of street space quality, from both the expert and the public perspectives， the study discussed the influence mechanism of physical parameters and public perception comprehensively. Through the comparative analysis of street physical features and perceptual features, the problem of spatial design quality of urban streets were diagnosed objective and scientific .It proposed a method of locating street space design problems in coastal cities.The study not only will reflect the urban landscape current situation ,but also provide the basis to optimize the quality of urban street space design efficiently and large-scale. Moreover,it will promote the scientific development of urban construction and planning.

ACKNOWLEDGEMENTS

Firstly, I would like to express the deepest appreciation to Prof. Weijun Gao and his wife. It is an honor to be a student of Prof. Gao . Although the past three years of study have been difficult and unforgettable for me, I have gained too much guidance and influence from Mr.Gao . I have obtained a new understanding and appreciation of my life.

Secondly, I would like to express my appreciation to my friends who have encouraged each other and studied together.They are Yao Fu，Yue Wang，Gonghu Huang，Lifei Song. Thank you for all the help and support have given me. Also, I would like to express my thanks to my students in Room 407, thank you for all your hard work and company.

Finally, many thanks to my family for their love and encouragement, especially my mother and my husband.

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ABSTRACT

Based on streetscape big data and computer vision technology,the streets of typical coastal cities Qingdao and Fukuoka were selected as the site to explained the correlation between physical features and the perceptual features of urban coastal streets to evaluation of the quality of street space.Combining the existing evaluation indexes of spatial perception from the expert and the public point of view , the study discussed the influence mechanism of physical parameters and perception. It proposed a method of locating street space design problems in coastal cities.The study not only will reflect the urban landscape current situation ,but also provide the basis to optimize the quality of urban street space design efficiently and large-scale. Moreover,it will promote the scientific development of urban construction and planning.

The chapter1 is research background and purpose of the study.In the process of urban regeneration, the environmental problems such as lack of vitality,confused urban style and features appeared in urban streets. Improving the quality of urban environment has become a link to improve the quality of urban space. The urban street is a characteristic and important part of the urban space, the street landscape has a combination of artificial and natural features, which is attractive and charming. Therefore, it is particularly important to build an accurate evaluation model with effective methods to further measure and predict public perception of space. The study will locate the problem of spatial design quality of coastal urban streets accurately, reflect the urban landscape, provide the basis for subsequent large-scale and deeper theoretical research of urban streets.

The chapter2 is literature review of street space features and quality.Based on the web of science database, this chapter analyzes the highly cited literature in related fields with CiteSpace visual analysis tool. Firstly, the research progress and planning strategies in the field of spatial perception, physic features and space design quality were combed. The evaluation methods and influencing factors were analyzed from the perspectives of subjective perception assessment and objective measurement. Secondly, the two perspectives of perceptual features and physical features were collated. The research on the relationship between street spatial characteristics, perceptual features and design quality were sorted out. The evaluation methods from the perspectives of street physical features and perceptual features was combed. Finally, A correlation analysis about the clustering results of related literature was conducted with the help of CiteSpace to discussed the problems and innovations in the research area.

The chapter3 is research method.The main research methods and measurement in urban streets were introduced. It included the method of urban street images collection based on streetscape big data. Streets spatial perceptual evaluation used semantic difference method (SD). Streets physical features used semantic segmentation technique based on deep learning (deeplabv3+).

The chapter4 is measuring and analyzing physical features of urban streets. y analyzing the data of each physical feature obtained, we mainly focus on the data depiction of seven physical features, namely, Greenness, Vehicle and Pedestrians Occurrence Rate, Proportion of Buildings,the Vertical Interface, Interface Enclosure Degree, Openness, as well as the preliminary discussion of the data results after simple data processing. In this chapter, the analysis will be carried out in the sections of overall description of sampling point data, sampling point analysis, data trend analysis, comparison of road segments, and preliminary discussion of each physical feature combined with the current status of the street. The analysis concluded that the street features, current problems and differences between Qingdao Coastal Streets,Meiji Streets and Coastal Streets in Fukuoka, Japan. The use of image recognition technology for urban street space data processing, can more clearly and intuitively reflect the current situation of the street. A finer and more comprehensive understanding of the constituent elements of the street. To provide a reference for the creation of future urban street scenes, a preliminary discussion on strategies to improve the quality of street space.

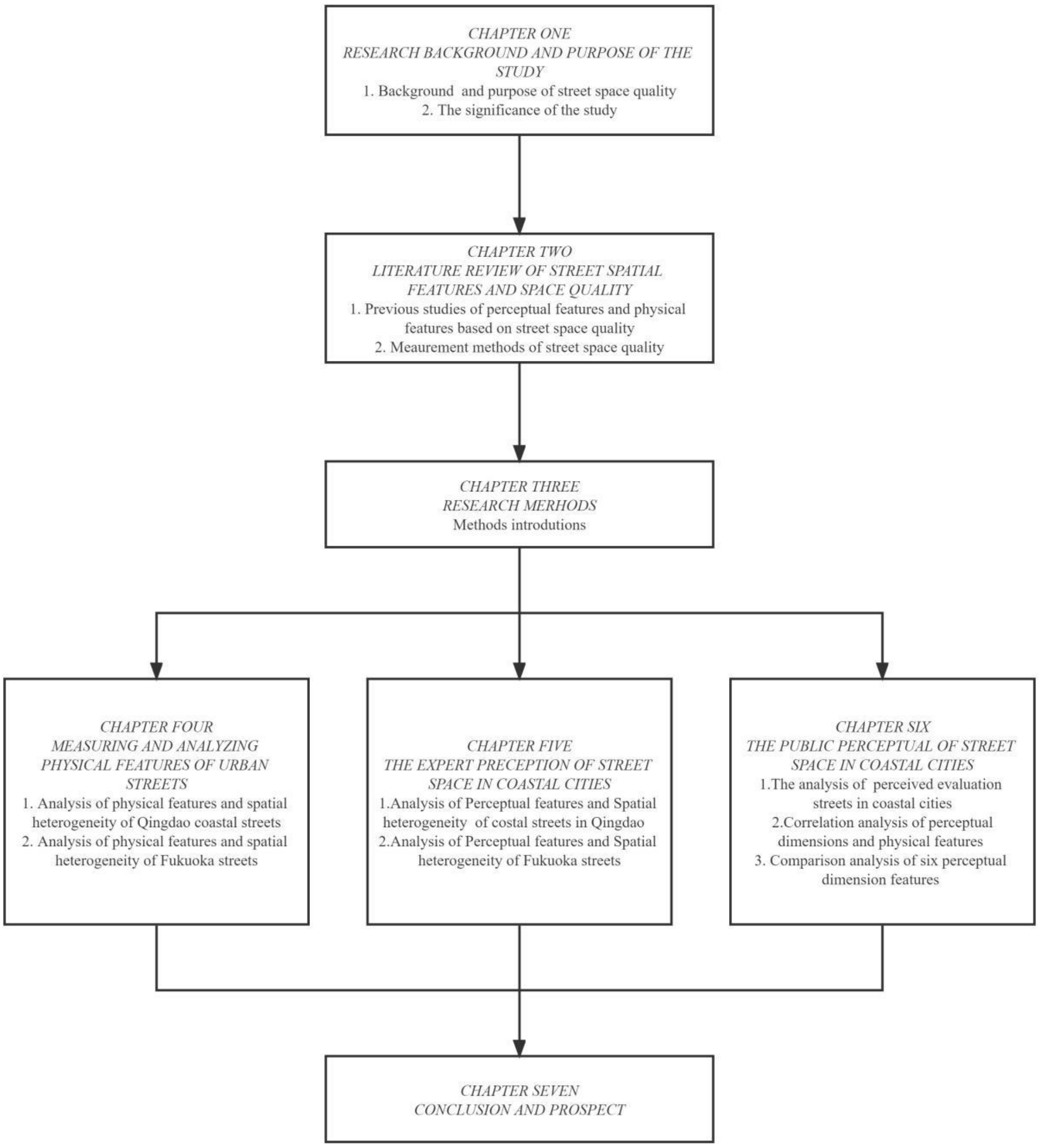
The chapter 5 Improving spatial quality and public perception of urban street space was an important work of urban regeneration. In this chapter, the study used machine learning semantic segmentation, GIS and Semantic difference (SD) methods to obtain the spatial data and perceptual evaluation of Qingdao Coastal Streets and Fukuoka Streets.Each of the six perceptual features, imageability, enclosure, human scale, transparency, complexity and nature, was taken as dependent variables and the corresponding physical features was taken as independent variables. The six regression models were established and the influence rules of spatial parameters on public perception were obtained in order to measure . Based on the results of perceptual features evaluation, the overall coastal streets were divided into three types, Open streets, Mixed streets and Biophilic streets. Meanwhile the Fukuoka streets were divided into three types, Low perception streets , High perception and Coastal streets . In all the types urban streets, the nature was the most significant perceptual feature due to the high greenness; the complexity was the lowest perceptual feature because of the low landscape diversity. In addition, Qingdao Coastal Streets and Fukuoka Streets were analyzed in terms of spatial heterogeneity.

The chapter 6 is the public perception of street space in coastal cities. It analyzed the distribution of perception dimension in street landscape and the relationship between perception dimension and landscape factors. In this study, Qingdao Coastal Streets and Fukuoka Streets were selected as the study sites. Get sample photos on Baidu Street View and Google Street View through Python. By analyzing each established scale with SD method, the concept and structure of the object could be quantitatively described. We calculated the standardized values of the perceptual dimension characteristic data in the samples, facilitate the comparative analysis of perceptual dimensions and the visual analysis of perceptual dimensions distribution.We also conducted the correlation analysis on the six dimensions of the sample perception data to determine the relationship between them and judge the positive or negative impact between each perception dimension. The study identified the impact of physical factors in street space on six perceptual dimensions.and analyzed the physical feature elements of street landscape.

The chapter7 is conclusion and prospect.Summarizes the conclusions of the each chapters and the optimization strategies of urban streets were proposed.

呂 美 博士論文の構成

Research on Spatial Perception and Physical Features of Urban Streets based on Street View Big Data and Computer Vision Technology



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Chapter 1

RESEARCH BACKGROUND AND PURPOSE OF THE STUDY

CHAPTER ONE: RESEARCH BACKGROUND AND PURPOSE OF THE STUDY

1.1 Background and Purpose

The urbanization rate of major developed countries in the world is higher than 70% in 2020. The urbanization rate more than 90% in Japan,while more than 60% in China .The overall environment of urbanization has entered the "stock era". In the process of urban regeneration, with the continuous increase of urban density, the traditional street scale is changed by the motorization-oriented urban construction mode.The environmental problems such as lack of vitality,confused urban style and features ,car congestion appeared in urban streets. It has impacted the natural environment, street safety, public health and many other aspects. As an important part of urban public space, good design quality of urban streets contribute to public interaction, promote regional harmony[1]. It shows the urban style and features, characteristics and economic development.

In The Death and Life of Great American Cities, Jane Jacobs proposed that the first thing in mind is the street when people think about a city. Meanwhile， the street is the main public space and the most important "organ" in the city[2]. In 1999, American Guide to Street Design for Healthy Communities pointed out that urban streets can also cultivate the sense of belonging of users. Therefore, street space quality is closely related to the construction of ecological city and healthy city (Fig1-1).

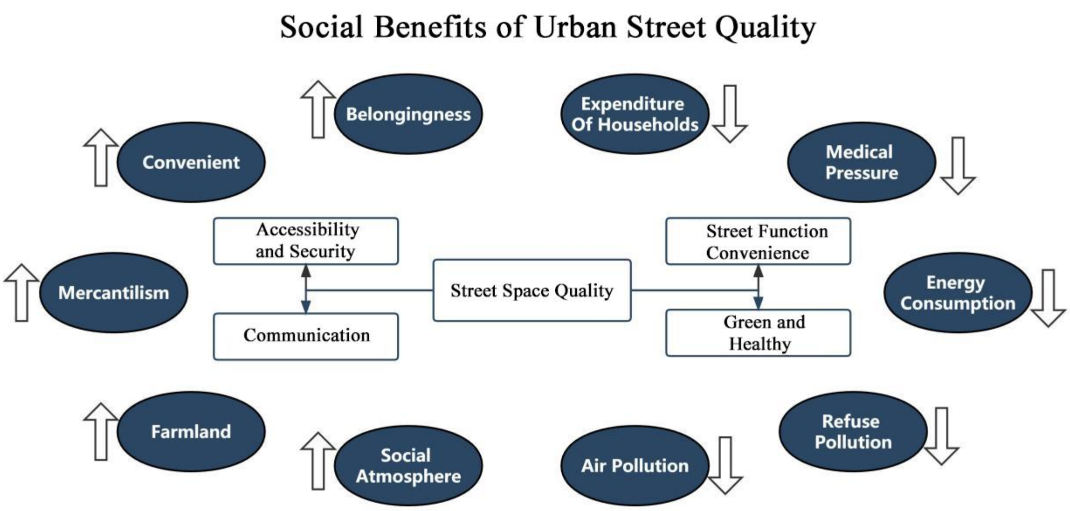

Fig 1-1 Social Benefits of Urban Street Quality

The street space is defined by the architectural interface on either side, whose intrinsic order forms the physical spatial pattern. It shows not only the spatial associations that exist between urban places and areas, but also indicates the volume of human activity and trajectories of movement[3]. The objective urban elements :form, visibility, use and significance influence the perception and understanding of urban spatial quality.They are extremely important for measuring spatial quality.Therefore, a detailed interpretation of the objective physical features is useful in determining the street space quality[4].

The current entry points for research into the quality of street space are as follows: Quantitative research based on the physical space form of the street, through a series of objective indicators to study and evaluate relevant indicators, such as greening rate, visible sky rate, building density, height to width ratio, degree of motorisation; qualitative research from the perspective of public subjective perceptions with regard to safety, security, continuity, comfort and attractiveness ; describing spatial quality according to residents travel dynamics, involving indicators such as accessibility and convenience.

The measurement of street features is an effective method to evaluate the overall street quality based on the close relationship between the built environment and the public activity[4]. With the improvement of computer technology, the measurement of objective physical features has changed from field survey and questionnaire to quantitative measurement of scale[5].

Since vision is the primary factor that constitutes perception, some scholars use image evaluation methods to inform the design of urban streets with the help of the results of human evaluation images[6].The results generated by the image evaluation of the urban landscape are used to construct an evaluation system for the spatial quality of urban streets[7]. However, there are limitations to the evaluation of urban spatial quality through human assessment combined with image observation, such as the small number and scale, and the discrepancies with field perception[8].With the improvement of computer vision technology , the convenience of big data collection of streetscape images and VR panoramic technique, the study deficiencies have been improved.The combination of techniques can objective and accurate spatial information about the street in three dimensions

While obtaining the physical features of the street, it is necessary to improve the measurement method of visual pedestrian perception and explore the relationship between physical features and the visual elements of the street environment[9]. However, currently, study on the quality and characteristics of street space mostly emphasized the availability of data and technology, and the measurement of street space quality from a subjective perception perspective is not effectively combined with the analysis of physical features of urban streets. Therefore, the influence mechanisms and quantification methods of user perceptions and physical features in the measurement of street space quality in the big data era need to be studied in depth..

1.2 Significance of the study

1.2.1 Demand for urban regeneration in stock era

In the urban regeneration of the stock era, there is an urgent need to realize the people-oriented and optimize build environmental to meet the diverse development needs of residents. Many government departments around the world have made it clear that residents will choose a healthy lifestyle, because of the improvement of the overall street environment in the region, so as to improve the well-being and health of residents[10][11]. The basic way to improve the quality of urban life and one of the ways to solve the problems of global warming, social inequality, environmental degradation and public health is enhancing the walkability of city streets[12].

1.2.2 Public demand for healthy travel

Walking is an important life experience for residents. In the process of walking, people can feel the street life and form a cognition of the city. Walking can promote health. Related studies showed that keeping walking could positively promote health problems such as obesity, type 2 diabetes, cardiovascular diseases. It can also improve the growth of bones and reduce depression levels to some extent. Therefore, on September 2012, Chinese government departments issued relevant guidelines and proposed to promote the construction of urban bicycle and pedestrian transportation systems in all aspects in order to improve the urban habitat and promote sustainable development[13].

1.2.3 Big data drives new changes in urban street planning

Compared to traditional urban planning, urban research supported by big data technology will lead to a shift from traditional spatial planning to dynamic spatial planning, and promote the transformation of urban planning and governance from a conductive to a scientific approach. With the transformation of the street from a single traffic function to a comprehensive function, it is particularly important to construct a model for measuring and evaluating the quality of street space that combines perception and objective physical characteristics to further help urban planners, designers and decision-makers pinpoint the problems that exist in street space.

1.2.4 Accurate and scientific diagnosis of urban street problems in coastal cities

The coastal cities have the most attractive and charming landscape in urban streets,especially the coastal streets.It can enhance urban imagery and improve street environmental quality. The high-quality environment in the streets can promote the development of tourism and economy. The blue-green spaces played an important role in the mental health, such as urban parks, groves, rivers and coasts. Therefore, pinpoint the problems of the streets, highlight the spatial features , coordinate the relationship between landscape elements, from the designer's point of view,satisfy the needs of the public aesthetic become the important contents of human settlements environment research in coastal cities.

1.3 Research purposes

The streets of typical coastal cities Qingdao and Fukuoka were selected as the sites, which based on index related to street space quality evaluation. We measured of street by integrating multiple sources of big data in order to obtain the physical features. Based on streetscape big data and computer vision technology, scientific, objective and rapid measurement methods were adopted to improve the physical features of streets and interpret the spatial features of urban streets. Combining the existing evaluation indexes, from both the expert and the public perspectives,the study discussed the influence mechanism of physical parameters and perception. Through the comparative analysis of street physical features and perceptual features, the problem of spatial design quality of urban streets were diagnosed objective and scientific. It proposed a method of locating street space design problems in coastal cities. The optimization strategy provided for the existing space design problems. The study not only will reflect the urban landscape current situation, but also provide the basis to optimize the quality of urban street space design efficiently and large-scale.

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Chapter 2

LITERATURE REVIEW OF STREET SPATIAL FEATURES AND SPACE QUALITY

CHAPTER TWO: LITERATURE REVIEW OF STREET SPATIAL FEATURES AND SPACE QUALITY

2.1 Introduction

Urban construction has brought about the expansion of motor vehicle roads, and the pedestrian street has been squeezed and replaced. However, the urban construction mode dominated by motor vehicles has brought many problems. Many researchers became to focus on how to improve urban street space quality. Currently, the research field shifted from the construction of street environment walking system to focus on the relationship between street space characteristics, design quality and street space qualities. The research methods also shifted from the traditional field investigation and questionnaire for the large-scale quantitative measurement by using the current science technology. Based on the web of science database, this chapter analyzes the highly cited literature in related fields with CiteSpace visual analysis tool. Firstly, the relevant concepts are defined in this study. Secondly, the two perspectives of perceptual features and physical features were collated. The research on the relationship between street spatial characteristics, design quality were sorted out. The evaluation methods from the perspectives of street physical features and perceptual features was combed. Finally, A correlation analysis about the clustering results of related literature was conducted with the help of CiteSpace to discussed the problems and innovations in the research area.

2.2 Related concepts defined

2.2.1 Street space

Kevin Lynch was the first to propose the theory of urban imagery, which explored the influence and significance of the five objective elements: path, edge, district, node and landmark on urban space[1].Of these,the path should come first among the elements of the physical form , and other elements need to be arranged along and connected to the road.Street space is a linear public space enclosed by buildings on both sides of the street, an open place for public interaction and activities for the residents, as well as a certain traffic function.

In the study, we defined street space as the three-dimensional space enclosed by the street and a series of facilities such as buildings and greenery on both sides of the street.

2.2.2 Streetscape

A good streetscape has a huge impact on the overall appearance of the city.It not only assumes an important traffic function, but also has a positive effect on the pleasure and happiness of the inhabitants.A streetscape is a landscape formed by the road and surroundings.The streetscape can be divided into a horizontal interface factor, a vertical interface factor and a street furniture factor. The horizontal interface factor includes the sky, road surface, motor vehicles, non-motor vehicles, etc;The vertical interface factor includes building enclosure, plants, fences, etc.;The street facility factor includes commercial facilities, amenities, transportation facilities, etc.

2.2.3 Street physical features

The physical composition and environmental characteristics of the street space are the carrier for people and activities. The differences influence the street space quality[2].Previous research shown that a good physical environment, appropriate greenery, rich landscape elements, distinctive architecture, high quality and continuous pedestrian space, an easily accessible transport network, a low sense of enclosure and open views had an important impact on the quality of the street.As far as the measurement of physical characteristics is concerned, most studies have objectively quantified the quality of physical space from three perspectives: connectivity, comfort and usability of the street space.

2.2.4 Street perceptual features

In terms of the subjective street space perceptual features , Carmona specifies quality evaluation criteria that reflect the social, economic and environmental characteristics of urban street space, such as accessibility, attractiveness, comfort, inclusiveness, vitality, uniqueness and safety[3].Field measurements were used to summarise five operational street design qualities within the street space:

imagery, legibility, enclosed space, human scale, and transparency by Reid Ewing. By quantifying the subjective residents perceptions of the environmental quality of urban street space can be indirectly reflected.

2.2.5 Street spatial quality evaluation

The study of the quality of street space consists of the objective physical space and the subjective psychological perception of the users.The objective physical features reflect whether the streets have the ability to satisfied the needs of people in the street space, and is the basis for judging the space quality ; the degree of recognition of the street space reflects the subjective feelings of people in the street space.

The street spatial quality evaluation refers to the assessment of the physical environment and the level of people satisfaction needs in the street space. The former refers to the objective physical space such as pavement, infrastructure, landscape features, greenery, pavements and architectural interfaces in the street space; the latter mainly refers to the expression of the results of users' higher-level spiritual perceptions such as comfort, safety and pleasure in the use of the space.

2.3 Experimental study of the street spatial features and spatial quality

Urban features design and public health have been linked to street space qualities research in previous studies[4]. The previous urban theories laid a theoretical foundation for the study of contemporary urban and street space characteristics, including urban diversity theory, urban image theory, spatial place theory, public interaction theory, urban catalyst theory, urban compilation theory and so on[2]. New technologies such as street view images and semantic segmentation provide technical support for the study of large-scale space features of streets.

2.3.1 Spatial characteristics and quality evaluation of streets based on objective physical features

Sealens, handy, and other scholars proposed the theory that the street spatial quality influences residents' travel behavior[5]. Early scholars concluded that physical features affecting street spatial quality include features such as residential density, land use combination, and street design[6][7][8][9]. There is a high degree of contribution among the physical features that make up the built environment and they are used to measure the quality of the built environment[37]. Four of these indicators, junction density, net residential density, retail floor area ratio, and land use combination, comprise a street space qualities index that has been supported by at least 12 published papers, which show that the same or similar indicators are significantly and positively associated with street space qualities and physical activity[10][11][12][13][14][15][16][17][18][19][20][21][22].

In recent years, research on street space qualities focused on more microscopic issues. Scholars begun to focus on the aesthetic features, greenery, traffic safety, the quality of walking trails, weather, recreational facilities, and other potential derivatives of the physical environment.It shown that infrastructure and aesthetics of pedestrian areas prove to be associated with recreational walking. The mixed land use and density may also influence the aesthetic quality of the walking environment [23]. Other aesthetic features also influenced street space qualities, such as attractive architecture or urban design[11][24], noise, air pollution or physical impairment[25][26][27](annoying features) , parks or natural areas[28][29][30](green spaces) and etc[31].

In the early studies, Quantitative evaluation of street spatial features such as street greening, enclosure and sidewalk scale is also difficult to carry out, and less attention is paid to the impact of street spatial features on street spatial quality. street spatial quality has been studied in relation to the physical features of urban design[32]. Because it is difficult to measure the physical features of streets, the design quality of street space based on street spatial quality is limited to a few street space features such as sidewalk width and street tree density[33]. Traditional research methods of street space features are often described by sociology, environmental behavior and other disciplines.

For example,obtaining information on both sides of the street or plots through field research or existing data requires a lot of work and the support of other disciplines[34]. Scholars have proposed some methods to calculate sky openness, such as geometric analysis method, projection computation method, GPS method, spherical calculation method, shading calculation method[35][36]. Tanglian found the inflfluence of street interface signs on pedestrian behaviour by mapping methodology. The greeness is often studied by photography， simplify the greening information of the sampled landscape photos, and obtain the data by calculating the greening area in the human vision[37].

At present, with the development of street view images and machine learning technology, solving the problem of measuring street landscape elements[38] is helpful to understand the influence of street micro-level spatial features on street space qualities in the city. For example, Yang Junyan et al. based on Baidu Street View Big Data, constructed a street feature evaluation system and evaluated the street space qualities by identifying the relevant traffic elements such as motor vehicles and walking paths in street view pictures[39]. Related studies show that the spatial features and streets quality are related to the physical elements of the streetscape, such as building, sky, greenery, sidewalk, road, street width. Previous studies have proved that the greening and open space layout, building density, street space features in street space will directly affect the behavior and mood of pedestrians[40][41][42]. At the same time, the spatial features of the street have an impact on the street quality , such as green landscape index[43], sky openness index[44], long sight line [45],critical buildings, pedestrian space[46], enclosure[47][48], width of the sidewalk [49](Tab2-1).

Table 2- 1 Analysis of Influencing Factors of Street Features and Quality

NO.	Year	Author	Impact elements	Title	Source
1	1983	Nasar	diversity, nuisances, enclosure, clarity	Adult viewers' Preferences in Residential Scenes A Study of the Relationship of Environment Attributes to Preference	Environment and Behavior
2	2009	Ewing and Handy	imageability, enclosure, human scale, transparency, complexity	Measuring the Unmeasurable: Urban Design Qualities Related to Walkability	Journal of Urban Design
3	2011	Lwin and Murayama	normalised difference vegetation index, greenness	Modelling of urban green space walkability: Eco-friendly walk score calculator	Computers, Environment and Urban Systems
4	2015	Li et al	green view index	Assessing street-level urban greenery using Google Street View and a modified green view index	Urban Forestry & Urban Greening
5	2016	Dubey et al	safe, lively, boring, wealthy, depressing, beautiful	Deep Learning the City: Quantifying Urban Perception at a Global Scale	European Conference on Computer Vision
7	2017	Liang Cheng et al.	salient region saturation, visual entropy,green view index,sky-openness index	Use of Tencent Street View Imagery for Visual Perception of Streets	isprs
8	2017	Li Yin	Long sight line, The proportion of sky, imageability, enclosure, human scale, transparency, complexity	Street level urban design qualities for walkability: Combining 2D and 3D GIS measures	Computers, Environment and Urban Systems

9	2018	Shen et al	greenery, sky, building, road, vehicle	StreetVizor: Visual Exploration of Human-Scale Urban Forms Based on Street Views	IEEE Transactions on Visualization and Computer Graphics
10	2018	Ernawati et al	enclosure, legibility, human scale, transparency, complexity, coherence, linkage, imageability	People's Preferences of Urban Design Qualities for Walking on a Commercial Street	Series: Earth and Environmental Science
11	2019	Hamidi and Moazzeni	imageability, enclosure, human scale, transparency, complexity, Demographic, number of active patios, width of the sidewalk, number of parks	Examining the Relationship between Urban Design Qualities and Walking Behavior: Empirical Evidence from Dallas, TX	Sustainability
12	2019	Ye et al	street greenery, sky view, building frontage, motorisation, pedestrian space, diversity	The visual quality of streets:A human-centred continuous measurement based on machine learning algorithms and street view images	Urban Analytics and City Science
13	2019	E.HOOI and D. POJANI	imageability, enclosure, human scale, transparency, complexity	Urban design quality and walkability: an audit of suburban high streets in an Australian city	Journal of Urban Design
14	2020	Chen et al	green view	Quantifying the green view indicator for assessing urban greening quality: An analysis based on Internet-crawling street view data	Ecological Indicators

15	2020	L.G. Natera Orozco et al.	The Services Index，Safety Index，Environmental Index（Air Pollution Ratio，Ratio of Natural Areas）	Quantifying Life Quality as Walkability on Urban Networks:The Case of Budapest	Springer Nature Switzerland AG
16	2021	L. Dai et al.	greenness,openness,enclosure,imageability,walkability,blueness,traffic flow	Analyzing the correlation between visual space and residents' psychology in Wuhan, China using street-view images and deep-learning technique	City and Environment Interactions
17	2021	X. Ma et al.	greenness,openness,enclosure, imageability,walkability	Measuring human perceptions of streetscapes to better inform urban renewal: A perspective of scene semantic parsing	Cities
18	2021	Ernawati	Complexity, Coherence, Imageability	The Role of Complexity, Coherence, and Imageability on Visual Preference of Urban Street Scenes	Series: Earth and Environmental Science
19	2021	Qiu et al	Enclosure, Human Scale, Complexity, Imageability	Subjectively Measured Streetscape Perceptions to Inform;Urban Design Strategies for Shanghai	International Journal of Geo-Information
20	2022	Tao et al	greenness, openness, enclosure, walkability, imageability	Measuring the Correlation between Human Activity Density and Streetscape Perceptions: An Analysis Based on Baidu Street View Images in Zhengzhou, China	Land

21	2022	Xu et al	Greenness, Walkability, Safety, Imageability, Enclosure, and Complexity	Associations between Street-View Perceptions and Housing;Prices: Subjective vs. Objective Measures Using Computer;Vision and Machine Learning Techniques	Remote Sensing

2.3.2 Research on the spatial features and quality of streets based on subjective perception

Vision is an important part of human perception and the most direct way to get a sense of the environment. During the development of street street space qualities research, scholars began to focus on human perception in street environment. Using residential areas as the site, scholars put forward to understanding the street landscape visual features from the perspective of visual perception[50]. The spatial features and quality of the street are composed of the objective spatial quality of the street and the subjective psychological perception of the users[51]; The features of street physical environment can accurately reflect the objective spatial quality of the street, but it cannot capture people's overall perception of the street environment. People's perception of physical elements of street space and their perception of its formation is an important content to evaluate the quality of street space[52]. Subjective perception refers to the deeper inner spiritual perception involving human safety, comfort, beauty under the action of urban material space. 51 perceptual qualities are summarized in the literature on visual preference and visual assessment[53] in architecture, landscape architecture, environmental psychology and urban design literature[54][55](Tab2-2). By further investigating the eight perceptual features of imagery, legibility, enclosed space, human scale, transparency, linkage, complexit and coherence, Ried Ewing found that imagery, legibility, enclosed space, human scale and transparency can be operationalized. Li Yin, Shen, Ernawatideng and other scholars explored the spatial features that influence the quality of street design through these five perceptual features[56][57][58]. A human-machine adversarial framework to obtain urban perceptual distributions was proposed by Yao et al, training the sample set with six perceptual features: Safety, Lively, Boring, Wealthy, Depressing, and Beautiful.And using the method of deep learning to evaluate the images[59] to map the perceptual distribution within the city.

Liu Yingbin evaluated the comfort, tolerance and resistance of residents in the block by questionnaire method, and established the evaluation system of walking environment,then established an evaluation system for the walking environment[60].

The efficiency of the field research method is low, and it is limited to a small area, and there is some doubt whether the research results are large-scale scenes. Subjective evaluation mostly adopted psychophysical method -SD (Semantic Differential), also known as semantic analysis method, which was put forward by Charles E. Osgood in 1957[61][62]. SD method uses adjective pairs to measure human intuition and has been successfully used by scholars to evalute the physical environment. Previous studies have shown that the high walking safety in blocks with poor public security or high crime rate is obviously reduced[63][64][65][66]. Adequate street lighting systems contribute to high pedestrian safety[67]. The number of resting facilities and street trees that facilitate travel has been shown to improve pedestrian walking comfort. At the same time, diversified street greening helps to improve the aesthetics of the street environment. Through the analysis of each established scale, the concept and structure of the research object are quantitatively described. At present, SD method is used to evaluate the landscape perception of parks[68][69], streets[705], residential areas[71] and squares[72] in cities.

Table 2- 2 Perceptual qualities

Adaptability	Distinctiveness	Intricacy	Richness
Ambiguity	Diversity	Legibility	Sensuousness
Centrality	Dominance	Linkage	Singularity
Clarity	Enclosure	Meaning	Spaciousness
Coherence	Expectancy	Mystery	Territoriality
Compatibility	Focality	Naturalness	Texture
Comfort	Formality	Novelty	Transparency
Complementarity	Human Scale	Openness	Unity
Complexity	Identifiability	Ornateness	Upkeep
Continuity	Imageability	Prospect	Variety
Contrast	Intelligibility	Refuge	Visibility
Deflection	Interest	Regularity	Vividness
Depth	Intimacy	Rhythm	

2.4 Research on the measurement of street features based on street space quality

Currently, the measurement studies in the street space quality are mainly based on the perspective of urban morphology and environmental behavior. The studies were chosen one or more streets to research the spatial quality. The data were obtained and analyzed through methods such as field survey, big data collection or machine learning. The methods for measuring the spatial features can be divided into traditional methods and new methods. The new methods includes big data and computer vision technologies.

2.4.1 Traditional methods

The traditional measurement methods mainly include map marker, field counting , interview, questionnaire, and field survey.

In the measurement analysis the street walking quality, William Witt first made a qualitative observation of human activities, and manually collected environmental features such as architectural forms, street facilities and environmental factors to investigate how human activities were affected by street space quality in the city [73]. Handy et al. (2006) argued that the street space quality influences walking behavior after taking into account the preferences and attitudes of neighbors. However, the individual objective features can not directly reflect the pedestrian experience[74]. In order to obtain the perception data of pedestrians walking in the street, many scholars have analyzed how pedestrians visually perceive the street space quality through interviews, surveys, audits and field observations[75][76][77]. On the other hand, residents respond to their satisfaction and perceived state of the environment in the form of a scale. In 2002, Professor Sallis proposed the Neighborhood Environment street space qualities Scale (NEWS) to explore the influence of neighborhood environment on people's street space qualities, which included environmental factors such as perceived of residential density, street connectivity, aesthetics, mixed land use diversity, and traffic safety[78](Tab2-2).

The traditional research method is based on questionnaire, which is convenient for more subjective evaluation of the street space quality. On the one hand, the Likert scale is used to quantify pedestrian perception of accessibility, safety, comfort and attractiveness in the street street space[79][80][81][82]. For example, the field survey and interview method in “Public Space and Public Life Survey Method” put forward by Jan Gehl had been proved to be directly related to people's subjective perception[83][84]. Some scholars conducted questionnaires to determine local visual indicators and psychological conditions through the scores of pedestrians[85][86].

2.4.2 New methods based on big data and computer vision technologies

Perceptual evaluation is greatly subjectively influenced and data collection is difficult. Therefore, it is difficult to measure in a large scale environment. Streetscape big data and computer vision technologies (machine learning, VR) can make up for the lack of perceptual evaluation.

The advance of computer technology has provided the new tools to explore the street space qualities. The method of measuring street street space qualities has been changed, because the computer vision technology and the convenience of big data collection of street view images. This change is from walking perceptions based on interview transcripts to quantitative measurements, with the indicator system construction based on field survey and questionnaire as a transition[87]. The advance of methods solved to the disadvantages of insufficient samples for manual evaluation and the difficulties of deal with data, alleviates the limitations in cost, time and measurement scale. Meanwhile, it is also easy to compare between different cities. Due to the streetscape map and the development of the computer vision technology, Scholars achieve the measurement and evaluation of spatial features in the whole urban streets.

Street view images are the static photos based on human visual scale to observe urban street elements, which can represent the urban objective environment. It has the characteristics of wide coverage, batch and objectivity, and is important for studying the objective urban environment from both subjective perception and objective environment perspectives[88]. Currently, Google, Baidu, Gaode and Tencent are the main data source, they can offer 360° panoramic photos for users. Some scholars have confifirmed the reliability of street view image for studying the quality of the street environment by comparing the street view image with the results of field scoring[89][90][91]. Street view images were used to measure the features of the street elements for some studies, including studies on street space qualities, three-dimensional (3D) urban reconstructions[92][93][94], specific scene recognition[95], investigations of plant and animal species[96][97][98], route selection[99], perceived safety evaluation[100], evaluation of the visual perception of streets[101][102]and urban design qualities.

Moreover, street view images provide information about street micro-environmental factors such as roadway, sidewalk, greenery, which can further perfect the street space qualities measures. street space qualities evaluations can be tried in the city level. The advance of machine learning have provided possibilities to deal with large-scale data[103]. The Urban studies with machine learning are in a rapid development phase, the major directions including computer vision and natural language understanding[104]. Machine learning can conduct the correlation analysis between the urban big data and individual public cognitive behavior, such as computer identify features in image and semantic segmentation. In the previous studies , most scholars have focused on 1-2 physical features which led to the lack of systematicity and comprehensiveness in the researches, such as greenness or openness[105]. Be supported and influenced by developments of data set and machine learning techniques, the semantic segmentation can identify the landscape elements in the street view images. It can analyse the constituent elements of the objective urban environment. For example, by extracting sky areas can be analysed the openness [106]and the relationship between sky view rates and walking behaviour[107]; by extracting vegetables can be evaluated the level of greenness in the street space. In addition, pedestrians, buildings, fences and traffic signs can be classified for relevant studies. Due to the combination of machine learning and street view images, researchers can identify features from complex street environments which is helpful helps to efficiently evaluate street space quality and street design quality[108].

Meanwhile, in the researches of street walking quality, the vsualisation technologies provides the virtual experiences of a range of walking needs, be helpful to research the walkability and visual walkability. Virtual reality (VR) technologies provides the possibilities to gain true experiences of real street environments[109]. Sensors and computer vision technology have become more universal and cost-effffective method for tracking pedestrians in real-time[110]. Li has built a deep learning model based on visualization techniques for further measure visual perception in the street space quality [111].

2.5 The review of street space quality based on the citespace

2.5.1 Data Sources and Methods

This study uesd the citespace software to analyze the literature based on the core database of WOS (web of science) core collection for data analysis. The search was conducted for keywords related to the subject "street design qualities" , the time span for data extraction was set from 2003 to 2022. Finally, The search formula is determined as TS=((“street design qualities”) OR((“street perceptual features”)OR ((“street physical features”)OR ((“street space qualities”)OR ((“street space qualities”OR“perceptual features” OR “physical features”OR “measurement”OR “big data”) AND((“street design qualities”) OR (“perceptual features” OR “physical features”OR “measurement”OR “big data”)). The study removed some irrelevant publications, Finally, 7556 valid research data samples were obtained to visual analysis. The literature about street space qualities were analyse for learn the number of publications, sources of literature journals, and publication institutions. The number of publications is increasing year on year.

The number of publications has a significant increase in 2017(Fig2-1). It indicated that the hot topic ofstreet space qualities continue to grow in the last two decades, scholars pay more attention to their spatial quality.

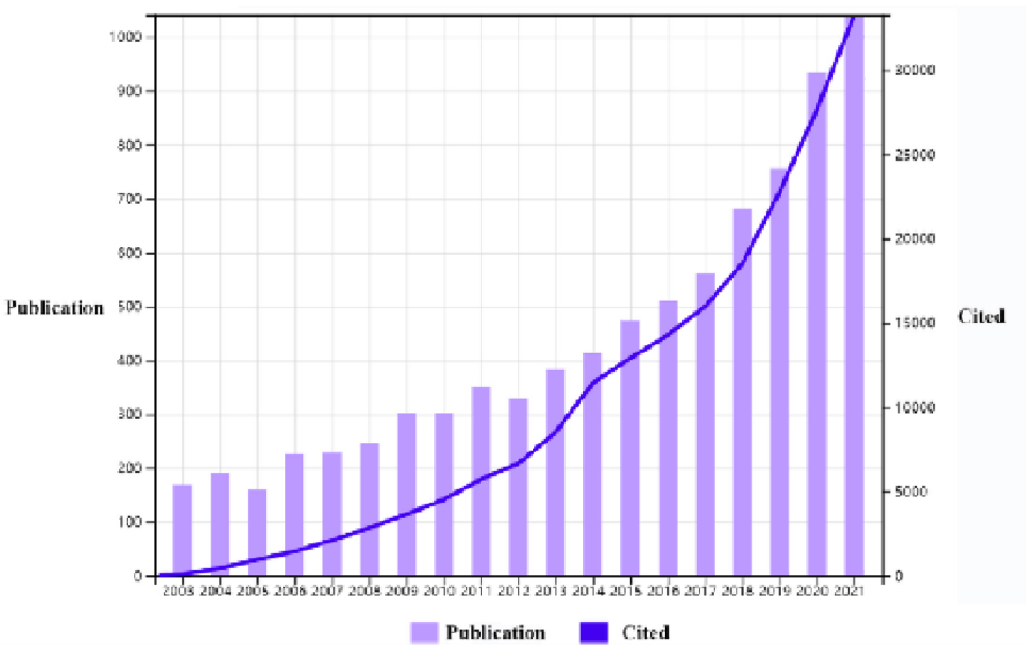

Fig 2-1 The number of street space qualities publications

According to the journals of literature, the top five cited journals are sensors, Sustainability, Building and environment. The result reflects that the research level of the main literature on street space qualities mainly focuses on the Engineering, Physics and Environmental Science Ecology(Fig2-2).

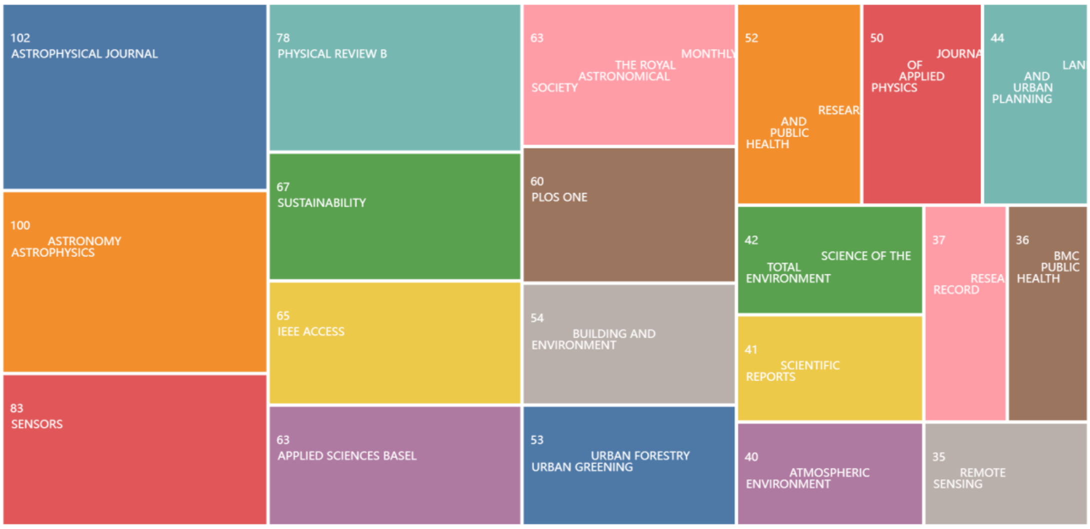

Fig 2-2 The top 20 cited journals of street space qualities

2.5.2 Literature clustering analysis

The literature of street space qualities and street features are from the web of science for the last 20 years, The study conducts clustering of highly cited literature by citespace, Co-citations are often found in two or more papers[112]. The cited parts can be the topics, theories or research methods in the field of study. The analysis of co-citation clusters shows the clear trends and research frontiers in the field, and identifies relationships between the research frontiers.

Sample data formed a knowledge map of literature co-citations, it analysed the theoretical structure of the "street space qualities" research field by the forms of a visualisation. In the citespace operation setting, the time slice was set to 1. In the knowledge atlas of literature clustering in CiteSpace, there were 766 nodes (N=766), 1393 (E=1393) lines that connected the nodes and formed five clusters(Fig2-3). In the mapping, nodes and links in grey and blue were older studies, while nodes and links in red are newer studies. The different colors of the nodes corresponded to the time when they were referenced[113].

Nodes were the literature, and their size indicated the total frequency of citations in the literature. The mapping of the co-citation network showed that the research of street space qualities in the urban street has a typical early state. The network mapping was concentrated with overlapping and fewer branches of research. There was a strength of correlation between the literature and they could be interpreted and explained to each other. Some of the key nodes were located at the junction of the knowledge clusters, and served as a bridge between the clusters. It provided theoretical support and direction for in-depth research. In the research of urban street space qualities, The co-citation network showed a clear division of knowledge groups and a strong correlation between groups. Many key nodes formed the literature clusters and the lines showed the correlation with each other in the same color.

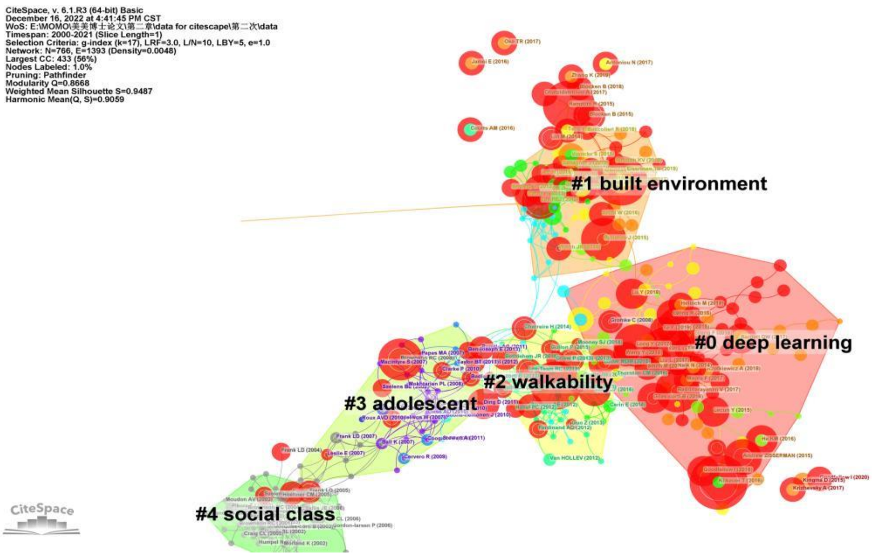

Fig 2-3 The literature co-citation analysis

2.5.3 Trending Topic of Timezone Research

The Timezone shows the development of the field in a temporal dimension and the correlation between the literature. Timezone help to find the change of the research hotspots of street space qualities in the temporal dimension and to keep track of future trends. It showed that the research on street space qualities is on a good trend, with an increasing variety of hotspots(Fig2-4). The development of street space qualities studies has been divided into two phases as follows:

(1) The research of the street walking quality (2003 - 2010)

During the period 2003-2010, researches focused on the street walking quality. At present, urban walking behavior is the main focus of environmental and policy initiatives in public health[2]. Urban critics and New Urbanism Planning scholars advocated that build pedestrian-friendly streets and neighborhoods for increased pedestrian walking[114]. Since the 1990s, scholars in the fields of public health and transportation had conducted earlier research. The field of transportation always working on the relationship between the built environment and travel behavior. Researchers also considered the influence of the built environment on walking[115][116]. .More studies found that physical environmental attributes were associated with physical activies[117][118][119]. While the physical activities were related to with different perceptual and objective environmental attributes[120][121]. In recent years, the intersection of urban planning and public health fields has become a frontier research area of walkability. Researchers and planners begun to pay attention to the importance of the street environment on walking behavior.Practitioners need to understand the specific characteristics of the built environment[122][123] and design streets in order to promote more physical activities[124][125][126][127][128]. In fact,a good street environment will promote walking behavior, otherwise it will restrict travel[129]. scholars began to introduce ecological models into their research.Ecological modelling is a method of sociological research which emphasizes controlling for the effects of external variables on dependent variables by measuring them in a real environment[130][131]. It found that environmental features were more closely related to physical activity.Neighbourhood environment was found to be more closely related to youth physical activity, and walking mode of transport was significantly associated with perceived residential density, land use allocation, street connectivity[132][133], aesthetics and safety. Through the development of research, there has been a greater focus on the rational planning of streets at the micro-spatial scale, the quality of the landscape along the street, and the facilities along the street. The research content and themes shown a diffuse correlation. This period has seen an increase in relevant research methods. The in-depth study of the factors influencing walkable street space has contributed to the development of urban planning while gaining social and disciplinary recognition.

(2) The research of the street space quality (2010 - Now).

In this period, with the improvement of the street walking quality, scholars are not focusing on this field. The study of the overall street space quality is gradually carried out. Early research data about street space quality were mostly obtained by traditional methods. The form of relevant data collection includes field survey and questionnaires for the public or experts. SD, AHP, and satisfaction evaluation were used to analyze data. The methods can quantify the human perception of the spatial environment in the streets. Due to the small sample size, long time consuming and slow update, it is difficult to carry out a large scale survey and research. With the development of the big data, it is possible to conduct a whole and macroscopic study of street space quality. Big data is characterized by large size, many types and easy to collect, thus it has broken the limitations of collection data in the previous studies. With the rapid development of computer vision technology such as Deep learning, it achieved rapid processing for big data and could accurately measure street features. Based on big data collection and analysis technology, the study has achieved the study of the street space quality in a large scale, and improved the accurate and science of the quantitative evaluation for the space quality. It is convenient to carry out a more in-depth study of the street space quality.

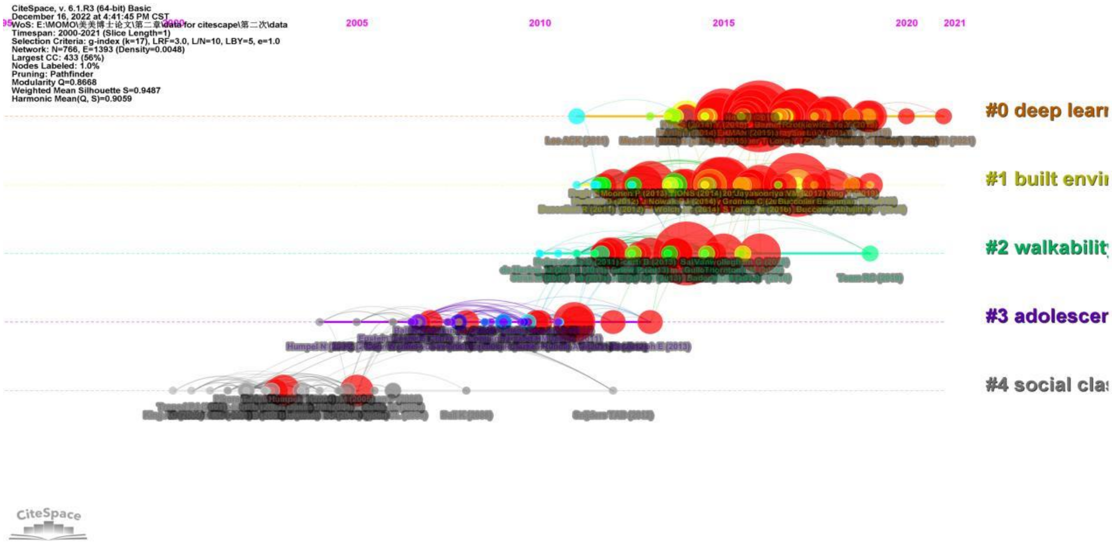

Fig 2-4 The Timezone of topic clusters

2.5.4 Conclusion

2.5.4.1 The trending of street space quality research

Based on a review of the relevant literature, it was found that the scope of research on the street space quality has gradually expanded with the evolution of measurement methods. Living streets were firstly studied. They are streets where people daily interaction and walking for transport. The residential neighbourhood is regarded as one of the most commonly analysed places in the environmental psychology and is important for the development of emotional relationships[134]. Living streets include residential streets, commercial streets, office streets, but the studies lack the analysis of the street space quality for special streets, such as the urban coastal streets.

From the study scope, some studies were selected one or more streets to research the spatial quality by Field survey. The studies scope is small. Meanwhile, these studies enhanced the street space quality by physical environment such as seats, plant species, and landscape vignettes in streets. With the development of big data and computer vision technology, the trouble in the technical was broken. This has led to the study of street space gradually expanding from micro space to the macro level of the overall urban space. The research focus has also gradually moved from a single case to a more systematic and structured level. They promoted the depth and breadth of research on the street space quality.

2.5.4.2 Measurement trends

(1) Perceptual features

It can enhance the pleasantness and emotional well-being by establishing a connection with the public psychology and perception. First, safety has been found to be the fundamental need for people in the built environment [135], it includes traffic safety and social safety. The teenager active transport to the places had the positively with high traffic safety and negatively with crime threat[100]; Unsafe environments could be contacted with high levels of environmental, physical and mental stress, It can affect quality of life and mental health[136][137][138][139]. Aesthetic and attractive are the difficulty for pedestrians to experience higher levels of walking needs in everyday walking environments[6]. some studies suggested that comfort was an important requirement for walking. Comfort refers to the degree of satisfaction, ease and safety[140][141][142]; Aesthetic refers to the degree of interest and happiness in the walking environment[143][144](Fig2-5).

