

Article

The Impact of Street Space Perception Factors on Elderly Health in High-Density Cities in Macau—Analysis Based on Street View Images and Deep Learning Technology

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Abstract: The urban space environment has been proven to be related to the health of the elderly. However, as a high-density city, Macau's limited urban space must cope with the growing population and the arrival of an aging society. In the existing studies, less attention has been paid to Macau, especially the relationship between Macanese elderly and urban space. This study uses Baidu Street View (BSV) on the Macau Peninsula and conducts field surveys to obtain street view data to evaluate the openness, greenness, interface coverage, and road area ratio of street space and its association with the physical and mental health of the elderly and social health. The results show that the data truly reflect the overall street space conditions on the Macau Peninsula. The street openness, greenery rate, and interface enclosure are all related to the elderly in various evaluations in areas with a higher population dependency index and aging index. Human space perception is related to health gain, and road area ratio is weaker than other indicators. The research results have certain policy implications and have practical significance for city managers and designers.

Keywords: street view data; deep learning; street space; elderly health; macau

1. Introduction

The expansion of cities and the increase in population density have put greater stress on the urban space environment (air pollution, lack of public space and facilities, etc.), and these problems will also lead to physical and mental illnesses of various types in urban residents. People's attention to the urban space environment has led to a series of studies. For example, congestion in urban space can lead to mental stress [1], brain damage, and Alzheimer's disease due to air pollution [2]. An experimental study in northern Italy showed that urban space is tightly structured and by a good

public transport system. It is easy to increase the opportunity to go out to participate in activities and socializing, thereby reducing the risk of depression, especially for women and the elderly [3]. Subjective perception of the objective physical space environment in the city will affect residents' use of space and trigger a series of health-related behaviors [4].

The health problems of the elderly in urban residents are gradually being paid attention to by researchers in different disciplines, because population aging is becoming a global problem, and Macau, as a blend of Chinese and Western cultures, faces double problems: Limited land area and continuous growth of the number of people. According to Dermographia's ranking of world population density in 2019, Macau ranks fifth in the world [5]. According to relevant research, 84.5% of the elderly population in Macau suffer from one or more chronic diseases [6], which not only affects the quality of life of the elderly, but also affects medical services and socioeconomics. All of them have caused a heavy burden to Macau. In high-density cities, such as Macau, many elderly people live in urban historic districts because of the familiar community culture and spatial environment. Because older people are less mobile than younger people, older people have shorter social and activity radii. In addition, the elderly in Macau spend most of their daily life in the surrounding public space. One of the reasons for this is the limited urban living space. High-density and mixed-use urban planning models usually mean that different space types are closer and more possibilities for outdoor activities occur, enabling people to make better use of public space in the neighborhood and generate more social opportunities [7], the pressure of urban renewal and limited land area are the main restrictions on the adequacy and quality of public space provided by the block [8].

Several research results show that a healthy lifestyle can improve the physical activity function of the elderly, delay the onset of disease and improve the quality of life [9], a good lifestyle is related to the aging adjustment of the elderly [10], lifestyle helps promote and improve health, and participation in outdoor activities through urban street space is one of them. In most studies, the research content is related to European and North American cities, while Asian research is still insufficient, especially in special high-density cities such as Macau. This is in contradiction with the current situation of Macau's aging society (by 2025, the proportion of the elderly population is expected to reach 16.3%, Macau will become an aging society) [11]. Compared with young people, the elderly are more affected by the surrounding space environment due to their limited mobility [12]. Therefore, the research on the relationship between the perception of the street space environment and the health of the elderly has become one of the key contents in the discussion of urban design and public health in Macau, which also has important policy significance for Macau's response to the aging society and urban regeneration.

1.1. Spatial Perception and Health Gain

Urban researchers make pre-judgment and analysis of how residents perceive and use space places, they study which space content will affect residents' use of space and propose ways and methods for design updates [13]. In the "space-perception-behavior-health" research logic, we can abstract, extract, and classify the elements of the space environment to explore its laws and make them better used in services. Existing research usually supports the following viewpoints: Residents' perception of the urban space environment (including: Transportation, green space, noise, spatial scale, neighborhood facilities, informal spaces, etc.) will affect their behavior choices, well-being, and health outcomes [14–16]. The impact of the urban space environment on health is direct or indirect [17,18].