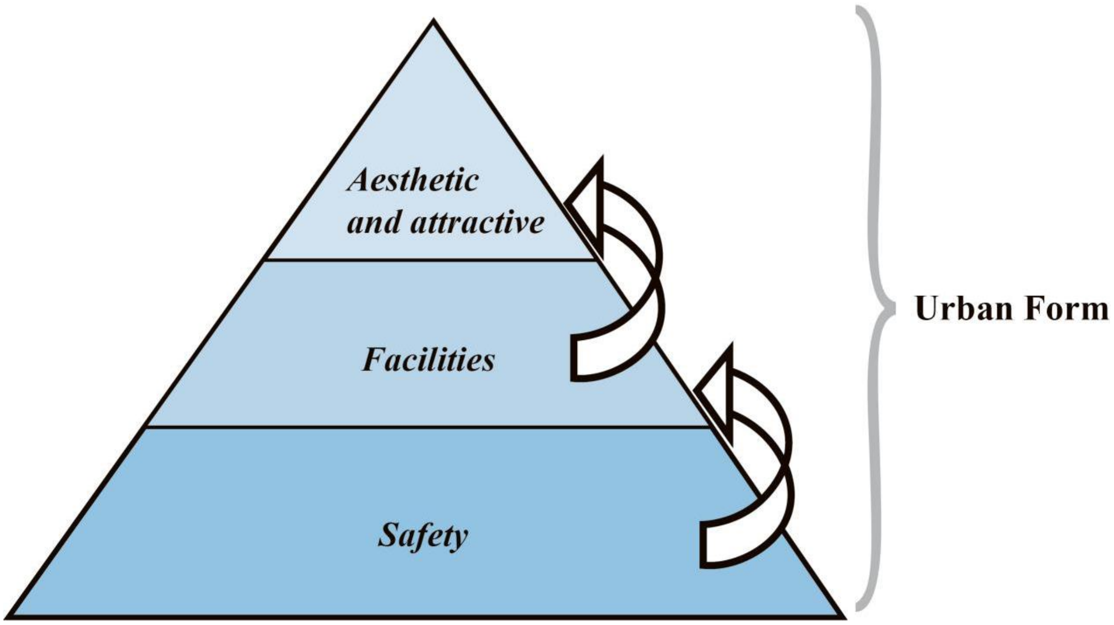

Fig 2-5 Maslow Hierarchy of Needs in the street space quality

(2) Physical features

With the development of big data and computer vision technology, new measurements methods and features that affect street quality have emerged[145]. In the early days, the main measurable indicators were relatively objective and easily quantifiable of meso-environmental factors, including classical indicators such as residential density, land use mix and road continuity[146][147]. Scientific evidence shown that meso-environmental factors had a significant impact on walking behaviour. The scholars proposed new indicators such as commercial to residential land use ratios and road intersection densities to increase measurement index[148][149]. Research on street space quality is increasingly focused on the micro-environment, exploring the impact features of street space quality, such as greenery, sky view index, building, enclosure, air quality, sidewalk quality[150][151][152]. The study of street space quality is more specific and the conclusions more scientific.

2.5.4.3 The trending of measurement methods

Traditional measurement methods have mostly used Field survey, questionnaire and GIS methods. It is difficult to measure the street features and to conduct relevant studies at a large city-level. With the development of computer vision technology and street view images big data, It provided a new paradigm for thinking about scientific research on walkability studies.Meanwhile,it also brought increasing impact to other areas such as business, economics and spatial behaviour.Many provinces have established science and technology platforms including 28 repositories of scientific and technological information technologies[153].Big data has replaced the role of traditional analytical theory in scientific research and is being widely used in geography and transport research[154].

2.6 The research of street space quality spotlight questions

European and American studies of urban space features and quality began earlier. Researchers used interviews and observations of walking to reveal the link between physical appearance and street quality through logical reasoning. In the process of the study for urban design quality and spatial characteristics, a number of indicators have been established to evaluate street space quality. With the development of computer technology, the research about objective and extensive streetscapes visual elements was increased. The study of street space quality focused on the relationship between subjective perception and physical features of space.Meanwhile，computer vision techniques and deep learning algorithms were used.

Japan tried to deal with urban street problems for a long time, but implementation of policies aimed at improving streets to facilitate walking lagged[155]. The streets design is based on the road structure where major urban roads are widened to accommodate the increasing number of traffic vehicles in Japan. However, in the Street Construction Order (1958), street space for pedestrian is largely ignored, with only a minimum standard pavement width. Correspondingly, scholars have also been active in research related to street space quality, for example Vichiensan and Nakamura learned from a comparative analysis for street space perceptions in Bangkok and Nagoya. The safety and security were seen as basic needs in Nagoya[156]. Street quality needs to be improved.

In China, the number of motor vehicles grown rapidly over the past 30 years, and the problems of urban street space were obvious. Chinese residents travel habits is different from Western, in terms of factors such as population density and road network density[157]. In the early studies of street space quality, Chinese scholars obtained basic data through expert scoring and questionnaire. Currently, the study of street space includes multiple perspectives such as the material composition in street space, urban design, and street morphology. The study selected historical districts, cultural tourism areas, and urban streets as study sites. The research focused on the quantification of quality and the construction of evaluation system, thus it could improve the quality in the street space. In the next studies, studies should be gradually paid to the attention to the intrinsic influencing mechanisms in street space quality.

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Chapter 3

RESEARCH METHODS

CHAPTER THREE: RESEARCH METHODS

3.1 Big data collection of streetscape

The study measures the components of the physical street environment and the individual subjective perception for the street environment. The research procedures include data collection, images identification, characteristics measurement and analysis. Therefore, the streetscape big data that can truly reflect the physical environment of the street is the best data for the research. Streetscape big data objectively and truly reflects the information of coastal city street environment from human eye perspective. Professional street image collection equipment or vehicle-mounted cameras according to a certain distance to full coverage record the urban street environment. In addition, Streetscape big data has the advantages of full coverage, large scale and high accuracy. Therefore, when the study used streetscape big data to analysis street spatial physical characteristics, we can ensure the reliability of the data, as well as the objectivity, truthfulness and validity of the measurement results.

3.1.1 The Sources of Streetscape Data

At present, there are three main sources of streetscape data that can be used research for urban spatial environment measurement, they include social network sharing platforms, social media sharing platforms, open map service platforms, and web search engine service platforms.

This study mainly uses street view data from the Open Map Service platform. The streetscape data of the Open Map Service platform have higher quality, its image data contains more complete information, such as uniform data formats and attributes, geographic coordinate information. In addition, the streetscape data provided by the Open Map Platform also features comprehensive coverage, large data scale, high resolution and fine precision. Therefore, the streetscape data provided by the Open Map Platform can reflect the characteristics of urban street space environment more realistically, these data facilitate objective and accurate to measurement the urban streets environmental characteristics. At the same time, the height and range of street view images collected by streetscape big data is similar to the range observed by human eyes' vision. Streetscape images can largely reflect the visual perception of people observing the street environment, it is possible to achieve a mutual correspondence between visual walkability perception and objective physical environment.

3.1.2 Advantages of Street view images

(1) Wide coverage

With the increasing development of data acquisition technology, street view images has become feasible method to evaluate the environmental quality of urban public space. Street view image acquisition in Internet mapping platforms usually needs to rely on street view vehicles to take pictures during their travels. However, due to the vehicles have not access to public spaces such as squares and green spaces, multi-angle street view images are often not available in these places. In this situation, Street view image acquisition can only capture such public spaces from certain angles, the shooting process is easy to receive the influence of street trees, vehicles and street facilities. However, street space as an important part of urban public space, street view images facilitate the study of urban public space. Image acquisition vehicle can enter and get a 360-degree view of the camera in most street space, except for some too narrow streets and pedestrian streets. Therefore, most street spaces in cities with streetscape data are covered by street view image acquisition points. In addition, many map platforms provide street view images that include multiple years of data, these data allow researchers to conduct comparative studies about changes of the streets environment quality in a temporal dimension.

(2) Objective and realistic

The street view angle is a close-up the people perspective, it can reflect what pedestrians see when they walk on the street. Street view data compared with images from social network sharing platforms， street view images can objectively reflect the condition of the street environment, The latter reflects the user's preferences and perceptions through shot composition, repetition of key imagery. For example, people often upload images with beautiful environments to Internet platforms. This image data without subjective preferences, is the basis for a rapid reflection of the built environment quality on a large-scale street space.

(3) Rich elements

Due to the object of streetscape is the real street space, it includes the some elements that exist in the sight range of people in the street space, such as natural elements (sky, mountains, water, vegetation), built environment elements (buildings, roads, green belts, signs), mobile elements (Pedestrians, vehicles). The rich street elements can be judged by accurate image segmentation and recognition technology to determine the location and contour of elements different types in the street view images, which is conducive to further research on the composition and spatial distribution pattern of streetscape elements.

(4) Easy to collect

In fact, Baidu, Google and other map platforms all provide API interfaces to obtain street view images, Taking Baidu Panorama as an example, the width, height, pitch, and fov parameters can be fixed for each street view acquisition point, and only the location or panoid and heading parameters need to be determined for different angles of different acquisition points. The acquisition procedure can be completed through Python programming.

3.1.3 Basic Procedures of street view images collection

Since Google Maps launched Street View service in 2007, Google Street View has quickly become a "big data" source with high resolution and free access for the public. Street view images are usually taken by special cameras mounted on street view acquisition vehicles, the overlapping images captured by these cameras are reconstructed into a 360° view and linked to the GPS data of the capture point to determine the location of the images. Google Street View provides users with a 360° horizontal and 180° vertical panoramic view of the street, Google street view allows users to view different locations on the ground in the city of their choice and the views on both sides of the street. Street View is an emerging source of data for researchers. The streetscape data carried by the streetscape images can reflect the real-time characteristics of urban streets to a certain extent, which is of high research value in the direction of studying the visual walkability of urban streets and the components of urban interfaces. Today, Google Street View is available in 114 countries and regions around the world, but it is not yet available to Chinese users. Baidu Maps and Tencent Maps offer similar street view features, with Baidu Street View covering 372 cities in China and Tencent Street View covering 296 cities in China.

Table 3-1 Baidu map interface service parameter description

(Data Source: Baidu Map Open Platform)

Parameters Name	Required	Default Value	Description
ak	Y	None	User's access key, only supports browser-side ak and Android/OS SDK's ak, server-side ak does not support sn verification method
mcode	N	None	Security code. This parameter is required if ak for Android/IOS SDK
width	N	400	Image width, range [10, 1024]
height	N	300	Image height, range [10, 512]
location	Y	None	Coordinates of the panoramic position point in the format: ing<longitude>, lat<dimension>, e.g. 116.313393, 40.047783
coordtype	N	bd0911	Coordinate types of panorama location points. Currently supports bd0911 (Baidu coordinates), wgs8411 (GPS coordinates) and gcj (google, gaode,

			soso coordinates)
polid	Y	None	The id of poi, the property is usually obtained through the place api interface. polid sets the display scene of the panorama together with panoid and location, with the priority of polid>panoid>location. Among them, the panoramic view obtained according to polid is the best
panoid	Y	None	Panorama id, panoid together with polid and location set the display scene of panorama, the priority is polid>panoid>location
heading	N	0	Horizontal view, range [0, 360]
pitch	N	0	Vertical view, range [10, 360], fov=360 to display the whole panorama
fov	N	90	Horizontal range, range [10,360], fov=360 to display the whole panorama

Automated image acquisition process first use the Open Street Map to obtain the interception administrative boundary map and urban road network data. The study uses ArcGIS 10.3 to generate random sampling points in the above road network with a minimum spacing of 50m between sampling points [1][2]. In addition, the study manually removed sample points located on the boundary of two adjacent streets in order to reduce the influence of adjacent streets. The study collect street view images by setting API parameters based on the API interface provided by Baidu Maps and Google Maps developer platform (Table3-1), the API parameters include user development key, image size, sample point coordinates, vertical view angle, horizontal view angle and field of view. In the study, we input the coordinate points of the street view images and adjust the relevant API parameters. The study use the Python program to automatically acquire urban street images by writing code. We acquire street view images in 8 directions at each sampling point in order to simulate the pedestrian's perspective in the street space (Fig 3-1). The heading parameters set to 0, 45, 90, 135, 180, 225, 270 and 315. The pitch parameter set to -45, 0 and 45, respectively. The fov parameter is set to 60. Image size set to 960×820.

Fig 3-1 Street View Image Acquisition Example Diagram

3.1.4 Study area selection

3.1.4.1 Study area of Qingdao

Qingdao is a typical coastal city in the Shandong Peninsula of China. The study site is located in the waterfront district of south Qingdao (Fig 3-2). Its 17.2 km long winding coastline between Xilingxia Rd and Donghai Middle Rd features seascape, mountainous views, and historical and cultural artifacts that make it a unique urban landscape and tourist destination.

Users can obtain static street view images from different angle by modifying the Baidu Maps API[3]. In the study, we used the “Create Random Points” in ArcGIS, to generate sample points along the streets. Based on the visual distance of pedestrians and the previous researches[4][5], we chose the 50 meters interval criterion[6]. A total of 344 sample points were generated . To ensure that the simulated visual field and horizontal sight were close to the real experience of pedestrians[7], the pitch angle was set at 0[8] and the heading angles respectively were set at 0, 45, 90, 135, 180, 225, 270 and 315. Then, Baidu Street View (BSV) images in the eight horizontal directions at each sample point can be automatically obtained by Python. Moreover, with the help of the “Time Machine” in Baidu Maps, more than 90% of the BSV images which taken in May and June from 2017 to 2021 were obtained. It could avoid the impact of seasonal changes.

Fig 3-2 Distribution map of the site and sample points

3.1.4.2 Study area of Fukuoka

Fukuoka is a topical costal city in Japan which is surrounded by sea on three sides, the coastline length 310 km. It has a particularly privileged natural environment. The study cho se urban streets in Fukuoka, totally 11.4 km, as research site (Fig 3-3),which contained Meiji streets and costal streets.

Google Maps can be used to obtain street view images of other countries except China. Compared with static images, Google Maps can observe street views from a specific angle. Therefore, this paper utilised Google Maps (https://www.google.co.id/maps) to obtain the street view images of Fukuoka streets. Collecting point was the same principles as the selection of selecting the sample points in Qingdao Coastal Streets, it based on the OSM road network data and the 50 meter interval standard used in most studies, this study used the random point selection function module of ArcGIS 10.6 to generate sampling points along the road. A total of 381sampling points were generated and the longitude and latitude coordinates of each sample point were calculated. Subsequently, the GSV images of each sample point were automatically crawled with the help of python and 8 angles (0, 45, 90, 135, 180, 225, 270 and 315) of GSV images were selected in the horizontal direction for capture. After removing two invalid sampling points (GSV is indoor landscape), a total of 381 valid sampling points and 3040 corresponding GSV images were obtained. Finally, closing the pictures into 381panoramas.

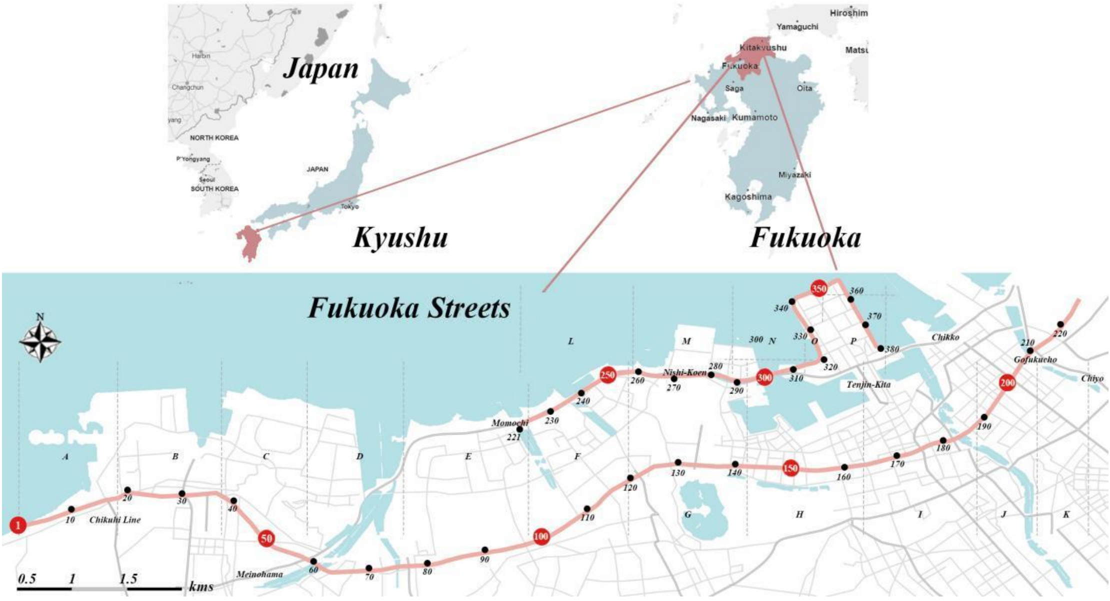


Fig 3-3 Distribution map of the site.

3.1.5Application in urban environment

As a kind of figurative data, streetscape pictures can be considered to a certain extent as a reflection of the objective urban environment, as well as a static picture frame of certain elements in the city in a human-oriented visual scale, which is of great significance for studying the quality of urban street space from the dual perspective of subjective perception and objective environment [8]. Currently, the image data used to reflect and study the perception of urban street environment can be broadly classified into two categories based on the content and attributes of the data. The first category is the urban streetscape data based on the relevant network platform. The streetscape data has the characteristics of coverage shopping, objective and real, rich elements and convenient collection. It can reflect the urban street environment from the perspective of human eyes. Another type of data is based on social network shared image data uploaded by users, such as Weibo image data. This type of data is lower in magnitude than street view data, and mainly reflects people's subjective impressions of relevant elements in the urban environment [9]. Based on these two types of image data, and with the support of the above-mentioned computer technology and related spatial analysis technology methods, the spatial measurement of urban streets based on image big data can be divided into two research paradigms based on image content elements and image metadata, depending on the parameters of the images themselves and the research contents and results.

3.1.5.1 Based on the content elements of street view images

The study of spatial measurement of urban streets based on the content elements of image data is mainly based on the deep learning method to try to explore the landscape features and many details of the image data at the level of the displayed content, and then analyze, count and evaluate these details, and finally obtain the study of spatial measurement of urban streets. For example, Li et al. used Google Street View images to analyze the greenness index of 300 sample points along a block in Manhattan and used the same method to evaluate the greenness level of sample points and plots along the street and correlate it with the income level of residents [10]. Based on the Google Street View map, Long Ying et al. used machine learning to automatically identify the number of pedestrians in the street and conducted a related study based on this method [11]. Harvey also based on Google Street View images and the identification of the content and elements in the collected street view data to find the interrelated element relationships and to score the street safety [12]. In the study of the spatial measurement of urban streets based on the content elements of the images, the existing studies can be further classified into two types of studies, environmental characterization and environmental diagnosis, depending on the analysis orientation and content of the image data.

In summary, the study of street space measurement based on the content elements of streetscape images focuses on "looking at the pictures", i.e., identifying the state of the objective urban environment and its possible influence on people's environmental perception through the recognition of streetscape image content. Therefore, such studies are largely oriented to analyze the urban environment from a single dimension, rather than the patterns formed by the interaction between people's subjective perceptions and the objective environment, and the correlations and characteristics between the subjective and objective.

3.1.5.2 Based on the metadata of street view images

Streetscape image metadata refers to the information describing the attributes of image data, and the metadata of city's street image contains the shooting location, upload time, description label, exposure parameters, and geographic information of the image [13]. Compared with the urban street measurement research based on the content elements of streetscape images, it is easier to reveal the meaning of urban imagery in spatial structure. Therefore, urban street metrics research based on streetscape image metadata largely continues the five elements of imagery proposed by Kevin Lynch, and investigates the cold and hot spots of urban imagery environment, as well as the overall spatial level of urban streetscape landscape structure [14]. Most of the studies on the spatial measurement of urban streets based on street image metadata are based on user uploaded Internet street images, such as Flickr, Panaromio and Weibo, etc., and are conducted by correlating the uploaded spatial point information and attribute information corresponding to the street image data with urban perception [15]. The most representative study of this kind is Eric Fischer's study of urban imagery trajectories based on Flickr image metadata. By retrieving the location of photos from the search API of Flicker image data, and obtaining the fast/slow passage status based on the span of time and the distance of the coordinates, and drawing lines between them, he creates the first atlas in the field of urban imagery that can reflect the trajectory of urban imagery.

3.2 The measurement method of physical features in urban street

3.2.1 Concept of Semantic segmentation

Semantic segmentation is an integral part of computer vision technology. As one of the important tools for image understanding, it not only has important theoretical and application values in many fields but also is one of the most challenging tasks at present. Image semantic segmentation is the process of classifying each pixel of the input image one by one. Semantic segmentation method can divide objects of different categories and locations in the image into their own independent sub-regions along their boundaries. According to the grayscale value of each sub-region, it generates the corresponding color annotated image for observation and differentiation. Semantic segmentation can be applied not only to static 2D and 3D images, but also to videos[16].

For example, the semantic segmentation technique in city street scenes can classify all interest categories in the scene at pixel level. Vehicles, driving areas, sidewalks, vegetation, near pedestrians, roads, traffic signs, street lights, buildings on both sides, etc. are extracted from the images with rich environmental information to assist in decision. In the semantic segmentation task, the input to the task is an RGB color image and the output corresponds to a color segmentation result of the same size. As shown (Fig 3-4), the input image a is an RGB color image and the output image b is an ideal segmentation of pixel clustering based on semantics. Semantic segmentation of images is indispensable in the fields of transportation, medical, military, and agriculture. Image semantic segmentation as a pixel-level image recognition technique is more accurate compared to other techniques.

Fig 3-4 A color segmentation result

Traditional semantic segmentation methods are mainly implemented by extracting image features (color features, texture features, geometric features, etc.). However, due to the extremely complex visual relationships in real-world city streets, the variety of target objects is complex, the spatial location is not uniform and the imaging results are highly susceptible to light interference. This makes the semantic segmentation task in city street scenes a complex problem. These problems restrict the accuracy and efficiency of semantic segmentation of city streets, which cannot meet the needs of autonomous driving and smart cities for semantic segmentation applications. The key data cannot be fully utilized. Deep learning technology, which has developed rapidly in recent years, provides a new solution for semantic segmentation of urban streetscape in the era of big data.

Deep learning is one of the most rapidly developing branches of machine learning in recent years. Compared with traditional machine learning, deep learning is essentially a learning method with multiple layers, the extraction of shallow, medium and deep image features is accomplished through the combination of layers. Compared with traditional methods, deep learning-based methods rely entirely on existing data and are able to learn continuously until the best semantic information extraction method is obtained [17].

3.2.2 Semantic segmentation based on deep learning

Deep learning combined with image semantic segmentation has become a major research direction in image semantic segmentation. Because the deep learning, especially convolutional neural networks, into the field of computer vision has dramatically improved the accuracy of results for a variety of tasks such as image classification. This solves more problems than traditional image semantic segmentation. The mainstream deep neural networks currently applied to semantic segmentation of images are mainly transformed from networks used for image classification. The representative one is the fully convolutional neural network, which replaces the final fully connected layer of the image classification network with a convolutional layer.

Google team has proposed DeepLab series of models in order to solve the problem that full convolutional neural network loses part of the detail information and resulting in less detailed output results. DeeplabV1 uses FCN for image segmentation. It adopts null convolution to expand the Receptive Field of the network and Conditional Random Field (CRF) to refine the edge features. The operation does not increase the computational load of the network, but also improves the accuracy of model segmentation. DeeplabV2 adds a void space pyramid pooling ASPP module based on DeeplabV1, which extracts image features at different scales by using dilation convolution with different dilation rates to achieve better feature fusion. Meanwhile, the post-processing operation is performed by using fully-connected CRF, which in turn leads to better segmentation results. DeeplabV3 uses different serial and parallel dilation convolutions, that is Multi Grid strategy, to capture multi-scale feature information. DeepLabv3+ adds a decoding module to the DeepLabV3 network to capture the low-level spatial information while recovering more detailed information to obtain the desired segmentation results (Fig 3-5).

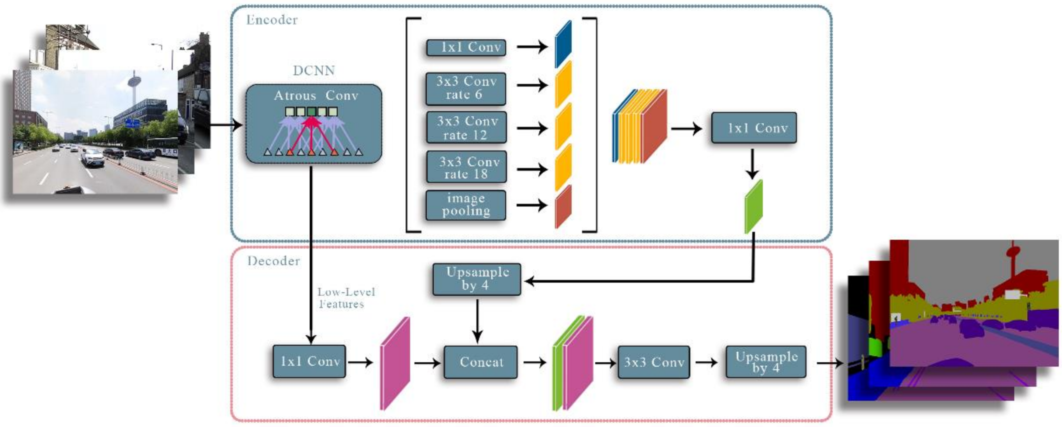


Fig 3-5 DeepV3+ Network Architecture

3.2.3 The physical features selection

The study used Deeplabv3+ to divide the landscape elements in street view images. Deeplabv3+ is more efficient than other deep learning architectures, especially in memory footprint and execution time[18]. It has more accurate for labels such as buildings, sky, cars and roads[19]. The Street elements are divided into 20 Labels,and the overall accuracy rate can achieve 90.40%[20]. The BSV images were input into Deeplabv3+, as shown in fig 3-6, which can clearly extract the streetscape elements.

In addition, we used the Open Street Map and remote sensing images tools in ArcGIS, to obtain sidewalk widths, road widths and building height. Meanwhile, we borrowed from Harvey's creative way which combining GIS with SVP data, automatically obtaining information such as Spatial Walk Index, Car Travel Index and Building Height[21]. Based on previous studies[22][23][24][25], we selected and identified 25 important street physical features (Tab 3-2, Fig3-7).

Fig 3-6 Semantic segment

Table 3-2 Physical features of street space

Perceptual features	Physical features	Formula or source	Expression	Definition
Imageability	Building with identifiers	$BI_i =$ The number of buildings with identifiers		It refers to the buildings with unique style, complex shapes, large sizes and are impressive
	Pedestrians	$P1_i = \frac{1}{n}\sum_{i=1}^{n} P1_n \{i \in (1,2,\ldots,n)\}$	$P1_n$ denotes the proportion of pedestrian pixels, the sum indicates the total number of pedestrians pixels in each image.	It refers to the ratio of pedestrian pixels in the overall street space pixels include rider, standing and sitting person.
	Lawn	$L1_i = \frac{1}{n}\sum_{i=1}^{n} L1_n \{i \in (1,2,\ldots,n)\}$	$L1_n$ denotes the proportion of lawn pixels, the sum indicates the total number of lawn pixels in each image.	It refers to the ratio of lawn pixels with large area in the overall street space pixels.
	Spatial indicative	$S1_i = \frac{1}{n}\sum_{i=1}^{n} L2_n + \frac{1}{n}\sum_{i=1}^{n} S2_n + \frac{1}{n}\sum_{i=1}^{n} P2_n$ $\{i \in (1,2,\ldots,n)\}$	$L2_n$ denotes the proportion of traffic light pixels, $S2_n$ denotes the proportion of traffic signs, $P2_n$ denotes the proportion of pole pixels.	It refers to the ratio of light and traffic signs pixels in the overall street space pixels.

	Landscape with identifiers	$LI_i =$ The number of landscape with identifiers		It refers to the conspicuous landscape.
Enclosure	The vertical interface	$VI_i = \frac{1}{n}\sum_{i=1}^{n} B1_n + \frac{1}{n}\sum_{i=1}^{n} T1_n + \frac{1}{n}\sum_{i=1}^{n} W1_n$ $\{i \in (1,2,\ldots,n)\}$	$B1_n$ denotes the proportion of building pixels, $T1_n$ denotes the proportion of tree pixels, $W1_n$ denotes the proportion of wall pixels.	It refers to the ratio of landscape elements pixels to the vertical interface pixels.
	Interface buildings difference	$IBD_i = \left\| \overline{B}_N - \overline{B}_S \right\|$	B_N denotes the proportion of north side buildings pixels, B_S denotes the proportion of south side buildings pixels.	It refers to the differences between the buildings vertical interface on the sides in the street space.
	Openness	$O_i = \frac{1}{n}\sum_{i=1}^{n} S3_n \{i \in (1,2,\ldots,n)\}$	$S3_n$ denotes the proportion of sky pixels, the sum indicates the total number of sky pixels in each image.	It refers to the ratio of visible sky pixels to the overall pixels.

	Interface enclosure degree	$\mathrm{IED_i} = \dfrac{\frac{1}{n}\sum_{i=1}^{n} B1_n + \frac{1}{n}\sum_{i=1}^{n} T1_n + \frac{1}{n}\sum_{i=1}^{n} W1_n}{\frac{1}{n}\sum_{i=1}^{n} P3_n + \frac{1}{n}\sum_{i=1}^{n} F1_n + \frac{1}{n}\sum_{i=1}^{n} R_n}$ $\{i \in (1,2,\ldots,n)\}$	$B1_n$ denotes the proportion of building pixels, $T1_n$ denotes the proportion of tree pixels, $W1_n$ denotes the proportion of wall pixels, $P3_n$ denotes the proportion of pavement pixels, $F1_n$ denotes the proportion of fence pixels, R_n denotes the proportion of road pixels.	It refers to the degree which spatial interface is enclosed by landscape elements in the streets.
Transparency	Interfacial porosity	$IP_i = \dfrac{\frac{1}{n}\sum_{i=1}^{n} IPS_n}{\frac{1}{n}\sum_{i=1}^{n} VPHL_n} \{i \in (1,2,\ldots,n)\}$	IPS_n denotes the interface pore space pixels in the vertical interfacial. $VPHL_n$ denotes the vertical pixel of the highest landscape element of the space façade.	It refers to the ratio of interface pore space pixels to the overall pixels in the vertical interface.
	The openness of coastal interface	$OCI_i = S_{cb}$	S_{cb} denotes the proportion of sky pixels oriented to the coastal side in image	It refers to the open degree in the coastal interface.
	The openness of inland interface	$OII_i = S_{ib}$	S_{ib} denotes the proportion of sky pixels oriented to the inland side in image	It refers to the open degree in the inland interface.

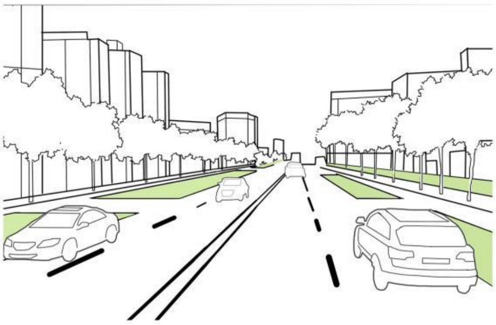
	Proportion of active uses	$A_i = \frac{1}{n}\sum_{i=1}^{n} A_n \{i \in (1,2,\ldots,n)\}$	A_n denotes the proportion of active uses pixels, the sum indicates the total number of active uses pixels in each image.	It refers to the ratio of the places with specific using to the overall pixels, such as recognize the landscape, lawns, parks, waters, signs and specific using buildings (schools and churches).
Human scale	Walkable area	Source: GIS	the width of the sidewalk	It refers to the width of the sidewalk.
	Traffic Space	Source: GIS	the width of the roadway	It refers to the width of the roadway.
	Walkable Streets	$W1_i = \frac{\frac{1}{n}\sum_{i=1}^{n} P3_n + \frac{1}{n}\sum_{i=1}^{n} F1_n}{\frac{1}{n}\sum_{i=1}^{n} R_n}\{i \in (1,2,\ldots,n)\}$	$P3_n$ denotes the proportion of pavement pixels, $F1_n$ denotes the proportion of fence pixels, R_n denotes the proportion of road pixels.	It refers to the ratio of walkable street pixels to the overall pixels.
	Building height	Source: GIS	The height of tallest building at the sample point.	It refers to the height of tallest building in the street.
	Street height to width ratio	$H_i = \frac{\lvert \bar{H}_N + \bar{H}_S \rvert}{D_I}$	H_N denotes the average value of north buildings height, H_S denotes the average value of south buildings height, D_I denotes the street width.	It refers to the ratio of the average value of buildings height to the street width.

Complexity	Landscape diversity index	$SHDI = -\frac{1}{n}\sum_{i=1}^{n}(P_i * \ln P_i)$	ln denotes the landscape log, P_i denotes the proportion of the entire communtity made up of landscape elements i.	It refers to the richness degree of the landscape elements that be observed in the street.
	Vehicle occurrence rate	$V1_i = \frac{\frac{1}{n}\sum_{i=1}^{n}C_n + \frac{1}{n}\sum_{i=1}^{n}T2_n + \frac{1}{n}\sum_{i=1}^{n}B2_n + \frac{1}{n}\sum_{i=1}^{n}T3_n}{\frac{1}{n}\sum_{i=1}^{n}R_n}$ $\{i \in (1,2,...,n)\}$	C_n denotes the proportion of car pixels, $T2_n$ denotes the proportion of truck pixels, $B2_n$ denotes the proportion of bus pixels, $T3_n$ denotes the proportion of train pixels, R_n denotes the proportion of road pixels.	It refers to the proportion of vehicle attendance in the road space.
	Architecture color diversity	$CEI_i = 1 - \frac{1}{n}\sum_{i=1}^{n}\left(\frac{P_{ij}}{\sum_{i=1}^{J}P_{ij}}\right)^2$	P_{ij} denotes the number of j buildings color pixels in i image, J indicates the total number of the building colors in i image.	It refers to the richness degree of the building colors that be observed in the streets.
Nature	Natural landscape	$N_i = \frac{1}{n}\sum_{i=1}^{n}W2_n + \frac{1}{n}\sum_{i=1}^{n}F2_n$ $\{i \in (1,2,...,n)\}$	$W2_n$ denotes the proportion of water pixels, $F2_n$ denotes the proportion of forest pixels.	It refers to the ratio of the natural landscape pixels to the overall pixels.

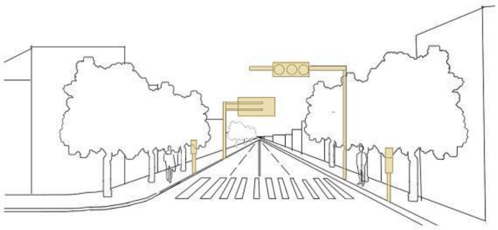
	Greenness	$G_i = \frac{1}{n}\sum_{i=1}^{n} T1_n + \frac{1}{n}\sum_{i=1}^{n} G_n$ $\{i \in (1,2,\ldots,n)\}$	$T1_n$ denotes the proportion of trees pixels, G_n denotes the proportion of grass pixels.	It refers to the ratio of trees and grasses pixels to the overall pixels.
	Natural to artificial ratio of the vertical interface	$VI_i = \frac{\frac{1}{n}\sum_{i=1}^{n} T1_n}{\frac{1}{n}\sum_{i=1}^{n} B1_n} \{i \in (1,2,\ldots,n)\}$	$T1_n$ denotes the proportion of tree pixels, $B1_n$ denotes the proportion of building pixels.	It refers to the ratio of the natural pixels to the artificial pixels in the vertical interface.
	Natural to artificial ratio of the horizontal interface	$HI_i = \frac{\frac{1}{n}\sum_{i=1}^{n} G_n + \frac{1}{n}\sum_{i=1}^{n} W2_n}{\frac{1}{n}\sum_{i=1}^{n} R_n + \frac{1}{n}\sum_{i=1}^{n} P3_n}$ $\{i \in (1,2,\ldots,n)\}$	G_n denotes the proportion of grass pixels, $W2_n$ denotes the proportion of water pixels, R_n denotes the proportion of road pixels, $P3_n$ denotes of pavement pixels.	It refers to the ratio of the natural pixels to the artificial pixels in the horizontal interface.

Building with identifiers

Pedestrians

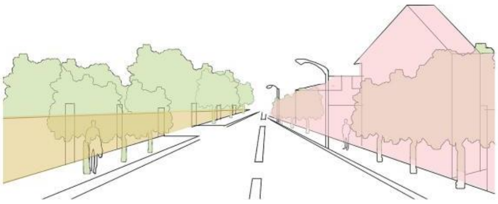


Lawn

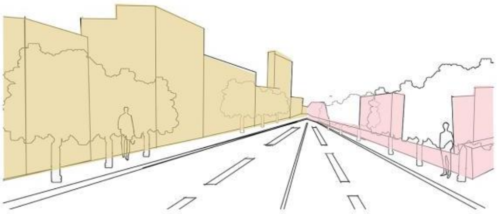


Spatial indicative

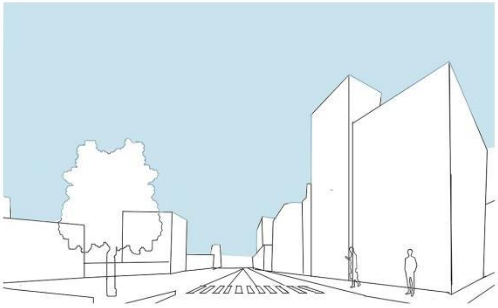
Landscape with identifiers



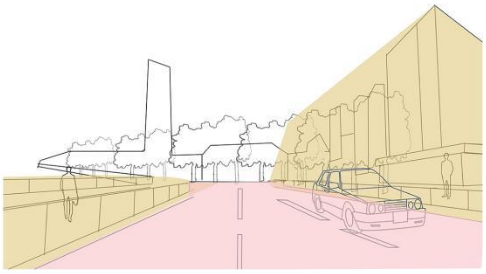
The vertical interface



Interface buildings difference

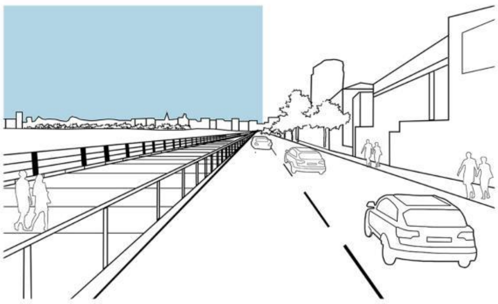


Openness

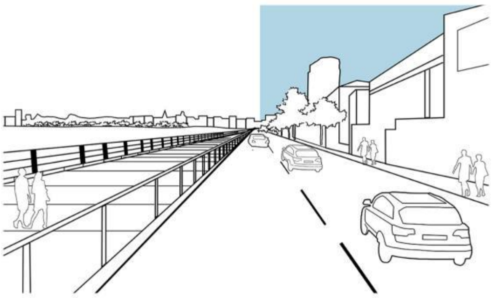


Interface enclosure degree

Interfacial porosity

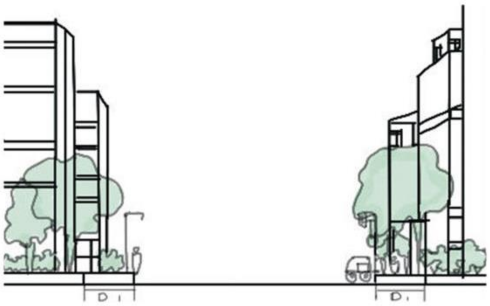


The openness of coastal interface

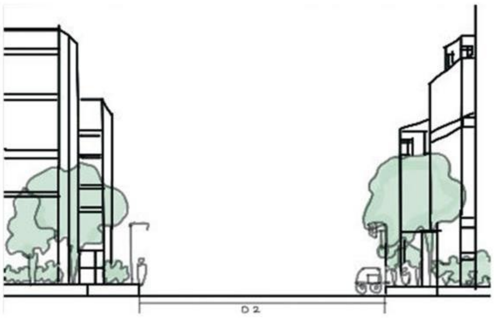


The openness of inland interface

Proportion of active uses

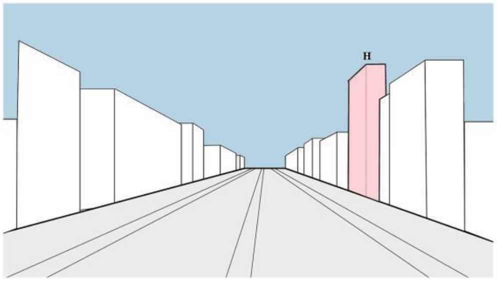


Walkable area

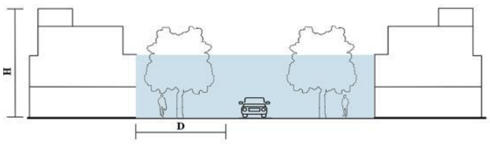


Traffic Space

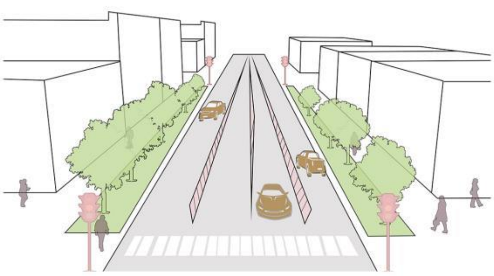
Walkable Streets



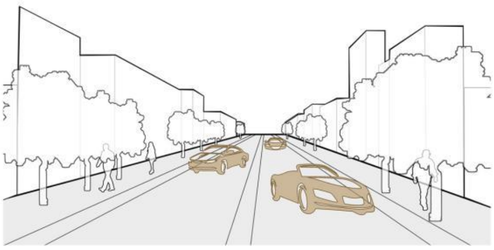
Building height



Street height to width ratio



Landscape diversity index



Vehicle occurrence rate

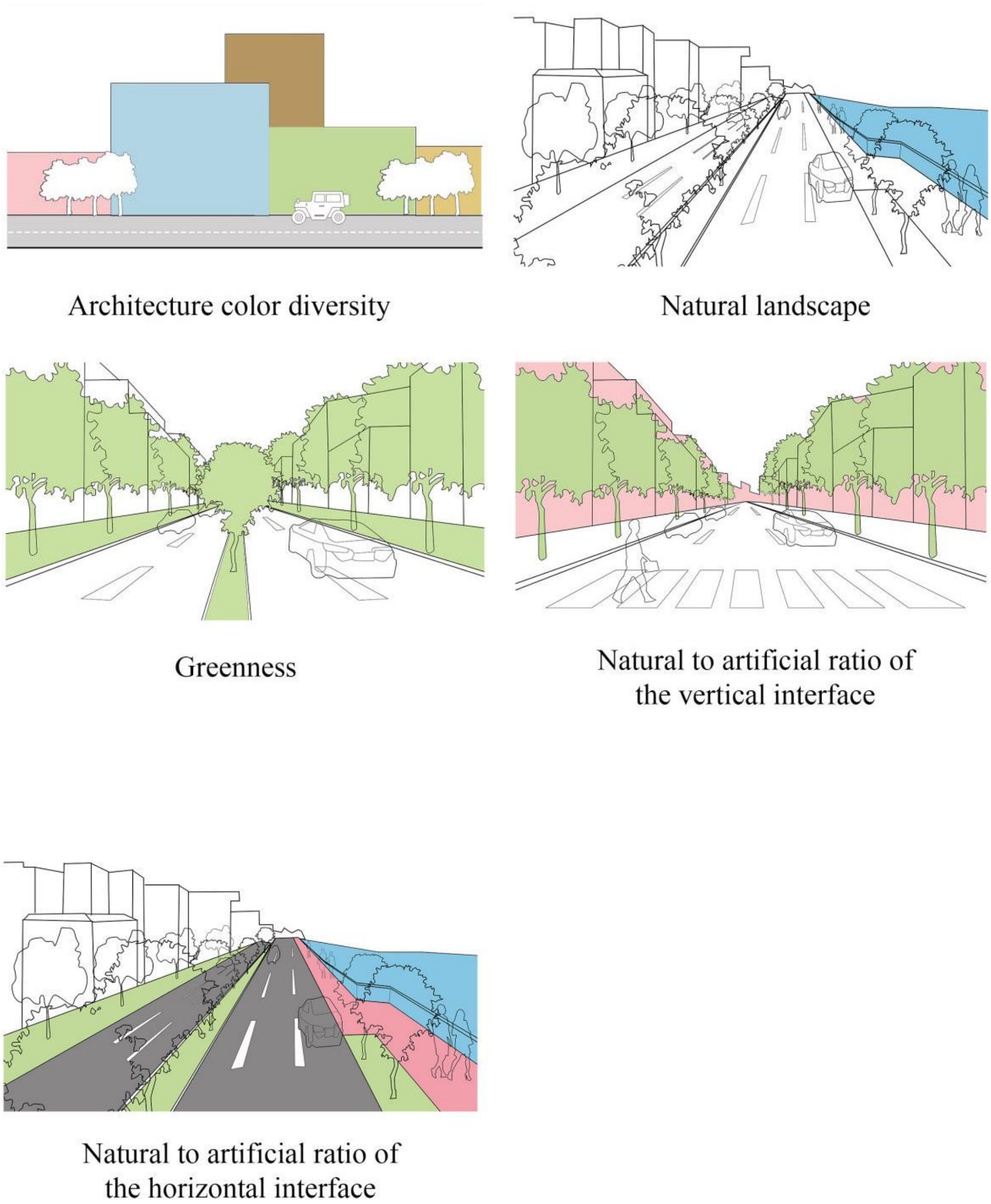


Fig 3-7 Sketch of physical features

3.2.4 Application in street Environment Measurement

The development of online streetscape images, such as Google, Baidu and Tencent suppliers, provides an ideal data source for semantic segmentation technology based on convolutional neural network deep learning. Many researchers attempt to automatically segment the image through different classification of visual perception elements and divide the visual elements in the image into different categories. Thus, pixel-level semantic information is extracted in the study. Gong, Peng[26], Zhang[27], Liu et al[28]. Used high-resolution streetscape images at the micro level to synchronously analyze and evaluate the streetscape characteristics of the overall city and organized visual elements into feature indicators 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 from multiple scales. At the same time, on the basis of considering the spatial heterogeneity, the geographically weighted principal component analysis method is used to analyze the environmental perspective factors describing the street canyon and the urban scene is analyzed as an element to quantitatively measure the visual appearance of the urban environment. In addition, as an important part of the overall urban space environment, the spatial structure of street space is very complex.

3.3 The perception evaluation

3.3.1 Introduction of SD method

The semantic difference method (SD method), this method was first mentioned by Charles Egerton Osgood et al in American psychology and published in The Measurement of Meaning in 1957. The SD method is defined in the text as a psychometric method, also known as a perception recording method. The SD method was first used in psychological experiments as a common method in psychological research, but after the 1990s, it gradually faded out of psychology and other related fields and was more often used in medicine, architecture, planning, interior engineering, landscape evaluation, commodity development. The SD method is developing rapidly in China and covers a wide range of areas, concentrating on various aspects of landscape evaluation in residential areas, scenic areas, parks, green areas in landscaping.

In the SD method, adjective pairs describing the visual walkability of a street can be used on a Likert scale to form an SD questionnaire, and then, based on past knowledge and experience existing in human cognition, subjects make scale judgments on the evaluation items of the sample on the questionnaire, and finally the results are quantitatively analyzed by the research.

3.3.2 Basic Procedures of SD method

3.3.2.1 Selection of evaluation samples

When study use SD method to evaluate the factors of visual walkability in urban streets, the evaluation process is often more detailed, we should focus on streamlining the number of street view images to improve the operability and authenticity of the evaluation. However, previous studies are not reasonable and correct selection criteria. Streetscape features may have large differences between the better street view images and poorer street view images. In addition, if the number of samples is too less, some landscape features that affect street walkability will not be reflected.

In this study, we performed distance analysis of the coastal city street network in ArcGIS 10.0 software, study selected two typical sample points that can represent the characteristics of the street segment based on every 500 meters, Meanwhile, we made a panoramic image of the streetscape of each sample and used SD method to evaluation each panoramic image, in order to better evaluate the visual walkability of the coastal city streets.

3.3.2.2 Identification of evaluation indicators

(1) Identification of adjective pairs

SD evaluation methods often require the collection a large number of adjective pairs that can characterize the evaluation target [29], the process of semantically describing and modifying information about the landscape space using landscape concepts and vocabulary according to the characteristics of the landscape environment and the research objectives. The selection of pairs and adjective pairs needs to follow certain principles so that the survey can accurately perceive the feeling of the place through adjective pairs. When selecting adjective pairs, firstly, adjective pairs that can easily form opposite meanings are selected and adjective pairs that are not very relative are removed. Secondly, the balanced symmetry of each adjective pair on both sides of the midline should also be maintained. In addition, familiar adjective pairs are selected as much as possible and infrequently used adjective pairs are removed. For the number of adjective pairs, there is no clear rule in the related research, and by referring to the values of a large amount of related literature, it can be found that the number of adjective pairs is selected with the highest frequency from 20 to 30 pairs. The process of performing semantic descriptions and modifications. To ensure the accuracy of the findings, it is necessary to discuss whether adjective pairs have sensible and measurable features.

(2) Selection of evaluation scale

After the adjective pairs are selected, the evaluation scales need to be selected. The evaluation scales are generally divided into 5, 7, and 11 paragraphs. Whether the evaluation scales are 5, 7, or 11 paragraphs, they must be centrally symmetric with odd numbers. Therefore, a 5-point scale was used in this study. The 5-point scale is easier for the test subjects to grasp and to make accurate responses during the scoring process. The evaluation indexes in order are: very poor, poor, fair, good, and very good. The corresponding scores are1, 2, 3, 4, 5 in order. (Table 3-3)

Table 3-3 Evaluation scale

(Data Source: Self-drawn by the author)

Very poor	Poor	Fair	Good	Very good
1	2	3	4	5

3.3.2.3 evaluation subjects and surveys

(1) Selection of evaluation subjects

After recognizing the choice of adjective pairs and evaluation scales, it is necessary to determine the reasonable selection and number of survey respondents. After reviewing a large amount of literature, the SD method usually selects 20-50 people as the respondents [30] and the selection of the age and gender of the respondents should be as comprehensive and balanced as possible, and in special cases a category of people can be investigated. It does not focus on analyzing the perceived differences in landscape quality between different social groups. In addition, a large number of studies have shown that there is no significant difference in the evaluation of landscape visual subjectivity between the group with higher professional quality and the general group. The SD method involves a lot of specialized vocabulary, and it is difficult for the non-specialized public to effectively know and understand the evaluation content of the landscape. Therefore, the respondents selected for this paper are teachers, students, and designers of related majors.

(2) Questionnaire based on SD method

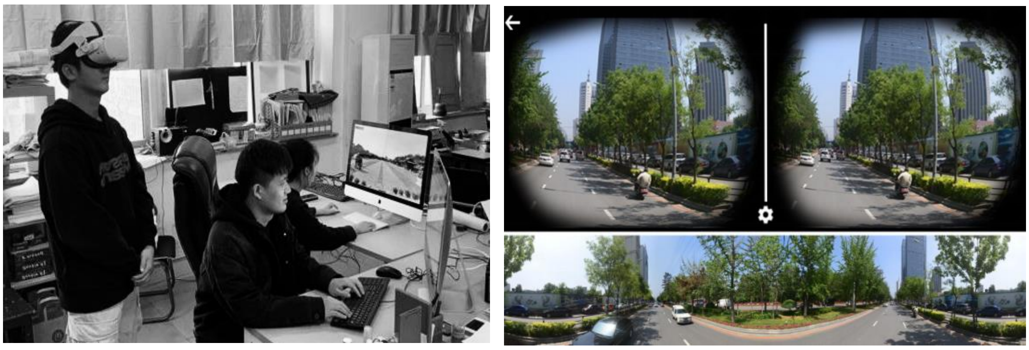


Fig 3-8 Urban street evaluation using VR panoramic equipment

The best way to evaluate using the SD method is to place the test subjects in real city street scenarios, however, practical conditions make it difficult to bring all test subjects into the field. Therefore, compared with the traditional slide evaluation test method, the visual walkability evaluation test in this paper uses head-mounted VR devices to show a more realistic street space environment for the subjects, so that they can provide a more realistic visual experience of the street (Fig 3-8). In this study, the contents and methods of street visual walkability were first introduced to each respondent, the meaning of the different factors and their adjective pairs and the meaning of the evaluation scale were explained, and then images of different street scenes of urban waterfront streets were shown to them through streetscape photos. Finally, data on the number of evaluation samples, evaluation scales and evaluation results were obtained. Immediately afterwards, the projector connects the VR headset to the ipad or computer device and projects the selected typical samples in the VR for random playback, with the playback time of the panoramic image of each typical sample point controlled at 15 seconds. Testers sequentially evaluated the street visual walkability factor on a typical sample with VR devices on their heads. The scoring scale was based on a 5-point scale from -2 (negative) to 2 (positive), and the testers informed the screeners of the scoring by dictating the questionnaire, which was filled out truthfully by the screeners.

3.3.2.4 Evaluation data statistics

In this study, the raw data from the questionnaires were tallied and the mean values were derived using a computer-related program (Excel). The Excel software was used to process and calculate the mean of each evaluation factor for each sample, as well as the summed mean. The formula of the integrated average is shown in foumula 1. The data results are summarized with the table.

$$M_s = \frac{\sum_m f}{N}$$

In the formula, Ms is the summed mean value, f is each factor, N represents the number of samples.

3.3.3 Application of SD method in spatial environmental evaluation

The evaluation study of the spatial environment is an integrated and multidisciplinary research field. For the spatial landscape elements Osgood (1955) conducted a relevant study and analyzed the preference of elements in the process of landscape combination comprehensively by the semantic difference method (SD method), which focuses on the importance of the selection and semantic description of landscape elements in order to continuously improve the visual quality of the landscape and describe the landscape elements in more depth. In the 1970s, the evaluation of spatial environments focused on the value of spatial physical features relative to each other, where Dearinger, Calvin et al. analyzed in depth the reasons that influence the visual quality of spatial environments, the semantic difference method (SD method) was used to describe different preferences, and the importance of the selection and semantic representation of alternatives for the constituent elements of spatial environments was elaborated. Zhang Junhua (2004) evaluated the landscape of Liaocheng Jiangdi Paradise using the SD method. The paper describes in detail the SD method and its application in the planning and design survey and analysis, and provides suggestions for the subsequent further improvement of Liaocheng Jiangdi Paradise [31]. Sujian Yu (2012) conducted a comprehensive perception study of park landscapes using the SD method, with sound and taste environmental factors as landscape perception components, combined with factor analysis to derive factors that affect the visual effects of park landscapes [32]. Wu Dewen et al. (2015) used SBE-SD integrated evaluation method, hierarchical analysis method, and GIS to evaluate and analyze the visual landscape in the boundary area of urban-type scenic spots, and came up with a control method for the boundary area of urban landscape [33]. In addition, Chen Luyao (2017) and others used the SD method to evaluate street vitality in the old urban areas of Luoyang, which provided an objective basis for future planning schemes [34] Sun Dong et al. (2020) studied the visual quality of urban waterfront parks based on the SBE method and SD method, established an evaluation model of urban waterfront parks and made a detailed analysis of the landscape elements that affect the visual quality of waterfront parks, providing constructive opinions on the construction and development of urban waterfront parks [35]

In summary, the evaluation objects of urban spatial environment include various types of residential space, park space or road space, etc. Among the landscape evaluation methods, the SBE method, SD method and AHP method (hierarchical analysis method) are more common.

3.4 Prospects for street space and spatial perception

Urban streets with good quality have been shown to promote community development and social and economic prosperity, the street quality has become a key consideration for urban planners and designers when building urban neighborhoods. Spatial perception is a subjective concept that describes the quality of the environment and is therefore difficult to measure objectively and quantitatively. However, by objectively quantifying Spatial perception at the street level, planning and design strategies for developing urban streets can be effectively assisted.

With the advancement of computer technology and the development of crowd sourcing map services, computer vision technology based on streetscape big data has become an important trend in urban spatial characterization, along with the emergence of computerized auditing methods that can objectively and extensively analyze urban streetscape elements. It effectively makes up for the deficiency of insufficient assessment volume in previous studies. In addition, with the application of virtual reality (VR) technology and convolutional neural technology of deep learning, it also overcomes the limitations of previous studies to a certain extent and shows great potential in the perceptual study.

3.5 Summary

In this chapter, first, Method of acquiring streetscape big data for coastal city streets is introduced, the coastal city street view images sources: Google Maps, Baidu Maps, Gaode Maps er al. The second contains the basic procedural methods for streetscape big data acquisition. Meanwhile, SD method is introduced for quantitative street quality evaluation of coastal city streets, which contains sample selection, index determination, evaluation object selection and investigation and statistics. Finally, the spatial environmental characteristics of streets in coastal cities are measured based on computer vision technology. The semantic segmentation method of deep learning is mainly applied to recognize and analyze the urban street view images.

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Chapter 4

MEASURING AND ANALYZING PHYSICAL FEATURES OF URBAN STREETS

CHAPTER FOUR: MEASURING AND ANALYZING PHYSICAL FEATURES OF URBAN STREETS

4.1 Introduction

In the study of street space quality, the seven physical features of Greenness, Openness,the Vertical Interface, Proportion of Buildings, Interface Enclosure Degree, Pedestrians and Vehicle Occurrence Rate are very important to study the urban environment. The seven physical features are representative of the general spatial environment in the urban streets. Therefore, this study provides a detailed analysis of seven important physical features.

Meanwhile, 344 sample points were selected from Qingdao Coastal Streets and choose these seven physical features for study; the 381 sample points were selected from Fukuoka Street. Greenness, Openness,the Vertical Interface, Proportion of Buildings, Interface Enclosure Degree, Pedestrians and Vehicle Occurrence Rate were studied.

4.1.1 Greenness

Greenness originated from visual environmental science [1], It means the percentage of green landscape in human vision. Greenness was proposed by the Japanese scholar Yoji Aoki in 1987 to measure the greenery of urban three-dimensional space and to express the relationship between green materials and human perceptions in human habitation environment [2].Subsequently, Ono et al. (1993) put forward the theory of Greenness, which further explained the specific indicators of the relationship between Greenness and human perception. In 2004, the Japanese government incorporated Greenness into the regular index of urban greenery evaluation [3]. In the process of exploring Greenness, the traditional method of Greenness research is mostly manual. Greenness should be calculated by taking photos at fixed points and supplemented by manual hand-drawing [4]. With the progress of network science and technology in recent years, the image acquisition and calculation of Greenness can be carried out in the form of street view images based on deep learning. A series of open source models for semantic segmentation of images, such as convolutional neural network models (CNN), fully convolutional networks (FCN), and other common models [5]. After being trained by the dataset, which can calculate Greenness automatically. It can be used to identify street view image elements, including vegetation, roads, buildings, sky.

4.1.2 Openness

With the rapid development of urbanization in China, especially in mega-cities with dense high-rise buildings, the original broad sky horizon is divided into wellhead-shaped and block-shaped narrow horizons. The resulting visual depression and heat island effect are gradually being concerned by the urban planning academic circles.

Sky View Factor(SVF) is used to measure the degree of Openness of the open space，which refers to the percentage of the sky that a person can see in space in the total visual field[6]. SVF expresses the geometric space parameter of the degree of Openness of urban space to the sky. Its numeric value is between 0 and 1, the larger the numeric value the higher the SVF. Oke (1987), Grimmand (2001), and Unger (2004) used skyheilos and ENVi-met can simulate continuously varying SVF and finally derive the average SVF of the area. Oke.T.R based on Street Gorge Model and Courtyard Model, studied the geometric algorithm of SVF and the relationship between SVF and aspect ratio.The spatial significance of SVF is to express the degree of closure of urban space. The smaller SVF will mean that the exterior space of urban blocks is relatively closed[7].

In recent years, there are multiple perspectives on the study of SVF. Examples include the physical environmental science, the field of atmospheric sciences and the urban planning.In different literature, SVF is also often referred to as sky viewable range, sky viewing, sky Openness, sky visibility factor, sky dome visibility, terrain Openness, and many other designations[8].

4.1.3 Enclosure

Enclosure is one of the important perceptual features in the street design quality. Three physical features can explain the degree of enclosure in the street space such as the Vertical Interface, proportion of builidings and Interface Enclosure Degree

(1) Interface Enclosure Degree

Street space is a framework built by interfaces. The space enclosed by hard interfaces in three-dimensional as a stage for Greenness, which works together with Greenness to influence pedestrians who travel through it.It is generally believed that the enclosure of soft landscape has a positive effect on public perceptual experience, while hard enclosure has the opposite effect. The hard enclosure with high enclosure usually accompanied by negative emotions such as depression and dullness. The width-to-height ratio(D/H)of streets and buildings is one of the most important expressions of enclosure in the vertical dimension.

In order to evaluate the enclosure in terms of the scale of the neighborhood, many scholars have proposed the spatial factor index of neighborhood enclosure. The index indicates the enclosure of the neighborhood building boundaries to the internal space of the whole neighborhood.

As for the calculation method of circumference, some scholars have indirectly expressed the enclosure through the Openness of buildings along the streets of the neighborhood. Some scholars also have proposed that the enclosure consists of concepts such as the aspect ratio of external section, planar permeability, sky visibility, and the height difference of the ground rising or sinking.

(2) The Vertical Interface

The Vertical Interface refers to the ratio of landscape elements pixels to the Vertical Interface pixels. The main elements in the Vertical Interface including buildings, vegetable, walls and poles. Accordingly, enclosure is the degree to which street canyons are visually enclosed by the sides of buildings, walls, trees and other vertical elements[9]. Buildings and trees are physically separated from indoors and outdoors in urban environments. In this study, the outdoor buildings and trees are regarded as the subjects of the Vertical Interface. They are the most visually dominant objects that form the basic structure of street space, For example, Jiang et al. (2015) suggested that trees cover density influences human stress, and a tree canopy augments the enclosed feeling[10]. The degree of enclosure in the streets has a certain effect on the mood of pedestrians[11]. The enclosed spaces made up of buildings and plants that tends to produce an impression of higher security for users, thus providing more opportunity for physical activities and walking in the streets. Therefore, The Vertical Interface is highlighted as the primary feature in the street design qualities.

(3) Proportion of Buildings

The buildings along the street are an important part and the main spatial boundary in the street space. In the study, the Proportion of Buildings refers to the ratio of buildings pixels to the total pixels. It denotes constraints of the built environment on the pedestrian spatial perception. The building facades along the street play a very important role in forming the physical space and visual corridor in the streets. The visual corridor of the landscape in the direction of pedestrian traffic, previous studies have shown that the buildings make up two-fifths of the spatial surface. Other elements are the roadway, the sky and the end of the street. The large size of the buildings blocks the view and affects the pedestrian's overall perception in the street space.

4.1.4 Pedestrians and Vehicle Occurrence Rate

Crowd Gathering refers to the concentration of crowd activities in the street space, and its core is the people engaged in various activities in the street space. The coastal street is an open public space in the city and people tend to be highly congregate. At the same time, the randomness of the crowd flow, the convergence of the entry and exit of some hot spots and the residence time, it is easy to cause local or global traffic congestion. Then the research of the crowd gathering in the street space is an essential part. With the development of big data technology and the mature application of digital image processing technology, it has become an important method to use image processing technology to monitor crowd dynamically.

With the deepening of urbanization, the traffic flow in urban streets tends to increase. This situation leads to more complicated traffic situation on urban streets. The research on the incidence of vehicles can analyze some traffic situations in urban streets. It is beneficial to put forward corresponding renewal strategies to create safe and comfortable streets.

4.2 Research Methodology

4.2.1 The method of semantic segmentation based on deep learning

In recent years, with the development of computer deep learning, deep neural networks have replaced traditional image processing or and become the mainstream approach in many research areas of image vision. Currently, deep learning techniques, represented by convolutional neural networks, are successfully applied in a variety of fields such as detection, object recognition and semantic segmentation[12]. Image semantic segmentation is the process of classifying each pixel of the input image one by one.Semantic segmentation method can divide objects of different categories and locations in the image into their own independent sub-regions along their boundaries.According to the grayscale value of each sub-region, it generates the corresponding color annotated image for observation and differentiation. The semantic segmentation technique in city street scenes can classify all interest categories in the scene at pixel level. Vehicles, driving areas, sidewalks, vegetation, near pedestrians, roads, traffic signs, street lights, buildings on both sides, etc. are extracted from the images with rich environmental information to assist in decision.In the semantic segmentation task, the input to the task is an RGB color image and the output corresponds to a color segmentation result of the same size. Semantic segmentation of images is indispensable in the fields of transportation, medical, military, and agriculture.Image semantic segmentation as a pixel-level image recognition technique is more accurate compared to other techniques. The algorithm running time, segmentation accuracy and the storage space for hardware need to be strictly controlled[13].

4.2.2 ArcGIS Methodology

In addition, we used the Open Street Map and remote sensing images tools in ArcGIS, to obtain sidewalk widths, road widths and building height. Meanwhile, we borrowed from Harvey's creative way which combining GIS with SVP data, automatically obtaining information such as Spatial Walk Index, Car Travel Index and Building Height[14].

4.3 Physical Features

4.3.1 Physical features of Qingdao Coastal Streets, China

4.3.1.1 Greenness

(1) Overall description

1) Overall evaluation

Greenness is the percentage of green landscape within person's view. It is more accurate and intuitive compared to indicators such as green area ratio and green coverage. Therefore, Greenness is an important index to measure the quality of street space, which can objectively reflect the real situation of green volume of urban street space. According to the data, the average Greenness value of 344 sample points in Qingdao Coastal Streets was 0.344(Fig4-1), which meant that the average percentage of green vegetation in the human view range was as high as 34.4%. This indicated that the overall green vision rate of Qingdao Coastal Streets was high. As shown in the figure, the distribution of green eyesight rate of all sample points in the study area was shown. From the spatial distribution of Greenness, the overall distribution of Greenness of Qingdao Coastal Streets shown a characteristic of alternately increasing from east to west. The high value points and low value points were staggered and linearly distributed. There were no large areas of high value points concentration.

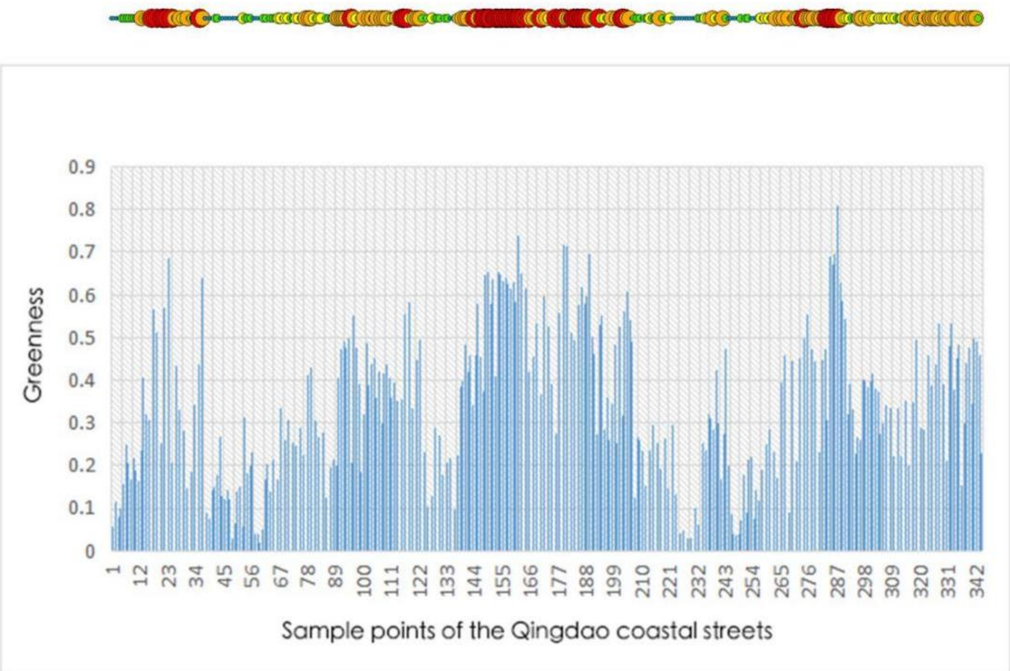


Fig 4-1 Greenness of sample points in Qingdao Coastal Streets

2) sample point analysis

Among the 344 sample points in Qingdao Coastal Streets , the high value of Greenness was concentrated in Shanhaiguan Road and Taipingjiao 1 Road. Moreover, high value points and low value points were distributed in Aomen Road and Xilingxia Road, which indicated that the distribution of Greenness in two sections of roads was very uneven. Both streets have a common feature that local roads will be adjacent to urban public green spaces, therefore will have sample points with high Greenness. In addition to this, the local road was in the commercial building area, which was mostly hard green space, so there will be a sample point of low Greenness. The maximum value of green view rate among 344 sample points was 0.811, which was located at point NO.287 of Taiping Road. the minimum value of Greenness among sample points was 0.019, which was located at point NO.059 of Aomen Road. (Tab 4-1)

Table 4-1 Greenness statistics at sample points

Average value	Median value	Maximum value	Location of sample point	Minimum value	Location of sample point
0.344	0.521	0.811	Taiping Road point NO.287	0.019	Aomen Road Point NO.059

3) Trend analysis

Based on the definition of street Greenness in this experiment, the street Greenness was quantified and measured for 344 sample points on Qingdao Coastal Streets. The Natural intermittent grading method was used to conduct the numerical statistics and sample size distribution statistics of the Greenness of sample points. The statistical results shown the features of "irregular fluctuations of multiple peaks", the areas with higher values of sample points shown irregular and violent fluctuations.

In this section, according to the Natural Intermittent Grading method , the Greenness of Qingdao Coastal Streets could be classified into five grades, which were 0%-15.4%, 15.4%-27.5%, 27.5%-39.7%, 39.7%-54.5% and 54.5%-81.1%(Fig4-2). In this study, all sample collection points were divided into five intervals based on five levels: low value interval (0%-15.4%), lower value interval (15.4%-27.5%) middle value interval (27.5%-39.7%) higher value interval (39.7%-54.5%) and high value interval (54.5%-81.1%). The low value of the Greenness in the interval 0%-15.4% of the total, accounting for 15.4% of the total, belonged to the poor level of greenery. The index in the interval 15.4%-27.5% accounted for 24.1% of the total, the index in the interval 27.5%-39.7% accounted for 21.2% of the total. Greenness in the interval 39.7%-54.5% accounted for 25% of the total, in the interval greater than 54.5%-81.1% accounted for 14.2% of the total. The overall value of Greenness of Qingdao Coastal Streets was high. The results of a social survey published by Japan's Ministry of Land, Infrastructure, Transport and Tourism shown that an environment with a high Greenness was peaceful. It promoted business atmosphere and gathered people around it. For the first time, an official document acknowledges that the Greenness above 25% gave the public a better sense of green, so Greenness above 25% has become a green building target in many cities. In 67.4% of the points, the Greenness was higher than 0.25. Overall, the greening level of Qingdao Coastal Streets met the basic requirements.

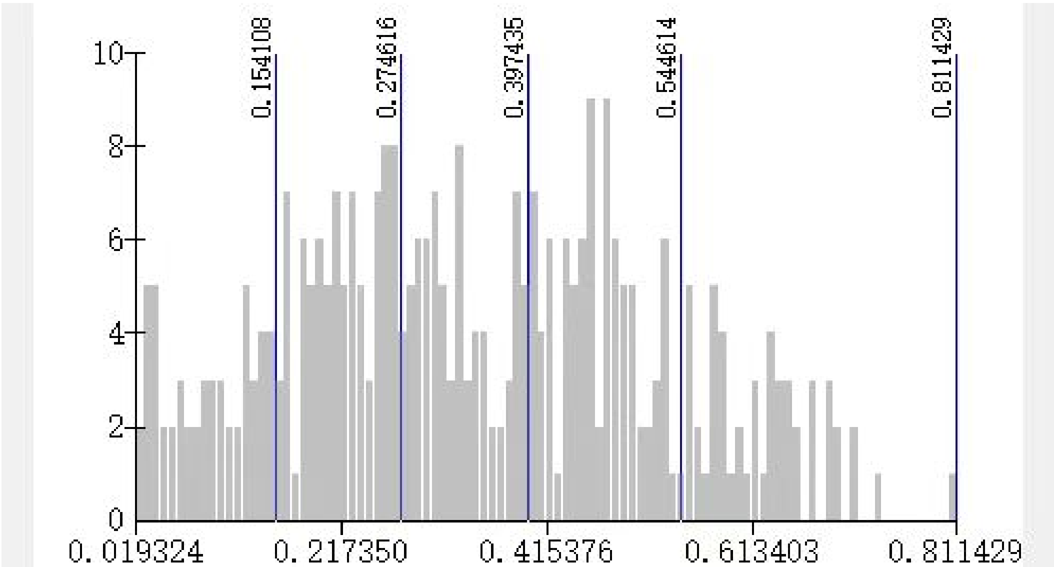


Fig 4-2 Distribution trendency diagram about Greenness of sample points

(2) Segment description

1) The average segmentation point of 12 sections

According to the road name, the whole section of coastal road was divided into 12 sections, the average value and standard deviation of Greenness of each road were calculated respectively. The average value of the Greenness of each sample point was regarded as the street Greenness, the Greenness of Qingdao Coastal Streets was plotted in descending order by the Greenness of each street, which shown that the range of the street Greenness was 0.25-0.62. The Greenness of each road from high to low were Shanhaiguan Road, Taipingjiao First Road, Wendeng Road, Taipingjiao Fourth Road, Laiyang Road, Southeast Middle Road, Zhuhai Branch Road, Nanhai Road, Aomen Road, Xilingxia Road, Donghai West Road and Taiping Road.(Fig4-3)

According to the criteria of Japanese scholar Natsuhi Origahara, the Greenness of Qingdao Coastal Streets was divided into five levels: 0-5% (poor greening level), 5%-15% (poor greening level), 15%-25% (average greening level), 25%-35% (high greening level) and ≥35% (high greening level). This grade could judged that the overall visible green amount of Qingdao Coastal Streets was high and the level of greenery was good. Data analysis shown that the average greening level (average greening rate of 15%-25%) in these 12 road sections was Taiping Road, accounting for 8.3%. The road sections with high greening level (average Greenness of 25%-35%) were Xilingxia Road, Nanhai Road, Donghai West Road, Macao Road and Zhuhai Branch Road, accounting for 41.7%. The road sections with high greening level (average Greenness > 35%) were Laiyang Road, Wendeng Road, Shanhaiguan Road, Taipingjiao First Road, Taipingjiao Fourth Road and Southeast Middle Road, accounting for 50%. Among them, Laiyang Road, Wendeng Road, Shanhaiguan Road, Taipingjiao First Road, Taipingjiao Fourth Road and Southeast Middle Road, the average green vision green of these six roads was greater than the overall average Greenness (34.36%).

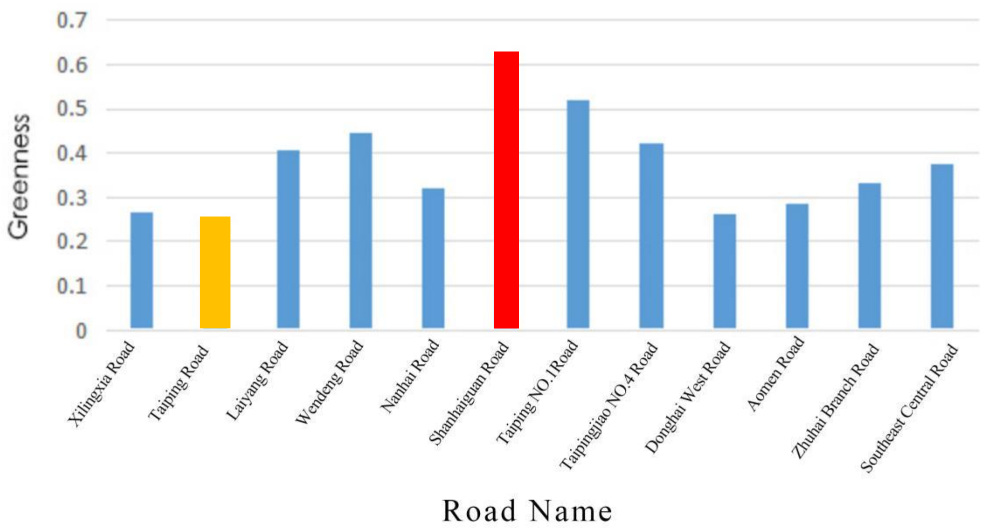


Fig 4-3 Average Greenness of every segment sample points in Qingdao Coastal Streets

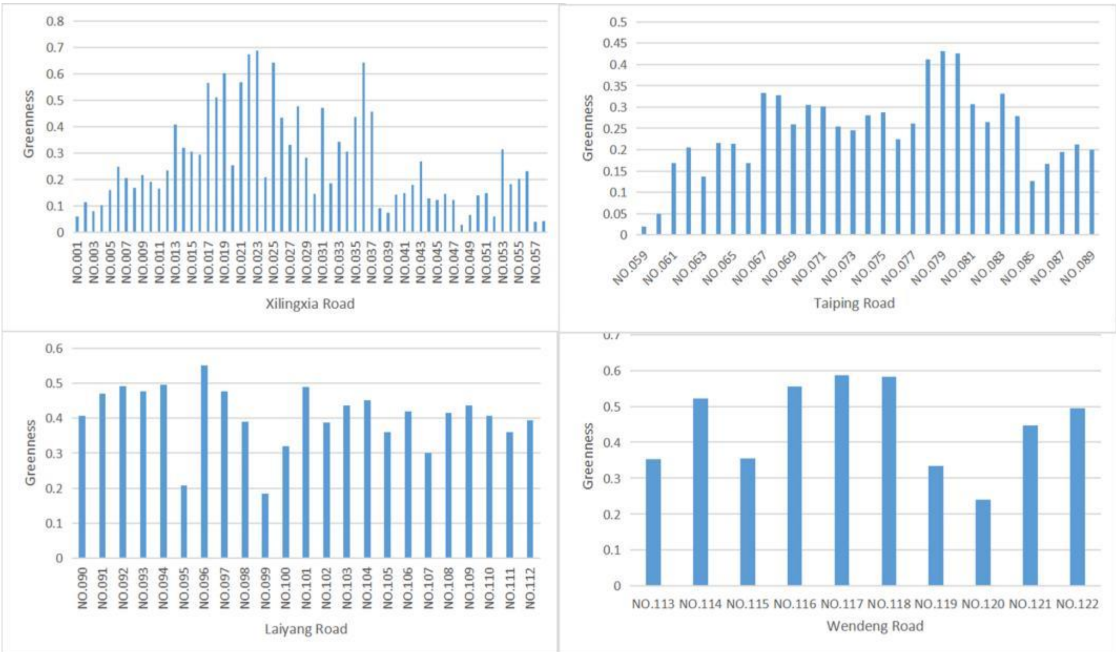
2) The comparative differences and reasons of each segment

As shown in the 12 graphs above, it could be seen that the Greenness values of Xilingxia Road, Taiping Road, Nanhai Road, Taipingjiao I Road, Taipingjiao IV Road, Donghai West Road and Aomen Road fluctuate greatly. This indicated that there was some variation in the distribution of greenery on these roads. The Greenness values of Laiyang Road, Shanhaiguan Road and Zhuhai Branch Road were relatively smooth, indicating that the greening distribution of these roads was relatively even and the greening effect was smooth and continuous.

From the analysis of the data of the observation points, there was still variability in the average

Greenness of different road sections. With the lowest average Greenness value of 24.54% for Taiping Road, which meant that a small amount of basic greenery could be seen in the site. This part of the observation point was mostly composed of coastal coastal recreational space and commercial buildings, so there was less greenery arrangement and thus lower Greenness. The highest average Greenness value of 61.86% was found in Shanhaiguan Road, which is located within the Badaguan Scenic Area and was public green space. The site was rich and diverse in plant species, forming a better green environment. Therefore has a high average green view rate.

The green vision rate of Shanhaiguan Road and Taipingjiao 1 Road was significantly higher than other roads. Shanhaiguan Road was in a scenic area, which made its average Greenness high(Fig4-4). The high average Greenness of Taipingjiao Road 1 was related to its lush road greenery on both sides of the road. The large percentage of green area on the map surface increased its green view rate. Average green vision green in the medium level included Hainan Road, Wendeng Road, Taipingjiao 4, Laiyang Road, Southeast Central Road, Zhuhai Branch Road. The average Greenness was relatively low including Aomen Road, Xilingxia Road, Donghai West Road, Taiping Road. This street interface was mostly in the form of buildings, with less greenery and wider roads. The map surface has a low percentage of green area and a low value of Greenness. More than 50% of the streets were above the average value, the percentage of streets with low greenery was very small.



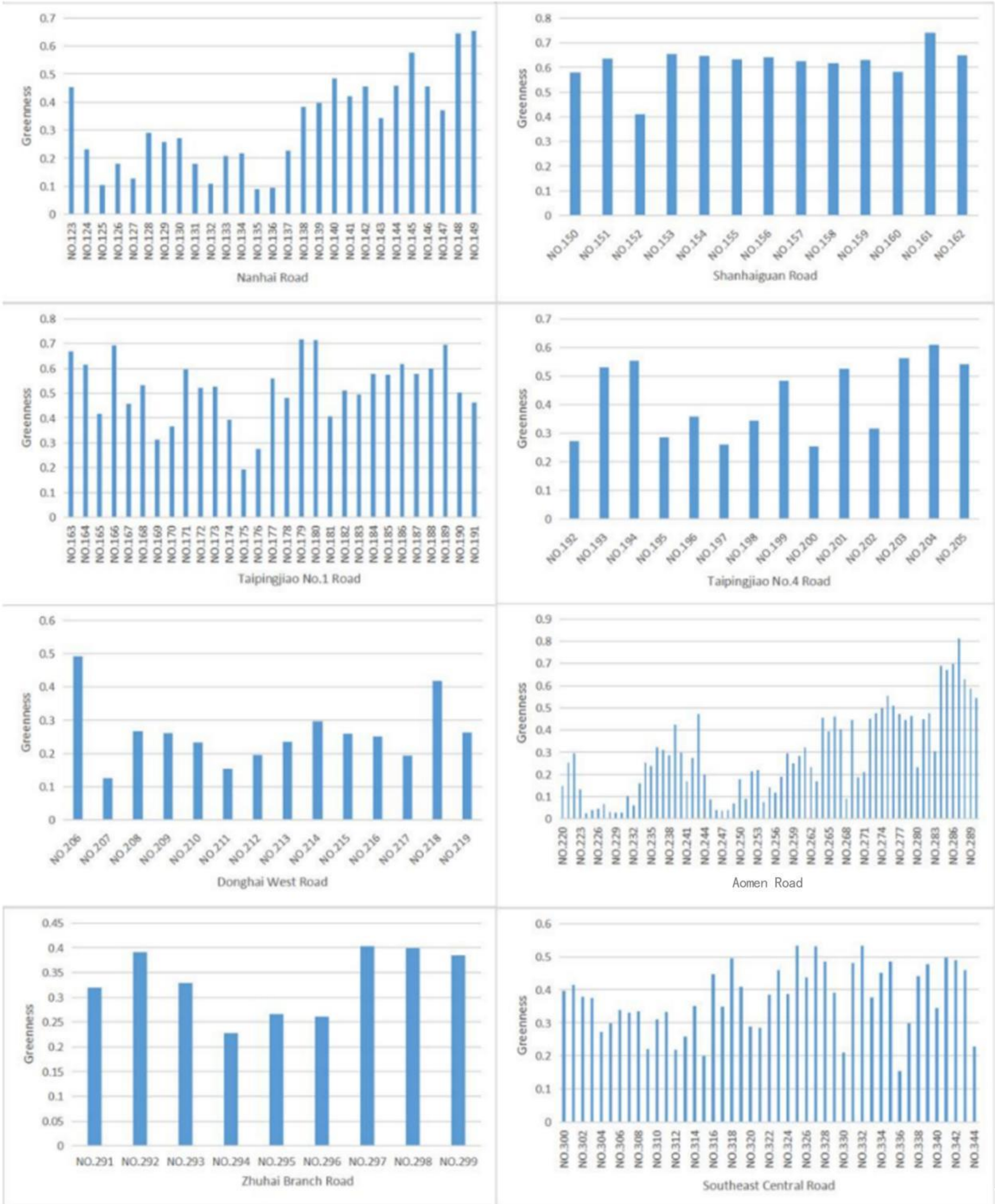


Fig 4-4 Greenness of every segment sample points in Qingdao Coastal Streets

3) Standard deviation of segmented roads

By comparing and analyzing the average Greenness, the standard deviation of Greenness and its coefficient of variation for each road section of Qingdao Coastal Streets, it could be concluded that the average Greenness value was negatively correlated with the standard deviation value and the coefficient of variation, the standard deviation was positively correlated with the coefficient of variation(Fig4-5). This meant that the lower the value of the mean Greenness, the higher the value of the standard deviation and the higher the coefficient of variation. In probability statistics, the standard deviation could reflected the degree of dispersion of data set. When the means were not the same, we needed to exclude the cases where the means were not equal in size. Therefore, the concept of standard deviation coefficient was introduced for comparing the magnitude of fluctuations in different data sets. A large standard deviation and a large coefficient of variation for a section of road indicated that the fluctuation of the Greenness at each observation point on that road varies significantly. At the same time, it also indicated that the Greenness of the observation points were not evenly distributed on the street. The standard deviation of Greenness was large, the green arrangement of this section of the road was not uniform, the continuity and stability was poor(Tab4-2).

Table 4-2 Segmented Greenness data

Number	Road Name	Average	Standard deviation	Coefficient of variation
A	Xilingxia Road	0.264	0.179	0.678
B	Taiping Road	0.245	0.094	0.384
C	Laiyang Road	0.406	0.087	0.215
D	Wendeng Road	0.447	0.115	0.257
E	Nanhai Road	0.322	0.164	0.51
F	Shanhaiguan Road	0.619	0.071	0.115
G	Taipingjiao No.1 Road	0.519	0.129	0.249
H	Taipingjiao No.4 Road	0.421	0.128	0.303
I	Donghai West Road	0.26	0.093	0.356
G	Aomen Road	0.286	0.195	0.681
K	Zhuhai Branch Road	0.331	0.064	0.192
L	Southeast Central Road	0.374	0.099	0.263

The standard deviation of the Greenness of each road from high to low were Shanhaiguan Road, Taipingjiao 1 Road, Wendeng Road, Taipingjiao 4, Laiyang Road, Southeast Middle Road, Zhuhai Branch Road, Nanhai Road, Aomen Road, Xilingxia Road, Donghai West Road, Taiping Road. The standard deviation of Aomen Road was significantly higher than other regions. The Greenness of Aomen Road shown fluctuating changes, the higher values were mainly distributed in the points near the public green areas. The other road sections divided by public green areas were mostly commercial buildings and have the low Greenness. This has resulted in uneven and discontinuous distribution of greenery. The standard deviation of Shanhaiguan Road was low, the Greenness shown average distribution of high values. Because the road section was all located in scenic area, each sample point was better greened, thus creating the phenomenon of low standard deviation of high average Greenness on Shanhaiguan Road. That is, the greening level of Shanhaiguan Road was high, the Greenness was evenly distributed, the greening continuity was good.

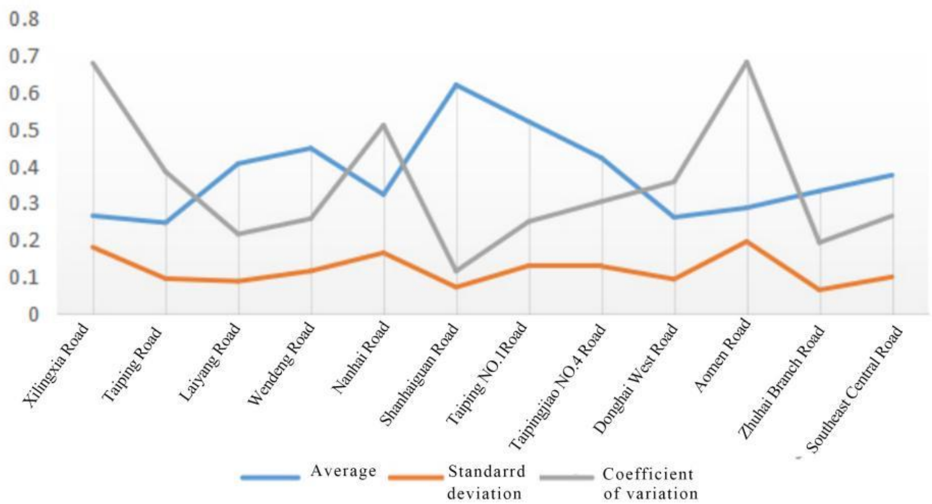


Fig 4-5 Coefficient of variation Greenness of every segment sample points in Qingdao Coastal Streets

(3) Discussion based on data results

According to the analysis of the green view rate of each observation point, the average Greenness of 12 road sections and the standard deviation of Greenness of Qingdao Coastal Streets, it was known:

1) The relationship between Greenness and park green space

The observation points with a Greenness greater than 0.25 accounted for 67.4% of the total. The streets with an average Greenness greater than 0.25 accounted for 91.7% of the total. It could be seen that the overall greening level of Qingdao Coastal Streets was good. From the spatial layout of the green space along the coast, there were many green spaces in the coastal space, which will create a better level of greenery. According to the location of the road sections with higher average Greenness, it could be concluded that the average Greenness of the road sections near the park green space was generally high. The average Greenness of roads such as Shanhaiguan Road and Taipingjiao Road reached 056.9. This indicated the combination of street and green space system, which could increased the Greenness and create a good landscape effect. This result was the general impression of people. This means that streets near urban green areas will have a more natural landscape effect. Other urban roads will have a little less green effect.

2) Influencing factors of Greenness

The average Greenness of the 12 road segments was greater than 24%, which all meet the general level of greening standards. However, there was variability in the average green view rate among the road segments. By comparing the differentiated elements of greening and spatial composition of each road section and other related studies, it could be concluded that the high or low Greenness was related to the plant morphological index, plant configuration form, width of the road, vertical greening and other factors.

Plant features: Planting greenery and other landscape elements is the most effective way to improve the Greenness. The canopy, plant height, diameter at breast height and species of trees affected the Greenness. When plants are planted more densely and grow better, their green view rate will increase.

Plant configuration: Many current urban street greening designs were often dominated by a single tree, which was monotonous and lacked a sense of hierarchy. Combining shrubs and vines to form a good plant configuration effect, which can enhance the diversity of plants in urban street green belts and also improve the landscape effect and interest of some roads.

Road grade: Due to the different road grades, widths and greening forms, the road Greenness was not the same. Because when the road is too wide, the proportion of greenery on both sides will become smaller, thus making the Greenness lower. When the width of the road becomes smaller, the proportion of greenery on both sides will become larger, thus the green view rate will become larger. Streets with high street greening level have large amount of greenery, then the Greenness became high. Streets with low grades can use some shrubs or herbaceous plants to make the greenery smaller.

Vertical greening: From the perspective of visual or spatial experience, people's perception of three-dimensional level of greenery was more intuitive. Therefore, the focus on improving the amount of greenery on the street façade, which could improved the Greenness. This was also the first priority for the improvement of street space quality. In addition, the greening of building balconies and roofs was used to improve the Greenness at a microscopic level and created a more pleasant street appearance.

3) Standard deviation of Greenness and greening continuity

It was known from the standard deviation of the Greenness: the larger variation coefficient, the greater the Greenness dispersion, which indicated the existence of a discontinuous distribution of greenery. Due to the lack of greenery on the viewing platform and incomplete greenery on the carriageway in this section of the road, there was a kind of uneven distribution of greenery. In the future, the Greenness can be improved by increasing the greening of hard spaces and improving the greening configuration.

4) The relationship between Greenness and functional area

Some research shown that the Greenness was related to the functional nature of the road. The functional nature of roads could be divided into residential, commercial and ecological nature. The ranking of its Greenness: ecological nature road > residential nature road > commercial nature road. In the analysis of the streets Greenness with different functions, the ecological roads were usually located in scenic areas or near public green areas. It had better greening effect and uniform distribution, so the Greenness was higher. To create a good living environment, noise and exhaust fumes from the carriage way were blocked, private and quiet living space was created. Residential road greening should use large trees to form a continuous shade line, which will also form a better road greening effect. Most of the commercial streets have open squares. In order to avoid blocking the view of the commercial along the street, a permeable green landscape should be created. It should have smaller plant crown width and wider plant spacing. Therefore there were fewer plants and its Greenness will be lower.

5) The relationship between Greenness and other physical features

Greenness is very closely related to spatial Openness and street enclosed space. These are often two opposing indicators in the spatial quality evaluation factor and their trends are mostly negatively correlated. The street is green when the Greenness is high, because the street trees on both sides grow well and the canopy is large. In the human perspective, it will obscure the sky, which means the Openness of the space becomes lower. Greenness and street enclosure are two opposing indicators in spatial quality evaluation factors. Their change trends are mostly positively correlated. The green landscape is the main element of the enclosed space. The sense of street enclosure can be influenced by the variation in their growth, number and arrangement.

6) Greenness and human feelings

Greenness is to assess the amount of green in urban streets from the pedestrian's perspective and the dimension of urban space. It emphasizes the three-dimensional visual effect and represents a higher level of urban greening construction. Greenness is an important index to evaluate the urban landscape environment. The level of street Greenness level directly affects space quality . Studies have shown that the level of street green vision affects pedestrian psychology and physiology. In this study, only 4% (15/344) of the 344 observation points in Qingdao Coastal Streets did not meet 5% Greenness. Some studies have shown that when the green view rate of street space was less than 5%. People perceive the amount of green poorly, which was not conducive to positive heart emotions. That was, the comfort of the street space was poor. Comfortable spatial environment and natural environment, which was the prerequisite and basis for prompting human activities. People prioritize their comfort needs in space over higher-level needs such as emotion, belongingness and aesthetics.

The greenery was one of the influential elements in the street space that made the comfort level directly perceivable. Another influencing factor was the spatial scale. Green vegetation provided ample shade in hot weather. They could provided a relatively comfortable place for shelter from the wind and rain. Thus, the Greenness could be used as a quantitative indicator of street greening.Therefore, the Greenness could indirectly reflected the comfort of street space. Greenness and spatial comfort were positively correlated. In other words, the higher the Greenness, the better the spatial comfort.

4.3.1.2 Openness

(1) General Description

According to the formula for calculating the Openness, the data obtained from 344 sample points of Qingdao Coastal Streets were calculated and analyzed, and it was found that the Openness is the opposite of the green visual index. The Openness is usually lower at points with high green visual index. And the height to width ratio of buildings around the road is also an important factor affecting the Openness and the comfort level of people in the street.

(2) Analysis of sample Points

According to the data obtained from 344 sample points, it is found that the high values of Openness are mainly located on the east and west sides of Qingdao Coastal Streets, and the low values are located in the middle section(Fig4-6). The Openness of each sample point shows a trend distribution of high in the east and west and low in the middle. Therefore, the east and west sides of the whole Qingdao Coastal Streets have higher Openness and higher street space comfort, while the middle section has lower space comfort.

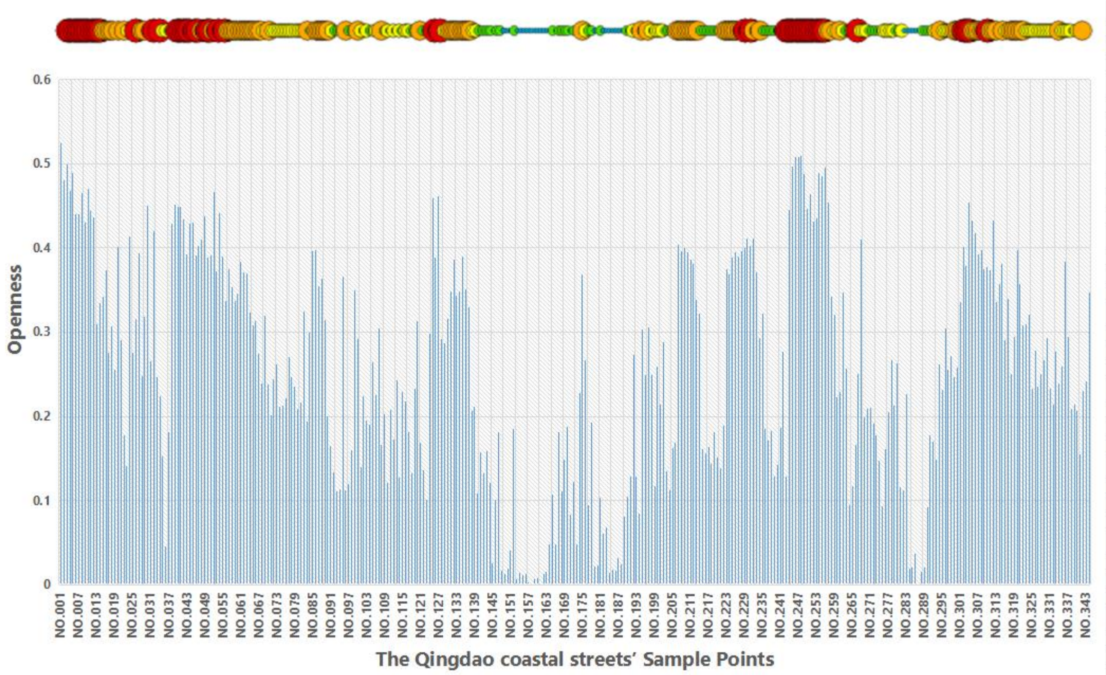


Fig 4-6 Openness of sample points in Qingdao Coastal Streets

(3) Trend Analysis

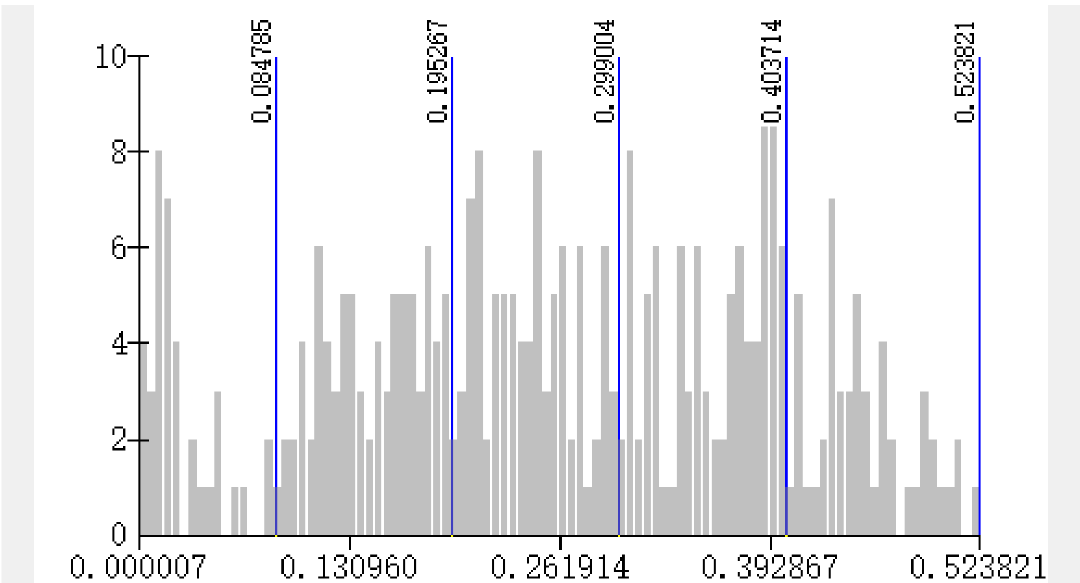


Fig 4-7 Distribution trendency diagram about Openness of sample points

The natural intermittent point grading method was used to conduct numerical statistics and sample size distribution statistics of the Openness at the sample points, and the sample size distribution showed "multi-peak fluctuations"(Fig4-7). It means that multiple intervals with higher values of sample points appear and form multiple peaks in this way, but the sample size of each interval fluctuates drastically and without rules. The number of sample points in the interval [0.00007,0.085] is 38, accounting for 11%; The number of sample points in the interval [0.085,0.195] is 79, accounting for 23%; The number of sample points in the interval [0.195,0.299] is 87, accounting for 25.3%; The number of sample points in the interval [0.299,0.404] is 91, accounting for 26.5%; The number of sample points in the interval [0.404,0.524] is 49, accounting for 14.2%.

(4) Segment Comparison

Similarly, Qingdao Coastal Streets is divided into 12 sections according to the road names. By calculating the average Openness of each road section and considering it as the Openness of that section, a bar chart of the Openness of Qingdao Coastal Streets was drawn. The average Openness of Qingdao Coastal Streets is 0.258, and there are 5 out of 12 road sections that exceed the average, accounting for 41.7%(Fig4-8). It indicates that the Openness of the whole Qingdao Coastal Streets is low. The highest Openness value was 0.368 for Xilingxia Road and the lowest Openness value was 0.024 for Shanhaiguan Road. In contrast, the green visual index of Xiling Road is lower at 0.264, while the green visual index of Shanhaiguan Road has a higher value of 0.619. A comparison with the green visual index reveals that the higher the green visual index, the lower the Openness. The reason for this is that the canopy of street trees can shade the sky what resulted in a low Openness, thus showing that the green visual index has an inverse effect on the Openness. Combined with the road grade of Qingdao Coastal Streets, it can be seen that the Openness is higher when the road grade is higher, and lower when the road grade is lower(Fig4-9). Therefore, the coupling analysis with the road level shows that the Openness decreases along the road level. The higher the road grade, the stronger the traffic sex function, the better the view observed by pedestrians, and the higher the Openness(Tab4-3, Fig4-10).

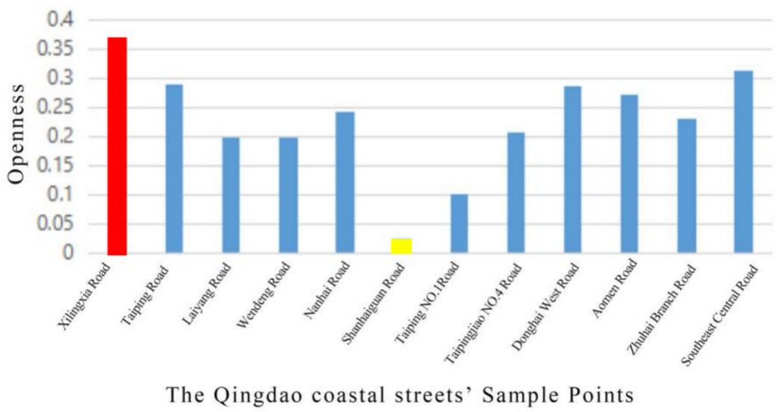


Fig 4-8 Average Openness of every segment sample points in Qingdao Coastal Streets

Fig 4-9 Openness of every segment sample points in Qingdao Coastal Streets

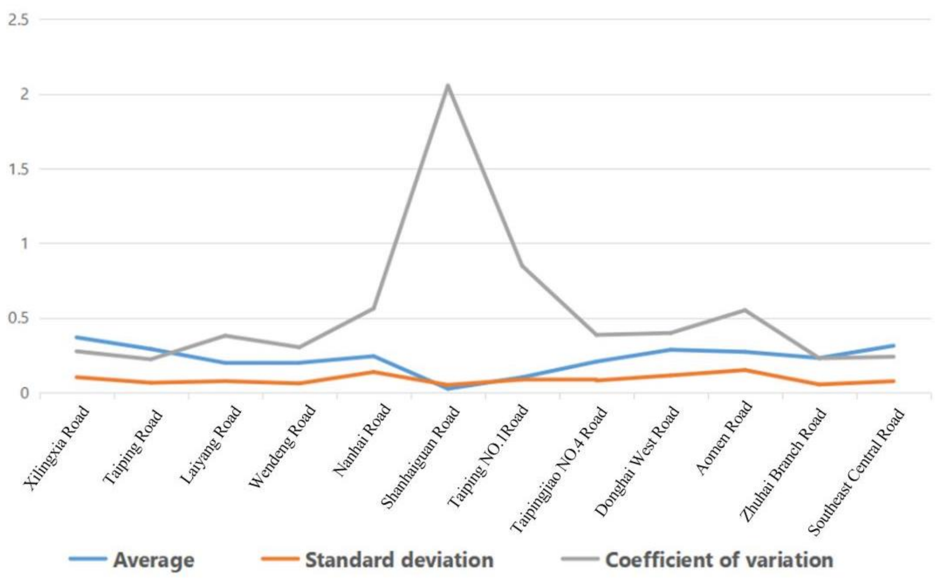


Fig 4-10 Coefficient of variation Openness of every segment sample points in Qingdao Coastal Streets

Table 4-3 Segmented Openness data

Number	Road Name	Average	Standard deviation	Coefficient of variation
A	Xilingxia Road	0.368	0.101	0.274
B	Taiping Road	0.29	0.064	0.221
C	Laiyang Road	0.197	0.075	0.379
D	Wendeng Road	0.198	0.0598	0.301
E	Nanhai Road	0.242	0.136	0.561
F	Shanhaiguan Road	0.024	0.0493	2.054
G	Taipingjiao No.1 Road	0.101	0.086	0.846
H	Taipingjiao No.4 Road	0.206	0.0792	0.384
I	Donghai West Road	0.285	0.113	0.397
G	Aomen Road	0.271	0.149	0.549
K	Zhuhai Branch Road	0.23	0.0525	0.228
L	Southeast Central Road	0.312	0.0744	0.238

(5) Analysis and Summary

In general, the space comfort of Qingdao Coastal Streets is relatively good. Many of the sections with low sky visibility indices are due to vegetation screening, not a deficiency in road space, even on Shanhaiguan Road, which has the lowest Openness. The reason for this is the high amount of greenery in the section, and the tree canopy shades the sky, but the spatial comfort of the section remains good and does not reduce the feeling of human psychological comfort.

4.3.1.3 Proportion of Buildings

(1) Overall evaluation

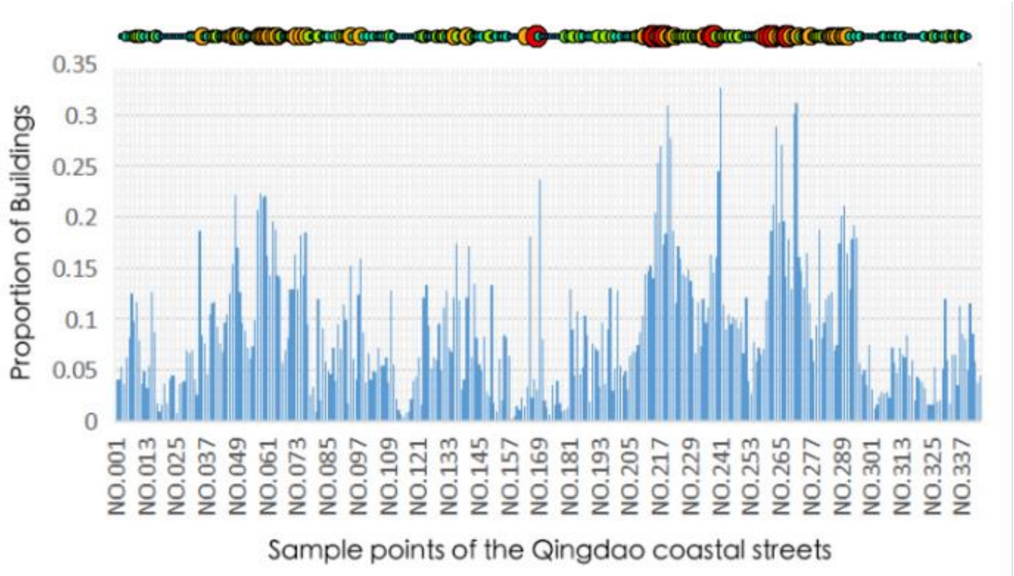


Fig 4-11 Proportion of Buildings of sample points in Qingdao Coastal Streets

According to the definition of building proportion, The overall average building ratio of 344 sample points in Qingdao Coastal Streets Street was 0.0892.It shows that the number of buildings on the street is relatively low.The Proportion of Buildings with 214 points was higher than the average, accounting for 62.20% of the total number, The standard deviation of the total building proportion of 344 sample points in coastal Road Street of Qingdao was 0.0634, The total standard deviation value is small, It shows that the buildings are evenly distributed.As shown. Observing the space trend of buildings, We can draw the conclusion that the high-value points are concentrated around 217, 241 and 265 points, while the low-value points are concentrated around 13, 85, 121, 301 and 325 points, and there is a big gap between the high-value points and the low-value points near 169 points.The data rised alternately from east to west.(Fig4-11)

(2) Description of sample points

Among the 344 sample points, the maximum value is No.241 located on Aomen Road, with the data of 0.3276.The other high values are 263 points with the value of 0.2891, 270 points with the value of 0.3009, 220 points with the value of 0.3099 and 271 points with the value of 0.3123, all of which are located on Aomen Road.The minimum value is 0.001671728 at 115 points on Wendeng Road, and the other low values are 0.0029 at 158 points on Shanhaiguan Road, 0.0046 at 159 points, 0.0062 at 114 points on Wendeng Road and 0.0069 at 173 points on Taiping Road.