When new technologies and new data for the study of cities continue to appear, it adds more possibilities to the "space-perception-behavior-health" research path, providing more detailed spatial characteristics and more accurate behavior and perception. The record avoids the problems of extensiveness, credibility, time and effort, and validity of judgment in the previous research, thereby more accurately describing "the relationship between the urban physical space environment and the health of residents, which are the influencing factors, and passed the basic question is what kind of behavior affects residents and what kind of behavior will result." There are mature theoretical

explanations for the impact of the space environment on human health and behavior. We can recognize it through stress reduction theory (SRT) [19], attention recovery theory (ART) [20], and Social Cognitive Neuroscience [21]. The perception of how the environment affects the spirit, the mental stress caused, and their overall health. “Evolutionary adaptation” and “Biological adaptation” are considered in SRT as sources of positive perceptions of the environment. For example, since early humans concealed food resources into a green space environment, such an environment would have a positive recognition for them [19]. In ART theory, people’s daily stress and mental stress need to be buffered, which can be improved by a positive understanding of the environment [20]. People’s perception of the space environment may indirectly affect health through health-related behaviors, such as sports and social activities that are important to their health [22,23], people’s sense of smell will be related to the space environment [24]. Arabian–Russell Model theory (AR model) states that people’s emotions are affected by environmental perceptions, and then their emotions may affect their behavioral choices. For example, when people have a positive view of an environment, they are more likely to stay in that environment and participate in activities [25]. Therefore, a positive view of the street space environment may increase the tendency of older people to participate in leisure activities and social interactions with others.

1.2. Elderly Health and Space Environment

According to the WHO’s definition of health, health is considered to be an overall state of complete physical, mental, and social health, rather than disease and weakness in a pure sense. Combining this definition, there are three ways to get healthy, namely outdoor leisure activities, contact with the natural environment, and social interactions [26]. In terms of cultural background, society, economy, etc., the cultural and spatial environments and ecological environments in different regions are also very different. At the same time, there are also large differences in population distribution, service levels, and urban infrastructure [27,28]. These characteristics directly or indirectly affect the elderly’s perception and interaction with the space environment [29]. In many studies, environmental attributes have been shown to play a positive role in coping with aging societies. At the same time, it is pointed out that the elderly are not only the fastest-growing subgroup of the population but also the group with the least physical activity [30].

- Urban outdoor public space and elderly leisure activities. Anner et al. emphasized that the characteristics of the environment may become a major obstacle to the “participation in activities” of the vulnerable elderly when systematically examining the impact of the environment on healthy aging, and emphasized the correlation between the spatial environment and the level of physical activity [31]. Regular exercise can prevent and treat many diseases (including those related to the central nervous system). Physical exercise can reduce mental illness and neurodegenerative diseases (including depression, Parkinson’s disease, Alzheimer’s Disease, cognitive impairment, and dementia). Regular and proper physical exercise will help maintain the normal functioning of the brain and nerves [32,33]. In general, a lot of evidence shows that participating in regular physical exercise has great benefits for the physical health of the elderly, and it also benefits and slows down the aging process [34–37]. Therefore, public space in the neighborhood should attract the elderly to go and carry out sports activities. In the existing research, the corresponding evaluation attributes [38] are determined from the dimensions of usability, accessibility, and security, as follows: Legibility [39,40], internal and external connections [41], accessible sidewalks and reachability [42–45], adequate lighting [46]. We should analyze in depth the order in which the elderly obtain information through spatial perception, because, in a limited space environment, it is important to know what should be done first if it is not possible to fully meet the needs of the elderly.

- Green space and elderly health. The process of contact with the natural environment can promote human health and well-being [47,48], and has a positive effect on blood pressure, cholesterol, and stress reduction [49]. Devries reports that possible reasons for the positive effects include improvements in air quality, stimulation of physical activity, the convenience of social interaction, and

the restoration and reduction of stress [50]. Among them, stress relief provides the most reasonable and comprehensive explanation [51]. Therefore, the health benefits of exposure to nature are primarily related to psychosocial health. By interacting with the green space every day, the elderly can get more happiness and increase their social connection and sense of belonging [52,53]. Older people are immersed in nature and feel less stressed [54]. Based on the above discussion, setting street space can improve the health of the elderly by improving color and natural elements.