(3) Trend Description

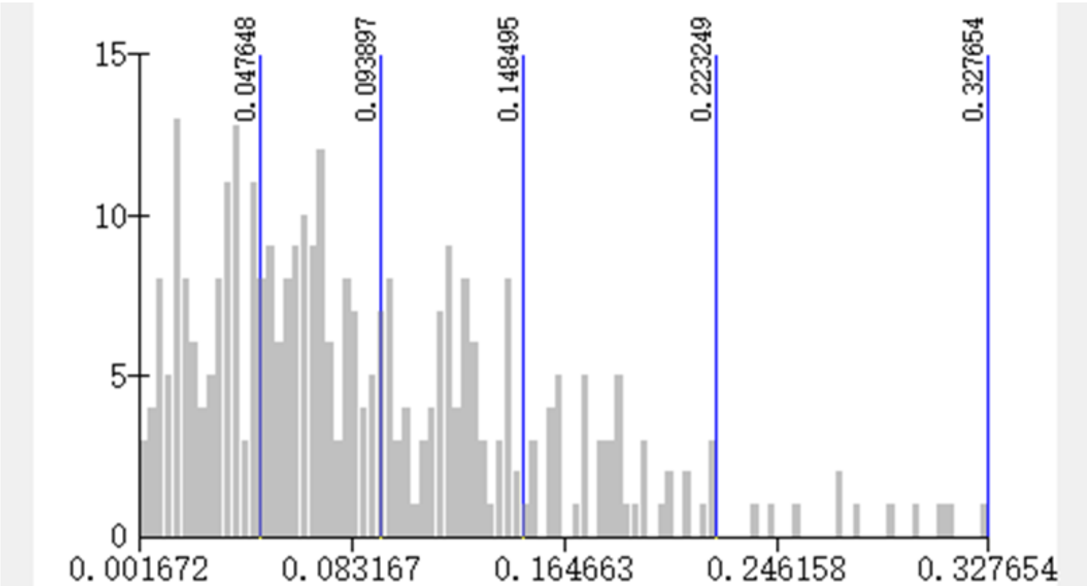


Fig 4-12 Distribution trendency diagram about Proportion of Buildings of sample points

Quantitatively measure the Proportion of Buildings in 344 sample points of Qingdao Coastal Streets.The natural discontinuity grading method was used to make numerical statistics and sample size distribution statistics on the building proportion index of sample points.There were more middle and low values and fewer high values. According to the classification method of natural discontinuities, the proportion data of coastal Road buildings can be divided into five grades, which were 0.001672-0.047648, 0.047648-0.093897, 0.093897-0.148495, 0.148495-0.223249 and 0.223249-0.39 respectively(Fig4-12).The five levels correspond to the low value interval, the lower value interval, the median value interval, the higher value interval and the high value interval.The number of low-value intervals was 104, accounting for 30.23% of the total; There were 104 low-value intervals, accounting for 30.23% of the total; The number of median areas was 81, accounting for 23.55% of the total; There were 43 high-value intervals, accounting for 12.50% of the total; The number of high value intervals was 11, accounting for 3.20% of the total.

(4) Segment description

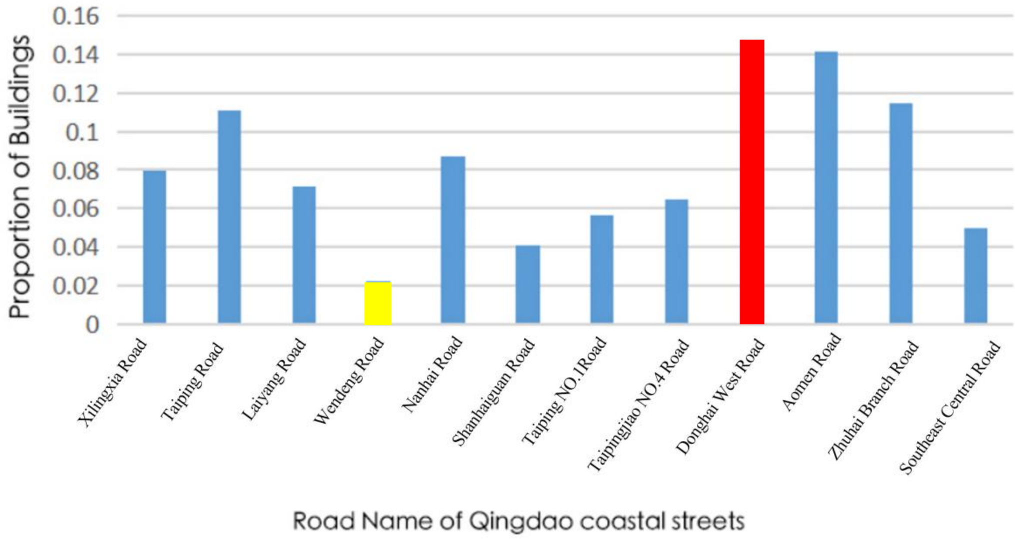


Fig 4-13 Average Proportion of Buildings of every segment sample points in Qingdao Coastal Streets

The whole section of coastal Road was divided into 12 sections according to the road names, and the average and standard deviation of buildings in each section were calculated respectively(Fig4-13,Tab4-4). We can know that the high value points of building proportion were located in Donghai West Road, Aomen Road and Zhuhai West Road, which were 0.1476, 0.1411 and 0.1144 respectively.From the panoramic view of Baidu map, we can know the reasons: there are buildings on both sides of Donghai West Road, which are high and few in number, and are commercial office areas, and a small part of them are residential buildings; Most of the roads on both sides of Macao are residential buildings with a large number of buildings and small spacing; One side of Zhuhai Branch Road is mostly a high-rise residence, while the other side is a small villa, with a small building spacing and a large number.The low values were 0.0218, 0.0404 and 0.0493 in Wendeng Road, Shanhaiguan Road and Donghai Middle Road respectively.Looking at the panoramic view of Baidu map, we know that there are many trees on both sides of Wendeng Road and few buildings; One side of Shanhaiguan Road is a single-family villa with large building spacing, and the other side is a tree; There are few buildings in the East China Sea, and both sides are mostly green.According to the standard deviation of building interface, we can know that although the Proportion of Buildings in Donghai West Road, Aomen Road and Zhuhai Branch Road was high, the standard deviation of buildings in Wendeng Road, Donghai Middle Road and Taipingjiao Road was small (Fig4-14).According to the coefficient of variation, the number of buildings in 12 roads fluctuated slightly.The Proportion of Buildings in the two roads is listed in the histogram, and it can be found that there was a big difference in the Proportion of Buildings in Shanhaiguan Road and

Zhuhai West Road(Fig4-15).

Fig 4-14 Proportion of Buildings of every segment sample points in Qingdao Coastal Streets

Table 4-4 Segmented Proportion of Buildings data

Number	Road Name	Average	Stabdard deviation	Coefficient of variation
A	Xilingxia Road	0.080	0.050	0.636
B	Taiping Road	0.111	0.060	0.546
C	Laiyang Road	0.071	0.038	0.542
D	Wendeng Road	0.021	0.019	0.873
E	Nanhai Road	0.086	0.041	0.478
F	Shanhaiguan Road	0.040	0.038	0.964
G	Taipingjiao NO.1 Road	0.056	0.053	0.944
H	Taipingjiao NO.4 Road	0.064	0.032	0.505
I	Donghai West Road	0.147	0.062	0.424
J	Aomen Road	0.141	0.068	0.485
K	Zhuhai Branch Road	0.114	0.062	0.549
L	Southeast Central Road	0.0493	0.027	0.561

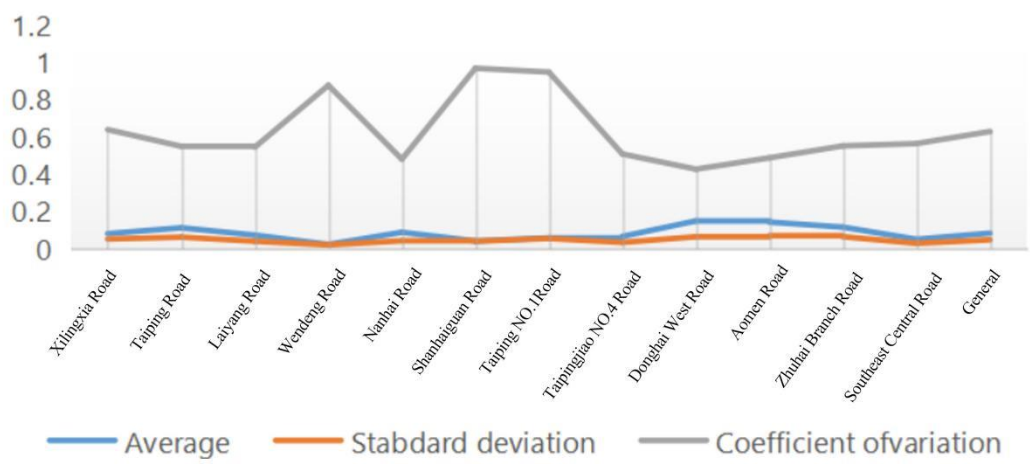


Fig 4-15 Coefficient of variation Proportion of Buildings of every segment sample points in Qingdao Coastal Streets

4.3.1.4 The Vertical Interface

(1) Overall evaluation

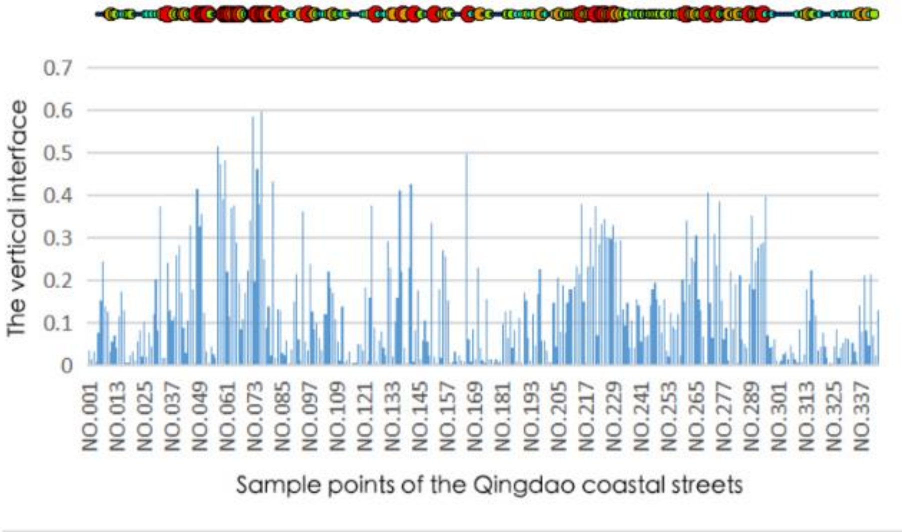


Fig 4-16 The Vertical Interface of buildings of sample points in Qingdao Coastal Streets

According to the definition of interface enclosure difference,the overall average closure difference of 344 sample points in Qingdao Coastal Streets Street was 0.128261506.The closed difference of 208 points was higher than the average closed difference, accounting for 60.47% of the total number.The standard deviation of total interface enclosure difference of 344 sample points in coastal Road Street of Qingdao was 0.12150739.The high total standard deviation indicates that buildings, trees and fences are evenly distributed(Fig4-16). Looking at the trend of the interface closed space, we can conclude that the value near 73 o'clock was high, and the values of 277, 133 and 145 were unevenly distributed.

(2) sample point description

Among the 344 sample points, the maximum value was 76 at Taiping Road, with a value of 0.5963; The other high values were 0.5849 at 72 points, 0.5142 at 57 points, 0.4976 at 165 points and 0.4823 at 60 points.76, 72 and 60 points were located on Taiping Road, 57 points were located on Xiling Road and 165 points were located on Taipingjiao Road.The minimum value was 0.0012 at 152 o'clock in Shanhaiguan.The value of the low value distributed at 217 points on Donghai West Road was 0.0015, that at 53 points on Xiling Road was 0.0016, that at 173 points on Taipingjiao Road 1 was 0.0018 and that at 117 points on Wendeng Road was 0.0019.

(3) Trend description

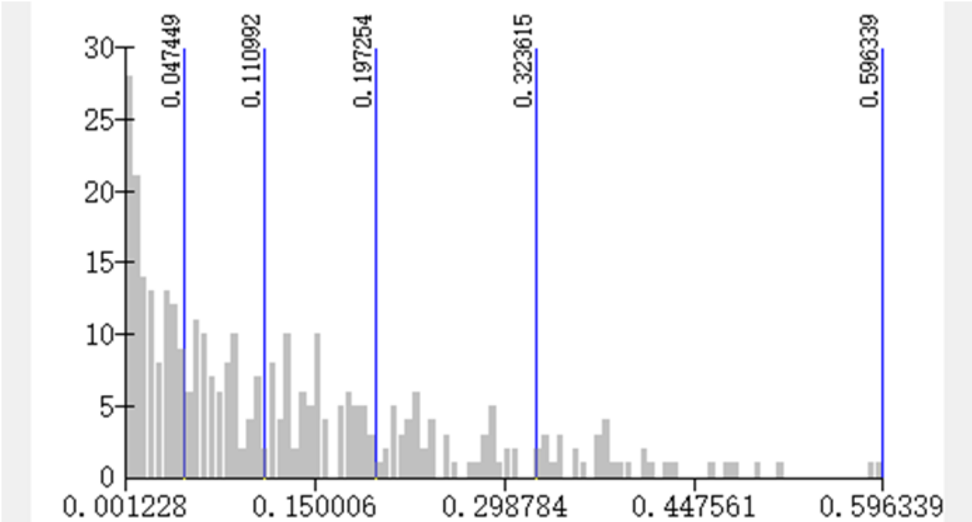


Fig 4-17 Distribution trendency diagram about the Vertical Interface of sample points

The interface enclosure of 344 sample points on Qingdao Coastal Streets was measured quantitatively.Numerical statistics and sample size distribution statistics were carried out on the interface enclosure index of sample points by using the natural discontinuity grading method.As shown in Figure . According to the classification method of natural discontinuity points, the data of coastal road interface enclosure were divided into five grades, which were 0.001381-0.047449，0.047449-0.110992，0.110992-0.197254，0.197254-0.323615，0.323615-0.596339(Fig4-17).Five levels corresponded to low-value intervals, low-value intervals, median intervals, high-value intervals and high-value intervals.The number of low-value intervals was 117, accounting for 34.01% of the total. There were 73 low-value intervals, accounting for 21.22% of the total. The median are was 73, accounting for 21.22% of the total. There was 48 high-value intervals, accounting for 13.95% of the total. The number of high value interva was 33, accounting for 9.59% of the total.

(4) Segmented description

The whole section of coastal Road was divided into 12 sections according to the road names, and the average value and standard deviation of interface enclosure values of each section were calculated respectively(Fig4-18,Tab4-5). The high value points of interface enclosure were located in Donghai West Road, Taiping Road and Zhuhai West Road, which were 0.1834, 0.2241 and 0.1902 respectively.From the panoramic view of Baidu map, we can know the reason: there are buildings on both sides of Donghai West Road, a few of which are residential buildings, and there are street trees and shrubs planted in separate cars on both sides. Taiping Road has a fence on one side and buildings on the other side, and there are street trees on both sides, which are flourishing. Zhuhai Branch Road is mostly high-rise residential buildings, and street trees are planted on both sides.The low values were 0.0381, 0.0750 and 0.0619 in Wendeng Road, Taipingyi Road and Donghai Middle Road respectively.Looking for the panoramic view of Baidu map, we know that Wendeng Road is low in shrubs, with no buildings on both sides, Taiping Road with few buildings, Donghai Middle Road with few buildings, and most of the greening is low shrubs.Lu Yuan Yixin , Alan Jacobs and others think that the ratio should generally be between 1: 1 and 1: 3 at the city scale. In urban environment, buildings and trees are physically separated from indoor and outdoor. The degree of street closure has a certain influence on pedestrians' emotions, and it is positively related to residents' safety perception in this area[1].According to the standard deviation of interface enclosure, we can know that although Taiping Road and Zhuhai Branch Road account for a high Proportion of Buildings, their standard deviation values are large, while those of Wendeng Road, Donghai Middle Road and Taipingjiao Road are small. According to the coefficient of variation, the numerical fluctuation of closure in 12 roads is small(Fig4-19).

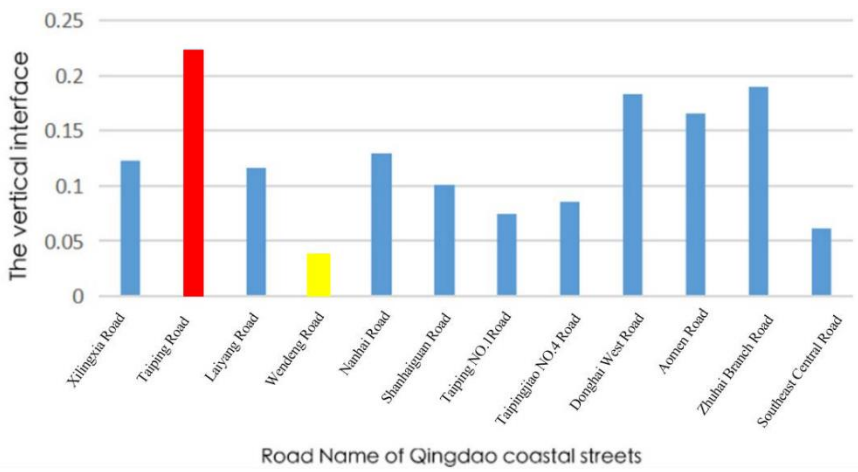


Fig 4-18 Average the Vertical Interface of every segment sample points in Qingdao Coastal Streets

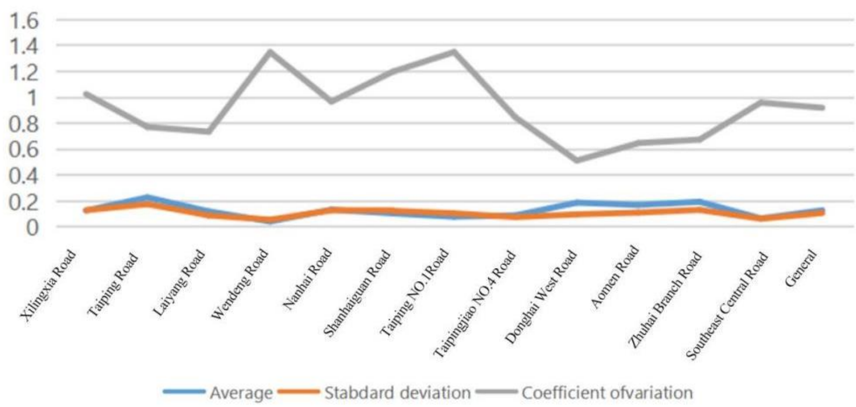


Fig 4-19 Coefficient of variation the Vertical Interface of every segment sample points in

Qingdao Coastal Streets

Table 4-5 Segmented the Vertical Interface data

Number	Road Name	Average	Standard deviation	Coefficient of variation
A	Xilingxia Road	0.123	0.125	1.021
B	Taiping Road	0.224	0.172	0.767
C	Laiyang Road	0.116	0.085	0.73
D	Wendeng Road	0.038	0.051	1.344
E	Nanhai Road	0.13	0.125	0.963
F	Shanhaiguan Road	0.101	0.12	1.194
G	Taipingjiao NO.1 Road	0.075	0.101	1.345
H	Taipingjiao NO.4 Road	0.085	0.072	0.841
I	Donghai West Road	0.184	0.093	0.508
J	Aomen Road	0.166	0.107	0.642
K	Zhuhai Branch Road	0.19	0.127	0.67
L	Southeast Central Road	0.062	0.059	0.955

4.3.1.5 Interface Enclosure Degree

(1) Overall evaluation

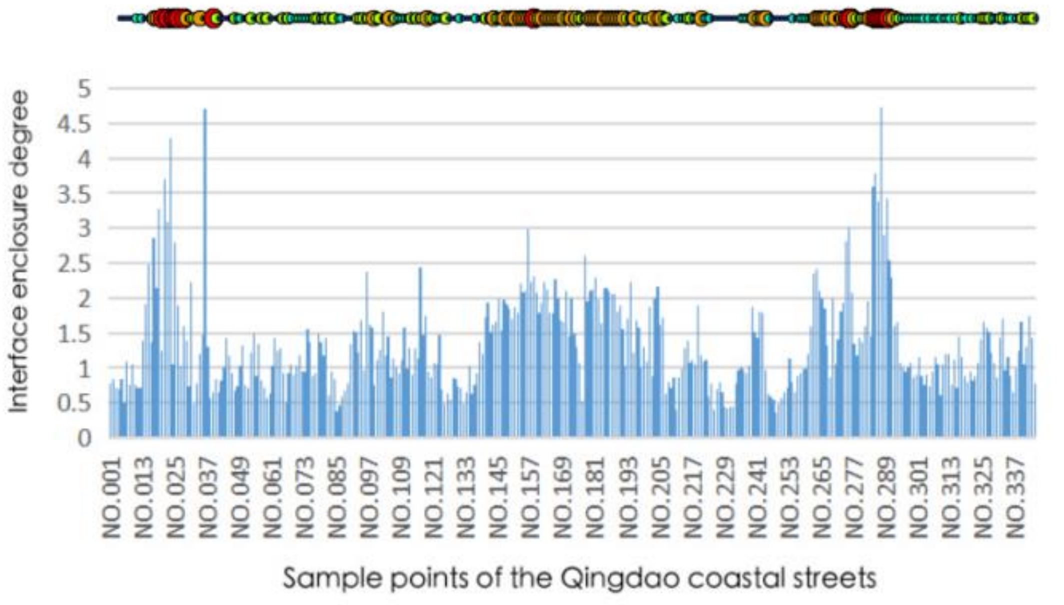


Fig 4-20 Interface Enclosure Degree of buildings of sample points in Qingdao Coastal Streets

As an important measure index to quantify urban enclosure, Interface Enclosure Degree is widely used in the study of street spatial form. Lu Yuan Yixin pointed out in his research that the size and proportion of streets can affect people's visual, psychological and other experiences, and can also directly represent the architectural interface and geometric features of streets and valleys[2]. the overall average Interface Enclosure Degree of 344 sample points in Qingdao Coastal Streets was 1.3485.The ideal value of circumference should be 1 ~ 2, and a value greater than 3 is acceptable[3].The circumference of 201 points was higher than the average, accounting for 58.43% of the total number.The standard deviation of total circumference of 344 sample points in coastal Road Street of Qingdao was 0.6986.The high total standard deviation indicates that the distribution is uneven.Observing the spatial trend of the fitness, we can conclude that there were many high values in 13-25 and 277-289 points, and the low values were concentrated around 85, 121, 133, 119 and 253.High values were concentrated on the east and west sides(Fig4-20).

(2) sample point description

Among the 344 sample points, the maximum value is 287 located at Aomen Road, and the value is 4.7349. The other high values are 4.7067 for No.36 Xiling Road, 4.2800 for No.23, 3.6953 for No.21 and 3.7789 for No.285 Aomen Road.The minimum value is 0.3617, located at No.248 Aomen Road. The other low values are 0.3757 at No.85 Taiping Road, 0.3969 at No.225 Aomen Road, 0.4243 at No.230 and 0.4042 at No.211 Donghai West Road.

(3) Trend description

The circumference of 344 sample points of Qingdao Coastal Streets was measured quantitatively. The natural discontinuous point classification method was used to make numerical statistics and sample size distribution statistics on the sample points' enclosing index.According to the classification method of natural discontinuity points, the circumference data of coastal Road can be divided into five grades, which were 0.361719-0.834503, 0.834503-1.245490, 1.245490-1.776342, 1.7642-2.6343, and 2.6343-4(Fig4-21). Five levels corresponded to low-value intervals, low-value intervals, median intervals, high-value intervals and high-value intervals. The number of low value intervals was 79, accounting for 22.97% of the total.There were 109 low-value intervals, accounting for 31.69% of the total.The median area was 115, accounting for 33.43% of the total.There were 63 high-value intervals, accounting for 18.31% of the total.The number of high value intervals was16, accounting for 4.65% of the total.

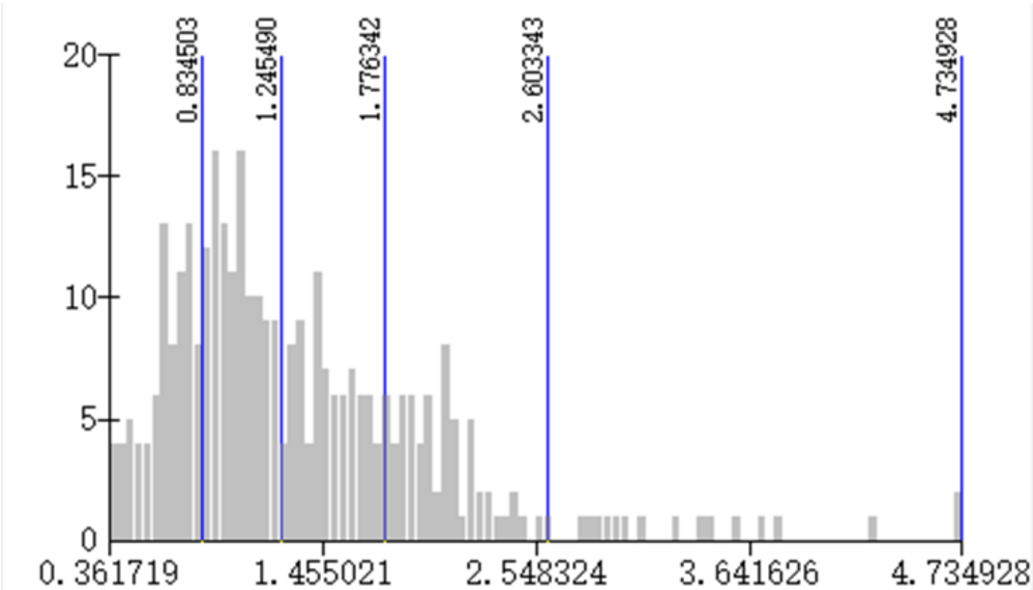


Fig 4-21 Distribution trendency diagram about Interface Enclosure Degree of sample points

(4)Segment description

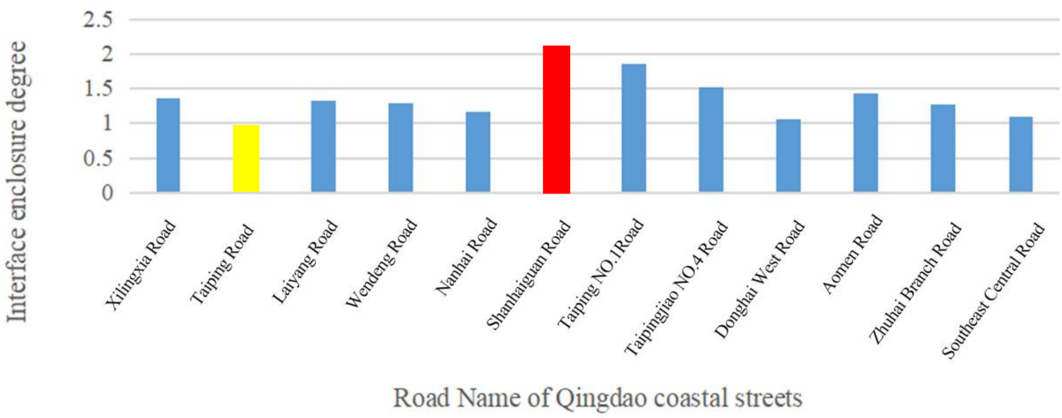


Fig 4-22 Average Interface Enclosure Degree of every segment sample points in Qingdao Coastal Streets

The whole section of coastal Road was divided into 12 sections according to the road names, and the average value and standard deviation of the circumference were calculated(Fig4-22,Tab4-6).we can see that the high value points of circumference are located in Shanhaiguan Road, Taipingjiao Road 1 and Taipingjiao Road 4, which were 2.1004, 1.8518 and 1.5273 respectively.From the panoramic view of Baidu map, we can know the reasons: Shanhaiguan Road is narrow, with lots of walls and buildings on both sides. Taipingjiao Road 1 is narrow, and walls and walls on both sides are high. Taipingjiao Road 4 is narrow, with tall and lush trees.The low values were at Taiping Road, Donghai West Road and Donghai Middle Road, which were 0.9666, 1.0558 and 1.0985 respectively.Looking up the panorama of Baidu map, we know that the road at low value point is wider than the road at high value point, and the elements such as trees, walls and buildings are less than those at high value point.Therefore, we can draw a conclusion: when the interface enclosure is high, the relationship between the two sides and the street is relatively close, and the street space will give people a feeling of compactness and depression; When the degree of street enclosure is low, it will dilute the sense of boundary of space, giving people the feeling of Openness and emptiness. The value of street enclosure can't directly represent the quality of street space, but it needs to be analyzed in combination with specific streets. However, too high or too low index calculation results can indicate that the street space quality is poor[4].According to the standard deviation of interface enclosure, we can know that the standard deviation of Xiling Road, Nanhai Road and Aomen Road was larger, while the median standard deviation of Taiping Road, Shanhaiguan Road and Donghai Middle Road was smaller.According to the coefficient of variation, it can be seen that the numerical fluctuation of the circumference of 12 roads was small(Fig4-23).

Table 4-6 Segmented Interface Enclosure Degree data

Number	Road Name	Average	Standard deviation	Coefficient of variation
A	Xilingxia Road	1.370	0.936	0.682
B	Taiping Road	0.966	0.319	0.330
C	Laiyang Road	1.317	0.360	0.273
D	Wendeng Road	1.291	0.462	0.358
E	Nanhai Road	1.173	0.521	0.444
F	Shanhaiguan Road	2.100	0.317	0.150
G	Taipingjiao NO.1 Road	1.851	0.405	0.219
H	Taipingjiao NO.4 Road	1.527	0.426	0.279
I	Donghai West Road	1.055	0.396	0.375
J	Aomen Road	1.428	0.9179	0.642
K	Zhuhai Branch Road	1.278	0.442	0.346
L	Southeast Central Road	1.098	0.295	0.269

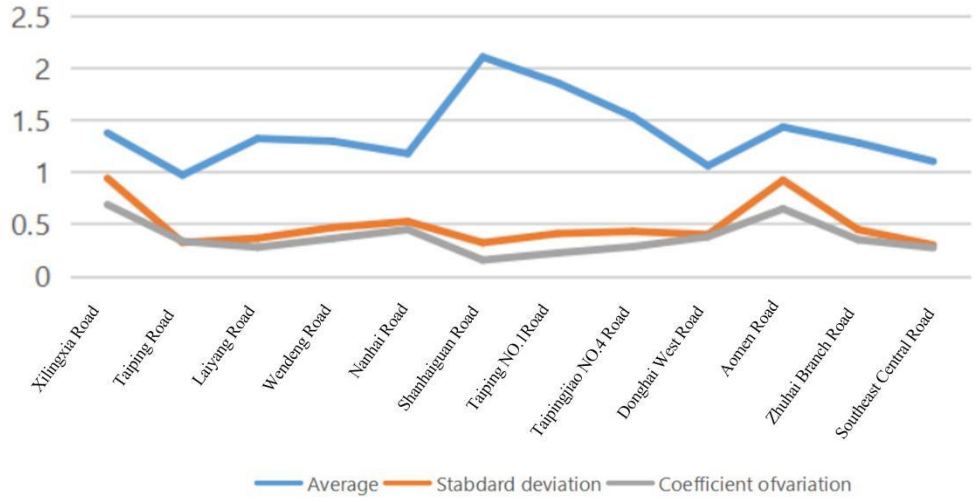


Fig 4-23 Coefficient of variation Interface Enclosure Degree of every segment sample points in Qingdao Coastal Streets

(5) Overall street space description

Among the 12 roads, Wendeng Road, Donghai Middle Road, Taipingjiao Road and Shanhaiguan Road had low average building ratio and average closure value.According to the panorama of Baidu map, we can find that these roads have similarities. There are few buildings, no walls, greening and roadside trees on both sides of the road.The Proportion of Buildings and the average closure value in Donghai Road, Zhuhai Branch Road, Aomen Road and Taiping Road were higher.There are buildings on both sides of these roads, without walls, and there are greening and roadside trees on both sides.So we can draw a conclusion; Architecture plays a dominant role in average closure value.Among the 12 roads, Taiping Road and Donghai West Road had higher average closure and lower average circumference.According to the panorama, we can find that there are many buildings on these two roads, with greening and roadside trees on both sides, no fence and wide roads.The average closure value of Wendeng Road and Taipingjiao Road was low, and the average value of circumference was high.We can find that there are fewer buildings and narrower roads.The average value of closure and enclosure of East China Sea Road was low, because there were fewer buildings and wider roads.The average value of road closure and enclosure in Macao was high because of the many buildings and narrow roads.Therefore, we can draw the conclusion that the width of the road is dominant in the average circumference(Tab4-7).

Table 4-7 The average value of the enclosure characteristics in Qingdao 12 sections

Number	Road Name	average of Proportion of Buildings	average of the Vertical Interface	average of Interface Enclosure Degree
A	Xilingxia Road	0.079	0.122	1.370
B	Taiping Road	0.110	0.224	0.966
C	Laiyang Road	0.071	0.116	1.317
D	Wendeng Road	0.021	0.038	1.291
E	Nanhai Road	0.086	0.129	1.173
F	Shanhaiguan Road	0.040	0.100	2.100
G	Taipingjiao No.1 Road	0.056	0.074	1.851
H	Taipingjiao No.4 Road	0.064	0.085	1.527
I	Donghai West Road	0.147	0.183	1.055
G	Aomen Road	0.141	0.165	1.428
K	Zhuai Branch Road	0.114	0.190	1.278
L	Southeast Central Road	0.049	0.061	1.098

4.3.1.6 Pedestrians

(1) Overall evaluation

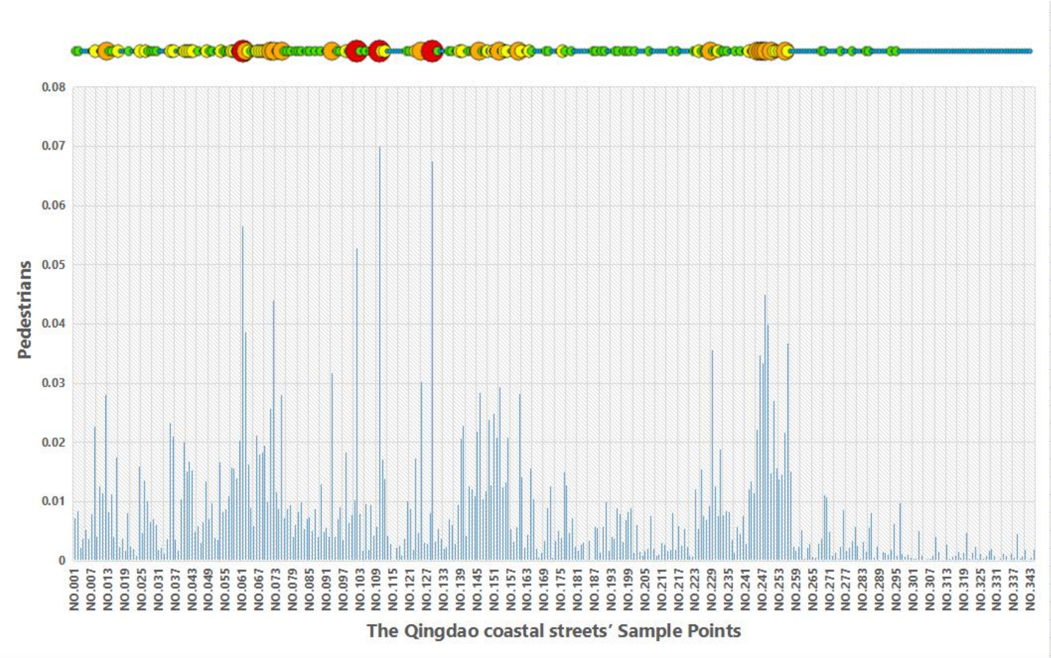


Fig 4-24 Pedestrians of sample points in Qingdao Coastal Streets

According to the definition of pedestrians in this study, the pedestrians of Qingdao Coastal Streets is measured. The results show that the average pedestrians degree of Qingdao Coastal Streets road sample points is 0.0084, which means that the percentage of pedestrians in the street space is only 0.84% within the human viewpoint(Fig4-24). It shows that the pedestrians do not gather into groups, the pedestrians in the space is weak, and the space is not dynamic enough.

(2) Analysis of sample Points

Based on the data obtained from 344 sample points, the highest value interval of the pedestrians was found to be located in [0.045, 0.069] and the lowest value interval in [0, 0.005]. The percentage of the highest value interval is 1.45% and the percentage of the lowest value interval is 51.5%.

(3) Trend Analysis

The natural discontinuity grading method was used to calculate the pedestrians and sample size distribution of Qingdao Coastal Streets, and the sample distribution showed a "precipitous decline"(Fig4-25). According to the distribution trend graph the peak is located in the low value area, which indicates that the overall the pedestrians of Qingdao Coastal Streets is low and the street space crowd vitality is insufficient. The number of samples in the interval [0,0.005] is 177, accounting for 51.5%. The number of samples in the interval [0.005,0.013] is 100, accounting for 29.1%. The number of samples in the interval [0.013,0.025] is 46, accounting for 13.4%. The number of samples in the interval [0.025,0.045] is 16, accounting for 4.7%. The number of samples in the interval [0.045,0.069] is 5, accounting for only 1.45%. Therefore, the the pedestrians on Qingdao Coastal Streets is low, and the lack of activities of the crowd in the street space.

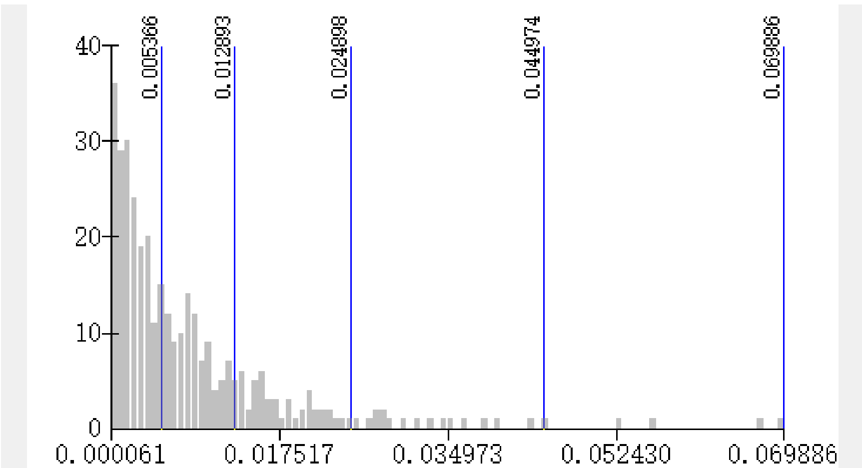


Fig 4-25 Distribution trendency diagram about pedestrians of sample points

(4) Segment Comparison

The whole coastal road is divided into 12 segments according to the road name, and the average pedestrians of each segment is taken as the the pedestrians of the section. The the pedestrians of each section is used to plot the bar distribution of the whole coastal road. Among them, Donghai Zhong Road has the lowest pedestrians of 0.0012; Taiping Road has the highest pedestrians of 0.0151(Fig4-26). According to the distribution map, the pedestrians of Qingdao Coastal Streets shows a sharp downward trend, and most of the road sections are not vibrant enough. The pedestrians on Taiping Road, Laiyang Road, Nanhai Road and Shanhaiguan Road is higher than the average of the whole Qingdao Coastal Streets, on the other hand, Xilingxia Road and Aomen Road are similar to the total average. While Wendeng Road, Taipingjiao I Road, Taipingjiao IV Road, Donghai West Road, Zhuhai Branch Road and Donghai Middle Road are below the total average. The analysis of the street pictures revealed that Taiping Road and Nanhai Road, which are close to tourist attractions. The presence of a walkway or resting facilities along the road increases the number of pedestrians staying on the roadway. Therefore, the concentration of people in these sections was higher than the overall average and made the space of the section more dynamic.

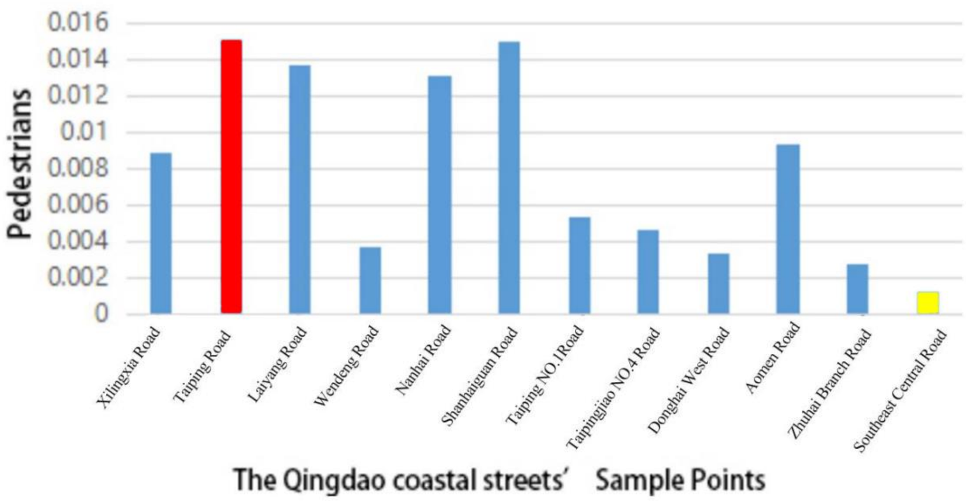


Fig 4-26 Average pedestrians of every segment sample points in Qingdao Coastal Streets

(5) Analysis and Summary

According to the average pedestrians of the whole Qingdao Coastal Streets and the comparative analysis of the pedestrians of the 12 divided sections, it is found that the pedestrians of the street is mainly related to the availability of activities or rest facilities on both sides of the road. The road sections located in tourist attractions usually have stores, seating and activity areas beside the road, which greatly increases the time spent by the crowd, resulted in a higher spatial vitality of the road compared to other road sections. And located in the city's main road sections of traffic flow, roadside generally did not have too much space for rest and stay. Finally, the crowd is instinctively afraid of vehicles in the psyche and will not stay too long, so the pedestrians value will be lower(Tab4-8).

Table 4-8 Segmented pedestrians data

Number	Road Name	Average	Standard deviation	Coefficient of variation
A	Xilingxia Road	0.0088	0.0064	0.7343
B	Taiping Road	0.0151	0.0123	0.8176
C	Laiyang Road	0.0137	0.0167	1.2207
D	Wendeng Road	0.0037	0.0032	0.8794
E	Nanhai Road	0.0131	0.0137	1.0492
F	Shanhaiguan Road	0.015	0.0093	0.6221
G	Taipingjiao No.1 Road	0.0053	0.0044	0.8464
H	Taipingjiao No.4 Road	0.0046	0.0030	0.6681
I	Donghai West Road	0.0033	0.0023	0.721
G	Aomen Road	0.0093	0.0105	1.1319
K	Zhuai Branch Road	0.0027	0.0031	1.1641
L	Southeast Central Road	0.0012	0.0012	1.0574

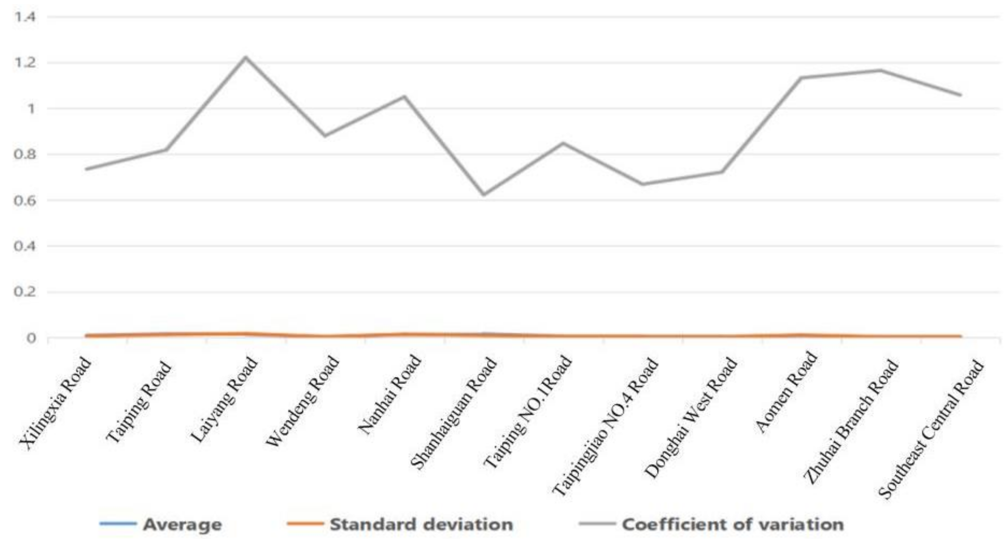


Fig 4-27 Coefficient of variation pedestrians of every segment sample points in Qingdao Coastal Streets

4.3.1.7 Vehicle Occurrence Rate

(1) General Description

Numerous studies on the relationship between street safety and the street environment have shown that there is a strong correlation between vehicles and the perceived safety of people in the street space. The results of street safety tests show that people are only willing to actively use it when pedestrians feel sufficiently safe in the street. In this study, the vehicle disturbance index will be selected as an index to evaluate the safety of streets. According to the definition of Vehicle Occurrence Rate, the lower the pixel area occupied by vehicles, the lower the Vehicle Occurrence Rate, and the higher the sense of security generated by the pedestrian psychology.

According to the definition of street Vehicle Occurrence Rate in this study, the street Vehicle Occurrence Rate of Qingdao Coastal Streets was tested based on the obtained database data. According to the data, the overall average Vehicle Occurrence Rate of Qingdao Coastal Streets street sample points is 0.104, which means that the percentage of vehicles within the observation range of human viewpoint is only 10.4% at 344 sample points.

(2) Analysis of sample Points

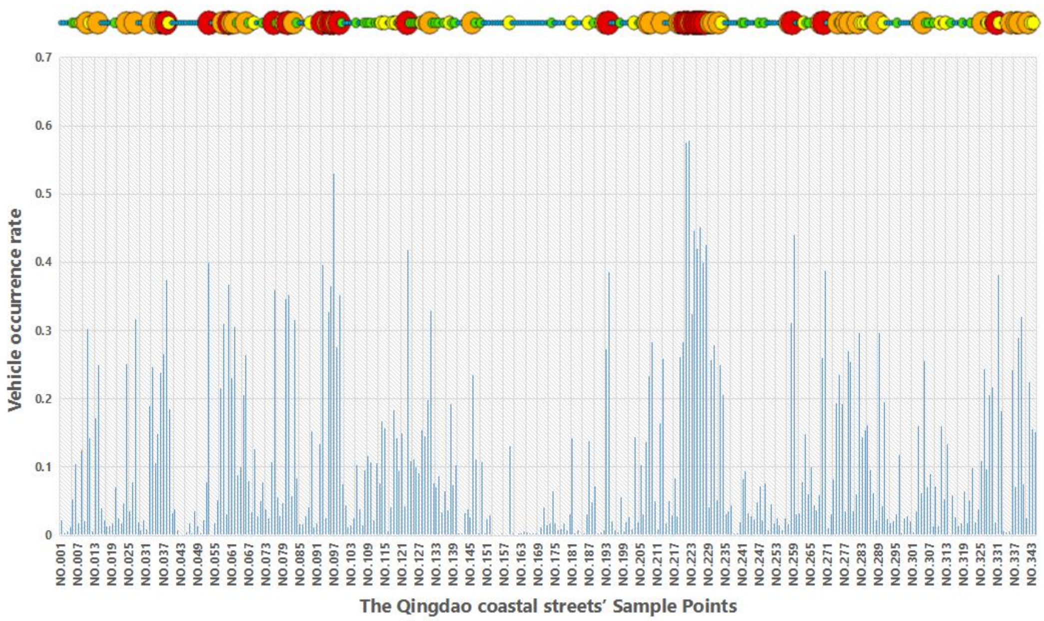


Fig 4-28 Vehicle Occurrence Rate of sample points in Qingdao Coastal Streets

Based on the data obtained from 344 sample points, the highest value interval of the vehicle disturbance index was found to be located at [0.346, 0.578] and the lowest value interval at [0, 0.051]. The percentage of the low value interval is 82.3%, and the number of sample points in the interval [0.346,0.578] with the highest Vehicle Occurrence Rate only accounts for 6.1% of the total sample points. It means that Qingdao Coastal Streets is in good condition for vehicles and the overall traffic flow is low. Besides, it is also find that the Vehicle Occurrence Rate at the sample points trend of low in the middle and high in the east and west(Fig4-28).

(3) Trend Analysis

According to the data statistics, the natural interruption point grading method was used to conduct numerical statistics and sample size distribution statistics for the Vehicle Occurrence Rate of 344 sample points, and it was found that the sample distribution of Vehicle Occurrence Rate of sample points showed a trend of "precipitous decline"(Fig4-29). From the distribution trend graph, it can be found that the larger the Vehicle Occurrence Rate, the smaller the number of sample points, while the smaller the Vehicle Occurrence Rate, the larger the number of sample points, so the two are negatively correlated. Otherwise, nearly 66.9% of the 344 sample sites had a Vehicle Occurrence Rate below the mean (0.104). The number of sample points in the interval [0, 0.051] is 175, accounting for 50.9%. The number of sample points in the interval [0.051, 0.117] is 66, accounting for 19.2%. The number of sample points in the interval [0.117, 0.218] is 42, accounting for 12.2%. The number of sample points in the interval [0.218,0.346] is 40, accounting for 11.6%. The number of sample points in the interval [0.346, 0.578] is 21 , accounting for 6.1%. Among them, the interval [0, 0.051] accounts for the largest proportion, while the interval [0.346, 0.578] accounts for the smallest proportion.

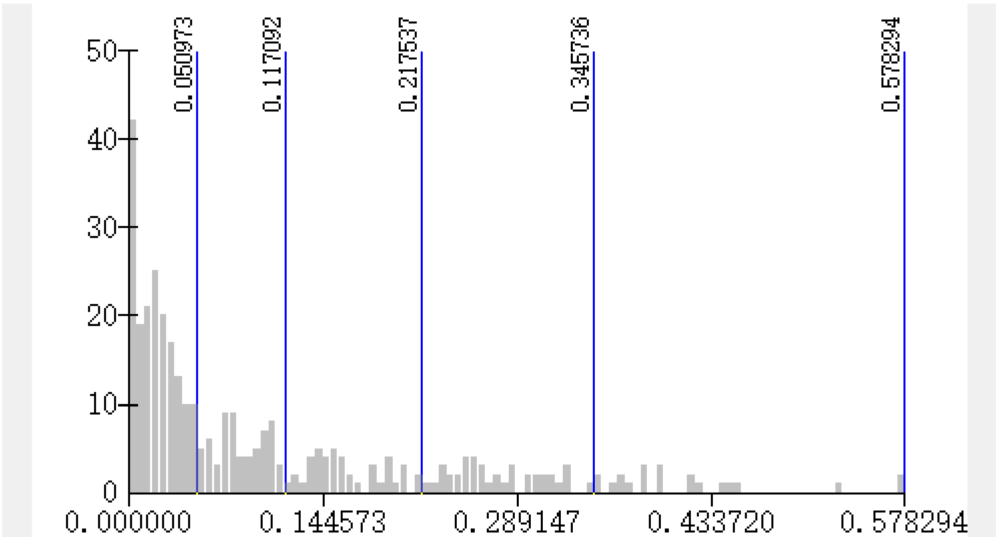


Fig 4-29 Distribution trendency diagram about Vehicle Occurrence Rate of sample points

(4) Segment Comparison

The whole section of the coastal road was divided into 12 sections according to the name of the road, and calculated the average value of Vehicle Occurrence Rate for each segment separately. The vehicle disturbance index was used to plot the bar distribution of vehicle disturbance index in Qingdao Coastal Streets(Fig4-30,Tab4-9). Among them, Aomen Road has the highest Vehicle Occurrence Rate of 0.147, while Shanhaiguan Road has the lowest Vehicle Occurrence Rate of 0.015. The Vehicle Occurrence Rate of Wendeng Road, Donghai West Road and Donghai Middle Road, which have high traffic flow within Qingdao Coastal Streets, are all similar to the total average value and are in good condition. While Aomen Road has a low traffic volume, its vehicle disturbance index is higher than the overall average, which is due to the fact that there are many parking spaces planned on both sides of the road. This reveals the characteristic that the more complex the spatial planning layout is, the higher the Vehicle Occurrence Rate is. The low vehicle disturbance index of Shanhaiguan Road is mainly due to the fact that this section is a secondary urban road with narrow roads. And Shanhaiguan Road is located near the tourist attraction Eight Pass scenic spot, more tourists, the vehicle driving is not convenient enough, so it leads to less vehicles through the road(Fig4-31).

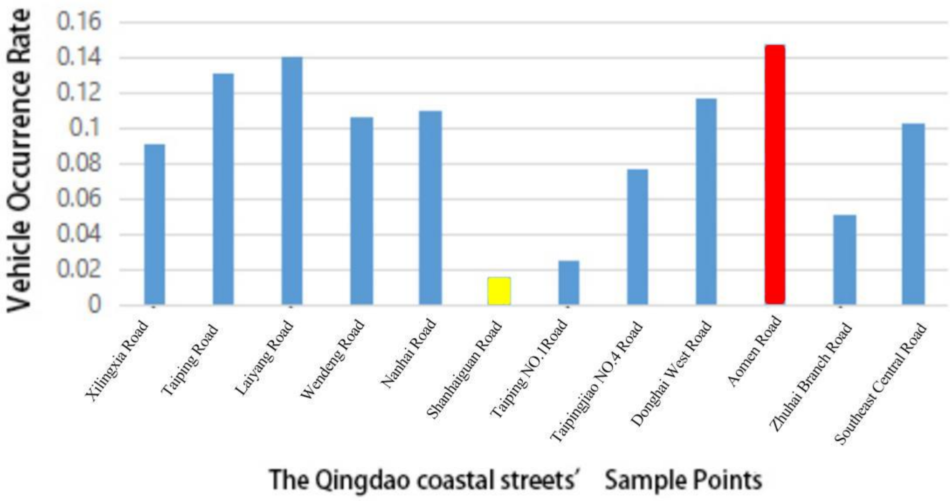


Fig 4-30 Average Vehicle Occurrence Rate of every segment sample points in Qingdao Coastal Streets

Table 4-9 Segmented Vehicle Occurrence Rate data

Number	Road Name	Average	Stabdard deviation	Coefficient of variation
A	Xilingxia Road	0.091	0.11	1.209
B	Taiping Road	0.131	0.121	0.927
C	Laiyang Road	0.14	0.153	1.094
D	Wendeng Road	0.106	0.062	0.59
E	Nanhai Road	0.11	0.097	0.886
F	Shanhaiguan Road	0.015	0.036	2.413
G	Taipingjiao No.1 Road	0.025	0.037	1.492
H	Taipingjiao No.4 Road	0.077	0.117	1.514
I	Donghai West Road	0.117	0.104	0.886
G	Aomen Road	0.147	0.153	1.039
K	Zhuhai Branch Road	0.051	0.063	1.233
L	Southeast Central Road	0.102	0.098	0.96

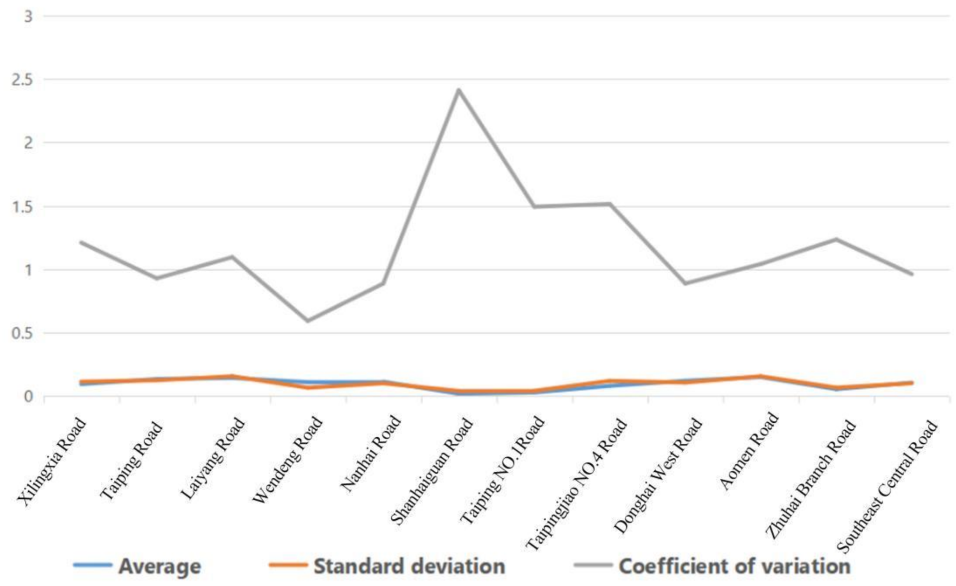


Fig 4-31 Coefficient of variation Vehicle Occurrence Rate of every segment sample points in Qingdao Coastal Streets

(5) Analysis and Summary

After the overall trend as well as the segmented comparative analysis, it was found that the vehicle disturbance index was influenced by several factors, but most of them were related to the road grade and road space layout. At first, the city's main roads as the main vehicle routes, which have several lanes, while secondary roads are generally single or double lanes, with narrower surfaces than the main roads. Second, parking spaces are usually available along secondary roads. Finally, secondary roads were not strictly managed and many vehicles were parked on both sides of the road, resulted in a higher vehicle disturbance index on secondary roads compared to main roads.

4.3.2 Physical features of Fukuoka Streets, Japan

4.3.2.1 Greenness

(1) General description

1) Overall evaluation

According to the data, the average value of Greenness of 381 sample points in Fukuoka Streets was 0.063(Fig4-32). In other words, the average percentage of Greenness in the human view range was 7.2%. It shown that the overall Greenness of Fukuoka Streets was extremely low. As shown in the figure, it showed the distribution of Greenness of all sample points in the study area. From the analysis of the spatial distribution of the Greenness, the overall distribution of the Greenness of Fukuoka Streets shown alternating features from east to west, with no large areas where high values were concentrated. The Greenness values shown alternating highs and lows. Compared with Qingdao Coastal Streets, the overall Greenness were low. The average Greenness was 0.281 lower compared with Qingdao.

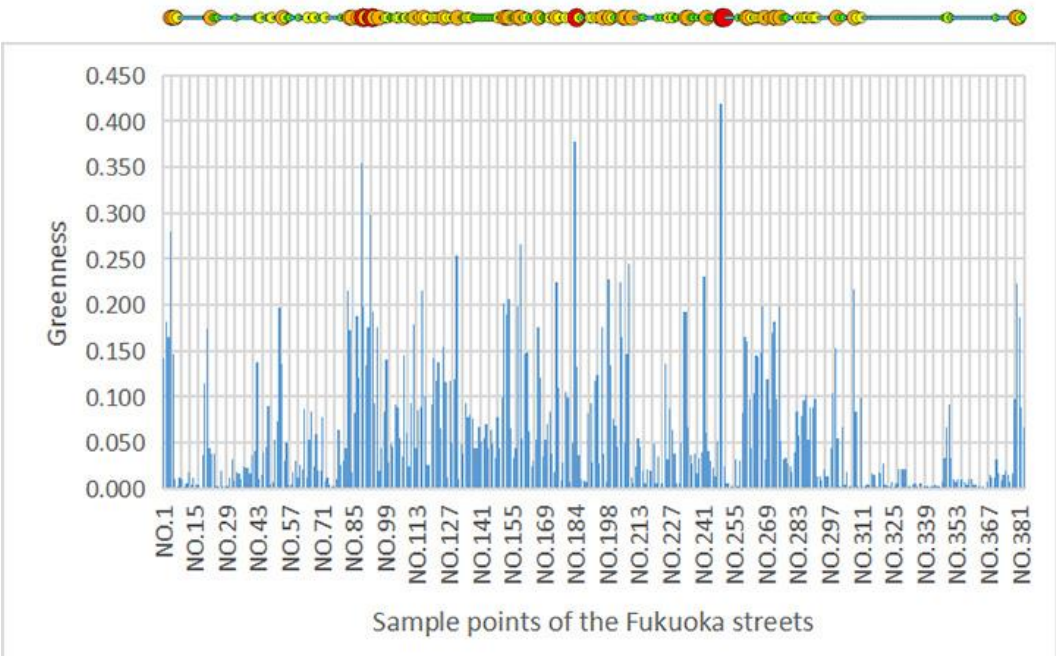


Fig 4-32 Greenness of sample points in Fukuoka Streets

2) sample point analysis

Segmenting the entire Fukuoka Streets according to major intersections. The streets were divided into 16 sections, named A, B, C, D, E, F, G, H, I, J, K, L, M, N, O and P in order from east to west. According to the statistical analysis, the 381 sample points of Fukuoka Streets with high value of Greenness were mainly scattered in A-section streets, E-section streets, M-section streets, H-section streets and J-section streets. The low value points were mainly scattered in section B streets, section A streets, section P streets, section N streets and section O streets. High value points and low value points were distributed in section F streets, section G streets, section L streets, and section I streets. It indicated that the distribution of Greenness of these three road sections appears to be unevenly distributed and discontinuous. Based on the street interface analysis, all three streets had good and relatively continuous overall street greenery. Only a few spots lack street greening, so there was a high or low variation in Greenness. 381 sample points of the maximum value of Greenness of 0.420, located in the I section of the road point NO.249. It was 0.475 lower compared with the highest Greenness of Qingdao Coastal Streets. It showed that there was a certain gap. The smallest value of Greenness among the sample points was 0.000, which were almost none planting in some sample points. Indicates that there were no greenery in the street at the point(Tab4-10).

Table 4-10 Greenness statistics for sample sites (GVI)

Average value	Median value	Maximum value	Location of sample points	Minimum value	Location of sample points
0.063	0.036	0.420	L.249	0	There were almost none planting in some sample points

3) Trend analysis

A quantitative measurement of the street Greenness was conducted for 381 sample points in Fukuoka Streets. Numerical statistics and sample size distribution statistics of the Greenness at sample points using the natural interruption point grading method. The statistics results showed a "stepped down" character. That was, the values of the sample points were mainly concentrated in the lower value domain. the high values showed the features of gradually decreasing.

According to the natural interruption point grading method, it was possible to categorize the Greenness of Fukuoka Streets into five classes(Fig4-33), which were 0%-2.80%, 2.80%-7.63%, 7.63%-14.83%, 14.83%-27.95% and 27.95%-41.96%. In this study, all sample collection points were divided into five intervals based on five levels, namely, low value interval (0%-2.80%), lower value interval (2.80%-7.63%), medium value interval (7.63%-14.83%), higher value interval (14.83%-27.95%) and high value interval (27.95%-41.96%). The low value range of the Greenness was 0%-2.80%, accounting for 43.57% of the total, which was a poor level of greening. Greenness in the range 2.80%-7.63%, accounting for 25.46% of the total. Those with Greenness in the range 7.63%-14.83%, representing 18.90% of the total. Greenness in the range 14.83%-27.95%, representing 10.76% of the total. The Greenness in the range of greater than 27.95%-41.96%, accounting for 1.31% of the total. The overall value of Fukuoka Streets Greenness was low. Only 2.10% of these points had a Greenness higher than 0.25. Therefore, it could be seen that the overall level of greenery in the streets of Fukuoka Streets was relatively low.

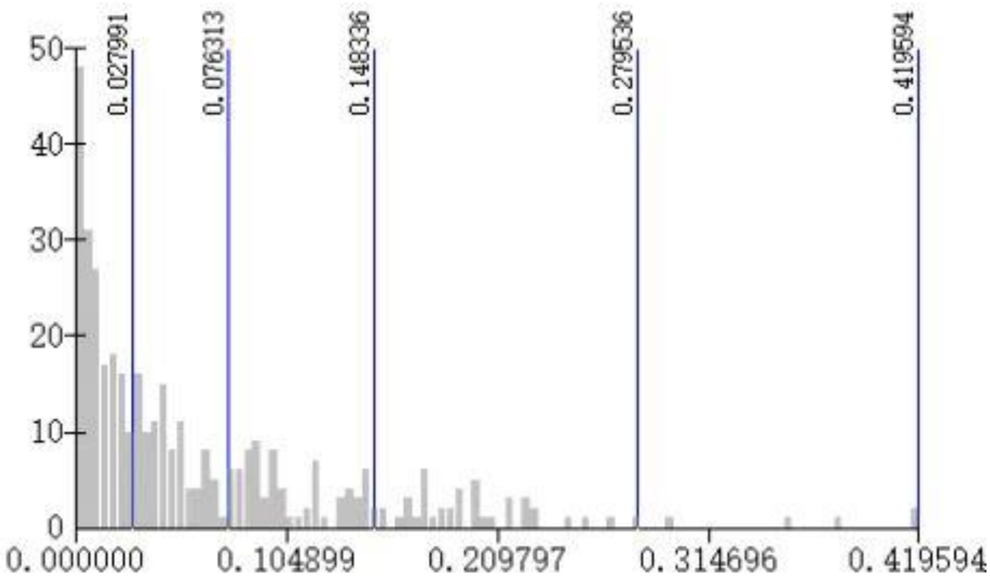


Fig 4-33 Distribution trendency diagram about Greenness of sample points

(2) Segment Description

1) The average segmentation point of 16 sections

Fig 4-34 Average Greenness of every segment sample points in Fukuoka Streets

The entire Fukuoka Streets, based on the major intersections, was divided more evenly into 16 segments. The mean and standard deviation of the Greenness of each segment were calculated separately. The mean value and standard deviation of Greenness for each segment were presented. Based on the histogram of the Greenness for Fukuoka Streets , the range of the road Greenness was found to be 0.008-0.182(Fig4-34). Among them, the average Greenness value of the A section of the road was more prominent. The average Greenness of E, F, G, H, I, J, L and M sections was located in the medium. The average Greenness value of B, C, D, K, N, O and P sections was low.

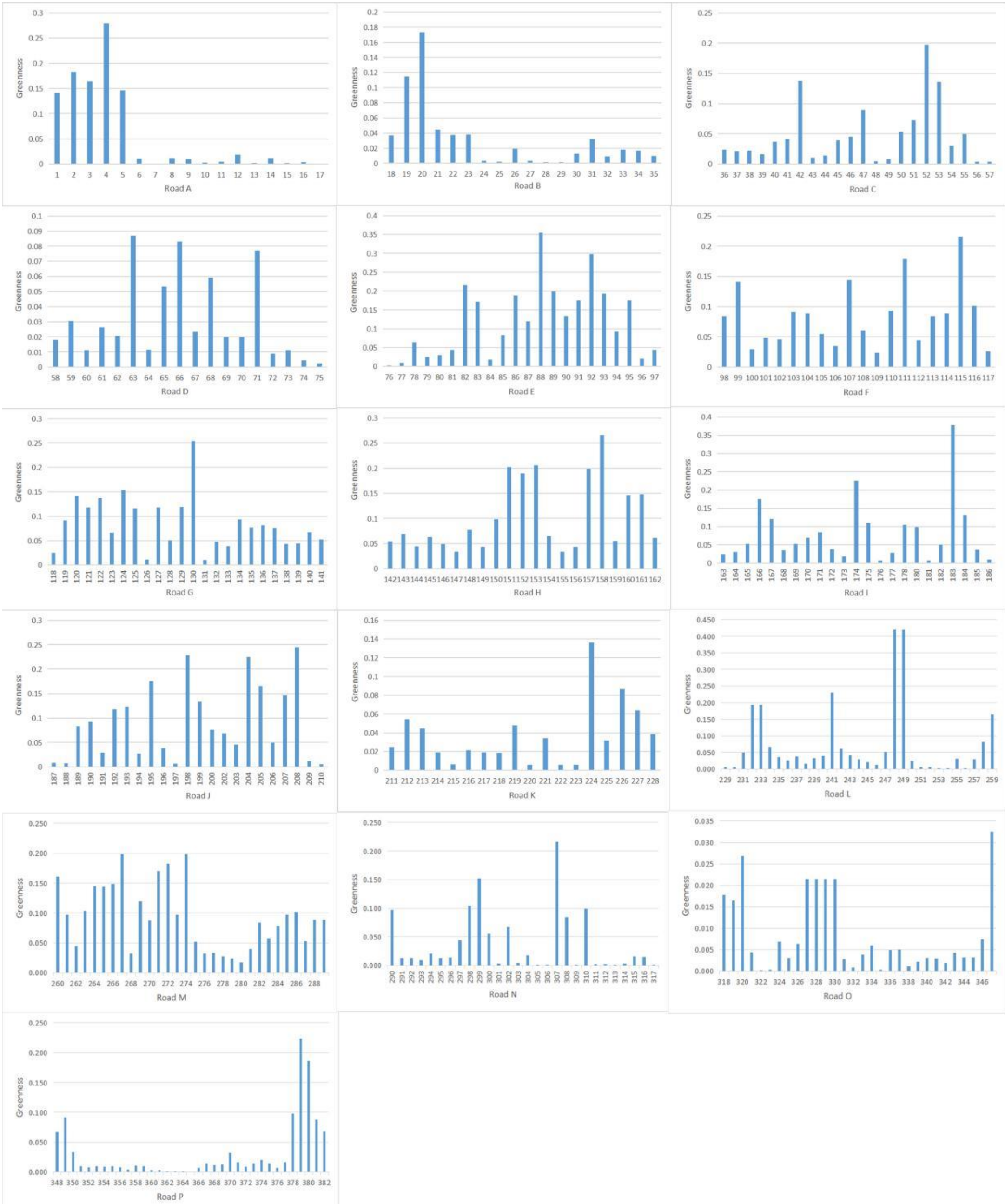


Fig 4-35 Greenness of every segment sample points in Fukuoka Streets

According to the criteria of Japanese scholar Natsuhi Origahara for classifying the level of Greenness, the average Greenness of 16 sections in Fukuoka Streets was classified into 5 levels(Fig4-35). Poor greening level (average Greenness 0-5%) of the road sections O, P, N, B, C, D, K, accounting for 43.75%. Poor greening level (average Greenness of 5% to 15%) of the road sections E, F, G, H, I, G, L, M sections, accounting for 50.00%. The general greening level (average Greenness of 15% to 25%) of the road section had A section, accounting for 6.25%. The average Greenness of these seven road segments, A, E, F, G, H, I , Land M was greater than the overall

Greenness average (6.30%). The Greenness was mainly concentrated at 0-0.15. This showed that the overall greening level of Fukuoka Streets was average.

2) Comparative differences of the paragraphs and the reasons

As shown in the 16 graphs above, it could clearly reflect the change of Greenness at each point on each section of the road. The histogram changes of the Greenness points of both A and B sections of the road were extremely high in the front part and extremely low in the back section. After analysis, it was concluded that the high value areas of both articles were adjacent to public green areas. The latter section of the road was basically no street greening along the road only a small number of low shrubs embellished with a sharp decline in street greening rate. However, from the Greenness values of the two sections of the road, the Greenness of the A section was significantly higher than that of the B section. The histograms of C and D sections of the road could be seen to have a low Greenness, with some individual points being slightly higher. The reason for this was that the road greening along the street was not continuous and the amount of greening was extremely low. There were only a few low hedges along the street, except for a few trees outside individual buildings that were dotted with greenery. At point 76-81 of Section E Road, there was only a small amount of road greenery and greenery dotted in front of buildings, so the Greenness was low. The second half of the street at 82-97 was very dense and lush greenery, so the Greenness was higher. F, G, H, I, and J sections of the road had a high rate of Greenness. The reason for this was the high street level, the high road level. Therefore, the road was rich in greenery, with many levels of greenery and trees and shrubs.The green accents in front of the building were also more abundant, so its roads had a high Greenness. In contrast, the K section of the street. The road grade was low, the road width was small, the walking area was also small. The area for greening was also small. The street greenery was discontinuous and small in volume, so the Greenness was low. L, N, O and P sections of the road are characterized by a low green view rate, which is due to the fact that the sample points are located on viaducts. So there is little or no greenery.

Compared with Qingdao Coastal Streets green view rate. It was obvious that the value of green vision rate of Fukuoka Streets was low. Road grade, road greening and the way the plants were matched were the main reasons for their low green view rate.

3) Standard deviation of segments

In addition to this, three indicators, namely, the average Greenness, the standard deviation of Greenness and its coefficient of variation, were compared and analyzed for each section of Fukuoka Streets(Fig4-36,Tab4-11). It could be seen that the values and standard deviations of the Greenness in Fukuoka Streets were low and do not vary significantly, no correlation was formed. In contrast to the standard deviation which was influenced by the size of the mean. The coefficient of variation, or standard deviation coefficient, was more indicative of the degree of dispersion in question. Compared the coefficient of variation of Greenness of Fukuoka Streets with the coefficient of variation of Greenness of coastal Road street in Qingdao, the analysis. It could be concluded that the large dispersion of the value of the Greenness of the Fukuoka Streets . The uniformity and continuity of the distribution of Greenness in each of its streets was lower than that of Qingdao Coastal Streets.

Table 4-11 Segmented Greenness data

Number	Average	Standard deviation	Coefficient of variation
A	0.058	0.088	0.480
B	0.032	0.045	1.400
C	0.048	0.051	1.054
D	0.032	0.028	0.876
E	0.121	0.098	0.810
F	0.084	0.052	0.621
G	0.085	0.055	0.643
H	0.102	0.071	0.697
I	0.082	0.085	1.038
J	0.092	0.077	0.835
K	0.037	0.033	0.900
L	0.075	0.110	1.457
M	0.093	0.054	0.583
N	0.038	0.054	1.401
O	0.008	0.009	1.078
p	0.032	0.051	1.597

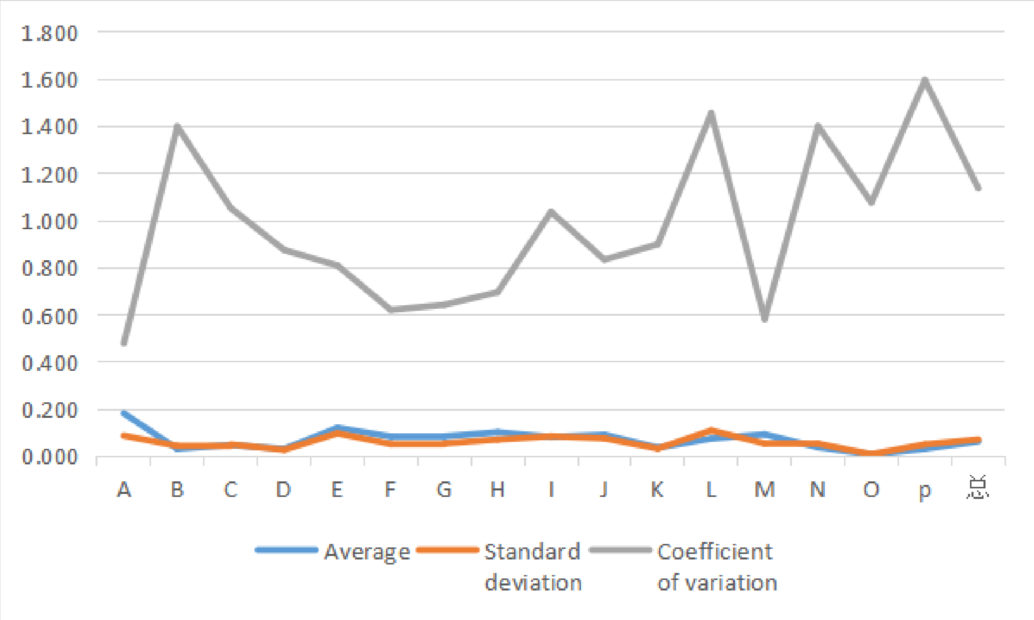


Fig 4-36 Coefficient of variation Greenness of every segment sample points in Fukuoka Streets

The standard deviation of section B, L, N, P roads was significantly higher than other areas. There was a large internal variation in the Greenness of the B section of the road. The Greenness showed a precipitous decline in. The higher values of Greenness were mainly distributed in the points adjacent to public green areas. And other road sections due to the basic absence of street greening, resulting in a low point of Greenness. That was, the phenomenon of uneven and discontinuous distribution of greenery. The points of L, N and P section of the road are mostly located on the viaduct, and the green view rate of the points on the viaduct is low. So it will come out with a huge difference in green ratings. Causes high standard deviation. The standard deviation coefficients for the F, G and H sections of the road were then lower. The Greenness showed an average distribution of high values. Because of the lush and dense street greenery in the section. This had resulted in the formation of a higher average Greenness and a lower standard deviation coefficient for the F, G and H section roads. That was, the greening level of Shanhaiguan Road was high, and the Greenness was evenly distributed, and the greening continuity was good.

(3) Discussion based on data results

Based on the analysis of the Greenness at each observation point in Fukuoka Streets,and the analysis of the average Greenness and the standard deviation of the Greenness for 16 road sections.

1) The relationship between green view rate and park green space

Ascending ranking of the Greenness of 381 points in Fukuoka Streets.The analysis of the points with high Greenness show that the common reason is that they were near public green areas. Because of the proximity to public green space, its street boundaries are rich in greenery, and thus a high Greenness is created. Its streets are also very well landscaped. Other city streets will also have very low values of street greenery because some of the streets are not well landscaped.

2) Influencing factors of green view rate

Unlike the Greenness of Qingdao Coastal Streets , the average Greenness of Fukuoka Streets only reaches 0.063, which is a significant difference. We compare the greening elements and spatial composition of Qingdao Coastal Streets with those of Fukuoka Streets. The analysis show that the low value of Greenness of Fukuoka Streets is related to the plant morphological index, the form of plant configuration, the width of the road, vertical greening, and other factors.

For plant features. Due to the influence of climatic condition factors and the different effects of plant species. It will make the tree canopy of Japanese street greening smaller and will have the visual effect that the plant greening is not lush. In addition to that, the street trees in Japanese streets were planted more sparsely. From the data comparison, it did made its Greenness lower.

For plant configuration. The current conditions of the Fukuoka Streets shown a very homogeneous and incomplete plant configuration. Many places were dotted with only a few trees or had only a few shrubs. The plant configuration level was not rich enough. Therefore the street has a low Greenness.

In terms of road grade. A comparison of the current status of the streets in each section of Fukuoka Streets shown that the street grade was lower, the roads was narrower, ,the walkable streets were very limited. Leaving little space for street greening. Some roads even appeared to have no street greenery. The higher grade roads were not only equipped with denser street tree greening, but also with hedge planting ponds in the middle of the road to divide the car road. Thus, the street has a high Greenness. But compared with Qingdao Coastal Streets, whether it is the lushness of street trees, the density of planting or the hierarchical mix of road greenery, the Fukuoka Streets were imperfect. This was also the main reason for the low overall rate of Greenness in Fukuoka Streets .

Vertical greening aspects. According to the literature we can concluded that human perception of three-dimensional dimensional greenery was more intuitive. However, from the analysis of the interface Fukuoka Streets and the interface of coastal Road street in Qingdao, three-dimensional greening was very lacking. Therefore, in order to improve the Greenness at the micro level in the future, we can consider focusing on enhancing the amount of greenery at the three-dimensional level of the street to improve the Greenness value. This enhances the spatial quality of the street and creates a more pleasant street appearance.

4.3.2.2 Openness

(1) General description

Modern medical research has found that an open field of vision can effectively relieve eye fatigue, thus affecting people's physical comfort. Therefore, 381 sample points were analyzed in Fukuoka Streets , NO.179 and NO.201 were located indoors. Therefore, they were not counted in the data analysis. According to the definition of Openness, the semantic segmentation method was used, which is the ratio of pixels of the sky in the street to the total pixels in the panorama, the Openness of 381 sample points was obtained in Fukuoka Streets.

(2) Analysis of sample Points

According to the data from 381 sample points, it was concluded that the overall average Openness of Fukuoka Streets was 0.435 , this average value was used as the Openness of Fukuoka Streets. At the same time, 381 data were drawn into a histogram, it was found that the maximum Openness of Fukuoka Streets was 0.669, which is NO.311. The minimum value of 0.081 was NO.299. It was also found that the Openness values were evenly distributed at each sample point in Fukuoka Streets. It shows that the whole street has a good view of the sky and high comfort of street space(Fig4-37).

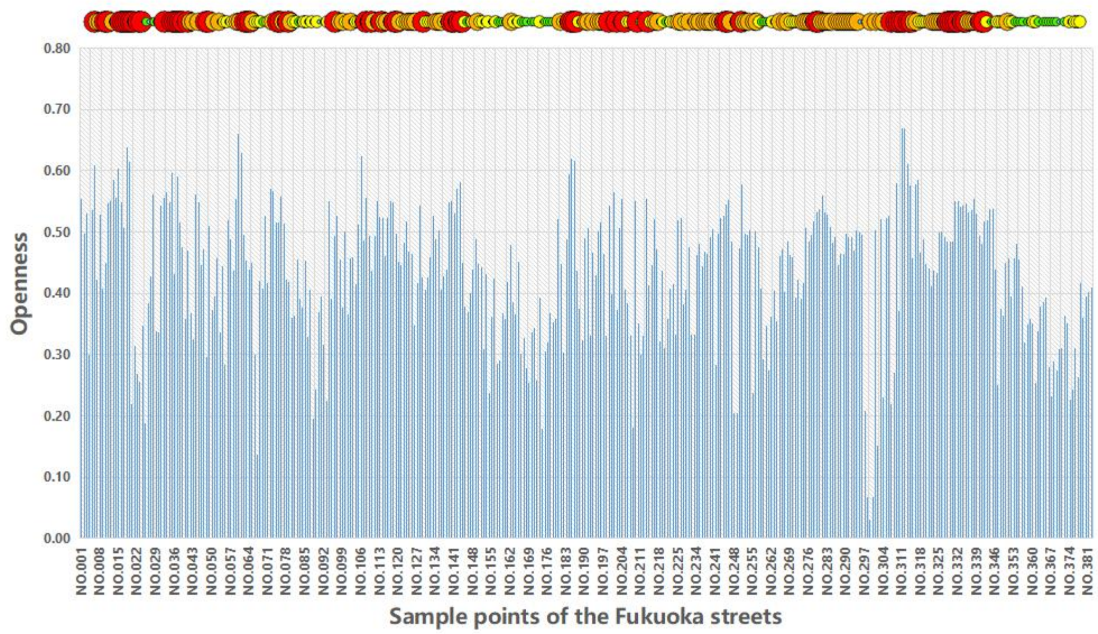


Fig 4-37 Openness of sample points in Fukuoka Streets

(3) Trend Analysis

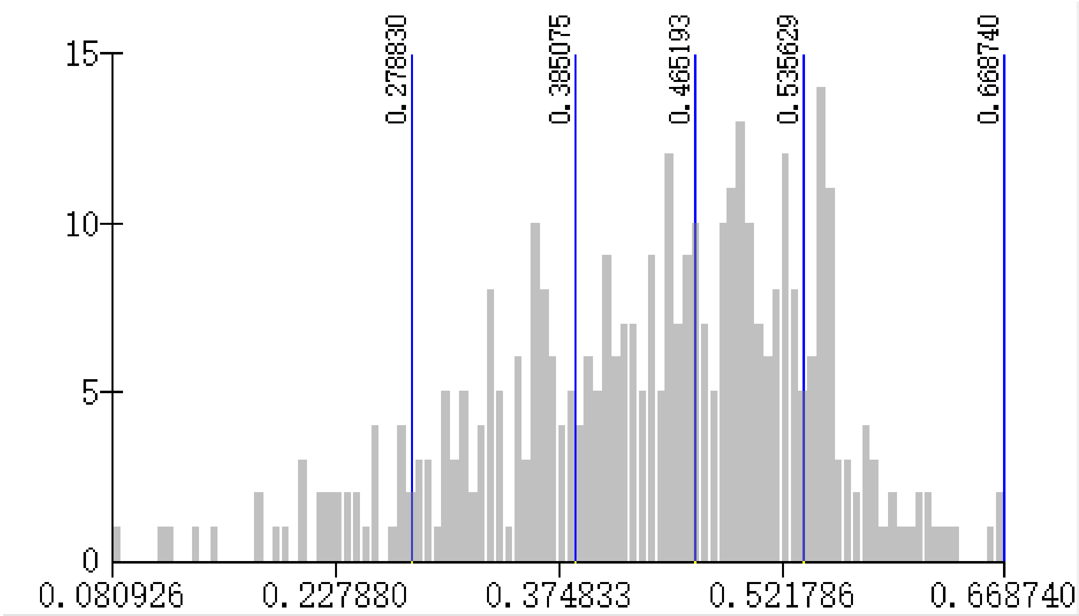


Fig 4-38 Distribution trendency diagram about Openness of sample points

The natural interruption point grading method was used to make numerical statistics and sample size distribution statistics on the Openness of sample points. The sample size distribution showed an irregular jagged "pyramidal" trend(Fig4-38). The number of sample points in the interval [0.081, 0.279] was 34 and its percentage was 8.9%. The number of sample points in the interval [0.279， 0.385] was 81 and its percentage was 21.3%. The number of sample points in the interval [0.385， 0.465] was 96 and its percentage was 25.2%. The number of sample points in the interval [0.465， 0.536] was105 and its percentage was 27.6%. The number of sample points in the interval [0.536， 0.669] was 64 and its percentage was 16.8%. Meanwhile, the interval with the largest number of sample points was [0.465， 0.536] and the interval with the smallest number was [0.081, 0.279]. The number of sample points that exceeded the total average (0.435) was 215, accounting for 56.4% of the total and more than half of the total. It shows that the sky view condition of the whole road of Fukuoka Streets is good and the street space can make pedestrians feel comfortable.

(4) Segmented Comparison

Fukuoka Streets were divided into 16 segments according to the distribution of sample points, the trend of Openness was plotted for each segment. The average value of Openness was also calculated separately for each segment. The average value of each section was used as the Openness and the individual data were plotted on a histogram of the Openness of the streets in Fukuoka Streets. The highest Openness value of 0.513 is found in Section A, while the lowest Openness value of 0.355 is found in Section P(Fig4-39,**Tab4-12**). The values of all sections are similar to the total average (0.435), vary up and down within 0.08. It can be found that the sky sight of each road section is good and even the lowest value (0.355) is not much different from the total average value. Through the panoramic view of each sample point, It can be found that the Openness value of section I is low, which is due to the fact that the section is located in a commercial area and its high density of tall buildings. The higher values of sections A, B, C and D are due to the fact that they are located near residential areas and away from the city center, the surrounding residential houses are of low height and do not have too much fencing of the sky view, so the sky view is excellent(Fig4-40,Fig4-41).

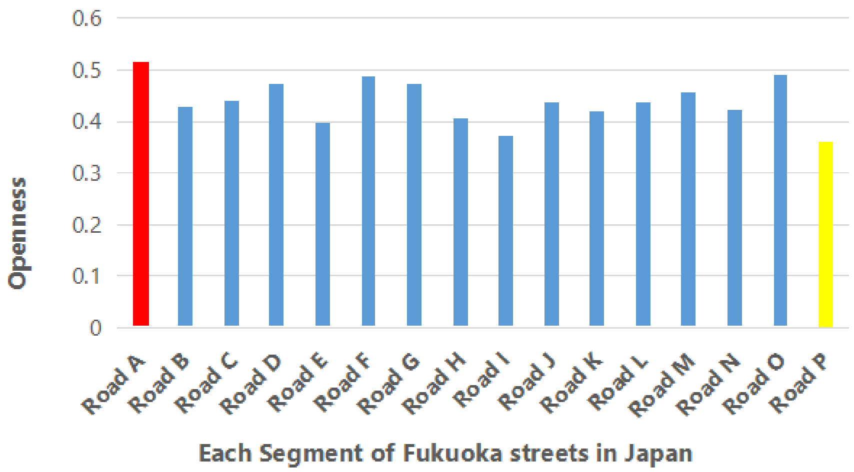


Fig 4-39 Average Openness of every segment sample points in Fukuoka Streets

Table 4-12 Segmented Openness data

Number	Average	Standard deviation	Coefficient of variation
A	0.513	0.079	0.154
B	0.428	0.149	0.35
C	0.439	0.087	0.198
D	0.472	0.120	0.256
E	0.398	0.098	0.248
F	0.488	0.062	0.128
G	0.472	0.054	0.116
H	0.406	0.086	0.214
I	0.372	0.107	0.289
J	0.436	0.100	0.231
K	0.42	0.087	0.208

L	0.436	0.103	0.236
M	0.455	0.067	0.147
N	0.424	0.188	0.443
O	0.491	0.061	0.124
P	0.355	0.069	0.194

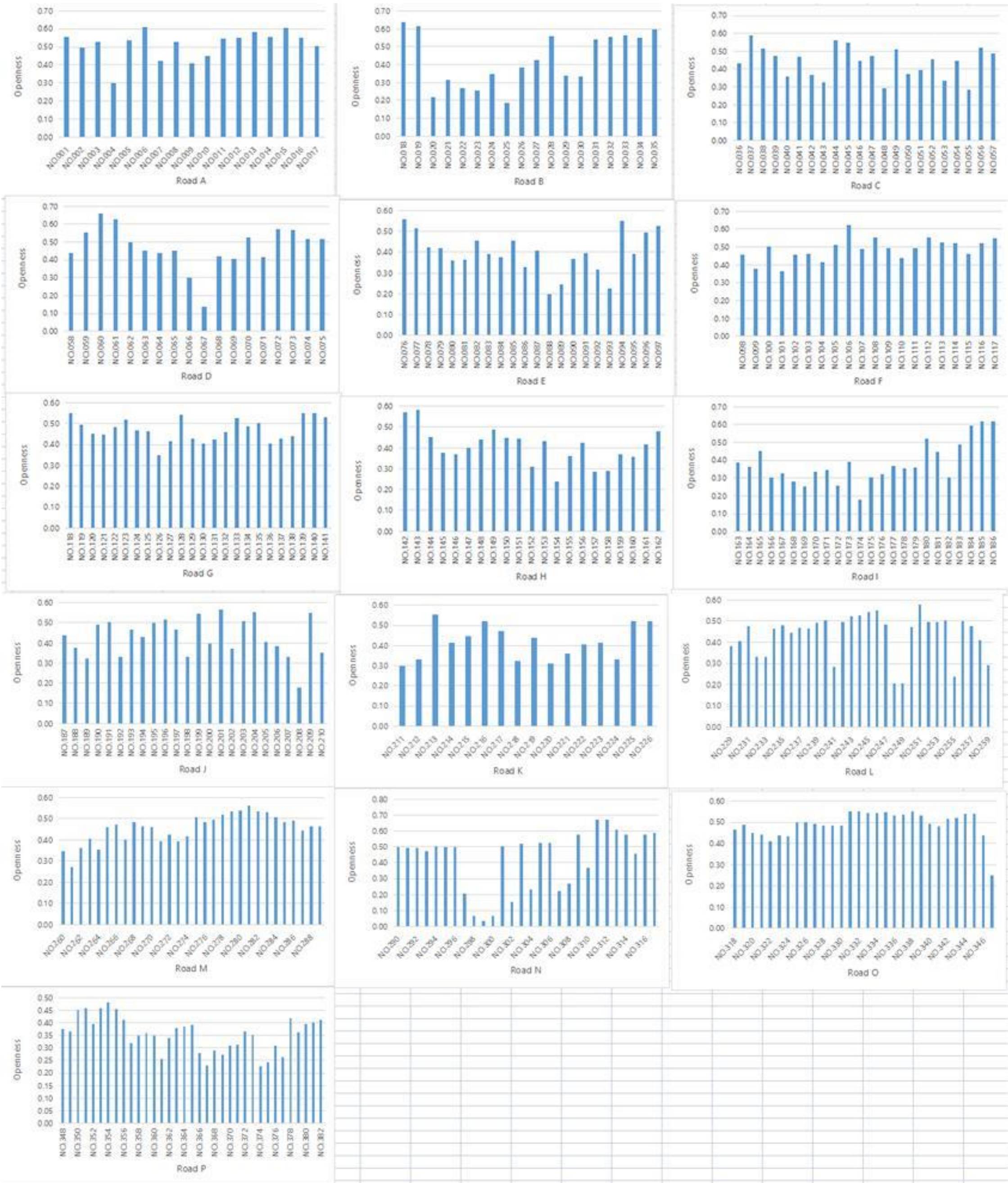


Fig 4-40 Openness of every segment sample points in Fukuoka Streets

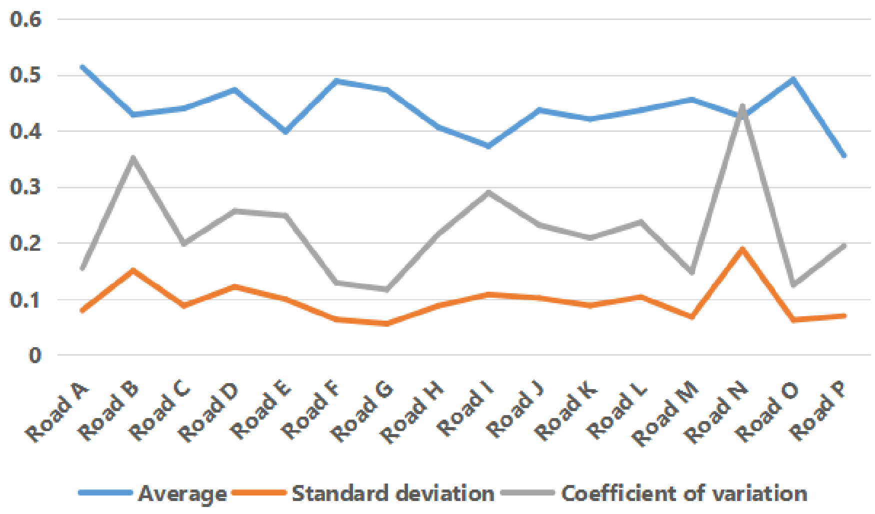


Fig 4-41 Coefficient of variation Openness of every segment sample points in Fukuoka Streets

(5) Analysis and Summary

Overall, the sky view of Fukuoka Streets is good. The Openness values of all road sections are stable within a range, there is little difference between the maximum and minimum values of each road section. It is proved that the street space is comfortable and pedestrians in this road section can promote the relaxation of psychology.

4.3.2.3 Proportion of Buildings

(1) Overall evaluation

In Japan,Fukuoka Streets take 381 points, two of these points are not discussed in the framing room, for a total of 381 points. The average proportion of building occupancy is 0.218. There are more buildings in the streets of Fukuoka Streets in contrast to Qingdao Coastal Streets. There are 117 points where the value of the proportion of building occupancy ratio is higher than the average, accounting for 51.32% of the total. The total standard deviation of 381 points is 0.124, which is a large value compared to Qingdao, indicating a more uneven distribution of street buildings in Japan. The coefficient of variation is 0.569, which indicates that the value of the building share does not fluctuate much. Looking at the spatial orientation of the building, we can conclude that the low value points are mostly distributed in 1-9 and 89-97, and the high value points are mostly distributed around the 25-point level, 169-177 and there is a huge difference between the high and low values of the data around the 17-25 and 57-65 points. The overall state is alternately undulating from east to west(Fig4-42).

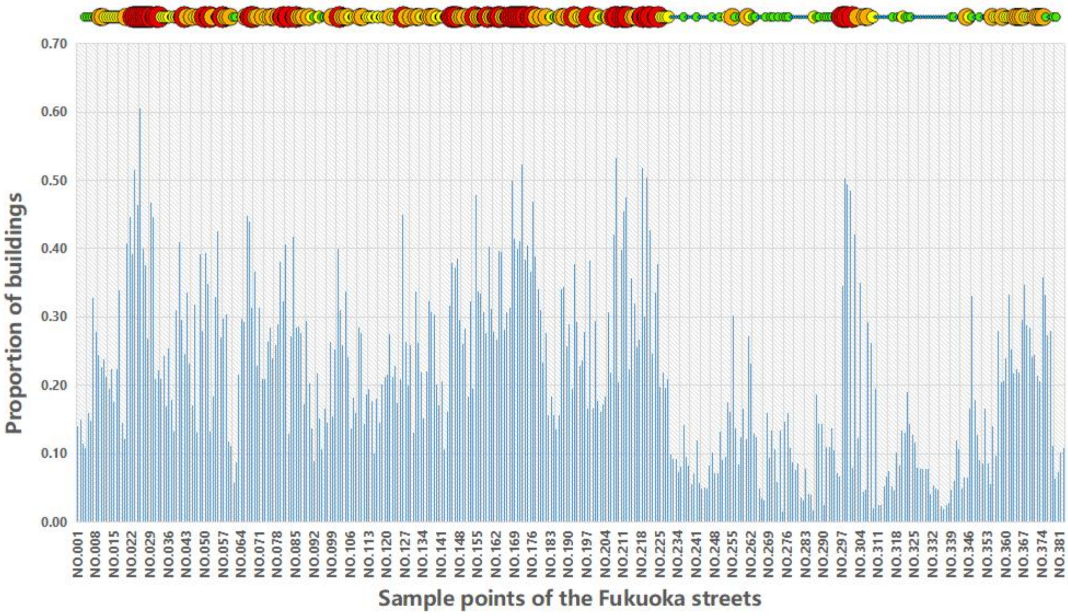


Fig 4-42 Proportion of Buildings of sample points in Fukuoka Streets

(2) sample point analysis

As shown in Figure , among 381 sample points, the maximum value is located at 25 points with a value of 0.605. We can tell from the photos that there are buildings on both sides of the street at this point, and that they are all high-rise. The remaining high values are 210, 172, 220 and 23 points with values of 0.533, 0.523, 0.519 and 0.515 respectively. with a minimum value of 274 points and a value of 0.016. According to the photo we can learn that the point is flanked by river water with less buildings; the remaining low value points are 62, 92, 115 and 142, with values corresponding to: 0.088, 0.09, 0.101 and 0.106.

(3) Trend analysis

The building occupancy ratio of 381 sample points in Fukuoka Streets and show streets was quantified and measured. And the natural interruption point grading method was used to conduct numerical statistics and sample size distribution statistics for the proportion of building occupancy index of sample points. As shown in Figure, the number of median values is higher and the number of sides decreases in order. There are five levels according to the natural interruption point method, 0.16-0.099, 0.099-0.174, 0.174-0.258, 0.258-0.367, 0.367-0.605, respectively(Fig4-43). Corresponding to low value intervals, lower value intervals, medium value intervals, higher value intervals and high value intervals. The number of low value intervals totaled 77, accounting for 20.2% of the total. The number of lower value intervals totaled 82, or 21.5 percent of the total. Median intervals accounted for 78 of the total, or 20.5 percent of the total. The number of higher values is

91, accounting for 23.9% of the total and the number of high value intervals is 52, accounting for 13.6% of the total.

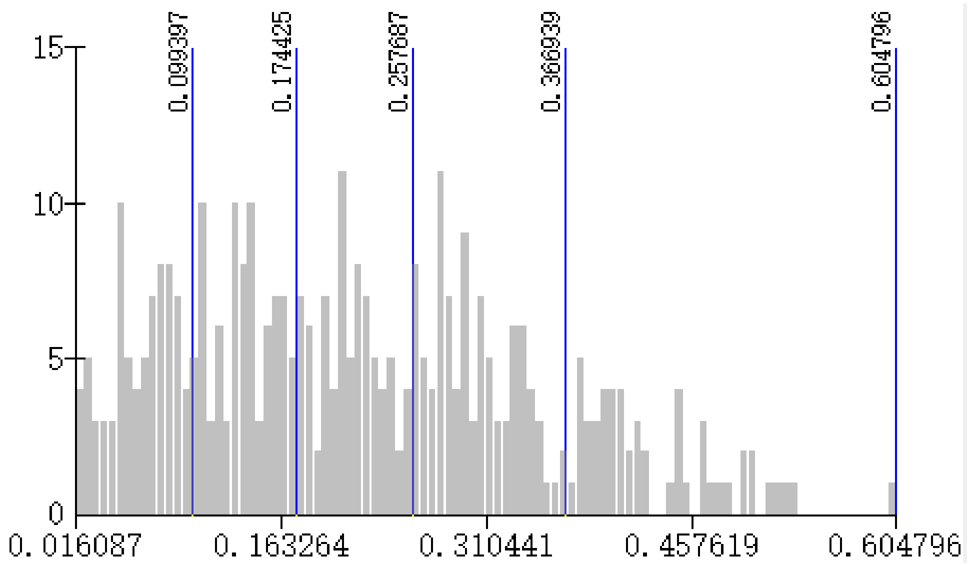


Fig 4-43 Distribution tendency diagram about Proportion of Buildings of sample points

Table 4-13 Segmented Proportion of Buildings data

Number	Average	Standard deviation	Coefficient of variation
A	0.198	0.068	0.342
B	0.339	0.142	0.42
C	0.276	0.092	0.334
D	0.254	0.111	0.439
E	0.239	0.095	0.398
F	0.219	0.077	0.352
G	0.239	0.069	0.29
H	0.298	0.087	0.291
I	0.337	0.109	0.322
J	0.269	0.098	0.365
K	0.338	0.106	0.315
L	0.111	0.056	0.505
M	0.103	0.063	0.616
N	0.165	0.159	0.966
O	0.091	0.063	0.691
P	0.201	0.09	0.447

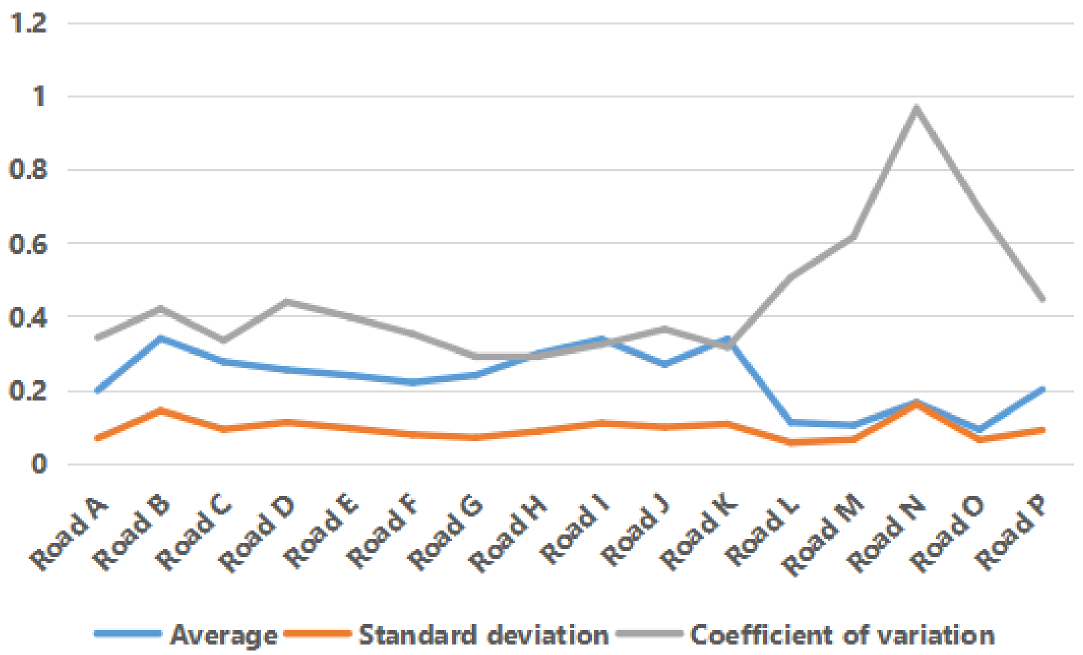


Fig 4-44 Coefficient of variation Proportion of Buildings of every segment sample points in Fukuoka Streets

(4) Segment Description

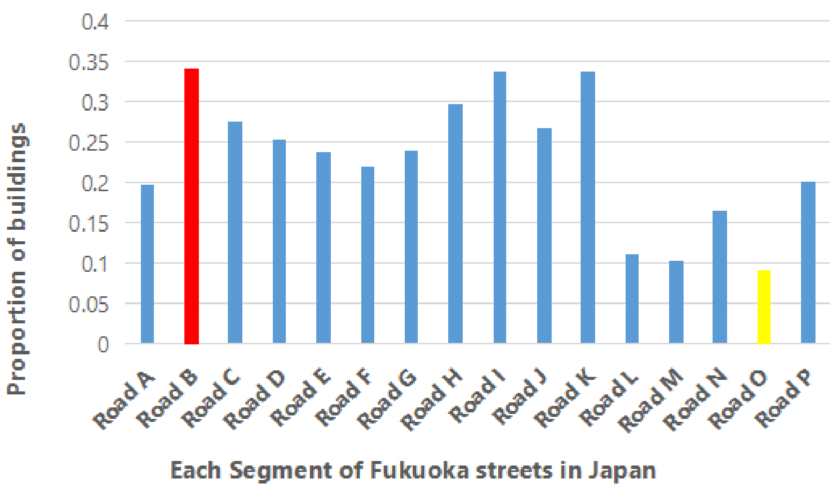


Fig 4-45 Average Proportion of Buildings of every segment sample points in Fukuoka Streets

We divided Fukuoka Streets and show streets into 16 sections, the number of sample points per segment is approximately equally. The mean, standard deviation and coefficient of variation of the building occupancy ratio of each road section were also calculated separately(Fig4-44, Fig4-45，**Tab4-13**). We can learn that:The building occupancy in sections A and F is lower than the values in other sections. A look at the panorama reveals that:Fewer buildings on both sides of the road in these two sections but B, I and K buildings account for a larger value than other sections. Observing the panorama we can learn that:There are more high-rise buildings and the buildings are more dense. The sections with smaller values of the standard deviation of building occupancy are A and G, indicating a more even distribution of buildings than the other sections. while the buildings in sections B and D with larger values are unevenly distributed compared to other sections. In terms of the coefficient of variation, the overall values do not fluctuate much. As shown in Figure 5, a separate histogram of the values for each section reveals that there are more buildings in the western part of section A road, a overall distribution of the G section of the road is relatively even, but there is one point where the Proportion of Buildings stands out. A more even distribution of buildings in general on K and J roads, and the rest of the section shows alternating ups and downs from west to east(Fig4-46).

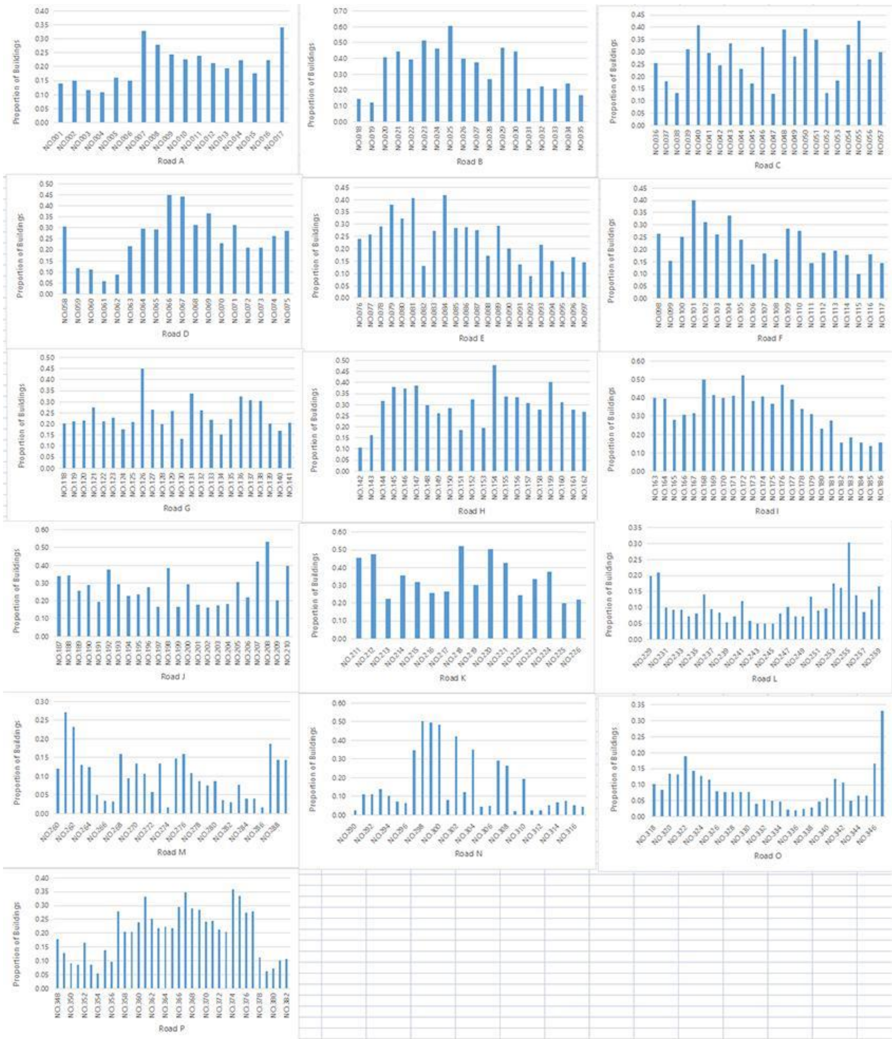


Fig 4-46 Proportion of Buildings of every segment sample points in Fukuoka Streets

4.3.2.4 Interface Enclosure Degree

(1) Overall evaluation

381 points were taken in the streets of Fukuoka Streets ,which were taken indoors without discussion, for a total of 381 points. The average interface enclosure is 0.281. Comparing with Qingdao Coastal Streets , Fukuoka Streets were low degree of closure. There are 185 sample points with values of interface enclosure higher than the average, accounting for 48.6% of the total. The total standard deviation of 381 points is 0.132, which is a small value compared to Qingdao, It shows that the distribution of buildings, fences and trees is more even in Japanese streets than in Qingdao streets, the coefficient of variation was 0.47. As in Figure, looking at the direction of the interface enclosure, we can conclude that the low value points are mostly distributed around sample points 57-65, the high value points are mostly distributed near the sample points 17-33, 153-177. There is a huge difference between high and low values of data near sample points 57-65 and 177-185. The overall appearance is irregular with multiple seals(Fig4-47).

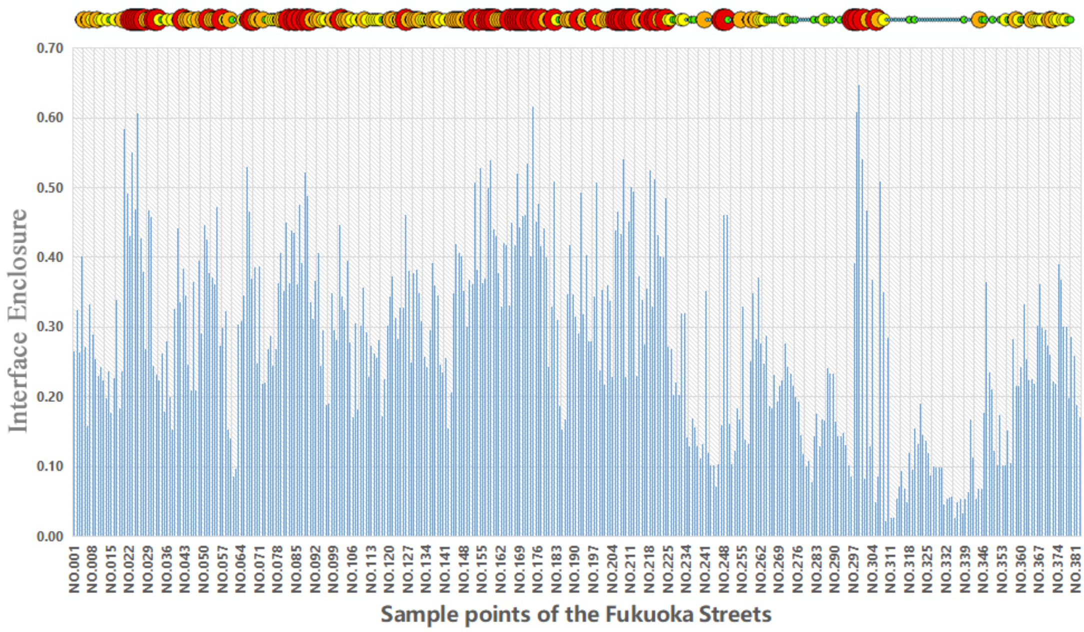


Fig 4-47 interface enclosure of sample points in Fukuoka Streets

(2) Analysis of sample points

As shown in Figure 2, among 381 sample points, the maximum value is located at point 299 with a value of 0.647. According to the photos we can learn that there are buildings on both sides of the street at this point, and they are all high-rise, with street trees on both sides of the road and no fences. The other high values are 25, 20, 23 and 210 points, and the values are: 0.606, 0.584, 0.551 and

0.544; The minimum value is 309 points, and the value is 0.022. According to the photos, we can know that there are rivers on both sides of the spot, with few buildings and no street trees and fences. The other low values are 62, 60, 186 and 59, and the values are 0.098, 0.141, 0.153 and 0.154 respectively.

(3) Trend analysis

The interface enclosure of 381 sample points in Fukuoka Streets was measured quantitatively. The natural discontinuity grading method is adopted to make numerical statistics and sample size distribution statistics on the closure index of sample points, As shown in Figure, the median number is larger, and the numbers on both sides decrease in turn. According to the natural discontinuity method, it can be divided into five grades, which are 0.022-0.145, 0.145-0.236, 0.236-0.32, 0.32-0.427, and 0.427-0.647 respectively (Fig4-48). There are 71 low-value intervals, accounting for 18.6% of the total; There are 78 low-value intervals, accounting for 20.5% of the total; The median interval accounts for 94 of the total, accounting for 24.7% of the total; There are 58 high-value ones, accounting for 21.7% of the total; There are 58 high-value intervals, accounting for 15.2% of the total.

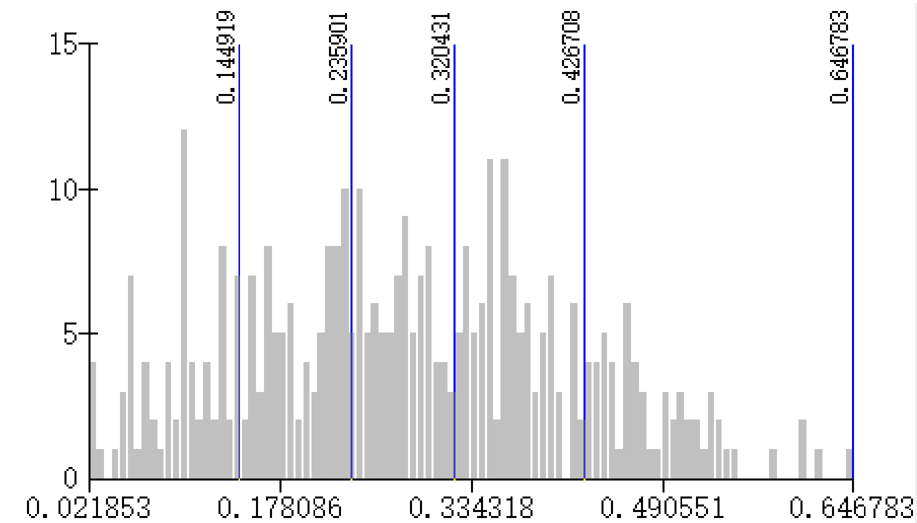


Fig 4-48 Distribution trendency diagram about interface enclosure of sample points

(4) Segment description

We divided Fukuoka Streets into 16 sections, the number of sample points in each section was basically average, and the average, standard deviation and variation coefficient of interface enclosure of each section were calculated respectively(Fig4-49，Tabl4-14). we can know that: The closure degree of sections A and D is less than that of other sections. Looking at the panorama, we can know: There are few buildings and greenery on both sides of these two sections of roads, and there is no fence; While the closure values of H, I and K are larger than those of other sections. Looking at the panorama, we can know: There are many high-rise buildings, with dense buildings and greenery on both sides. The road section with smaller standard deviation of interface enclosure is D, which indicates that the buildings, fences and greening of this road section are more evenly distributed than other roads; However, the buildings, greening and fences in the G section with larger values are unevenly distributed compared with other sections; From the coefficient of variation, the values from section A to section K do not fluctuate much, while there are significant fluctuations in the values from section L to section P.(Fig4-50).

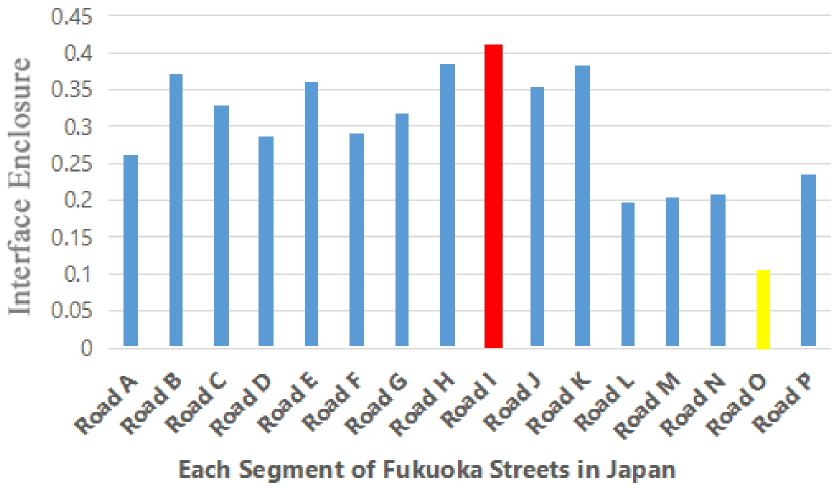


Fig 4-49 Average interface enclosure of every segment sample points in Fukuoka Streets

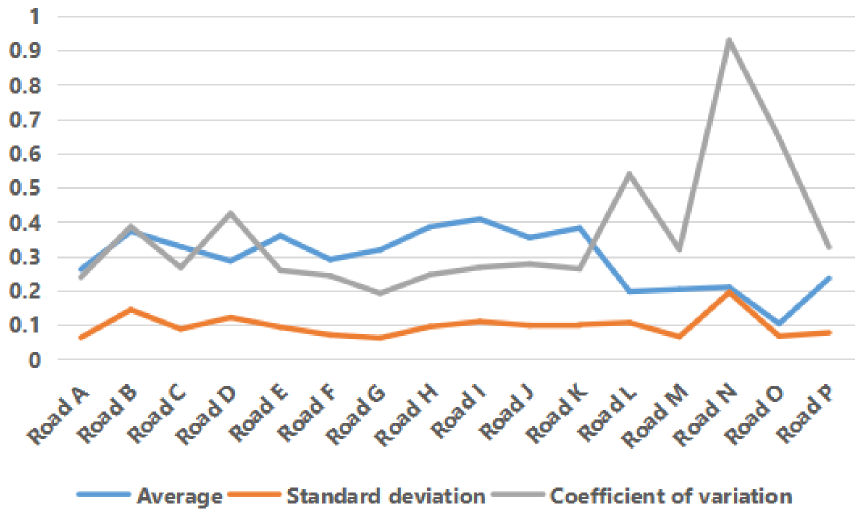


Fig 4-50 Coefficient of variation interface enclosure of every segment sample points in Fukuoka Streets

Table 4-14 Segmented interface enclosure data

Number	Average	Standard deviation	Coefficient of variation
A	0.261	0.062	0.238
B	0.372	0.144	0.386
C	0.328	0.087	0.266
D	0.286	0.121	0.424
E	0.359	0.093	0.259
F	0.29	0.07	0.242
G	0.318	0.061	0.191
H	0.385	0.094	0.245
I	0.408	0.109	0.267
J	0.353	0.098	0.277
K	0.382	0.101	0.263
L	0.197	0.106	0.538
M	0.203	0.065	0.319
N	0.209	0.194	0.928
O	0.103	0.066	0.644
P	0.235	0.077	0.326

(5) Overall street space

Among the 16 sections, A, D and F, the Proportion of Buildings and the value of closure are low. According to the panoramic picture, we can find the same points: Less buildings, less greening; While buildings of I, K, B and H have higher Proportion of Buildings and Interface Enclosure, Look at the panorama and find: There are many high-rise buildings, some of which are green. We can conclude that architecture is dominant in the interface closur(Tab4-15).

Table 4-15 The average value of the enclosure features in Japan 16 sections

Number	average of Proportion of Buildings	average of the Vertical Interface
A	0.198	0.261
B	0.339	0.372
C	0.276	0.328
D	0.254	0.286
E	0.239	0.359
F	0.219	0.29
G	0.239	0.318
H	0.298	0.385
I	0.337	0.408
J	0.269	0.353
K	0.338	0.382
L	0.111	0.197
M	0.103	0.203
N	0.165	0.209
O	0.091	0.103
P	0.201	0.235

4.3.2.5 Pedestrians

(1) General Description

Street space is an important part of public space, its core functions are transportation functions and providing a place for people to socialize, the latter of which gives the street its unique character. In general, the social subjects in the street can be divided into two categories. One is the interaction between pedestrians and users of street facilities, the other is the interaction between pedestrians and users of street-level buildings. Based on the above theory, 381 sample sites were analyzed in Fukuoka Streets. The semantic segmentation method was used, which is the ratio of pixels occupied by pedestrians to total pixels in the street in the panorama , the crowd aggregation index of 381 sample points was obtained in Fukuoka Streets.

(2) Analysis of sample Points

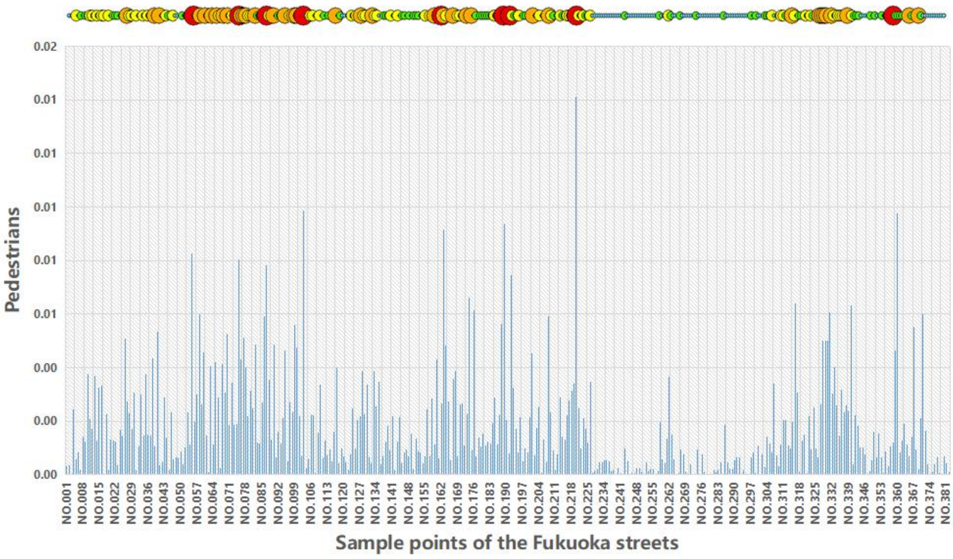


Fig 4-51 Pedestrians of sample points in Fukuoka Streets

According to the data from 381 sample points, it was concluded that the overall average pedestrians of Fukuoka Streets was 0.0018 . This average value was used as the pedestrians of Fukuoka Streets. According to this average value, it can be roughly known that there is less crowd activity in the whole street of Fukuoka Streets . The 381 data were also plotted as a histogram, it was found that the concentration of people in the streets of Fukuoka Streets,gradually increased from west to east, then started to decrease in the middle section before starting to increase again(Fig4-51). It can be presumed that there are main crowd activity places in the west and east of the sample point of Fukuoka Streets.

(3) Trend Analysis

The natural interruption point grading method was used to conduct numerical statistics and sample size distribution statistics of the pedestrians at the sample points.The sample size distribution showed a trend of "cliff-like decline"(Fig4-52). The number of sample points in the interval [0，0.001] was 145 and its percentage was 38.1%. The number of sample points in the interval [0.001，0.002] was 107 and its percentage was 28.1%. The number of sample points in the interval [0.002，0.0037] was 81 and its percentage was 21.3%. The number of sample points in the interval [0.0037，0.0066] was 39 and its percentage was 10.2%. The number of sample points in the interval [0.0066，0.0141] was 9 and its percentage was 2.4%. Meanwhile, the interval with the largest number of sample points was [0，0.001] and the interval with the smallest number was [0.0066，0.0141]. From this, it can be found that the values of pedestrians in Fukuoka Streets are mainly in the low value range, which indicates the poor crowd dynamics of the whole street.

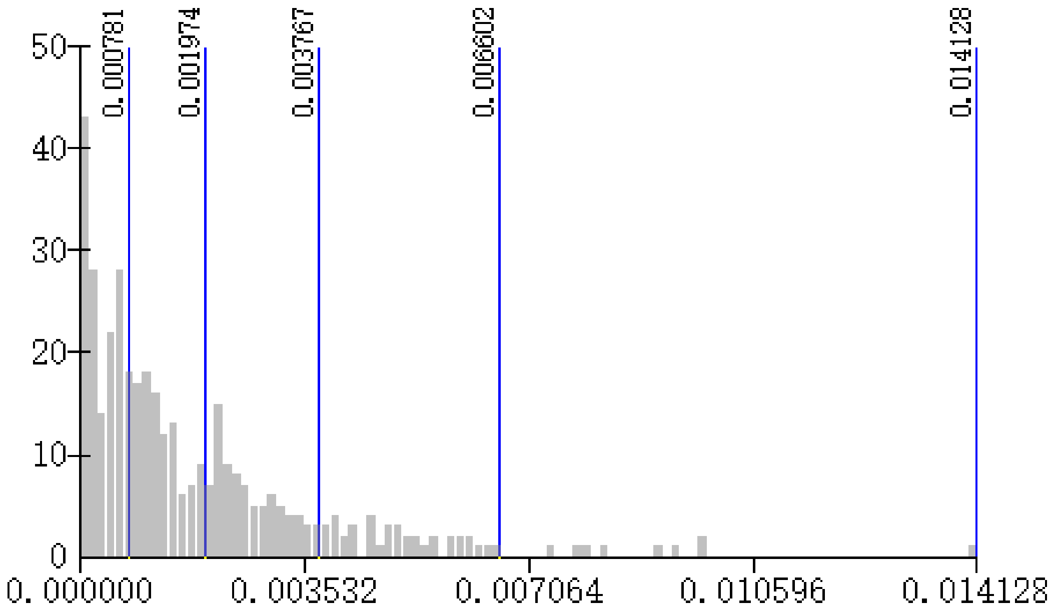


Fig 4-52 Distribution trendency diagram about pedestrians of sample points

(4) Segmented Comparison

According to the distribution of sample points,Fukuoka Streets was divided into 16 segments, the average value of pedestrians was calculated separately for each segment. The average value was used as the pedestrians of each road segment and these values were used to create a histogram of the pedestrians of Fukuoka Streets streets . According to the comparison, it can be found that the pedestrians degree of road section D has the largest value of 0.0032; the lowest pedestrians degree of road section L is 0.0003(Fig4-53,**Tab4-16**). By observing the panoramic view of each road section, we can find that road sections D, E and F are located in the prosperous area of the whole road section, there are more places for crowd activities around. Therefore, the pedestrian flow is higher compared to other road sections, resulting in a higher than average pedestrians (0.0018). While sections A, B and C are far from the downtown area of the city and located near residential areas, the streets have fewer pedestrians, so the pedestrians degree is lower than the average. Road section H is also located in the main road of the city, but its pedestrians value is lower than the average. This may be due to the lack of recreational facilities on this road and most of the pedestrians on the road are working white-collar workers. Therefore, it can be known that the pedestrians degree of the street is mainly related to whether there are activity places around the street and the number of places(Fig4-54).

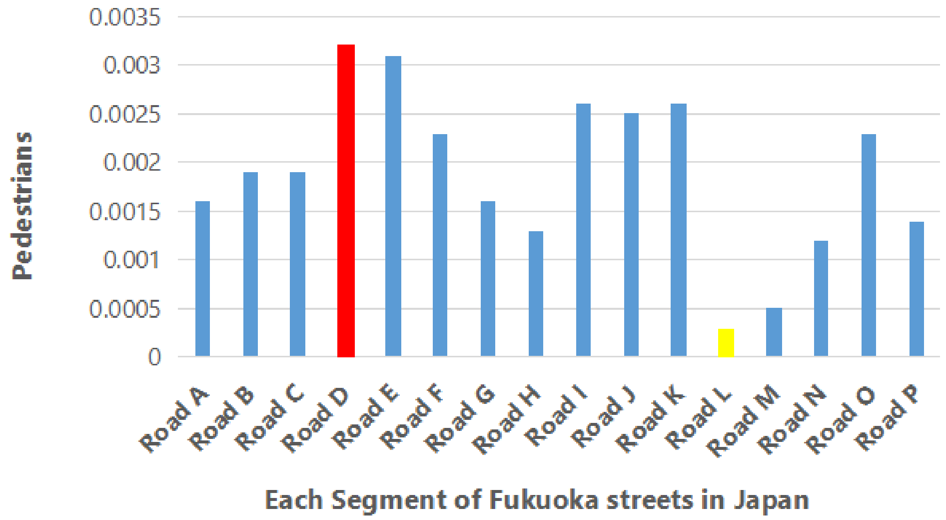


Fig 4-53 Average pedestrians of every segment sample points in Fukuoka Streets

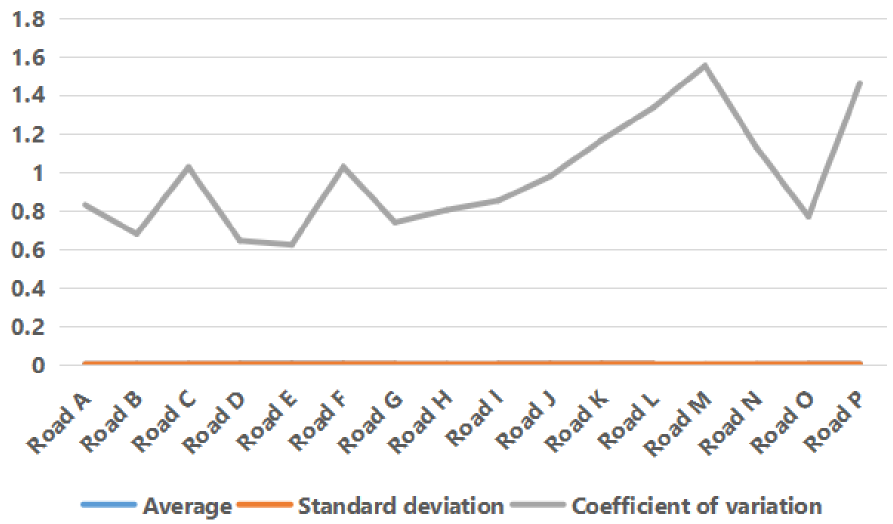


Fig 4-54 Coefficient of variation pedestrians of every segment sample points in Fukuoka Streets

Table 4-16 Segmented pedestrians data

Number	Average	Standard deviation	Coefficient of variation
A	0.0016	0.0013	0.827
B	0.0019	0.0013	0.676
C	0.0019	0.0019	1.023
D	0.0032	0.0021	0.641
E	0.0031	0.0019	0.62
F	0.0023	0.0024	1.025
G	0.0016	0.0012	0.737
H	0.0013	0.0011	0.801
I	0.0026	0.0022	0.849
J	0.0025	0.0024	0.975
K	0.0026	0.003	1.164
L	0.0003	0.0004	1.333
M	0.0005	0.0008	1.55
N	0.0012	0.0013	1.124
O	0.0023	0.0018	0.767
P	0.0014	0.0021	1.459

(5) Summary Of The Analysis

According to the analysis and comparison of various data, it is found that the overall pedestrians of Fukuoka Streets is low and the vitality of street space is insufficient. The reason for this is the lack of crowd activity around the street, resulting in a short residence time for pedestrians. At the same time, by comparing the road sections in residential areas with those in commercial areas, it can be found that the pedestrians in commercial areas is higher than that those near residential areas. This is also a direct indication that the degree of pedestrians is related to the availability of activity places around the streets. Therefore, enriching the variety of spaces near streets and increasing activity spaces are the most direct ways to enhance the vitality of streets and the degree of pedestrians.

4.3.2.6 Vehicle Occurrence Rate

(1) General Description

By analyzing 381 sample points in Fukuoka Streets, NO.179 and NO.201 were located indoors. Therefore, they were not counted in the data analysis. The analysis was based on panorama of 381 sample points in Fukuoka Streets. According to the definition of Vehicle Occurrence Rate, the semantic segmentation method was used, which is the ratio of the pixels occupied by the vehicles driving in the streets to the total pixels in the panorama, the Vehicle Occurrence Rate of 381 sample points was obtained in Fukuoka Streets.

(2) Analysis of sample Points

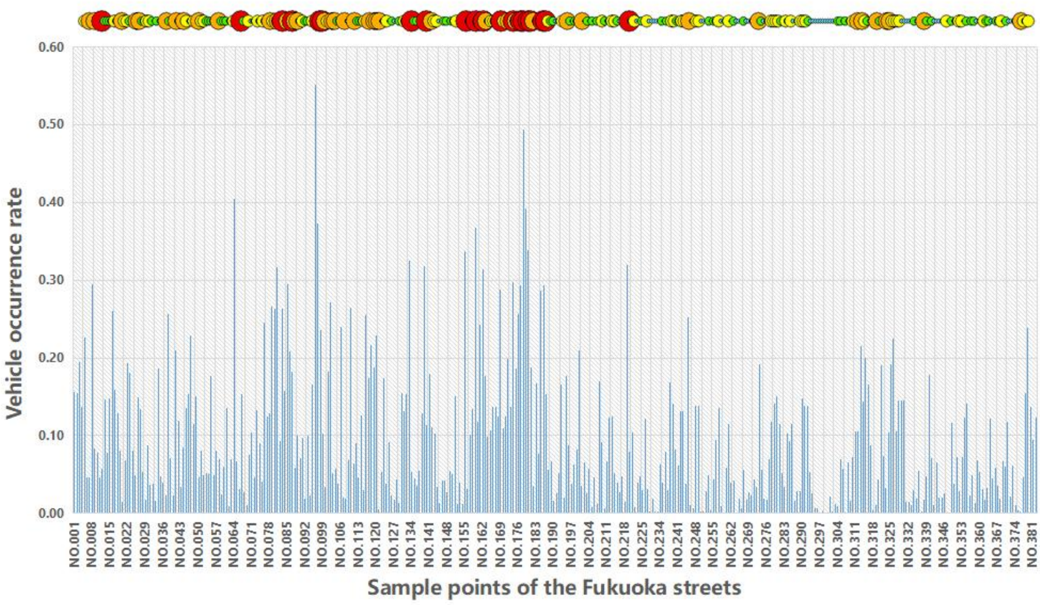


Fig 4-55 Vehicle Occurrence Rate of sample points in Fukuoka Streets

According to the data from 381 sample points, it was concluded that the overall average Vehicle Occurrence Rate of Fukuoka Streets was 0.098. The average value was used as the Vehicle Occurrence Rate of Fukuoka Streets, the percentage of vehicles within the observation range of human perspective was 9.8%. At the same time, 381 datas were drawn into a histogram, it was found that the incidence of vehicles showed a trend of high in the middle and low in the east and west in Fukuoka Streets(Fig4-55).

(3) Trend Analysis

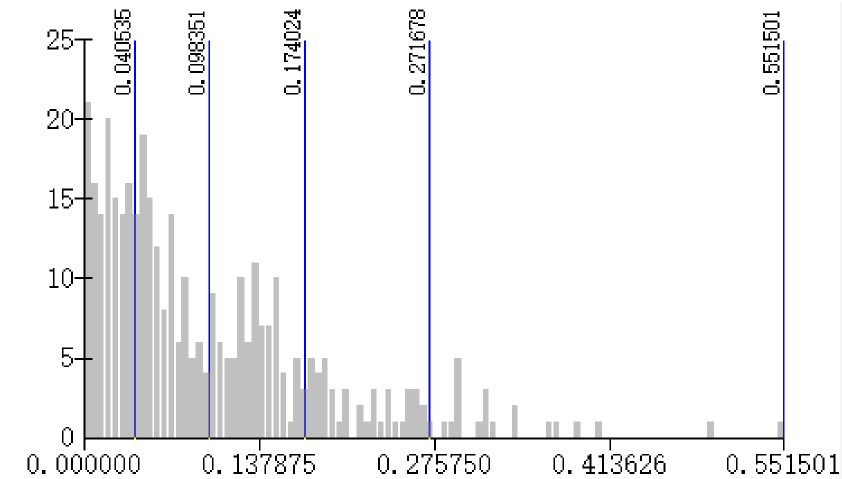


Fig 4-56 Distribution trendency diagram about Vehicle Occurrence Rate of sample points

Based on the data statistics, numerical statistics and sample size distribution statistics of Vehicle Occurrence Rate of 381 sample points were performed using the natural interruption point grading method. It was found that the distribution of Vehicle Occurrence Rate samples in sample points showed a "cliff-like decline" trend(Fig4-56). According to the data obtained from 381 sample points, the trend of sample point distribution was plotted. It was found that the Vehicle Occurrence Rate of nearly 59.8% of the 381 sample points were lower than the average (0.098), more than half of the number of sample points. It showed that the overall vehicle driving condition of the streets in Fukuoka Streets was good. [0, 0.041] The number of interval sample points was 123 and its percentage was 32.3%.; [0.041, 0.098] The number of interval sample points was 106 and its percentage was 27.8%.; [0.098, 0.174] The number of interval sample points was 88 and its percentage was 23.1%.; [0.174, 0.272] The number of interval sample points was 43 and its percentage was 11.3%.; [0.272, 0.552] The number of interval sample points was 20 and its percentage was 5.2%.; The largest share of the interval [0, 0.041] and the smallest share of the interval [0.272, 0.552]. Besides that, the highest value interval of Vehicle Occurrence Rate was located in [0.272, 0.552] and the lowest value interval was located in [0, 0.041]. Among them, the lowest value interval accounted for 32.3%, while the number of sample points in the highest value interval of Vehicle Occurrence Rate only accounts for 5.2% of the total sample points.

(4) Segmented Comparison

According to the distribution of sample points,Fukuoka Streets was divided into 16 segments, the average value of Vehicle Occurrence Rate was calculated separately for each segment. The average value was used as the Vehicle Occurrence Rate rate of each road section, the Vehicle Occurrence Rate rate was used to draw a histogram of the Vehicle Occurrence Rate of Fukuoka Streets. The highest Vehicle Occurrence Rate of 0.202 was found in Section I. The lowest Vehicle Occurrence

Rate of 0.061 was found in Section M(Fig4-57,Tab4-17). Through comparison, it is found that sections A, E and I are higher than the total average. Among them, sections E and I are located in the commercial area of the whole section, with a high traffic volume. Therefore, the Vehicle Occurrence Rate is high. And section A is located near residential areas, the number of people driving vehicles out of the house is higher, so the incidence of vehicles is also higher. However, sections J and K, which are also located in commercial areas of the roadway, their Vehicle Occurrence Rate is far lower than the total average. Therefore, the incidence of vehicles has little to do with whether the roadway is in the commercial area or not. Compared with section A, sections B and C are residential areas far away from urban commercial areas. Compared with section A, the incidence of vehicles in sections B and C is much lower. Therefore, it can be assumed that the incidence of vehicles may be related to the density of population living near the road section where they are located(Fig4-58).

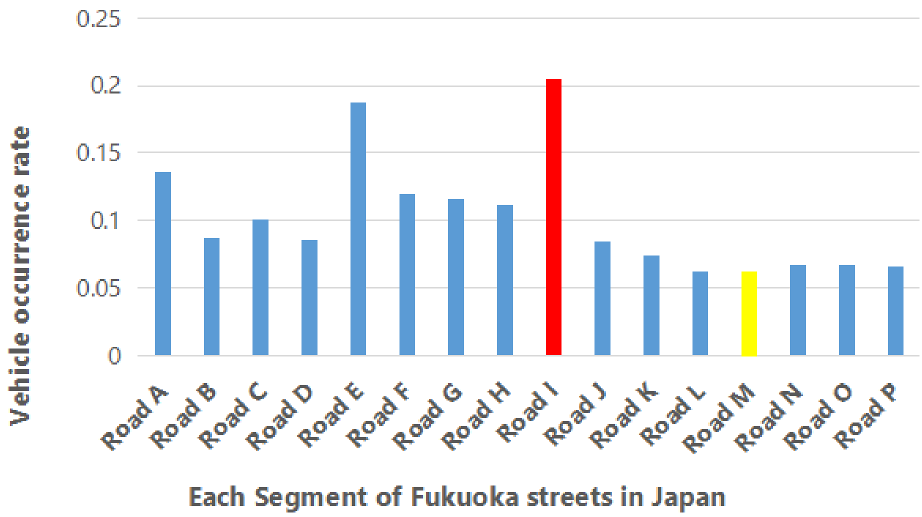


Fig 4-57 Average Vehicle Occurrence Rate of every segment sample points in Fukuoka Streets

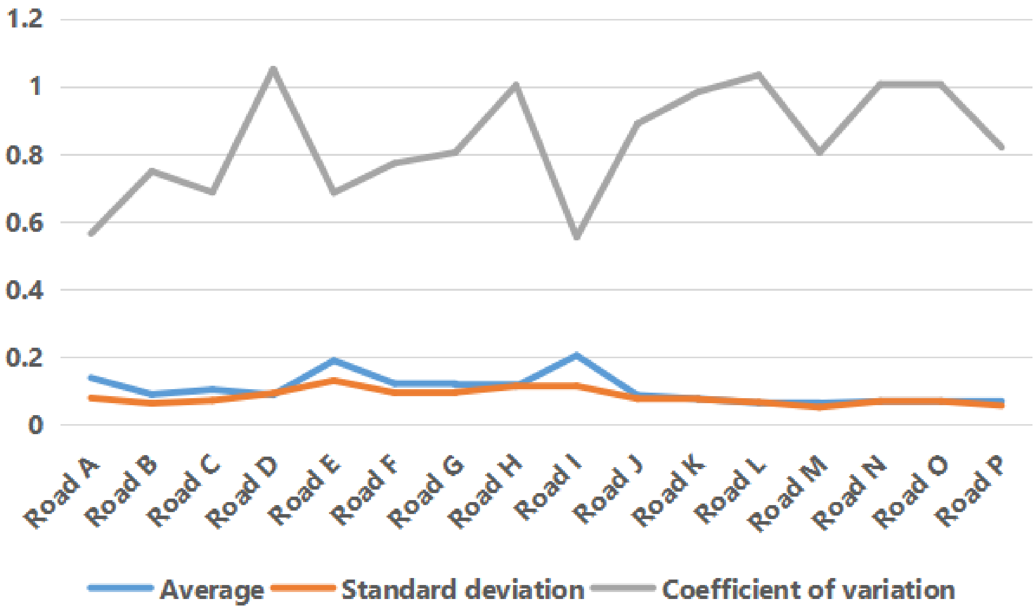


Fig 4-58 Coefficient of variation Vehicle Occurrence Rate of every segment sample points in Fukuoka Streets

Table 4-17 Segmented Vehicle Occurrence Rate data

Number	Average	Standard deviation	Coefficient of variation
A	0.136	0.077	0.563
B	0.087	0.061	0.747
C	0.101	0.069	0.685
D	0.086	0.09	1.05
E	0.187	0.128	0.684
F	0.119	0.092	0.771
G	0.116	0.093	0.803
H	0.111	0.111	1.002
I	0.202	0.112	0.552
J	0.084	0.075	0.888
K	0.074	0.073	0.982
L	0.062	0.064	1.032
M	0.061	0.049	0.803
N	0.067	0.067	1.005
O	0.067	0.067	1.003
P	0.066	0.054	0.818

(5) Analysis and Summary

After the overall trend and segmentation comparison analysis, it is found that Vehicle Occurrence Rate is affected by several factors. Under the same conditions, there are great differences in Vehicle Occurrence Rate, but it can be generally summarized that the Vehicle Occurrence Rate is related to the population density near the street. For example, the high incidence of vehicles in section A is due to the high number of people living around and people are traveling by vehicle, which affects the incidence of vehicles in that section. Section I is located in the commercial activity area of the whole road section, there are many surrounding activity places and facilities and it is located in the main road of the city, so the traffic volume is high and the incidence of vehicles is high. However, section K is also located near the commercial area, it has low traffic volume and low Vehicle Occurrence Rate, which may be due to the section being a new development area or other factors.

4.4 Conclusion

4.4.1 Greenness

At the theoretical level, this study helps to better understand the ecological meaning of Greenness in coastal cities and provides theoretical support for the selection of coastal street measurement indexes. At the practical level, it can clarify the main drivers of Greenness in several dimensions and provide techniques for the improvement of urban Greenness and green land management in the future. In general, Greenness is important for measuring or evaluating urban streets, rest spaces and landscape of the city.

4.4.2 Sky view rate

In the urban open space enclosed by buildings, the range proportion of the sky that people can see is related to the quality of urban space, the comfort of public activities and visual psychological expectations. The sky visibility factor is a quantifiable factor used to study the size of the sky that affects the public's viewing range[18].

The sky view rate is an evaluation of the overall spatial enclosure of the street. It is also a comprehensive evaluation of the street green view and building visibility. The higher the sky view rate, the more open the street space is, but the open space does not mean comfortable[19]. For example, if trees cover a large amount of sky, the sky vision rate of the street is lower for the boulevard, but the space feeling of the street is very comfortable. High-rise residential buildings with commercial buildings on the ground floor can cause the street space to be closed and create a certain sense of depression for pedestrians[20]. Although sky vision rate comprehensively considers street buildings and trees, it is necessary to combine Greenness and building vision rate when analyzing the fundamental factors that affect pedestrian activities.

Street sky Openness is an indicator that can be influenced by a combination of factors such as street skyline form and building height on either side.The level of street sky Openness directly affects the visual perception and space experience of pedestrians in the street.The vast sky can bring good visual effect to pedestrians, and the broad view makes people physically and mentally happy in the senses.But too wide a sky can also make people feel empty and give people a poor space experience. Too low street sky Openness will cause a sense of visual closure, making people feel depressed psychologically. It also affects the street wind environment and aggravates the heat island effect. Therefore, too high or too low street sky Openness can reduce the space quality of the street[21].

4.4.3 Interface Enclosure Degree

The relationship between street height, scale and width is evaluated by Interface Enclosure Degree. When the Interface Enclosure Degree reaches a certain value, the higher the value, the stronger the spatial oppression of the sidewalk[22].

The street enclosure can be derived by calculating the ratio of buildings, walls, columns, fences and trees in the street view image. It can objectively reflect the extent of the public space of the street formed by these elements[23]. Different types of streets have very different degrees of enclosure. In the traffic streets dominated by vehicles, the degree of enclosure is often low and it gives passers-by a sense of Openness and emptiness; In the pedestrian-scale commercial street, the streets have a high degree of enclosure and the compact space is convenient to form a good commercial atmosphere[25]. In a living street dominated by mixed scale of pedestrian and vehicles, the degree of enclosure varies with the function of the places on both sides of the road and the type of building[26].

The suitable space enclosure could take peace and comfort. Different types of streets have different appropriate ranges of enclosure values and cannot be generalized[27]. Therefore, there is no direct correspondence between the level of this index and the quality of street space, it needs to be analyzed differently in combination with different streets[28].

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Chapter 5

THE EXPERT PERCEPTION OF STREET SPACE IN COASTAL CITIES

CHAPTER FIVE: THE EXPERT PERCEPTION OF STREET SPACE IN COASTAL CITIES

5.1 Background

Nowadays, the urban construction has changed from "speed first" to "quality-oriented" in China[1][2][3]. The urban environment is increasingly linked to public well-being [4][5]. Meanwhile, scholars pay more attention to the human perceptual experience in urban space[6][7][8]. The core task of urban regeneration is to build an attractive urban space by improving the quality of urban space and displaying urban imagery [9][10][11].

Waterfront street is the most attractive composition part in the urban space[12][13][14][15][16]. It plays a positive role in maintaining the urban vitality[17][18][19][20].

Urban waterfront space is made up of natural and artificial landscape elements[21]. Urban waterfront space quality affects style and features of urban landscape [22][23], public behavior[24][25][26], physical and mental health[27][28][29]. Several studies have discussed the impact of urban waterfront space on public aesthetics and emotions[30][31]. In fact, the effective problem-solving step is to accurately quantify the public perception of the built environment for improving the quality of waterfront street space[32].

Therefore, applying an efficient method and constructing an accurate model are particularly important, which can measure and predict human perception of urban space.

The most attractive and charming distinct of Qingdao is the coastal street space [33][34], which obvious identifiable [14]. Urban style and features can express the external image of Qingdao [20]. However, some problems such as enclosed street, poor permeability interface, blocked seascape view and monotonous streetscape elements have seriously affected the Qingdao Coastal Streets quality during the rapid expansion of urbanization in the past decades [20][23][35].

Coastal landscape in Qingdao can enhance urban imagery[30] and improve environmental quality[22]. The high-quality environment in The Coastal Streets can promote the development of tourism and economy. The blue-green spaces played an important role in the mental health[8][36][37][38], such as urban parks, groves, rivers and coasts[39]. Therefore, how highlight the features of waterfront streetscape, coordinate the relationship between landscape elements, from the designer's point of view,satisfy the needs of the public aesthetic become the important contents of human settlements environment research in Qingdao [20].

In summary, the most critical questions in the study of Qingdao Coastal Streets are as follow: (1) Identifying the landscape elements quickly and accurately. (2) Measuring the main landscape perceptual features. (3) Revealing relationship among streets quality, landscape elements and landscape perceptual features.

The traditional methods for the street features are used field survey and available data to obtain the streets information [40][41]. Scholars have proposed some methods to calculate sky openness, such as geometric analysis method, projection computation method, GPS method, spherical calculation method, shading calculation method[42]. Tang found the influence of street interface signs on pedestrian behavior by mapping methodology[43]. Greenness is studied by photography method. The greenery information in the photos need to be simplified and calculate the proportion[42][44].

Previous studies have shown that vision was essential to the perception and space activities[45][46][47]. The perceptual of streets quality has a relationship with landscape elements. It depends on the physical components of the streetscape[48][49][50], such as buildings, fences, greening, road width, pedestrian space, motorization and sky[51][52][53][54]. Physical feature is an interesting and important part or characteristic of the streets elements that can be seen by human. The physical features can quantify street environment based on the visual information, such as floor area ratio, greenness, enclosure, height-to-width ratio, streets scale and tidiness[55][56][57][58]. Reid Ewing and Handy explored five physical features of street: imageability, enclosure, human scale, transparency, complexity, which were possible to measure urban design quality[59][60][61][62][63][64].

Ewing and Clemen have pointed out that systematic exploration of the measurement and performance of street space form is a necessary condition for constructing space and public life[62][65][66]. Classic academic studies demonstrated the physical space and street form were the basis for street activity[67][68][69].

With the advance of built environment quantitative studies, the measuring method of street physical space were developed, but there were few integrated applications of multiple methods. In recent years, street view image has become an important data source in urban studies, which provided the advantage of high accessibility, high resolution, and wide coverage[5][50][70]. Corresponding, street view image is extensively implemented in urban studies[71][51][72]. Almost 34% of studies used urban street view[73][74]. Street view image has been used to measure features including sky[75][76][77], buildings[61][75], water[78] and greening[79][80][81][82]. Some scholars have confirmed the reliability of street view image for studying the quality of the street environment by comparing the street view image with the results of field scoring[83][84][85][86][87].

The series of emerging techniques such as ArcGIS, Python and Machine Learning have provided possibilities to deal with large-scale data[2][10][88][89]. Be supported and inspired by developments of data set such as Cityscapes[90], Synthia[91], KITTI[92], especially machine learning techniques, many studies have been conducted to analyse human perceptions of urban appearance[5][93][94][95][96].

Semantic segmentation is a classification method of computer vision technology. It can automatically divide the landscape elements along their boundaries in the image.[97]. Semantic segmentation provides an objective measure of physical features in the street environment[77][85]. It is not only possible to assess vegetables[82][98], but also various landscape indices such as openness by extracting sky areas[99][100][101], and fences can be evaluated by extracting built-up areas[51]. DeeplabV3+ is an important Semantic segmentation model and proposed by Liang-Chieh[102][103].

Perception is the process of attaining awareness or understanding of sensory information[59]. The Semantic Differential (SD) Method was used for the visual perception of landscape and other fields[104][105][106]. The SD Method was proposed by the US psychologist Charles E. Osgood in 1957[107][108]. It is a type of [109]. The SD is universally applicable in semantic rating scale that captures the affective and cognitive components of respondents' attributions to selected concepts environment, landscape and architecture research[24][110][111].

In the study, The Qingdao coastal landscape streets were determined as the site. First, the street view images in 344 sample points were obtained by Baidu data source. We divided the landscape elements and quantified the physical features in the coastal street. Second, the 69 typical samples points were selected to evaluate the six perceptual features. Finally, the relationships between the physical features and perceptual features were comprehensive analyzed.

The research results can be applied to the construction and management in the urban coastal streets. It provided theoretical and technical support for the urban regeneration and space quality improvement.

5.2 Research Methodology

5.2.1 The method of perceptual features evaluation

The choice of feature adjective pairs is important before the evaluation of perceptual features by SD method[117]. By using the Delphi expert method, six SD features and corresponding adjective pairs were selected (Tab 5-1). The imageability, enclosure, human scale, transparency and complexity were summarized by Reid Ewing from the 51 perceptual features of urban spaces quality. They were the most important and easy-to-operate to measure the street environment. Many studies have proved that they were effective[72][112].

Table 5-1 Visual perceptual features and adjective pairs in SD method

Visual perceptual features	Adjectives in pair
Imageability	Ordinary—attractive
Enclosure	Open—enclosed
Transparency	Impassable—permeable
Human scale	Dissatisfied— satisfied
Complexity	Single—complicated
Nature	Artificial—ecological

We added nature features as the sixth perceptual feature. A lot of studies have confirmed that nature and the street environment quality were closely related[8][113][114]. Moreover, the proportion of plants and water was high, which also made nature to be a necessary feature in Qingdao Coastal Streets. The Coastal Streets were divided into street segments at 500 meter intervals, and two sample points were selected as typical sample points which could fully represent the landscape features of each street segment. A total of 69 typical sample points were selected out for SD experiments to further investigate the relationship between perceptual features and physical features (Fig 5-1). SD evaluation usually requires 20-50 observes with relevant expertise[115][116]. Therefore, the observes of the experiment included 30 Master students and 10 professional teachers who had academic backgrounds in architecture, urban planning, and landscape design. During the evaluation process, the perceptual features and corresponding pairs of adjectives were first explained to the 40 observers. Moreover, they were asked to focus on the streetscape rather than the quality of photos. Each photo was shown two minutes apart, the questionnaire uesd the Likert scale, the evaluation criteria were divided into five grades (1 low-5 high), the positive and negative adjectival expressions were compared with current events. By examining the evaluation results, 40 questionnaires were returned. After checking, all of them were valid.


NO.006
NO.009
NO.017
NO.019
NO.023
NO.025
NO.031
NO.034
NO.044
NO.050
NO.052
NO.055
NO.064
NO.067
NO.075
NO.079
NO.084
NO.087
NO.094
NO.096
NO.101
NO.103
NO.111
NO.116
NO.122
NO.124
NO.131
NO.137
NO.145
NO.149
NO.151
NO.154
NO.162
NO.166
NO.171

Fig 5-1 The images of 69 typical sample points.

5.2.2 Statistical analysis

We took perceptual features as dependent variables, screened out relevant physical features (Tab 5-1) as independent variables through stepwise method. The correlation and regression analysis also were carried out. The relationship between the perceptual features and the corresponding physical features at typical sample points was established by SPSS 25.0.

Then, we used the six regression equations of typical samples to calculate the predictive perceptual features of all sample points. K-Means Cluster Analysis was performed on the predicted values of 344 sample points. It is a classic and effective clustering analysis method [117][118][119]. According to the elbow rule, the number of clusters were set 2-4 to obtain the best clustering results. Finally, k=3 was considered to be the best.

K-Means Cluster Analysis provides a research ideas to analyze the spatial variability in The Coastal Streets[120], which is conducive to revealing the rules for styles and features in Qingdao Coastal Streets.

5.3Qingdao Coastal Streets

5.3.1 Perceptual features and physical features

All data acquired by semantic segmentation and GIS were brought into the equations to calculate the physical features of the 344 sample points. And the perceptual features of 69 typical sample points are evaluated. The six perceptual features: imageability, enclosure, human scale, transparency, complexity and nature were respectively the dependent variables. The corresponding physical features were the independent variables. The correlation and regression analysis were performed to create six multiple linear regression models.

5.3.2 The correlation analysis

As the correlation analysis shown in Table 5-2.

Table 5-2 Correlation analysis of perceptual features and physical features

Imageability	Building with identifiers	Pedestrians	Lawn	Spatial indicative	Landscape with identifiers
Pearson correlation	.574**	.537**	0.176	.331**	.742**
Enclosure	The vertical interface	Interface buildings difference	Openness	Interface enclosure degree	
Pearson correlation	.825**	-0.177	-.856**	.620**	
Transparency	Interfacial porosity	The openness of coastal interface	The openness of inland interface	Proportion of active uses	
Pearson correlation	.720**	.831**	.581**	.241*	
Human scale	Walkable area	Traffic space	Walkable streets	Building height	Street height to width ratio
Pearson correlation	-0.214	-.555**	.387**	-.613**	.416**

Complexity	Landscape diversity index	Vehicle occurrence rate	Architecture color diversity		
Pearson correlation	.602**	.337**	.568**		
Nature	Natural Landscape	Greenness	Natural to artificial ratio of the vertical interface	Natural to artificial ratio of the horizontal interface	
Pearson correlation	0.105	.632**	.593**	.301*	

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

(1) Imageability

As the correlation analysis shown in table 4-3, the study found that the main physical features affecting imageability included building with identifiers, pedestrians, spatial indicative and landscape with identifiers, which all were positively correlated with imageability. The landscape with identifiers (0.742), building with identifiers (0.574) were the strongest correlation with imageability. It showed that iconic buildings and landscapes could enhance imageability.

(2) Enclosure

The main physical features affecting enclosure included the the vertical interface, openness and interface enclosure degree. The the vertical interface and interface enclosure degree had a positive effect on the enclosure, while openness had a negative effect. The effect of sky openness on the enenclosed space is negative. The the vertical interface (0.825) had a strong correlation with the enclosure, which indicated that plants, buildings and walls could positively affect the enclosure. They could terminate the visual extension. Openness (-0.856) had a strong negative correlation with the enclosure.

(3) Transparency

The main physical features affecting transparency included interfacial porosity, the openness of coastal interface, the openness of inland interface and proportion of active uses. They were positively correlated with transparency, among which interfacial porosity (0.720) and the openness of coastal interface (0.831) were strongly correlated with transparency.

(4) Human scale

The main physical features affecting the human scale included traffic space, walkable streets, building height and street height to width ratio. The traffic space and building height are were negatively correlated with the human scale, Walkable streets and street height to width ratio were positively correlated with the human scale; Building height (-0.613) and traffic space (-0.555) had a strong correlation with human scale.

(5) Complexity

The main physical features affecting complexity were landscape diversity index, vehicle occurrence rate and architecture color diversity. The three physical features were positively correlated with complexity. The landscape diversity index (0.602) and architecture color diversity (0.568) had positively correlated with complexity. It showed that diverse landscapes and rich colors make the environment more complex.

(6) Nature

The main physical features affecting the nature were greenness, natural to artificial ratio of the vertical interface and natural to artificial ratio of the horizontal interface. They were positively correlated with the nature. The Greenness (0.632) and natural to artificial ratio of the vertical interface (0.593) had a strong positive correlation with nature.

5.3.3 The regression analysis

The six perceptual features were used as dependent variables and the physical features screened by the correlation analysis were used as independent variables. The independent variables were allowed to enter the regression model using stepwise regression analysis. The unsuitable physical features were removed one by one. Finally, the six models of the perceptual features were established (Tab 5-3).

Table 5-3 Regression analysis results

Dependent variables	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	VIF	R2	FSig	Regression model

		B	Std. Error	Beta						
Imageability	(Constant)	2.87	0.053		53.711	0.000**		0.694	0.000**	Y1(Imageability)=0.439*X (Landscape with identifiers) + 0.254*X (Pedestrians) + 0.144*X (Building with identifiers) + 2.87
	Landscape with identifiers	0.439	0.063	0.559	6.942	0.000**	1.378			
	Pedestrians	0.254	0.057	0.324	4.421	0.000**	1.138			
	Building with identifiers	0.144	0.064	0.183	2.238	0.029*	1.424			
Enclosure	(Constant)	3.297	0.07		47.299	0.000**		0.752	0.000**	Y2 (Enclosure) = -0.863*X(Openness)+0.198*X(Interface enclosure degree) +3.297
	Openness	-0.863	0.087	-0.753	-9.887	0.000**	1.544			
	Interface enclosure degree	0.198	0.087	0.173	2.269	0.027*	1.544			

Transparency	(Constant)	2.667	0.077		34.805	0.000**		0.74	0.000**	Y3(Transparency)=0.88*X (The openness of coastal interface) + 0.307*X (The openness of inland interface) + 2.667
	The openness of coastal interface	0.88	0.087	0.716	10.113	0.000**	1.272			
	The openness of inland interface	0.307	0.087	0.249	3.524	0.001**	1.272			
Human scale	(Constant)	2.928	0.094		31.028	0.000**		0.572	0.000**	Y4 (Human scale)= -0.617*X (Building height)-0.533*X (Traffic Space) + 2.928
	Building height	-0.617	0.097	-0.523	-6.366	0.000**	1.041			
	Traffic space	-0.533	0.097	-0.451	-5.491	0.000**	1.041			
Complexity	(Constant)	2.529	0.062		40.735	0.000**		0.505	0.000**	Y5(Complexity) =0.275*X (Landscape diversity index) +0.222*X (Vehicle occurrence rate) +0.215*X (Architecture
	Landscape diversity index	0.275	0.085	0.384	3.232	0.002**	1.85			

	Vehicle occurrence rate	0.222	0.063	0.309	3.54	0.001**	1.003			color diversity) +2.529
	Architecture color diversity	0.215	0.085	0.299	2.526	0.014*	1.847			
Nature	(Constant)	3.906	0.067		57.894	0.000**		0.464	0.000**	Y6(Nature)=0.323*X (Greenness) +0.245*X (Natural to artificial ratio of the vertical interface) + 3.906
	Greenness	0.323	0.087	0.428	3.708	0.000**	1.643			
	Natural to artificial ratio of the vertical interface	0.245	0.087	0.325	2.814	0.006**	1.643			

** It is significant at the 0.01 level.

* It is significant at the 0.05 level.

As can be seen from Tab 5-4, the main physical features that impact imageability include landscape with identifiers, pedestrians and building with identifiers. The R2 for the imageability model is 0.694, indicating that the regression line is a outstanding fit for the observations. The value of F is 49.122 and the p-value for F significance is 0.000, which shows that landscape with identifiers, pedestrians and building with identifiers are statistically significant predictors of imageability. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for landscape with identifiers, pedestrians and building with identifiers are all less than 10, indicating that the Based on the spatial features of Fukuoka Streets and combined with the literature studies related to street space and the features of Qingdao coastal street, Fukuoka Streets continues the six perceptual features of Qingdao coastal street: imagability, enclosure, human scale, transparency, complexity and nature. The 17 physical features were selected. As with the Qingdao coastal street, Fukuoka Streets also uses Deeplabv3+ to identify landscape elements of GSV images and uses ArcGIS geoprocessing functions to calculate the spatial data of the street. Accordingly, physical feature indicators were calculated for all sample points on Fukuoka Streets. Subsequently, their physical feature indicators were brought into the multiple linear regression model to calculate the perceptual feature indicators of the sample points. To analyse in depth the feature types of Fukuoka Streets street space and the subsequent comparative study with Qingdao coastal street, this study also carried out K-means cluster analysis on Fukuoka Streets, setting its number of clusters (k) to 2-5 and selected the clustering results at k=3 based on expert analysis to interpret its results.

re is no multicollinearity between physical features. The above shows that the results of the regression model for imageability are valid and that the regression model fits the original data well. The final regression model for imageability is: Y1(Imageability)=0.439*X(Landscape with identifiers) +0.254*X (Pedestrians) +0.144*X (Building with identifiers) +2.87. In the imageability model, landscape with identifiers, pedestrians and building with identifiers are directly proportional to imageability . An increase in the number of identifiers buildings and landscapes leads to a higher imageability value. The higher the number of people, the higher the imageability value.

As can be seen from Table 4,the main physical features that impact enclosure include openness, interface enclosure degree. The R2 for the enclosure model is 0.752, indicating that the regression line is a outstanding fit for the observations. The value of F is 99.96 and the p-value for F significance is 0.000, which shows that openness, interface enclosure degree are statistically significant predictors of enclosure. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for openness and interface enclosure degree with identifiers are all less than 10, indicating that there is no multicollinearity between physical features. The above shows that the results of the regression model for enclosure are valid and that the regression model fits the original data well. The final regression model for enclosure is: Y2(Enclosure)=-0.863*X(Openness)+0.198*X(Interface enclosure degree)+3.297. In the enclosure model, interface enclosure degree is directly proportional to enclosure , openness is inversely proportional to enclosure , indicating that the greater the proportion of sky, the worse the sense of enclosure.

As can be seen from Tab 5-4,the main physical features that impact transparency include the openness of coastal interface and the openness of inland interface. The R2 for the transparency model is 0.74, indicating that the regression line is a outstanding fit for the observations. The value of F is 93.938 and the p-value for F significance is 0.000, which shows that the openness of coastal interface and the openness of inland interface significant predictors of transparency. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for the openness of coastal interface and the openness of inland interface with identifiers are all less than 10, indicating that there is no multicollinearity between physical features. The above shows that the results of the regression model for transparency are valid and that the regression model fits the original data well. The final regression model for transparency is: Y3(Transparency)=0.88*X(The openness of coastal interface)+0.307*X(The openness of inland interface)+2.667. In the transparency model, the openness of coastal interface and the openness of inland interface are directly proportional to transparency. Openness of coastal interface has a large effect on transparency.

As can be seen from Table 5,the main physical features that impact human scale include building height and traffic space. The R2 for the human scale model is 0.572, indicating that the regression line is a good fit for the observations. The value of F is 44.037 and the p-value for F significance is 0.000, which shows that building height and traffic space significant predictors of human scale. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for building height and traffic space with identifiers are all less than 10, indicating that there is no multicollinearity between physical features. The above shows that the results of the regression model for human scale are valid and that the regression model fits the original data well. The final regression model for human scale is: Y4 (Human scale)= -0.617*X (Building height)-0.533*X (Traffic Space)+2.928. In the human scale model, building height and traffic space are inversely proportional . Indicates a reduction in the human scale by increasing the number of storeys in the building and the space for traffic.

As can be seen from Tab 5-4, the main physical features that impact complexity include landscape diversity index,vehicle occurrence rate and architecture color diversity. The R2 for the complexity model is 0.505, indicating that the regression line is a good fit for the observations. The value of F is 22.128 and the p-value for F significance is 0.000, which shows that landscape diversity index,vehicle occurrence rate and architecture color diversity significant predictors of complexity. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for landscape diversity index,vehicle occurrence rate and architecture color diversity with identifiers are all less than 10, indicating that there is no multicollinearity between physical features. The above shows that the results of the regression model for complexity are valid and that the regression model fits the original data well. The final regression model for complexity is: Y5(Complexity)=0.275*X(Landscape diversity index) +0.222*X(Vehicle occurrence rate)+0.215*X(Architecture color diversity)+2.529. In the complexity model, landscape diversity index,vehicle occurrence rate and architecture color diversity are directly proportional to complexity . The value of complexity is increased by increasing the style of the landscape, the percentage of vehicles and the variety of architectural colours.

As can be seen from Tab 5-4, the main physical features that impact nature include Greenness and natural to artificial ratio of the vertical interface. The R2 for the nature model is 0.464, indicating that the regression line is a good fit for the observations. The value of F is 28.514 and the p-value for F significance is 0.000, which shows that Greenness and natural to artificial ratio of the vertical interface significant predictors of nature. The t-values and corresponding p-values for the models are in the "t" and "sig" columns, with sig values less than 0.05, indicating that the independent variables in the models are significant. The VIF values for Greenness and natural to artificial ratio of the vertical interface with identifiers are all less than 10, indicating that there is no multicollinearity between physical features. The above shows that the results of the regression model for nature are valid and that the regression model fits the original data well. The final regression model for complexity is:Y6(Nature)=0.323*X(Greenness)+0.245*X(Natural to artificial ratio of the vertical interface)+3.906. In the nature model, Greenness and natural to artificial ratio of the vertical interface are directly proportional to nature. Enhancing the value of nature by increasing the area of plants and green spaces.

After obtaining the linear regression models for the typical samples, the physical features of the 344 sample points were brought into the linear regression models to obtain the all predicted data for the perceptual features.

5.3.4 Cluster analysis of perceptual features and spatial heterogeneity

To further analyze the styles and features in Qingdao Coastal Streets, K-Means Cluster Analysis was used to classify 344 sample points based on the six perceptual features.

Finally, the clustering result with k=3 was selected. Combining the characteristics of various types of streets, the first type street nodes are defined as Open Streets; the second type street nodes are defined as Mixed Streets and the third type street nodes are defined as Biophilic Streets.

Fig 5-2 Distribution of three types streets.

The fig 5-2 represented the spatial distribution of three types streets. The Open Streets were mostly located in Xilingxia Road, the east and west parts of Taiping Road, Nanhai Road, Donghai West Road, the west part of Aomen Road, the west part of Donghai Middle road. The Mixed Streets were mostly located in the middle part of Taiping Road and Laiyang Road, the Taipingjiao 4th Road, the east part of the Aomen Road, Zhuhai Branch Road and the east and west parts of the Donghai Middle Road. The Biophilic Streets were mostly located in the Huiquan Road , the east and west parts of Laiyang Road, Shanhaiguan Road, Huanhai Road, Taipingjiao 1st road and the east part of Aomen road.

(1) Perceptual features of overall Qingdao Coastal Streets

By analyzing the results of six perceptual features (Tab 5-4) in 344 sample points, the ranking was as follows: Nature > Enclosure > Human scale > Imageability > Transparency > Complexity.

Table 5-4 The result of perceptual features for various types streets

	Overall urban streets		The Open Streets		The Mixed Streets		The Biophilic Streets	
Perceptual features	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
Imageability	2.870	0.625	3.304	0.667	2.715	0.410	2.424	0.368
Enclosure	3.297	0.934	2.365	0.405	3.493	0.440	4.484	0.524
Transparency	2.667	1.043	3.789	0.439	2.270	0.552	1.509	0.439
Human scale	2.928	0.840	2.663	0.803	2.743	0.841	3.668	0.300
Complexity	2.529	0.488	2.722	0.366	2.657	0.411	2.002	0.401
Nature	3.906	0.479	3.537	0.212	3.920	0.273	4.483	0.484

In The Coastal Streets in Qingdao, the mean value of nature and enclosure were higher. The mean value of nature was highest and the standard deviation was lowest, which showed that the nature was outstanding and balance in overall coastal streets; The mean value of transparency was lower and the standard deviation was higher, it showed that the interface transparency in the overall street was poor and there is a unevenly distribution of it and the values also had some fluctuation; The mean value of complexity was lowest and the standard deviation was medium, it indicated that the complexity of the environment overall street is low and there is no significant differences. It showed that the interface transparency and the landscape complexity needed to be improved in the overall coastal streets.

(2) Perceptual features comparative analysis of the three types street space

A comparative analysis for six perceptual features of three types streets was conducted to study the spatial distribution of perceptual features more clearly. In the Open Streets, the transparency, imageability and complexity were outstanding; In the Mixed Streets, all perceptual features were medium; In the Biophilic Streets,the nature, enclosure and human scale were outstanding. There are both three high perceptual features and low perceptual features in the Open Streets and the Biophilic Streets, and the mix streets had two high perceptual features and four low perceptual features. The results showed that the distribution of perceptual features in the Open Streets and the biophilic street space was more significant and more outstanding.

As shown in Table 5-4 and Fig 5-3, the nature was high perceptual feature in all three types streets. It showed that there were high plant coverage and the richness layers of the plants in Qingdao Coastal Streets, they created a street environment which fulled of the nature. Meanwhile the nature was the highest in the Biophilic Streets, however, the standard deviation of nature in the biophilic street space was higher than the other two types of street spaces, it indicated that there are some nodes with low nature in the Biophilic Streets.

The transparency was high perceptual feature and the standard deviation was medium in the Open Streets, the street interface was transparent and the overall transparency of the space was high and balanced. The transparency was low in the Mixed Streets and the Biophilic Streets, the overall transparency of the street interface was poor.

The enclosure was high perceptual feature in the Mixed Streets and the Biophilic Streets. It was low in the Open Streets.

The human scale was high perceptual feature, and the standard deviation was low in the Biophilic Streets. It showed that the Biophilic Streets conform the human scale; The human scale was low in the Mixed Streets and the Open Streets, but the standard deviation was high, it indicated that most of the street node spaces do not conform to the human scale.

The imageability was high perceptual feature and the standard deviation was high in the Open Streets. It showed that the imageability distribution was not balanced and the value of imagerability was high fluctuating. The imageability was low perceptual feature in the Biophilic Streets and Mixed Streets. Due to lacking of iconic landscape and landscape diversity, it could not deepen the impression of the observers. The standard deviation of imagerability in the Biophilic Streets space was low, it can be seen that the imagerability of the overall costal street was low.

The complexity was the low perceptual feature and stably distributed in three types streets.

Fig 5-3 Perceptual features of various types streets in Qingdao.

(3) Comparative analysis of the six perception features for each type street space interior

It could be concluded from Figure 5-7, in the Open Streets, Transparency> Nature> Imageability> Complexity> Human scale> Enclosure. The transparency and nature were high, the enclosure was low. Compared with other features, the transparency and nature were better perceived by the pedestrians in the Open Streets.

In the Mixed Streets, Nature> Enclosure> Human Scale> Imageability> Complexity>

Transparency. Therefore, the nature and enclosure were high, the transparency was low. The large-size buildings and the dense street trees formed the enenclosed interface in the Mixed Streets.

In the Biophilic Streets, Enclosure > Nature > Human Scale > Imageability > Complexity > Transparency. The enclosure and nature were extremely high, human scale was high, the complexity and transparency were low. The lush street trees created a highly enenclosed interface, and The dense street trees were full of vision. The layered and lush natural landscape not only promoted the nature of the street, but also reduced the transparency of the street interface. The Biophilic Streets conformed the human scale. However, the significant plants landscape caused monotonous landscape space, and the complexity was reduced. The main landscape elements the biophilic street space were plants, buildings and roads, the single landscape element also reduced the complexity in the street.

(4) Comprehensive analysis of perceptual features and physical features

We counted the mean values of perceptual features (Tab 5-5) and physical features in The Coastal Streets,and respectively compared the overall streets with the three types of streets.

Table 5-5 The mean value of physical features

Perceptual features	Physical features	Overall urban streets	The Open Streets	The Mixed Streets	The Biophilic Streets
Imageability	Building with identifiers	1.753	2.377	1.597	1
	Pedestrians	0.008	0.011	0.006	0.008
	Lawn	0.062	0.069	0.055	0.064
	Spatial indicative	0.007	0.008	0.008	0.006
	Landscape with identifiers	2.276	2.908	2.09	1.563
Enclosure	The vertical interface	0.43	0.277	0.462	0.625
	Interface buildings difference	0.128	0.143	0.137	0.09

	Openness	0.258	0.392	0.229	0.09
	Interface enclosure degree	1.529	0.928	1.576	2.426
Transparency	Interfacial porosity	0.399	0.519	0.359	0.269
	The openness of coastal interface	0.296	0.522	0.211	0.073
	The openness of inland interface	0.144	0.227	0.124	0.043
	Proportion of active uses	0.128	0.145	0.108	0.134
Human scale	Walkable area	4.519	5.412	4.269	3.488
	Traffic Space	9.696	9.319	11.388	7.475
	Walkable Streets	0.443	0.422	0.366	0.607
	Building height	2.654	2.294	2.69	1.475
	Street height to width ratio	1.529	0.928	1.576	2.426
Complexity	Landscape diversity index	1.881	1.961	1.973	1.599
	Vehicle occurrence rate	0.104	0.117	0.107	0.075
	Architecture color diversity	2.157	2.615	2.269	1.225
Nature	Natural Landscape	0.009	0.017	0.006	0.002
	Greenness	0.344	0.187	0.366	0.559

	Natural to artificial ratio of the vertical interface	9.701	2.99	7.306	24.619
	Natural to artificial ratio of the horizontal interface	0.243	0.245	0.222	0.276

In the Open Streets, the mean value of the four perceptual features: transparency (3.789>2.667), imageability (3.304>2.870), enclosure (2.365<3.297), nature (3.537<3.906) were significant different with the overall streets. By comparing and analyzing physical features in the Open Streets with the overall street, it could be seen that the the vertical interface and interface enclosure degree were low in the Open Streets, while the openness, interfacial porosity, openness of coastal interface, openness of inland interface and walkable area were high. The Greenness and natural to artificial ratio of the vertical interface were low, which caused that the nature was reduced and the transparency of the street interface was improved. The building with identifiers and landscape with identifiers were higher. It showed that there were many unique buildings and landscapes in the Open Streets, the streetscape was more attractive to the observers.

In the Mixed Streets, The transparency (2.270<2.667) were lower than overall street. The other five perceptual features were similar to the overall street. In addition, the low interfacial porosity, the high interface enclosure degree and vertical interface indicated that the street interface transparency was poor in the Mixed Streets.

In the Biophilic Streets, all perceptual features: the nature (4.483>3.906), human scale (3.668>2.928), enclosure (4.484>3.297), complexity (2.002<2.529) and transparency (1.509<2.667), imageability (2.424<2.870) were very different with the overall street. The Greenness and natural to artificial ratio of the vertical interface were high , particularly, the natural to artificial ratio of the vertical interface was the highest. The result indicated that the plants coverage was extremely high, and the building density were low. Moreover, There were many high trees caused stronger nature. The vertical interface and interface enclosure degree were high. The openness, interfacial porosity, openness of coastal interface and openness of inland interface were low. The high-density vegetation and buildings formed the continuous and enclosed street interface, which enhanced the nature in the Biophilic Streets. However, they blocked view and caused the lower transparency. The street height to width ratio and walkable streets were higher, the traffic space and building height were lower. The result indicated that the streets had strong walkability. The small-size buildings created a street space which conformed to the human scale.

In addition, the landscape diversity index, vehicle occurrence rate and architecture color diversity were lower in the Biophilic Streets. The landscape elements and architectural colors were monotonous that reduced the complexity. Meanwhile, the building with identifiers and landscape with identifiers were lower. It indicated that the Biophilic Streets lacked the attractive landscapes and buildings that caused the low imageability.

5.4 Coastal streets of Fukuoka

5.4.1 Cluster analysis of perceptual features and spatial heterogeneity

In this study, all the data obtained by semantic segmentation and GIS were brought into the equation to calculate the physical features of 380 sample points. Then the physical features of 380 sample points were brought into the linear regression model to obtain all the predicted data of perceptual features.

To further compare and analyze the street features of Fukuoka Streets, this paper conducted K-means clustering on the perceptual features of 381 sample points of Fukuoka Streets and divided streets into three categories: Low Perception Streets, High Perception Streets and coastal streets (Fig 5-4).

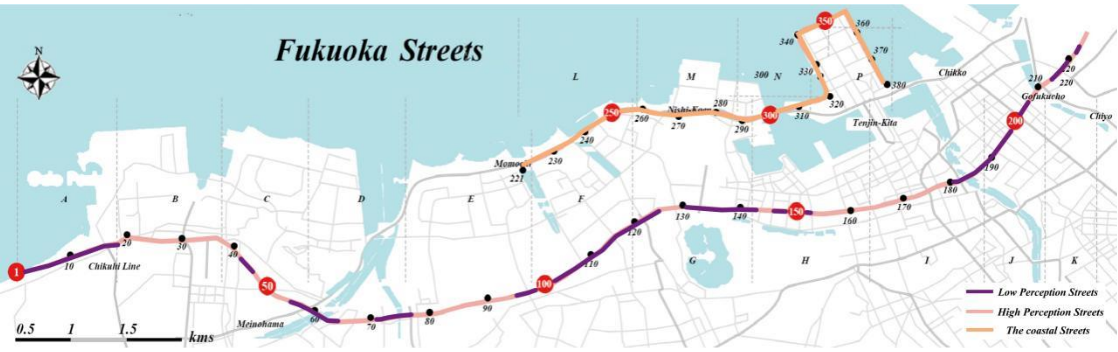

Fig 5-4 Distribution of three types streets.

5.4.2 Perceptual features of overall Fukuoka Streets

By analyzing the results of six perceptual features of 380 sample points in Fukuoka Streets (Tab 5-6), the order is as follows: transparency > imageability > nature > complexity > human scale > enclosure. In Fukuoka Streets, the average value of transparency and imageability was high. Among them, the standard deviation of transparency was high and the standard deviation of imageability was low, which showed that the overall imageability of Fukuoka Streets was strong and evenly distributed. The average values of nature, human scale and complexity were low. Among them, the standard deviation of complexity and nature was low, indicating that they were poor and their features were stable in the whole street. The mean value of enclosure was the lowest and the standard deviation was high. The result showed that the overall enclosing feeling of the street was poor, but its features were unevenly distributed and there were nodes with higher enclosure in the street.

Table 5-6 The result of perceptual features for various types streets

	Overall urban streets		The Low Perception Streets		The High Perception Streets		The Coastal Streets	
Perceptual features	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
Imageability	3.251	0.395	3.263	0.291	3.393	0.254	3.150	0.502
Enclosure	2.236	0.932	1.434	0.387	2.621	0.437	2.650	1.051
Transparency	4.027	0.835	4.701	0.289	3.812	0.342	3.610	1.000
Human scale	2.457	0.785	2.389	0.678	2.248	0.624	2.646	0.910
Complexity	2.409	0.329	2.371	0.284	2.593	0.322	2.320	0.322
Nature	2.709	0.389	2.535	0.095	2.604	0.145	2.920	0.526

5.4.3 Perceptual features comparative analysis of the three types street space

To study the spatial distribution of perceptual features of streets clearly(Fig5-5), this study compared and analyzed six perceptual features of three types of streets. In these three types street space, imageability and transparency were prominent perceptual features. Human scale, complexity, nature and enclosure were all low perception features.

From Table 5-6, it can be seen that the imageability was high and the standard deviation was low in Low Perception Streets (3.263) and High Perception Streets (3.393). The imageability was high and the standard deviation was medium in The Coastal Streets (3.150). These indicated that imageability in these three types of streets was significant and there was no obvious fluctuation. Fukuoka Streets contained many landmark landscape elements, among which there were many indicative signs. They increased the attraction of Fukuoka Streets to pedestrians, thus enhancing the impression of Fukuoka Streets..

Transparency was a highly perceptual feature in these three types of street space. The interface of Fukuoka Streets had strong transparency, open space, discontinuous and porous street interface and a strong sense of penetration in the street environment. Enclosure was the least significant low-perception feature and the overall enclosure of street space was poor.

Human scale was low in these three types of street space. Their standard deviation was high, which indicated that the whole street of Fukuoka Streets did not conform to the pedestrian scale, but there were street spaces in some nodes that conform to the pedestrian scale.

The complexity was low in these three types of street space. Their standard deviation was low, which indicated that the complexity of the whole streets of Fukuoka Streets was poor and the distribution was stable. The overall street color was single. The architectural style was unified and the landscape elements in streetscape were lacking., resulting in the low complexity of the street environment.

Nature was a low perceptual feature in these three types of street space. The result showed that the overall nature of Fukuoka Streets was low. In the three street spaces, the plant coverage area was small and the vegetation types were relatively consistent and the plant landscape lacked diversity and layering.

Fig 5-5 Perceptual features of various types streets in Fukuoka

5.4.4 Comparative analysis of the perception features for each type street space interior

Table 5-7 showed that transparency > imageability > nature > human scale > complexity > enclosure in the Low Perception Streets. In The Coastal Streets, transparency > imageability > nature > enclosure > human scale > complexity. Transparency and imageability were more significant. Complexity was less significant. The permeability of the street interface was more easily perceived by pedestrians than that of other landscape features. The sense of the boundary of the street interface was weak. The viewing horizon was more open and the street's sense of transparency was stronger.

In the space of High Perception Streets, transparency > imageability > enclosure > nature >

complexity > human scale. In the High Perception Streets, transparency, imageability and enclosure were more significant, while complexity and human scale were less significant. In the High Perception Streets, the buildings on both sides of the street were large and the arrangement of buildings was continuous. The width of the street was lower than the height of the buildings. By combining the above streetscape elements, a comfortable sense of closure was formed in the High Perception Streets.

5.4.5 Comprehensive analysis of perceptual features and physical features

Through the statistics of the average value of perceptual features and the average value of physical features (Table 5-7) of Fukuoka Streets as a whole and the three types of streets, a comparative analysis was made.

Table 5-7 The mean value of physical features

Perceptual features	Physical features	Overall urban streets	The Low Perception Streets	The High Perception Streets	The Coastal Streets
Imageability	Building with identifiers	2.068	2.460	2.960	1.169
	Pedestrians	0.002	0.002	0.003	0.001
	Spatial indicative	0.006	0.008	0.006	0.005
	Landscape with identifiers	3.105	2.930	3.040	3.292
Enclosure	the vertical interface	0.281	0.270	0.435	0.191
	Openness	0.435	0.512	0.344	0.431
Transparency	The openness of interface	0.435	0.512	0.344	0.431
Human scale	Walkable area	5.968	9.319	10.318	0.408
	Traffic Space	14.526	15.236	15.450	13.344
	Walkable Streets	0.199	0.235	0.267	0.126
	Building height	2.137	2.360	2.620	1.643
Complexity	Landscape diversity index	1.699	1.684	1.855	1.611
	Vehicle occurrence rate	0.098	0.123	0.117	0.065
	Architecture color diversity	1.958	2.540	2.710	1.000
Nature	Greenness	0.063	0.055	0.095	0.049
	Natural to artificial ratio of the vertical interface	0.466	0.277	0.389	0.672
	Natural to artificial ratio of the horizontal interface	0.027	0.037	0.049	0.006

In the Low Perception Streets, the average values of transparency (4.701>4.027) and enclosure (1.434<2.236) were significantly different from those of the whole street, while the other four perceptual features were similar to those of the whole street. By comparing and analyzing the physical features of the transparent street and the whole street, it can be seen that in the transparent street, the sky openness and interface openness were higher, while the vertical interface closure and building height were lower. In the Low Perception Streets, the sky accounted for a relatively large proportion in pedestrians' vision. At the same time, due to the low height of buildings on both sides of the street, the arrangement of buildings was relatively sparse, which formed a street interface with many pores, thus improving the overall transparency of the street and the openness of the space.

In the High Perception Streets, the average values of enclosure (2.621>2.236) and transparency (3.812<4.027) were significantly different from those of the whole street and the other four perceptual features were similar to those of the whole street. In the High Perception Streets, the vertical interface closure and building height were high, while the sky openness and interface openness were low. In the High Perception Streets, the buildings on both sides of the street were dense and continuous. The continuous street interface formed by the building facade enhanced the vertical interface closure of the street. In addition, the buildings on both sides of the street were higher in the closed streets, which also promoted the formation of the sense of street space closure.

In the Coastal Streets, the average values of enclosure (2.650>2.236) and transparency (3.610<4.027) were significantly different from those of the whole street and the other four perceptual features were similar to those of the whole street. Among them, the landscape with identifiers and the natural to artificial ratio of the vertical interface were high, while the building with identifiers, walkable area and building height were low. The Coastal Streets have a rich waterfront landscape and undulating terrain changes, which enhance the landscape with identifiers. In order to ensure the openness of The Coastal Streets and the sea view effect, there is a lower building height on both sides of the street.

5.5 Discussion

5.5.1 Perceptual features and physical features

The study takes Qingdao Coastal Streets of China and Fukuoka Streets, Japan as examples, the study discussed the impact of physical features on perceptual features in the streets.

The results of imageability were consistent with Quercia, the high imageability means the streetscapes are unique and attractive[122]. Some studies also showed that the iconic buildings and landscape elements can attract attention and make the street space more unique [17][123][124].

The results of the enclosure showed that the denser buildings and plants led to the less sky and higher enclosure[55][72]. It indicated that the plants, buildings and walls have a positive impact on the enclosure, and promote to form the sense of direction.

The openness of coastal interface was the most positive physical feature impacting transparency. The transparency is related to visual landscapes elements and human activity in the streets[125]. The transparency can be enhanced by reducing the density of buildings and tall shrubs. It can improve the visibility of the seascapes.

Human scale was negatively correlated with the traffic space and building height. It indicated that high-rise buildings and wide streets led to streets oppressiveness and affected the perception of human scale[56][57].

Complexity was strongly correlated with landscape diversity index and architectural colour diversity. Ewing thought that complexity is mainly influenced by architectural diversity and landscape elements. Rapoport found the complexity is related to the frequency of apparent differences seen by the observers[126].

The Greenness was the main physical features that impacting nature. The result was the same as Xu, the Greenness positively influenced the human perception on the nature in the streets[120]. The plants have positive impact on the urban streets design quality [127]. As the mainly element, it could improve the sense of nature by increasing the plants coverage[128].

5.5.2 The streets clusters

By combining with previous studies on Qingdao Coastal Streets[129][130][131] and Japan Fukuoka Streets, the result of streets clusters was almost consistent with the geographical distribution of types style and features districts which proposed by Han.

In addition, Jiang pointed out that the architectural style was slightly cluttered in some historic nodes[132]. Lang proposed that the spatial perception and walking experience were low on the old town sidewalk[20]. It also confirmed the results of K-Means Cluster Analysis .

In fact, the K-Means Cluster Analysis can accurately classify the spatial features of Coastal Streets. It obtains the features of each spatial type and the difference of various spatial types.

5.5.3 Spatial heterogeneity and comprehensive analysis

According to the comprehensive analysis of perceptual and physical features, it was found that the overall Coastal Streets were full of nature and vitality, however due to the lack of vegetation in the overall street, the nature in Fukuoka was much less than The Coastal Streets of Qingdao.

The natural environment had significant impact on human perception[133][134]. Vegetation is the important component of the urban ecosystem[8]. The vegetation coverage was generally high in Qingdao Coastal Streets. It had positive impact on emotions and psychology[135], and enhanced aesthetic perception[128]. Moreover The high positive effect of street greenery offsets the relatively low positive effect of the building frontage[136].

There were obvious difference in the Spatial features among the coastal street of Qingdao and Fukuoka Streets.

In the Open Streets of Qingdao, buildings were multiple styles and Medium-sized. The nature, imageability and transparency were high value feature, the enclosure was low. In the Low Perception Streets of Fukuoka Streets, there was consistent architectural style, with significant differences in building massing. Among them, Transparency is a high perceptual feature and the rest of the features are low perceptual features. The imageability make streets unique, the iconic landscapes and buildings facilitate the public to perceive street space. Medium-sized buildings can avoid the view blocked. The sense of penetration produced by the boundary opening, discontinuity and porosity intensifies the scenic beauty creation of open space unit. This result is consistent with the conclusion drawn by Tveit [137]stating that half-open space is preferred to a very closed one. The natural atmosphere and unobstructed view created the street space with sense of nature and transparent interface. In the blue space of waterfront streets, the depressing atmosphere can be reduced by the lower enclosure [8]. But the lower interface enclosure degree limits the street walkability and leads to less walking behaviors [4]. Moreover, the scenic beauty of the open space can be promoted by generating visual extension, since the visibility may evoke the imageability and gains viewers attention [138]. In the construction of Open Streets, the sense of enclosure should be Improved by enhancing the vegetation density.

In the Mixed Streets of Qingdao and enclosed street of Fukuoka, there were many modern buildings, high-rise buildings and wide streets. The complex streetscape enriched the visual perception. The nature and enclosure were significant, the human scale was lower. The High

Perception Streets can create the sense of safety, and provide the communication opportunities for the public[8][95]. But the high-rise buildings and wide roadways caused the worse perception of the human scale, Ewing considered that the human scale directly influence experience in urban street design. Alexander et al. state that the total width of the street, building to building,should not exceed the building heights in order to maintain a comfortable feeling of enclosure. Therefore, the sidewalk should be appropriately widen to enhance the human scale.

In the biophilic street of Qingdao, there were many historic buildings and lush landscape. The Biophilic Streets had the high nature, enclosure and human scale. But the imageability, transparency and complexity were low. The rich plant improved the vitality and nature, it created pleasant mood [5]. The degree of street enclosure is closely related to the density of buildings and trees [8]. The building density was low, and the lush vegetation formed a enclosed street interface. It enhanced the sense of enclosure and safety, but the enclosed interface blocked the views of seascape. Reid Ewing mentioned that trees play more important role than buildings for defining space in the streets with low density building [17].

Due to the plants were the dominant landscape element and buildings were less colorful in overall Coastal Streets of Qingdao, the complexity and imageability were both lower. The attraction of streets was depended on the complexity of streetscape[139][140]. In addition, the imaginability and transparency have important impact on walkability[63]. The comfortable walking experience is good for physical and mental health of people [142] and social and economic development[143]. The transparency of Qingdao Coastal Streets and the attractiveness of seascape can be enhanced, by reducing the plants on the seaview side, increasing the openness of the coastal viewing areas, enhancing the visibility of blue space, and controlling the rhythm between the openness and enclosure in the Qingdao Coastal Streets [72]. In addition, the complexity and imaginability of coastal streets can be enhanced by adding iconic buildings and landscape nodes. For Fukuoka Streets, it is the most important to enhance the greenery and sense of enclosure. The nature and enclosure of Fukuoka Streets can be enhanced by appropriately increasing the number of buildings and improving the street greenness, the enhancement of vegetation helps people to express their suppressed and discontented feelings. In addition, The Coastal Streets in Fukuoka Streets are necessary to improve the attention to the walking space, through the construction of walkable area, to meet the people's waterfront accessibility needs.

Comparing Qingdao Coastal Streets with Fukuoka Streets,we found that in the six types streets,The Open Streets in Qingdao coastal streets and The High Perception Streets in Fukuoka streets had the high value of imageability. The biophilic streets in Qingdao coastal streets had the highest values of enclosure ,hunman scale and nature, and had the lowest values of transparency and Imageability. The Low Perception Streets in Fukuoka Streets had the highest Transparency , and lowest enclosure and nature.

Comparing Qingdao Coastal Streets with Fukuoka Streets,we found that in the six types streets,the biophilic Streets had the highest values of beautiful and wealthy,while the Coastal Streets in Fukuoka Streets had the lowest values.The high perception streets in Fukuoka Streets had the highest values in safety and lively. The biophilic streets had the lowest value of safety ,while the the coastal streets in Fukuoka Streets had the lowest value of lively.The coastal streets of Fukuoka streets had the highest value of depressing and boring ,and the high perception streets in Fukuoka streets had the lowest value.

5.6 Conclusion

The quantitative methods were used to measure and evaluate the space features of Qingdao Coastal Streets and Japan Fukuoka Streets in the study. It also conducted correlation analysis, regression analysis and cluster analysis.

The study showed that each of the six perceptual features was influenced by the corresponding physical features. The imageability was mainly positively influenced by iconic architecture and landscape; the enclosure was impacted negatively by sky openness and positively by interface enclosure; The transparency was mainly positively influenced by interface openness, especially the coastal interface openness; Building levels and vehicular space were physical features that affecting human scale, both of which were negatively correlated with human scale; The complexity were not only influenced primarily by landscape diversity but also associated with vehicle incidence and building color; The physical features affecting the nature contained Green View Rate and vertical interface natural to artificial ratio. Green View Rate is the most dominant physical perceptual feature affecting nature. In Fukuoka Streets, the enclosure was the more prominent perceptual feature, the others perceptual features were low perceptual features.

Compared Qingdao and Fukuoka streets :For the whole urban streets, Qingdao Coastal Streets had an outstanding Nature and a high degree of Enclosure, while the Fukuoka Streets had a high degree of Transparency but a low degree of Enclosure; For the coastal streets,the Coastal Streets in Fukuoka corresponded to the Open Streets of Qingdao Coastal Streets.The study showed that the street spatial features of the coastal areas were similar and the evaluation results tended to be consistent.In general, the Complexity and Nature of Open Streets in Qingdao were higher than Coastal Streets in Fukuoka.

The results revealed that the influence mechanism of the physical features to the perception features in Qingdao Coastal Streets, and objectively reflected the landscape quality of the Qingdao Coastal Streets and Fukuoka Streets. It provided accurate data support for the study and design of urban Streets regeneration. That is important for urban streets planning and management, especially improving the design quality of coastal street space in Qingdao. In-depth study of the commonality between the physical features and psychological perception in urban street space, can not only comprehensive evaluate the street space quality, but also provide scientific support for the differentiated quality improvement strategies of street space in the coastal cities.

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Chapter 6

THE PUBLIC PERCEPTION OF STREET SPACE IN COASTAL CITIES

CHAPTER SIX: THE PUBLIC PERCEPTION OF STREET SPACE IN COASTAL CITIES

6.1 Introduction

With the development of the economy, the development of cities all over the world had changed from "high speed" to "high quality", the urban environment was more and more closely related to people's happiness index. It is particularly important to examine the relationship between public visual perception ,street features and the spatial quality.

Qingdao was an important coastal city of China, coastal streets play an important role in the urban development of Qingdao, and was a featured block of Qingdao. The quality of urban coastal space could affect urban landscape, public behavior of urban residents and their physical and mental health. It was characterized by the combination of natural and artificial features. The planning and construction of urban space were also affected by this. As a result, the street space was closed, the sea view was blocked, the air permeability of the street interface was poor, and the elements of the streetscape landscape were single. This series of problems leads to the poor quality of coastal streets in Qingdao.

Fukuoka, the capital of Kyushu, was the economic and cultural center of Kyushu. Meiji Streets and the Coastal Streets not only were important urban streets in Fukuoka, but also was an special part of urban space.Studying the urban landscape maintenance of Fukuoka Streets from the perspective of perceptual experience had positive significance for enhancing urban image, enriching urban space and improving environmental quality.

6.2 Site and method

6.2.1 Observers and evaluation method

By analyzing each established scale with SD method, the concept and structure of the object could be quantitatively described [1]. Because of its good applicability, this method had been widely used in environmental evaluation research [2][3]. 570 sample points were collected as typical sample data for SD feature evaluation. SD usually requires 20-50 evaluators with relevant professional knowledge. We adopted online questionnaire for the public. 100 questionnaires were recovered and 91 were valid.The panoramic images were used in the evaluation process and evaluated on a 5-point scale (1-5). Compare positive or negative adjective expressions with current events. In this case, the higher the score, the closer was to the average of the adjective on the right.

6.2.2 Data analysis

In the first stage, this paper uses SPSS26.0 to calculate the standardized values of the perceptual dimension characteristic data in the samples, so as to facilitate the comparative analysis of perceptual dimensions and the visual analysis of the distribution of perceptual dimensions.

In the second stage, SPSS26.0 was used to conduct Pearson correlation analysis on the six dimensions of the sample perception data to determine the relationship between them and judge the positive or negative impact between each perception dimension.

In the third stage, Pearson correlation analysis was conducted on the perception dimension and the physical feature data in street space to determine the influence of physical factors in street space on the six perception dimensions, the physical feature elements of landscape street were analyzed.

6.3 Result

EXCEL was used to conduct statistical analysis and counting of the six perceptual dimension eigenvalues in 570 samples, and the perceptual dimension data obtained by SD scoring was used to estimate the perceptive distribution in Qingdao Coastal Streets and Fukuoka Streets. First, the perception scores of all images of Qingdao Coastal Streets and Fukuoka Streets in Fukuoka, Japan were collected, then we then use street points as visual units to connect street Spaces through street points and their perceived scores.

6.3.1 Qingdao Coastal Streets spatial distribution analysis of perceptive dimension features

The spatial distribution of perceptual dimensional features could be measured in Figure7-1 and 7-2, where we found that emotional states differ geographically at the city scale and that some emotional state indicators were distributed in similar spatial patterns.

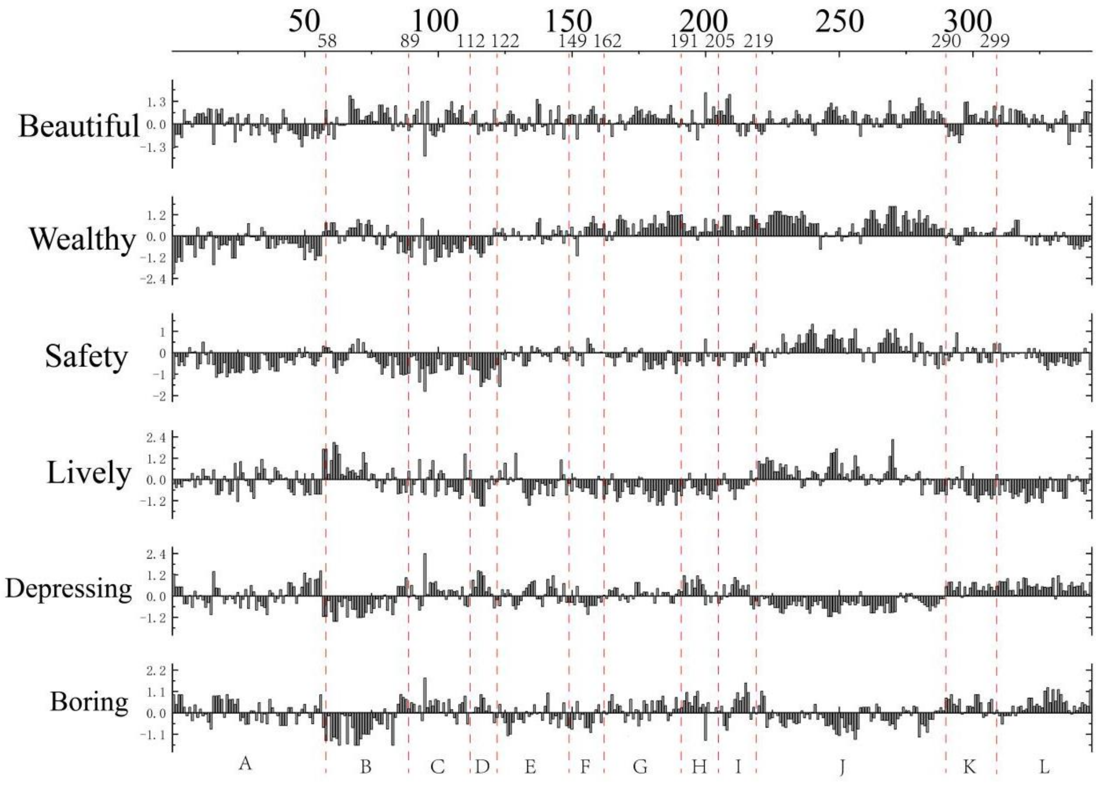

Fig 6- 1 Qingdao Coastal Streets Perceptual Dimensional Distribution

The average Beautiful perception score in Block A was -0.11, the average perception of affluence was -0.51, the average Safety perception was -0.45, the average perception of vitality was -0.09, the average Depressing perception score was 0.05 and the average perception of boredom was 0.07. The six perceptual features were more evenly distributed, with perceptions of Beautiful, wealthy, Safety and Lively scoring negatively on average and Depressingand Boring positively. One part of the sample in Block A had little street vegetation, bare ground, sparse and low buildings and relatively little environmental maintenance, with floating green algae, while another part was overly wooded and concentrated, with wide roads, lack of pedestrian space and a single color and plant level in the landscape. The high perceived vibrancy score of the district was due to the fact that this section of the street was a commercial Block with a high density of pedestrian and vehicular traffic and a relatively high number of shops.

The average Beautiful perception score in Block B was 0.35, the average Wealthy perception was 0.05, the average Safety perception was -0.36, the average Lively perception was 0.33, the average perception of the Depressingwas -0.50 and the average Boring perception was -0.60. This section of the street had open spaces, with a hierarchy of vegetation landscape distribution, but the plants were relatively monochromatic, mainly in dark colors, and the seafront had a large space to visit and attract crowds, with iconic buildings and a coordinated color scheme for the streetscape.

The average Beautiful perception score in Block C was 0.21, the average Wealthy perception was -0.69, the average Safety perception was -0.63, the average Lively perception was -0.16, the average perception of the Depressingwas 0.22 and the average Boring perception was 0.30. The perceptual dimension values of the sample photos were predominantly positive, with point 95 having a Beautiful rating of -1.84 and a perceived Safety rating of -1.80, which was the lowest rating point for Beautiful and Safety for the whole street, this was due to the fact that point 95 was under construction, the fence was blocked the view and there were no greenery, shoreline or other landscaping made it less beautiful. There were long stretches of construction sites with high traffic flow, few traffic lights and dense vegetation on both sides, and gave a feeling of congestion; at the same time there were some old buildings that were not properly maintained, with peeling siding on the building facades and many dirty rain stains inside the buildings.

The average Beautiful perception score in Block D was 0.02, the average Wealthy perception was -0.49, the average Safety perception was -0.98, the average perception of the Lively was -0.67, the average Depressing perception score was 0.52 and the average Boring perception was 0.20. The average Wealthy perception, Safety and Lively was lower, and the average perception of the Depressing and Boring was higher. This section was dominated by roads and green belts with lush vegetation, but lacked buildings and was sparsely populated, with traffic being the main function. Points 116 and 117 with a rating of -1.50 were the lowest rated points for the entire section of road, a section of street with a single view, a dense vegetated landscape and a low overall activity level.

The average Beautiful perception score in Block E was 0.11, the average Wealthy perception is 0.08, the average perception of the Safety was -0.16, the average perception of the Lively was -0.21, the average Depressingperception score was 0.10 and the average Boring perception was -0.22. Among them, points 269, 270 and 271 were at the highest affluence level of the whole street, with a rating of 1.66, as this section of the road was flanked by dense shopping malls, tall buildings, high population movements, well maintained vegetated landscapes and neat and tidy roads.

The average Beautiful perception score in Block F was 0.32, the average Wealthy perception was 0.35, the average Safety perception was 0.04, the average Lively perception was -0.52, the average perception of the Depressingwas -0.36 and the average Boring perception was -0.30. High scores for Beautiful and Wealthy, medium scores for Safety, negative scores for Lively, Depressing and

Boring perception, F was dominated by roads, predominantly vegetated with a few buildings and lush, evenly distributed vegetation.

The average Beautiful perception score in Block G was 0.32, the average Wealthy perception was 0.66, the average Safety perception was -0.33, the average Lively perception was -0.74, the average perception of the Depression was 0.12 and the average Boring perception was 0.21. The Wealthy perception was higher with negative values for Safety and Lively, positive values for Beautiful, Depression and Boring. This block was rich in landscape plants, plant community was an important factor affecting the landscape aesthetic value [4]. The buildings had various forms and rich colors, but the safety dimension was in the middle and lower level. Most of them were near the sea or are construction sites, and the enclosure of the construction sites was low, with many vehicles and narrow roads.

The average Beautiful perception score in Block H was 0.26, the average Wealthy perception was 0.41, the average Safety perception was -0.25, the average Lively perception was -0.53, the average perception of the Depression was 0.35 and the average Boring perception was 0.34. The Beautiful perception dimension is rated high, with the highest point being point 200 with a rating of 1.78. The open sky in this Block is in harmony with the color of the water and the buildings, and the rich variety and lushness of the vegetation gives the tour area a natural feel and a more layered space.

The average Beautiful perception score in Block I was 0.22, the average perception of the Wealthy was 0.71, the average perception of the Safety was -0.20, the average perception of the Lively was -0.30, the average perception of the Depression was 0.25 and the average perception of the Boring was 0.31. Point 240 was the point with the highest rating on the perception of the Safety dimension, with a score of 1.33 for this review, as the section of the street was well planned in order, with clean roads, less traffic and more space for visitors to walk.

The average Beautiful perception score in Block J was 0.33, the average perception of the Wealthy was 0.69, the average Safety perception was 0.30, the average Lively perception was 0.29, the average perception of the Depression was -0.49 and the average perception of the Boring was -0.27. Point 270 was the highest rated point in the entire section with a score of 2.25, due to the density of surrounding residential blocks, business buildings and commercial streets.

The average Beautiful perception score in Block K was -0.12, the average perception of the Wealthy was 0.01, the average perception of the Safety was 0.06, the average perception of the Lively was -0.32, the average perception of the Depression was 0.45 and the average Boring perception was 0.42. This section of the street scores high on the Depression and Boring perceptual dimensions, as this section of the street had single views, with more vegetated landscaping on both sides and sparse architecture. The street was functional because of the lack of entertainment venues near this section of the street.

The average Beautiful perception score in Area L was 0.23, the average Wealthy perception was -0.06, the average Safety perception was -0.22, the average Lively perception was -0.63, the average Depression perception score is 0.55 and the average Boring perception was 0.39. The block had positive values for Beautiful, Depressed and Boring, and negative values for Wealthy, Safe and

Lively. The street was dominated by roads with wide roads and open skies, roads with a few vehicles and a lack of pedestrian space, a concentration of trees and darker plants in the 300-332 sample and an even distribution of plants in the 333-344 sample, with more plants overall and a clear hierarchy of plants.

6.3.2 Fukuoka Streets spatial distribution analysis of perceptive dimension features

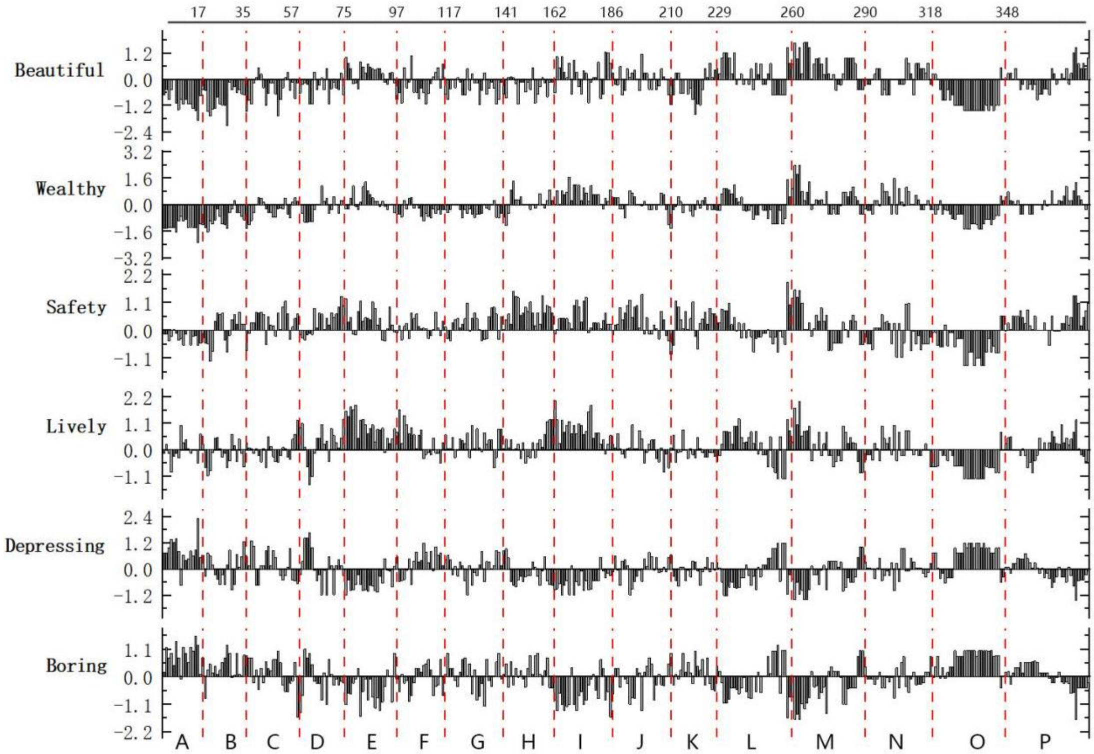

Fig 6- 2 Fukuoka Streets Perceptual Dimensional Distribution

The average value of the Beautiful in Block A of Fukuoka Streets was -0.94, which is lower overall because of the low buildings, poor colors and confusing wires in this section of the road. The average value of the Wealthy in Block A was -1.30, and most of the buildings were low-rise buildings, with no street trees on both sides of the street and narrow roads. The average value of Safety in Block A was -0.28. There were no fences on both sides of the street, and the wires were lower from the ground. The average value of the Lively in Block A was 0.02. The Lively of the street in this block was average, and the large area of street buildings was grayish white, but the concentrated vegetation at some points brought lively to the street. The average value of Depression in Block A is 0.82, the traffic flow in the street was less, the building color was lighter, and it looked desolate. The average value of Boring in Block A was 0.84, this block had a high Boring score., because the road design in this block pursues consistency, and there was no continuous street tree decoration and lacked color.

The average value of the Beautiful in Block B Fukuoka Streets was -0.97, which was low overall, and the No.24 was the lowest score in all samples. The environment of the streets in this block was chaotic, with few green plants and monotonous overall. The average value of Wealthy in Block B was -0.84, the overall average score of the perceived dimension of Wealthy was low, because most of the street buildings were grayish-white, the buildings were old and scattered, and there were few commercial buildings. The average value of Safety in Block B was -0.03, the streets were narrow, the road planning was poor, and the residential residence were close to the roads. The average value of Lively in Block B was -0.17, the streets lacked open entertainment squares, and the buildings at some points were relatively compact, which made the block boring. The average value of Depression in Block B was 0.09, with quiet streets, narrow roads and lacked of green plants.

The average value of the Beautiful in Block C Fukuoka Streets was -0.43, which was low overall. The buildings appearance was mostly arranged in geometric figures, and the branches and leaves of street trees on both sides of the road were sparse; the average value of Wealthy in Block C was -0.23, with sparse building and high sky openness. The average value of Safety in Block C was 0.34, with a high Safety value, wide roads, less traffic and no congestion. The average vitality of District C was 0.02. The street buildings in this block were the same, with single function and few featured landscapes. The average value of Depression in Block C was 0.13. This block was in an underdeveloped area, with a high Depression index and low color brightness of pavement and buildings. The average value of Boring in Block C was 0.05, No.56 was the lowest score, which was -1.60.

The average value of the Beautiful in Block D Fukuoka Streets was -0.34. This block lacked greenery decoration, and there were no clustered blocks. Most of the buildings were independent individuals with a single color. The average value of Wealthy in Block D was -0.19, the building color was dull and old, lacked of decoration and more stains on the exterior. The average value of Lively in Block D was 0.20, and the overall Lively of the block was average, with more residential and less commercial buildings. The average value of Depression in Block D was 0.16, the block was relatively open and the buildings were not clustered. The average value of Boring in Block D was -0.02, and some streets had decorative pavement, which increased the vitality of the streets.

The average value of the Beautiful in Block E Fukuoka Streets was 0.26; The average value of Wealthy in Block E was 0.20. This block had various building styles, dense buildings and many commercial buildings, so the scores of beautiful perception and wealthy perception in this block were higher. The average value of the Safety in Block E was 0.38. The street environment was open, the streets were clean and tidy, and the traffic flow was small, which gave people a great sense of security. The average value of Depression in Block E was -0.56, The average value of Boring in Block E was -0.51. This block was more prosperous and crowded, so the scores of Boring and Depression were low.

The average values of the Beautiful in Block F, G and H Fukuoka Streets were -0.24, -0.38 and -0.31, respectively. The street landscapes of these three blocks were similar, and the buildings were mostly light in appearance, with the same color and lack of decoration. The average value of Wealthy in Block F was -0.33, and that in Block G was -0.36; The buildings in these two streets were old in appearance, and the level of Wealthy was not high.

The average values of Safety of Blocks F-K were 0.14, 0.26, 0.76, 0.44, 0.35 and 0.41 respectively. The average perceived Safety score of these six blocks was very high, because the streets were wide and functional, giving people a great sense of security.

The average values of Lively in Blocks F were 0.39, 0.26, 0.34 and 0.77, respectively, which were higher overall. No.162 was the highest score of all points, which was 2.06, because this block was prosperous, it was a commercial block. The average values of depression in Blocks F-H were 0.31, 0.10 and 0.12 respectively. The average values of Depression in these three blocks were medium, because the street landscape was similar, and Block G was more prosperous, so the score was low.

The average value of Boring in Block F was -0.07. Shopping malls were dense in this block, and street trees with colored leaves were decorated on both sides of the street. The average value of Boring Block G was 0.06, the building style was unified, and lacked of entertainment places. The average of the Wealthy in Block I was 0.65. No.168 the highest point with a score of 1.66, Because of the high-rise and dense buildings in this block, and high crowd flow, the building facade consists of a large glass curtain wall. The average values of Boring in the H-J region were -0.28, -0.69 and -0.09. These blocks were commercial areas with developed economies.

The average value of the Beautiful in Block I of Fukuoka Streets was 0.24, and the average value of Depression in I Block was -0.53. Because this block was prosperous, well decorated and the building was high, its Beautiful value was higher and its Depression value was lower.

Fukuoka Streets had a Beautiful average of -0.05 in Block J and -0.33 in Block K; the buildings were cluttered, the plants lacked layers, and the buildings were more confusing and discordant in color; the Wealthy average in Block J and Block K was -0.03 and -0.09, the plants locked pruning, the growth was cluttered and locked layers, and the buildings were in a state of disrepair.

The Lively average for Block J Fukuoka Streets was 0.03, with the street vibrancy value increased by the predominantly warm colors of the buildings in the street and the green street trees; the Depression average for Block J was 0.03, with the streets being too wide and slightly desolate.

The Lively average in Block K was -0.04, with some of the sample buildings being dense and tall and more enclosed spaces; the Boring, average in Block K was 0.17, with too many buildings and fewer entertainment venues, and the Depression average in Block K was -0.09, with this section of the road being a commercial area and economically developed.

The block M to P are the coastal streets of the Fukuoka streets.

The mean value of the Block M Fukuoka street was 0.58 for Beautiful, 0.44 for Wealthy, 0.22 for Safety, 0.26 for Lively, -0.31 for Depressing and -0.46 for Boring.There was a small number of street trees in Block M . The buildings were colourful,modern and uniform.The street interface was harmonious and complete,small number of well-arranged street trees were planted on both sides of the street. Block M were spacious and open, the buildings were relatively low and the sky was open.

The mean value for Beautiful in the Block N was 0.07 and the mean value for Wealthy was 0.02. Some samples street space were too empty, lacked vegetation,dominated by motorised roads, with too much sky area and lacking landscape, while others were taken under overpasses, with taller buildings obstructing pedestrian views and low greenery, resulting in the whole street feeling closed and a poorer visual experience. The mean value for Safety was -0.17, with a lots of motorised roads and taller buildings, resulting in a reduced sense of Safety for pedestrians.

The mean value of Beautiful in Block O was -0.95, Wealthy was -0.73 ,Safety is -0.61, Lively was -0.68 , Depressing was 0.57 and Boring was 0.68.Lacking of landscape , excessive area of water and sky,lacking variation of the skyline and less vegetation cover caused the lack of vibrancy in the landscape;The buildings were low and old, caused low scores of Beautiful, Wealthy and Lively.Meanwhile,there were not enough fences on the roads near the water, which made a sense of insecurity to pedestrians, and caused the lower scores for Safety and Lively;Due to the lacking of landscaping, Depressing and Boring in high in Block O.

The mean value of Beautiful was 0.08 in Block P , Wealthy was 0.16, Safety was 0.39, Lively was 0.13 , Depressing was -0.12 and Boring was -0.01 .There were a large number of buildings in Block P , most of them were industrial buildings with dirty old building facades, and greenery and vegetation was sparse . The excessive number of factory buildings leads to an overall colour confusion and a more fragmented streetscape in Block P. The narrow roads and oversized buildings created the Depressing atmosphere.

6.4 Analysis of street perceptual dimensions scores

We calculated the average perceptual dimension for each perceptual dimension by calculating the average perceptual dimension for all sampling points on Qingdao coastal streets and Fukuoka Streets. The perception dimensions data scores at street level were indicated in the table， it showed a significant difference in the spatial distribution of perceptual dimensions between Qingdao coastal street and Fukuoka Streets.

6.4.1Qingdao Coastal Streets perceptual dimension

(1) Beautiful Perception Streets

Regarding Qingdao coastal streets, in terms of Beautiful perception, the average value of the Beautiful perception score dimensions of the sample was 0.188, with a probability of 68% for positive values and 32% for negative values.

High Beautiful Perception Streets: The road was open and the buildings along the street were neat and tidy (137, 280), beautiful buildings (94) with open sky, clean streets, colorful paving (200), abundant greenery and full of activity, the street trees were relatively dense and the planting was neat and orderly, created a strong natural atmosphere (96, 209, 269), abundant plant species and reasonable proportion of trees, shrubs and herbs could effectively improve the visual quality of the greenbelt trails[5], with open views and beautiful landscaping.

Low Beautiful Perception Streets: The movement of people and vehicles was chaotic, the fence created an enclosed space and the visibility of the sky was poor (95). The commercial area was sparsely landscaped, with widely spaced street trees, sparse foliage and small canopies (336), very wide streets, tall buildings, no vegetation decoration along the streets, overly open spaces and narrow streets where people and vehicles mix, made the street space very disordered (24). The surrounding dense cluster of high-rise buildings encroaches on the pavement while blocked the sky, exacerbated the sense of closure of the entire streetscape (48).

(2) Wealthy Perception Streets

In terms of Wealthy perception, the average value of the Wealthy perception dimensions of the sample was 0.116, with a probability of 54% for positive values and 46% for negative values.

High Wealthy Perception Streets: Highly ornate facade and large building volumes (270, 271), with iconic buildings, some of the photo samples had a lower proportion of buildings in the photo, were close to open water and green parks, had more intensive planting in the surrounding street space, and had a beautiful and green street environment (186, 269, 280).

Low Wealthy Perception Streets: Some of the streets were too narrow and congested, with a mix of pedestrians and vehicles (16, 24, 95), some streets were too wide and open, lacked street trees around the streets (1, 2, 4), and the building facades were more dilapidated (23, 24, 95), dense buildings in disrepair, old facades, dirty street environment (24), plants lacked pruning, overgrown and lacked layers (16, 23).

(3) Safety Perception Streets

In terms of Safety perception, the average value of the Safety perception dimensions of the sample was -0.201, with a probability of 33% for positive values and 67% for negative values.

High Safety Perception Streets: Low volume of street traffic, easy to manage, clean streets, relatively loose traffic flow (238, 239, 240), The street sections did not cause congestion and created an open space pattern (248, 256, 268). Streets with a predominantly residential function are planted with trees with large canopies to create shade to keep out car exhaust and noise, creating a quiet and pleasant environment (269, 277). The building was harmoniously colored, culturally distinct and orderly (248, 271, 294).

Low Safety Perception Streets: By analysis, streets with low perceptions of Safety were often close to the water, and although there were guardrails separating the water from the pedestrian space, they were low (1, 17). The streets were narrow and congested, with a mix of pedestrians and vehicles (83, 123). Overgrown and not managed vegetation grows indiscriminately, resulting in obstructed views, as well as fewer passing vehicles and pedestrians (17, 118, 119).

(4) Lively Perception Streets

In terms of Lively perception, the average value of the Lively perception dimensions of the sample was -0.179, with a probability of 37% for positive values and 63% for negative values.

High Lively Perception Streets: Some samples had a harmonious architectural style, clean building interfaces, contemporary street environments and buildings, and open street spaces with views (57, 58). Spatially segregated streets, densely planted and orderly arranged green belts with a clear hierarchy of plants (72, 129) and dense pedestrian and vehicular traffic (61, 62, 72).

Low Lively Perception Streets: Overgrown vegetation in some samples blocked pedestrian views and made the blocks appear crowded (116, 117, 182, 184). In other samples the streets were too wide, with widely spaced street trees, sparse foliage, small canopies and a lack of plant level variation (321, 326).

(5) Depressing Perception Streets

In terms of Depressing perception, the average value of the Depressing perception dimensions of the sample was 0.005, with a probability of 51% for positive values and 49% for negative values.

High Depressing Perception Streets: Overly open views, polluted sea surface, floated green algae in the water (1, 16, 56). Although the streets are lined with street trees, they were sparse and lacked shrubs and ground cover plants. At the same time, the yellowing leaves of the street trees made the plant landscape lacked life (50, 95, 143). The man-made structures might be a negative impact on the visual quality of the landscape[6].

Low Depressing Perception Streets: Open sky views and large-scale roads (57, 58, 61), the streets are harmoniously colored and the streetscape features are well arranged (70, 71, 72). There were landmark buildings (246, 247) formed a street space full of orders (62, 66).

(6) Boring Perception Streets

In terms of Boring perception, the average value of the Boring perception dimensions of the sample was 0.005, with a probability of 53% for positive values and 47% for negative values.

High Boring Perception Streets: Some of the samples contained a single plant layer with many tall trees forming more enclosed spaces (193, 215, 327). The pedestrian street was too wide, compared to the narrow green belt (328, 215, 330, 344) The building form was homogeneous, dominated by high-rise buildings (221, 330, 344), lack of decorative architectural features and lack of iconic spaces (193, 95).

Low Boring Perception Streets: Through the combination of water and plants, the water feature forms a harmonious relationship with the plants and facilities, and it enhanced the landscape quality of the site. The site was rich in activity facilities, which made the green landscape more vibrant (58, 200, 256). The lines of the buildings were hard and straight, but the lines of the plants were soft, and the combination of plants and architecture enriches the space (63, 69, 70).

6.4.2 Fukuoka Streets perceptual dimension

(1) Beautiful Perception Streets

Regarding Fukuoka Streets, in terms of Beautiful perception score, the average value of the Beautiful perception score dimensions of the sample was -0.17, with a probability of 43% for positive values and 57% for negative values.

High Beautiful Perception Streets: The street architecture was architecturally very modern and uniform, with a complete street interface and a harmonious color scheme (76, 82, 163). The street had open spaces with high sky openings and clear views of the street, and the building had large glass curtain walls (170, 180, 184) to increase the permeability of the space.

Low Beautiful Perception Streets: The commercial advertisements on the facade of the commercial building are cluttered, while the colors of the billboards overwhelm the colors of the building (27), resulting in incongruous colors and affecting the visual experience of pedestrians, and the wires are re confusingly classified (14, 15, 19, 20, 21). There were little street greenery, a lack of street trees (230, 305, 343), and a large number of commercial buildings and commercial complexes, resulting in a single spatial landscape element (7, 15, 35, 48). The sky and water are too open and the skyline lacks variety (305, 355). Some samples are mainly factories, with large building volume and single color. The streets are narrow and crowded, giving people a feeling of depression (362, 366).

(2) Wealthy Perception Streets

In terms of perception of the Wealthy, the average value of the Wealthy perception dimensions of the sample was -0.10, with a probability of 41% for positive values and 59% for negative values.

High Wealthy Perception Streets: The street was flanked by a number of high-rise buildings, the facades of which were closely aligned to create a continuous facade (79, 83, 84, 145), street boundaries were open and porous, with a strong sense of the permeability of the street spaces (66,79, 83, 84), the streets were neat and tidy, and the overall warm color of the buildings gives the street space a distinctive regional character (171, 172, 177), street trees were planted with regularity, and some richly layered plantings add distinctive design details to the street (83, 168, 170).

Low Wealthy Perception Streets: Some samples had over-spaced plant groups, too much greenery concentration and lack of natural appearance (1, 2, 3, 4), low building, lacking ornate decoration (6, 15, 19). The landscape facilities were not in harmony with the surrounding landscape, the pavement and facilities were poorly managed (15, 19, 27) and the building layout was cluttered and lacks a sense of hierarchy (6, 27, 210).

(3) Safety Perception Streets

In terms of Safety perception, the average of the Safety perception dimensions of the sample was 0.18, with a probability of 63% for positive values and 37% for negative values.

High Safety Perception Streets: Roads with high landscape quality were cleaner and had a simple and aesthetically pleasing pavement style (74, 145, 164). The street was sparsely vegetated on both sides, with a few low shrubs that did not obscure views and display the beautiful buildings in plain view (153, 171, 175). A proper building layout created a good sense of closure, provides the impression of a high degree of safety and provides opportunities for residents to interact in the city streets (157, 193, 198).

Low Safety Perception Streets: Some samples had wires closest to the ground and confused planning (9, 12, 15), excessive building massing, unclear levels and obstruction of pedestrian views (21,35,211), the width of the road had some narrow widths and the motorway had poor distinction from the pavement (20, 27), the flyover crosses over the street, gave a sense of oppression (211). Roads near the water lack railings, resulting in a reduced sense of safety(333， 334).

(4) Lively Perception Streets

In terms of Lively perception, the average value of the Lively perception dimensions of the sample was 0.16, with a probability of 62% for positive values and 38% for negative values.

High Lively Perception Streets: Some of the sample was dominated by buildings in commercial areas with high pedestrian density and high traffic volumes (100, 162, 176), the road surface was wide and clean, with a clear separation between pedestrian and vehicle space to meet traffic demands and maintain smooth traffic flow (76, 77, 80), some of the sample landmark views were rich, connected and completed inside the buildings could create a more ordered and at the same time vibrant streetscape (98, 176, 177).

Low Lively Perception Streets: A large number of surrounding trees in some of the samples were growing vigorously and the space was more enclosed (3, 4, 20). Some sites were cluttered with poorly graded trees (19, 20). Other samples lacked trees, spaces lacked botanical landscaping and roads lacked green decorations on both sides (18, 27, 43, 61). Traffic was loose and the incidence of vehicles is low (20, 27, 43).

(5) Depressing Perception Streets

In terms of Depressing perception, the average value of the Depressing perception dimensions of the sample was -0.004, with a probability of 48% for positive values and 52% for negative values.

High Depressing Perception Streets: Some samples had a greater concentration of plants and closed sites (4, 5). The lacked of shrubs and ground covers in the green spaces made the landscape stiff and unattractive (6, 15, 34). In other samples the space was too open, the buildings were sparse and the sky view rate was too high, (59, 60, 61). The lacked of vegetation on both sides of the road, low buildings and dull colors inside the buildings gave a sense of dilapidation (6, 15, 37, 331).

Low Depressing Perception Streets: A rich variety of architectural levels and colors in some samples (66, 68, 71), simple road surface decoration, punctuated by a few colored leafy street trees (165, 168, 170, 193), some of the samples had high building spacing, open views, rich landscape layers and a reduced sense of desolation (66, 58, 126), iconic building colors in harmony with the surrounding landscape colors and rich landmark views (89, 165, 168).

(6) Boring Perception Streets

In terms of Boring perception, the average value of the Boring perception dimensions of the sample was -0.004, with a probability of 51% for positive values and 49% for negative values.

High Boring Perception Streets: Streets had large areas of uninteresting and unattractive areas and featureless landscapes (6, 9, 13), the street composition was uniform, the residential buildings were too old and they were too uniform in scale and massing (14, 27, 220). There are more buildings and the building streets are closed and narrow, creating a tedious spatial atmosphere (2, 15, 27).

Low Boring Perception Streets: The areas with low boredom scores were mainly located along the main roads of the city, with a variety of building forms and a rich and harmonious color palette (56, 57, 88), the plants were harmoniously integrated with the buildings, with more greenery, made the landscape lively and interesting (52, 88, 90), and the architecture was unique in style and form, iconic and full of beauty (166, 171, 185).

6.5 Correlation analysis between perceptual dimensions

SPSS26.0 was used to conduct Pearson correlation analysis of the cross between the perceptual dimensions of Qingdao Coastal Streets and Japan Fukuoka Streets samples (Table 6-1 and Table 6-2).

6.5.1 Qingdao Coastal Streets cross-correlation analysis of the perceptual dimensions

Table 6-1 Qingdao Coastal Streets cross-correlation analysis table of the perceptual dimensions

Correlation		Beautiful	Wealthy	Safety	Lively	Depressing	Boring
Beautiful	Pearson	1	.434**	.284**	-0.068	-.343**	-.380**
Wealthy	Pearson	.434**	1	.459**	.153**	-.477**	-.360**
Safety	Pearson	.284**	.459**	1	.276**	-.360**	-.428**
Lively	Pearson	-0.068	.153**	.276**	1	-.581**	-.473**
Depressing	Pearson	-.343**	-.477**	-.360**	-.581**	1	.648**
Boring	Pearson	-.380**	-.360**	-.428**	-.473**	.648**	1
** At 0.01 level (two-tailed), Significant correlation							

The correlation analysis from the perception dimension showed that there was a positive correlation between Beautiful and Wealthy (0.536) and Safety (0.160) in Qingdao Coastal Streets, which reflected that Qingdao Coastal Streets pursues high-quality development and pays more attention to the improvement of street landscape while ensuring the functionality of the street. The correlation between the Beautiful and Boring (-0.377) and depression (-4.78) was very negative. Through research, high landscape quality samples which had abundant plants, open sky, harmonious functional buildings, these landscapes bring positive emotions to people, thus resulting in a significant negative correlation between the Beautiful and Boring and Depressing.

There were a positive correlation between Wealthy and Beautiful, Safety and Lively, and a strong negative correlation between Wealthy and Boring and depression. Because of the rich urban streetscape in the design process often take into account the functional and visual aesthetic factors, through the reasonable layout of buildings and plants to attract people.

Safety was positively correlated with beautiful, Wealthy and Lively, and negatively correlated with depression and Boring. It showed that the road function of Qingdao Coastal Streets was clearly divided, the road and sidewalk were clearly divided, so the overall order was good. However, the

Qingdao Coastal Streets were too close to the water, they would cause the person's insecurity, resulting in a low correlation between Safety and Beautiful. At the same time, when the trees were too heavily enclosed, the Safety perception could be reduced.

6.5.2 Fukuoka Streets cross-correlation analysis of the perceptual dimensions

Table 6-2 Fukuoka Streets cross-correlation analysis table of the perceptual dimensions

Correlation		Beautiful	Wealthy	Safety	Lively	Depressing	Boring
Beautiful	Pearson	1	.612**	.499**	.331**	-.490**	-.685**
Wealthy	Pearson	.612**	1	.513**	.458**	-.702**	-.595**
Safety	Pearson	.499**	.513**	1	.168*	-.462**	-.404**
Lively	Pearson	.331**	.458**	.168*	1	-.575**	-.476**
Depressing	Pearson	-.490**	-.702**	-.462**	-.575**	1	.608**
Boring	Pearson	-.685**	-.595**	-.404**	-.476**	.608**	1
** At 0.01 level (two-tailed), Significant correlation * At 0.05 level (two-tailed), Significant correlation							

On the Fukuoka Streets in Japan, there was a positive correlation between the Beautiful and Wealthy (0.612), Safety (0.499) and Lively (0.331). There was a negative correlation between Depressing (-0.490) and Boring (0.685). This was because large areas of Japan had been urban. Internationally, Japan had a higher urbanization rate, and its urban planning and architecture, mainly focus on micro-renewal. While pursuing high-quality development, it no longer focuses on the basic functions of street space during the transformation, but pays more attention to the aesthetic perception and vitality improvement of street landscape.

There was a significant positive correlation between Wealthy and Beautiful (0.612), Safety (0.513) and Lively (0.458). It was negatively correlated with depression (-0.702) and Boring (-0.595). This suggested that street affluence, not only increased the sense of beauty, but also increased the sense of vitality and safety of the street. Safety was positively correlated with Beautiful (0.499), Wealthy (0.513) and Lively (0.168), and negatively correlated with Depressing (-0.462) and Boring (-0.404). This indicates that high Safety streets tend to enhance aesthetic perception, be full of richness, and increase vitality.

6.6 The correlation of perceptual dimensions and physical features

SPSS26.0 was used to conduct Pearson correlation analysis of the perceptual dimension and street landscape elements of Qingdao Coastal Streets and Fukuoka Streets samples.

6.6.1 Qingdao Coastal Streets analysis of the correlation between perceptual dimensions and physical features

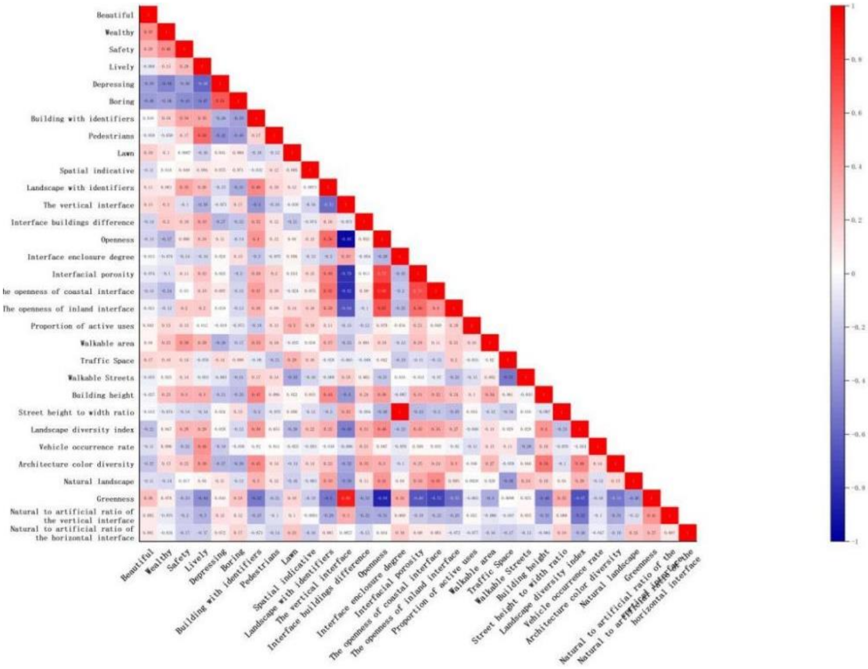

Fig 6- 3 Qingdao Coastal Streets analysis of the correlation between perceptual dimensions and physical features

Through the correlation matrix of variables (Fig6-3), the perceptual dimension and landscape elements of Qingdao Coastal Streets, China were included. In Qingdao Coastal Streets, building with identifiers were positively correlated with Wealthy (0.183), Safety (0.343) and Lively (0.351), but negatively correlated with Depressing (-0.288) and Boring (-0.346), which indicates that building with identifiers made the space more rich and more dynamic, and made the street space interesting and attractive. Building with identifiers and Beautiful were relatively independent, because whether the building with identifiers was beautiful or not would affect the Beautiful perception, rather than whether the building itself was iconic or not. Interface buildings difference was positively correlated with Wealthy, Safety (0.192) and Lively (0.329), and negatively correlated with Beautiful (-0.140), Depressing (-0.271) and Boring (-0.218). There were more buildings in the closed space, which made the block more functional, but too many buildings would lead to the increase of the wall area. As a negative factor, the wall might lead to obstructed sight lines, and the reduction of sunshine and increased pollution would reduce the visual aesthetic quality of the street landscape, left people with an ugly and boring feeling. Walkable area was positively correlated with Wealthy (0.228), Safety (0.392) and Lively (0.294), and negatively correlated with Depressing (-0.286) and Boring (-0.167). Walkable area as an important part of city street, the pacers in from the car and other traffic interference and damage, could be regular or temporary or full of naturalness, landscape and recreational space, so Walkable area increased would not only make the pacers more secure, at the same time made streets landscape space more rich, more energetic, full of fun. The number of building height

was positively correlated with Wealthy (0.231), Safety (0.300) and Lively (0.301), and negatively correlated with Depressing (-0.208) and Boring (-0.247). In the street landscape, especially in the commercial district, tall buildings tend to give people a sense of grandeur, and most of them were in shopping malls. Therefore, in the street, tall buildings gave people a feeling of wealth and vitality. Architecture color diversity was positively correlated with Wealthy (0.148), Safety (0.216) and Lively (0.390), and negatively correlated with Beautiful (-0.219), Depressing (-0.279) and Boring (-0.287). This was because the colors of the building facade were too disorderly, which would reduce the visual quality of the space.

6.6.2 Fukuoka Streets analysis of the correlation between perceptual dimensions and physical features

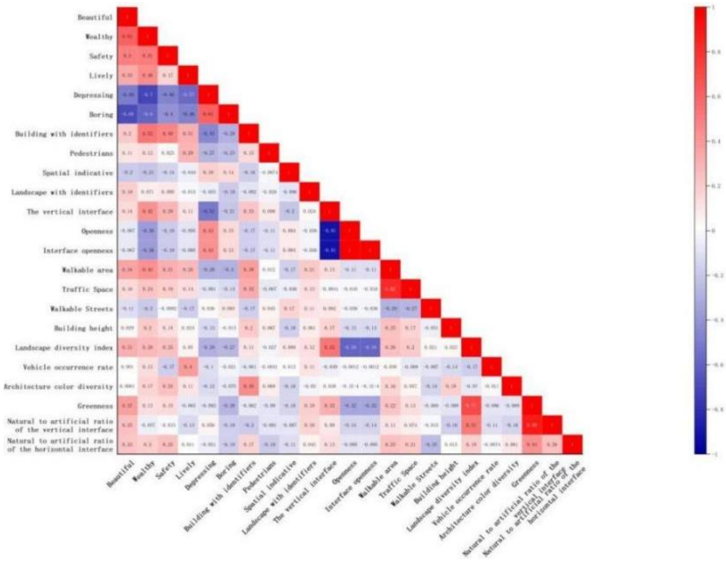

Fig 6- 4 Fukuoka Streets analysis of the correlation between perceptual dimensions and physical features

Through the correlation matrix of variables (Fig6-4), the perceptual dimension and landscape elements of Japan Fukuoka Streets were included. Building with identifiers was positively correlated with Beautiful (0.193), Wealthy (0.508), Safety (0.446) and Lively (0.274), and negatively correlated with Depressing (-0.401) and Boring (-0.277). In Japan's Fukuoka Streets, building with identifiers was related to Beautiful, which indicated that the overall visual quality of the building with identifiers on Fukuoka Streets was better than that of the building with identifiers on Qingdao Coastal Streets. Pedestrians was positively correlated with Beautiful (0.167), Wealthy (0.135) and Lively (0.259), and negatively correlated with Depressing (-0.227) and Boring (-0.201). It could be seen that urban residents were more longing for beauty and rich streets, which brought vitality to the whole city streets. It showed that it was important to mention the visual quality of city streets. The vertical interface was positively correlated with Wealthy (0.421), Safety (0.282) and Lively (0.176), and negatively correlated with Depressing (-0.510) and Boring (-0.202). Plants and buildings together form a rich and beautiful street scene, improved the overall visual quality. Walkable area was positively correlated with Beautiful (0.345), Wealthy (0.430), Safety (0.306) and Lively (0.264), and negatively correlated with Depressing (-0.282) and Boring (-0.301). Traffic Space was positively correlated with Beautiful (0.163), Wealthy (0.239), Safety (0.184) and Lively (0.136), and negatively correlated with Boring (-0.146). Landscape diversity index was positively correlated with Beautiful (0.234), Wealthy (0.242) and Safety (0.212), but negatively correlated with Depressing (-0.276) and Boring (-0.218). The rich and varied landscape enhances the visual quality of the entire street. The vibrant plants, the open sky, and the harmonious and unified architecture together constitute a rich urban landscape. Therefore, enriching the types of landscape elements was an important link to improve the visual quality of the street.

6.7 Comparison of six perceptual dimension features in China and Japan

Through the experimental analysis, Qingdao Coastal Street Beautiful, Wealthy score was higher than Fukuoka Streets Beautiful, Wealthy score; Fukuoka Streets Safety, Lively score was higher than Qingdao Coastal Streets score; Qingdao Coastal Streets and Fukuoka Streets score equally for Depressing and Boring.

Qingdao Coastal Streets had a positive Beautiful perception score rate of 68%, and Japan's Fukuoka Streets had a positive Beautiful perception score rate of 34%. The Beautiful perception score of Qingdao Coastal Streets was distributed in sections, while the Beautiful perception score of Japan Fukuoka Streets was distributed continuously. The Beautiful perception score of Qingdao Coastal Streets was higher than that of Japan Fukuoka Streets Because of the street waterfront, high sky openness, high green vision, the overall street pavement was better, the commercial blocks were concentrated, and the architecture had a modern sense, while the streets of Fukuoka Streets had a single color, the pursuit of unity in architectural design, less green plants, and the overall feeling was monotonous.

Qingdao Coastal Streets had a positive perceived Wealthy rate of 54%, and Fukuoka Streets had a positive perceived Wealthy rate of 36%. The reason for the high positive rate of perceived Wealthy in Qingdao Coastal Streets was that the street planning was better, the landscape quality of commercial nodes was high, many high-rise buildings were located in the commercial nodes, and the street function zoning was clear. The positive rate of perceived Wealthy in Fukuoka Streets was lower than that in Qingdao Coastal Streets, there were few high-rise buildings, fewer commercial nodes, scattered commercial buildings and less traffic flow.

The positive Safety perception rate of Qingdao Coastal Streets was 33%, and that of Fukuoka Streets was 72%. The positive rate of Safety perception of Fukuoka Streets was much higher than that of Qingdao Coastal Streets, because the buildings of Fukuoka Streets were relatively evacuated, the street traffic was less and not coastal, most of the streets were built very spacious, so it would not excessively cause residents insecurity, while the buildings on Qingdao Coastal Streets were tall and the coastal area gives people, insecurity, and the streets were mainly wide multi-lane Streets. And some motor and non-motor lane planning was not clear.

The positive rate of Lively perception of Qingdao Coastal Streets was 37%, and that of Fukuoka Streets was 67%. The positive rate of Lively perception of Fukuoka Streets was higher than that of Qingdao Coastal Streets, because the street scene of Fukuoka Streets was open and the sky was a positive visual element affecting the Lively perception. However, the dense buildings on Qingdao Coastal Streets and the low sky openness give people a sense of pressure.

The positive Depressing perception rate of Qingdao Coastal Streets was 51%, and that of Fukuoka Streets was 52%. Depressing of Fukuoka Streets was reflected in sparse street buildings, less shrub landscape, low green rate, building colors were mostly white, gray was not vibrant, giving people a sense of Depressing, Qingdao Coastal Streets Depressing perception was reflected in some buildings disrepair, building exterior walls were old, low residence, in some streets would also reflect the sense of the mess.

The positive Boring perception rate of Qingdao Coastal Streets was 53%, and that of Fukuoka Streets was 52%. The Boring of Fukuoka Streets was reflected in the uniformity of architectural color, function, scale and volume. The Boring perception of Qingdao Coastal Streets was reflected in the similarity of street landscape and planting planning, with a single landscape element and low complexity of architectural color.

Through the correlation analysis between perceptions, the cross Pearson correlation analysis was carried out to compare human perception in six perceptual dimensions. By comparing the tables, we found that some indicators were highly correlated, such as Beautiful-Wealthy and Depressing-Boring. More specifically, the correlation between these indicators was different between China's Qingdao Coastal Streets and Japan's Fukuoka Streets. For example, in China's Qingdao Coastal Streets, "Beautiful-Lively" was relatively independent, while in Japan's Fukuoka Streets, "Beautiful-Lively" had a positive correlation. For example, the correlation of "Beautiful-Safety, Beautiful-Depressing" was stronger on Fukuoka Streets in Japan, while the correlation was relatively lower on Qingdao Coastal Streets in China. We believe that this inconsistency was caused by the different urbanization processes of the two countries, which lead to the different features of the two urban landscapes, and more in-depth research was needed.

6.8 Discussion

In recent years, the research on urban perception has developed rapidly, and the research results have been applied in urban space aesthetics, urban security and urban public health[7][8][9]. There is ample evidence that well-designed urban environments helped shape the mood of residents through [10]. Most studies examining the impact of the urban physical environment on mental health have been measured by participant ratings [11][12]. Recently, a number of studies use the Street View data approach to analysis the perceptual dimensions of the urban environment [13][14][15]. Enhances Beautiful, Safely and Lively and contributes to the streetscape [16]. The perception that a good urban landscape will stimulate activity among city residents, increase resident interaction and improve resident satisfaction with city streets [17]. Lei Wang said that in the planning and construction of urban roads, there was no distinctive landscape, but rather a desire for uniformity, which led to a high level of Boring [18].

Greenery and sky in the streetscape are positive visual elements that positively influenced feelings of Beautiful, Wealthy, and Safety [19][20], but were negatively associated with depression [21][22][23][24]. Roads under overpasses often block the sky and other landscape elements because of the sheer volume of the buildings, which can have a negative impact on the perception of city dwellers [22][23][24]. There is a close relationship between the volume of traffic on the road, the flow of people and the perception of vitality [25]. Roads in city center tend to has high traffic and crowd flows [22][23][24]. Roads in city center tend to have high traffic and crowd flows [25]. There is a specific correlation between urban function and urban perception, and POI data can reflect the functional areas of the city [26][27]. Safety perception, Lively perception and settlement have a strong relationship [28]. The space surrounding the road, such as the landscape of a park or residential area, can also have an impact on people's perceptions [29][30]. At the same time, there were many other street features that might affect the psychological perception of residents, such as street hygiene, age of the road, infrastructure configuration, building density, building height, and perceived greenness of the street or ground.

6.9 Conclusion

In this study, we used the SD method to quantify the urban landscape perception (Beautiful, Wealthy, Safety, Lively, Depressed, and Boring) of Coastal Street in Qingdao and Fukuoka Streets in Fukuoka.

By analyzing the spatial distribution of perceptual dimensions and the features of high and low samples of perceptual dimensions, it is found that urban residents were more inclined to the urban street landscape with abundant greening, neat plants with natural range, beautiful building form and open sky, showing positive emotions (high Beautiful, high Wealthy, high Safety, high Lively, low Depressed, and low Boring). However, the sample photos with too high or too low greenery, as well as buildings with dilapidated and dirty facades, narrow streets and roads with heavy traffic flow shown negative emotions (low Beautiful, low Wealthy, low Safety, low Lively, high Depressed, and high Boring). In this paper, Pearson correlation analysis was conducted between the perceptual dimensions, it found that there was a strong positive correlation between "Beautiful-Wealthy", "Safety-Wealthy"and "Depressed-Boring", there was a strong negative correlation between “Depressed-Wealthy” “Lively-Depressed” and “Boring-Lively”. Pearson correlation analysis between perceptual dimensions and physical features revealed that building with identifiers, interface enclosure degree, openness, landscape with identifiers, walkable area, building height, and architecture color diversity were more correlated with perceptual features in Coastal Street in Qingdao. In the Fukuoka Streets, Fukuoka, building with identifiers, interface enclosure degree, openness, pedestrians, the openness of interface, walkable area, traffic space, Landscape diversity index were more correlated with perceptual features.

By analyzing the results, the valued the spatial quality of Beautiful, Wealthy, Safety and Lively in the coastal streets can enhance the spatial quality and created delightful spaces. Specifically for the street space, local remediation was the main focus, using materials that were in harmony with the overall spatial environment, and design styles to repair the inside of the building to improve the overall quality of the space. Pay attention to the combination of the green landscape and public space to create a high-quality activity space; keeping the space compact and leaving the corresponding pedestrian space for pedestrian use. Separation of vehicular and pedestrian traffic by the addition of appropriate green belts. Designing a vibrant spatial environment, enhancing the sense of enclosure of the activity space, creating a vibrant and safe activity space, and avoiding a space with a narrow view and a dark environment. At the same time, strengthen the daily management to maintain the remediation effect.

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Chapter 7

CONCLUSION

CHAPTER SEVEN: CONCLUSION

7.1 Conclusion

Based on streetscape big data and computer vision technology,the streets of typical coastal cities Qingdao and Fukuoka were selected as the site to explained the correlation between physical features and the perceptual features of urban coastal streets to evaluation of the quality of street space.Combining the existing evaluation indexes of spatial perception from the expert and the public point of view , the study discussed the influence mechanism of physical parameters and perception. It proposed a method of locating street space design problems in coastal cities.The study not only will reflect the urban landscape current situation ,but also provide the basis to optimize the quality of urban street space design efficiently and large-scale. Moreover,it will promote the scientific development of urban construction and planning.

The main works and results can be summarized as follows:

In capter one, RESEARCH BACKGROUND AND PURPOSE OF THE STUDY. In the process of urban regeneration, the environmental problems such as lack of vitality,confused urban style and features appeared in urban streets. Improving the quality of urban environment has become a link to improve the quality of urban space. The urban street is a characteristic and important part of the urban space, the street landscape has a combination of artificial and natural features, which is attractive and charming. Therefore, it is particularly important to build an accurate evaluation model with effective methods to further measure and predict public perception of space. The study will locate the problem of spatial design quality of coastal urban streets accurately, reflect the urban landscape, provide the basis for subsequent large-scale and deeper theoretical research of urban streets.

*In capter two ,*LITERATURE REVIEW OF URBAN STREET SPACE FEATURES.Based on the web of science database, this chapter analyzes the highly cited literature in related fields with CiteSpace visual analysis tool. Firstly, the research progress and planning strategies in the field of spatial perception, physic features and space design quality were combed. The evaluation methods and influencing factors were analyzed from the perspectives of subjective perception assessment and objective measurement. Secondly, the two perspectives of perceptual features and physical features were collated. The research on the relationship between street spatial characteristics, perceptual features and design quality were sorted out. The evaluation methods from the perspectives of street physical features and perceptual features was combed. Finally, A correlation analysis about the clustering results of related literature was conducted with the help of CiteSpace to discussed the problems and innovations in the research area.

In chapter three, RESEARCH METHODS have been presented. The main research methods and measurement in urban streets were introduced. It included the method of urban street images collection based on streetscape big data. Streets spatial perceptual evaluation used semantic difference method (SD). Streets physical features used semantic segmentation technique based on deep learning (deeplabv3+).

In chapter four, MEASURING AND ANALYZING PHYSICAL FEATURES OF URBAN STREETS. By analyzing the data of each physical feature obtained, we mainly focus on the data depiction of seven physical features, namely, Greenness, Vehicle and Pedestrians Occurrence Rate, Proportion of Buildings,the Vertical Interface,Interface Enclosure Degree , Openness, as well as the preliminary discussion of the data results after simple data processing. In this chapter, the analysis will be carried out in the sections of overall description of sample point data, sample point analysis, data trend analysis, comparison of road segments, and preliminary discussion of each physical feature combined with the current status of the street. The analysis concluded that the street features, current problems and differences between Qingdao Coastal Streets,Meiji Streets and Coastal streets in Fukuoka, Japan. The use of image recognition technology for urban street space data processing, can more clearly and intuitively reflect the current situation of the street. A finer and more comprehensive understanding of the constituent elements of the street. To provide a reference for the creation of future urban street scenes, a preliminary discussion on strategies to improve the quality of street space.

Greenness is important for measuring or evaluating coastal streets , rest spaces and landscape of the city.The result showed that the Greenness was excellent (35%) in the whole Qingdao Coastal Streets.Some bolcks ,such as Shanhaiguan road reached 45%.Ecological environment was good in Qingdao Coastal Streets.;The Greenness was low (7%) in the whole Fukuoka Streets,because this street was a traffic street.

The Openness reflects the degree of Openness in the street.The Openness of Qingdao Coastal Streets was 25%,while it reached 45% in Fukuoka Streets.The result explained that Fukuoka Streets space was open ,and had few trees.

The Proportion of Buildings reflects building density in streets.The Proportion of Buildings reached 27% in Fukuoka Streets,while only 8% in Qingdao Coastal Streets.Being a scenic in some blocks caused the low Proportion of Buildings in Qingdao Coastal Streets.

In chapter five, THE EXPERT PERCEPTION OF STREET SPACE IN COASTAL CITIES.Improving spatial quality and public perception of urban streets was an important work of urban regeneration. In this chapter, the study used machine learning semantic segmentation, GIS and Semantic difference (SD) methods to obtain the spatial data and perceptual evaluation of Qingdao coastal streets and Fukuoka Streets .Each of the six perceptual features, imageability, enclosure, human scale, transparency, complexity and nature, was taken as dependent variables and the corresponding physical features was taken as independent variables. The six regression models were established and the influence rules of spatial parameters on public perception were obtained in order to measure . Based on the results of perceptual features evaluation, the overall coastal streets were divided into three types, Open streets, Mixed streets and Biophilic streets. Meanwhile the Fukuoka Streets were divided into three types,Low perception streets ,High perception and Coastal streets . In all the types urban streets, the nature was the most significant perceptual feature due to the high Greenness; the Complexity was the lowest perceptual feature because of the low landscape diversity. In addition, Qingdao Coastal Streets and Fukuoka Streets were analyzed in terms of spatial heterogeneity.

The research results provided theoretical and technical support for the urban regeneration and spatial quality improvement of urban streets in Qingdao and Fukuoka.

In chapter six,THE PUBLIC PERCEPTION OF STREET SPACE IN COASTAL CITIES have been presented. By analyzing the spatial distribution of perceptual dimensions and the features of high and low samples of perceptual dimensions, it is found that urban residents were more inclined to the urban street landscape with abundant greening, neat plants with natural range, beautiful building form and open sky, showing positive emotions (high Beautiful, high Wealthy, high Safety, high Lively, low Depressing, and low Boring). However, the sample photos with too high or too low greenery, as well as buildings with dilapidated and dirty facades, narrow streets and roads with heavy traffic flow shown negative emotions (low Beautiful, low Wealthy, low Safety, low Lively, high Depressing, and high Boring).

In this paper, Pearson correlation analysis was conducted between the perceptual dimensions, it found that there was a strong positive correlation between "Beautiful-Wealthy", "Safety-Wealthy"and "Depressing-Boring", there was a strong negative correlation between “Depressing-Wealthy” “Lively-Depressing” and “Boring-Lively” .

Pearson correlation analysis between perceptual dimensions and physical features revealed that building with identifiers, Interface Enclosure Degree , Openness, square share, landscape with identifiers, walkable area, building height, and architecture color diversity were more correlated with perceptual features in Coastal Street in Qingdao. In the Fukuoka Streets, Building with Identifiers, Interface Enclosure Degree , Openness, Pedestrians, the Openness of Interface, Walkable area, Traffic space, Landscape diversity index were more correlated with perceptual features.

In chapter seven, CONCLUSION AND PROSPECT have been presented. Summarizes the conclusions of the each chapters and the optimization strategies of urban streets were proposed.

In summary, the study introduced the related mechanisms of physical and perception features in urban streets and concluded the trends, theory and methods for street space quality evaluation in coastal cities. From the expert and public perspective, it provided an in-depth study of urban streets in the coastal cities by comparative analyzing the physical and perception features of Qingdao Coastal Streets and Fukuoka Streets.

At the perceived features in the urban streets, The quantitative methods were used to measure and evaluate the space features of Qingdao Coastal Streets and Fukuoka Streets in the study. It also conducted correlation analysis, regression analysis and cluster analysis.

The study showed that each of the six perceptual features was influenced by the corresponding physical features. The Imageability was mainly positively influenced by iconic architecture and landscape; the Enclosure was impacted negatively by Sky Openness and positively by Interface Enclosure; The Transparency was mainly positively influenced by Interface Openness, especially the Coastal Interface Openness; Building Levels and Vehicular Space were physical features that affecting Human Scale, both of which were negatively correlated with Human Scale; The Complexity were not only influenced primarily by Landscape diversity but also associated with Vehicle Incidence and building color; The physical features affecting the Nature contained Green View Rate and Vertical Interface Natural to Artificial Ratio. Green View Rate is the most dominant physical perceptual feature affecting Nature. In Fukuoka Streets, the Enclosure was the more prominent perceptual feature, the others perceptual features were low perceptual features.

The results revealed that the influence mechanism of the physical features to the public perception features in Qingdao Coastal Streets, and objectively reflected the landscape quality of the Qingdao Coastal Streets and Fukuoka Streets. It provided accurate data support for the study and design of urban streets regeneration in coastal cities. That is important for urban streets in coastal cities planning and management, especially improving the design quality of coastal street space in Qingdao. In-depth study of the commonality between the physical features and psychological perception of the public in street space, can not only comprehensive evaluate the coastal street space quality, but also provide scientific support for the differentiated quality improvement strategies of urban street space.

At the physical features in the urban streets, At the theoretical level, this study helps to better understand the ecological meaning of Greenness in coastal cities and provides theoretical support for the selection of urban street measurement indexes. At the practical level, it can clarify the main drivers of Greenness in several dimensions and provide techniques for the improvement of urban Greenness and green land management in the future. In general, Greenness is important for measuring or evaluating urban streets, rest spaces and landscape of the city. Street Sky Openness is an indicator that can be influenced by a combination of factors such as street skyline form and building height on either side.The level of street Sky Openness directly affects the visual perception and space experience of pedestrians in the street.The vast sky can bring good visual effect to pedestrians, and the broad view makes people physically and mentally happy in the senses.But too wide a sky can also make people feel empty and give people a poor space experience. Too low street sky Openness will cause a sense of visual closure, making people feel depressed psychologically. It also affects the street wind environment and aggravates the heat island effect. Therefore, too high or too low street Sky Openness can reduce the space quality of the street. The relationship between street height, volume and sidewalk width is evaluated by Building View Rate. After the Building View Rate reaches a certain value, the higher the value, the stronger the spatial oppression of the sidewalk. The suitable degree of street space enclosure will give people a sense of peace and comfort. Different types of streets have different appropriate ranges of enclosure values and cannot be generalized. Therefore, there is no direct correspondence between the level of this index and the quality of street space, it needs to be analyzed differently in combination with different streets.

By analyzing the spatial distribution of perceptual dimensions and the features of high and low samples of perceptual dimensions, it is found that urban residents were more inclined to the urban street landscape with abundant greening, neat plants with natural range, beautiful building form and open sky, showing positive emotions (high Beautiful, high Wealthy, high Safety, high Lively, low Depressing, and low Boring). However, the sample photos with too high or too low greenery, as well as buildings with dilapidated and dirty facades, narrow streets and roads with heavy traffic flow shown negative emotions (low Beautiful, low Wealthy, low Safety, low Lively, high Depressing, and high Boring). In this paper, Pearson correlation analysis was conducted between the perceptual dimensions, it found that there was a strong positive correlation between "Beautiful-Wealthy", "Safety-Wealthy"and "Depressing-Boring", there was a strong negative correlation between “Depressing-Wealthy”“Lively-Depressed”and“Boring-Lively”. Pearson correlation analysis between perceptual dimensions and physical features revealed that Building with Identifiers, Interface Enclosure Degree , Openness, square share, landscape with identifiers, Walkable area, building height, and Architecture Color Diversity were more correlated with perceptual features in Qingdao Coastal Streets. In the Fukuoka Streets, Building with Identifiers, Interface Enclosure Degree , Openness, Pedestrians, the Openness of Interface, Walkable area, Traffic space, Landscape diversity index were more correlated with perceptual features.

By analyzing the results, the valued the spatial quality of Beautiful, Wealthy, Safety and Lively in the urban streets can enhance the spatial quality and created delightful spaces. Specifically for the street space, local remediation was the main focus, using materials that were in harmony with the overall spatial environment, and design styles to repair the inside of the building to improve the overall quality of the space. Pay attention to the combination of the green landscape and public space to create a high-quality activity space; keeping the space compact and leaving the corresponding pedestrian space for pedestrian use. Separation of vehicular and pedestrian traffic by the addition of appropriate green belts. Designing a vibrant spatial environment, enhancing the sense of enclosure of the activity space, creating a vibrant and safe activity space, and avoiding a space with a narrow view and a dark environment. At the same time, strengthen the daily management to maintain the remediation effect.

7.2 Optimization Strategies

7.2.1 Qingdao Coastal Streets

In terms of overall street perception evaluation, the coastal street in Qingdao was overall high in nature. This indicated that the planning and construction of this street focused on preserving the original vegetation. The design of the coastal streets combined with the natural landscape (forest and sea) reflected the adequate amount of planting.

The overall street enclosure and human scale was good. The imageability, transparency and complexity of the street could be improved. Designers should focus on and enhance the physical features associated with these three aspects of perceptual features.

In the Open Streets, this type of street has better transparency, nature and iamgeability, but poorer enclosure, complexity and human scale. In the process of improvement, the enclosure should be combined with the features in the street, while considering the interaction between each perceptual and physical feature. The enclosure in the street should be improved moderately by combining multiple features, not excessively and to extremes.

Since vision is one of the determining factors related to people perception , the complexity in the street influences the level of design of the space and the willingness of the public to travel. From a design and regenerate perspective, complexity can be enhanced by modulating architectural color, formal richness and landscape variety.

Policy makers should develop more detailed design guidelines to prevent the construction of monotonous built environments. Designers should enrich the architectural style and façade decoration while maintaining the continuity of the environment. This will further increase the visual richness and ornamental feel of the building. At the same time, this enhances the diversity of the street's landscape. Referring to the nature in the streets, add sufficient outdoor signage and road discovery.

This type of street contains commercial buildings that can encourage businesses to take advantage of the full outdoor environment, such as street cafes and other activities. In terms of human scale, designers should increase the number of "shaded corners" of streets[1]. Proactively create comfortable walkway widths, rest stops and street sidewalks that meet the pedestrian traffic needs.

In the Mix Streets, the improvement of architectural transparency can be solved by increasing the permeability of the coastal interface. For example, the construction of plants at appropriate locations, the adjustment of closed walls to fences and the addition of access to the seafront. The imageability can be increased by setting landmarks, square and attractive signs.

In the Biophilic Streets are characterized by high levels of enclosure and low transparency. This type of street is heavily vegetated and can be made visible to trimming vegetation. The landscape furniture and interactive landscape vignettes can create a sense of place in the building for enhancing transparency, imageability.

7.2.2 Fukuoka Streets

In the overall street perception evaluation, Fukuoka Streets have a high imageability and transparency. The overall design approach of the street was relatively uniform, with fewer building stories and higher Openness. However, the relative perceptual evaluation of nature, enclosure, complexity and human scale was poor. In particular, the overall Greenness was low and needed to be improved.

In the case of High Perception Streets and coastal streets, it is more consistent with the overall street perception evaluation. In response to the low Greenness in the street, the plant area is appropriately increased. In the design of landscape greenery, the hard landscape should meet its use function as well as cooperate with soft landscape such as plants.

The planting configuration should take full account of the year-round greening effect and the different functions of the space, while considering survival rates. The addition of public art, historic elements, attractive street furniture, more TOD (Transit-oriented Development) and mixed-use development can improve the enclosure and complexity of Fukuoka Street.

As far as Low Perception Streets are concerned, it is necessary to strengthen the updated management of the integrated pipe network. For example, aerial wires falling to the ground and elevated wires intricately erected in mid-air affect the overall aesthetics of the street, which need to be integrated into the underground pipe network system for unified design. In terms of human scale, designers should increase the "shaded corners" of streets to create comfortable sidewalk widths and rest stops.

The Coastal Streets in Fukuoka streets are a primary urban space for public viewing of the ocean, appreciating the scenery and perceiving the landscape. To enhance the street greenery of the area and ease the sense of oppression and prominence from the buildings, some of the buildings can be greened with three-dimensional plantings. By means of graded coastal elevation, ecological embankment, and planting alkali-tolerant plants, a planted soft shore can be created, with steps and platforms leading to the waterfront being added to increase the waterfront accessibility of the shoreline. To effectively boost the vibrancy and appeal of the area, targeted additions of Fukuoka Coastal Street tourism, commercial services, and public open spaces should be made. A continuous seating staircase and slope along the shore can be built to transform the waterfront open space into a popular urban balcony, improving view between the city and the sea. To strengthen the openness of the waterfront views and the integrity of the skyline, the number of artificial facilities such as buildings and constructions should be reduced.

Reference

[1]Yoshinobu Ashihara. The Aesthetic Townscape. Jiangsu Phoenix Literature and Art Publishing LTD (2017) ISBN: 978-7-5594-0439-8