Therefore, in the high-density neighborhood space environment, in the dimension of contact with nature, and the space color and landscape plants are the primary considerations. These could include the key standards of high-density vegetation [54,55], plants suitable for local growth, governmental provision, and the participation of elderly residents. Social communication is one of the important ways for the elderly to achieve social health, and street space is one of the carriers for its realization. Attention to the space environment of the elderly community is also a way to increase the social participation of the elderly [56–58]. Streets and their public spaces can reduce social isolation and provide appropriate places for social interaction, where environmental factors can positively affect informal social contact between neighbors [59]. More importantly, numerous studies have shown that certain environmental attributes can promote these informal social behaviors. Older people prefer to sit near activities such as sidewalks to observe their environment. Therefore, it is important to properly arrange the facilities suitable for the elderly [60], and to pay attention to the paths to these facilities [44].

In summary, street space and some attached public spaces have a significant effect on the health of the elderly. It is one of the important spaces for the elderly to carry out leisure activities. It is also a space for the elderly to share skills and even develop social networks. Each feature class in the space is playing a synergistic role. They are also subconscious elements for the elderly's screening activity space. The acquisition of each health content is not isolated. There is a connection between them. In the face of high-density areas, such as Macau, when street space in the city is limited, how to integrate some informal and scattered small spaces and play a role together also needs to be considered. At the same time, how to maintain the vitality of the space so that it can form a self-circulating system must also be looked at.

1.3. Research Problem

With the growth of urban data and the development of deep learning technology, urban researchers can collect large-scale street view images of the research area in a short time, which contain a large number of spatial information (sky, green view) [61–64] and ground object information [65], which provides more possibilities for research [66–68]. Street view, green space, and blue space can prevent depression in the elderly in China [63], for example, street view images were used to evaluate the perception of the built environment of the elderly in the Haidian District of Beijing through human-machine confrontation scoring process [69].

As shown above, previous studies have focused on the objective description of the physical space of the street from the perspective of the composition of the design elements of the street space environment. From the adaptability of the space user, the adaptation to the subject to the use of street facilities was described with focus on understanding the subjective feelings of users. Recent reviews indicate that deep learning methods are booming in the field of computer science and can be well applied to urban environment research [70]. In this study, we tried to establish a preliminary study on the assessment of Macau's urban streetscape dataset and the elderly to obtain health variables through spatial perception. The study aims to identify the relationship between spatial environmental elements and the health of the elderly. Therefore, the purpose is to evaluate street space in the study area through street view data. In areas where street view data are not available, field measurements are used to make up for the lack of data. Based on the existing research and the actual situation of the research object, the following research questions were designed:

- Overall environmental assessment of Macau Peninsula streetscape, assessing the current situation of street space in areas where the elderly live in concentrated areas;

- Obtain effective street view data from the perspective of the elderly, and conduct field observation and research.

2. Materials and Methods

2.1. Study Area

In Macau, 85% of people live on the Macau peninsula, which has an area of only 9.3 km². According to data from 2018, the population density of populations greater than or equal to 120,000 people/km² are Doca do Lamau, Horta e Costa e Ouvidor Arriaga, Fai Chi Kei, Barca, Areia Preta e Iao Hon, making them among the most densely populated areas in the world [71] (Figure 1).

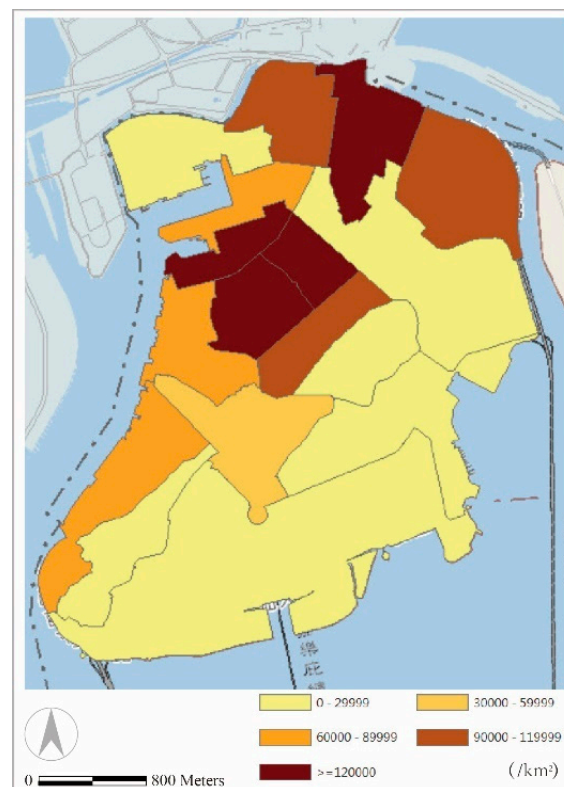


Figure 1. Population density distribution map of the Macau Peninsula.

2.2. Study Population

This study uses data from the 2011 census of the Macau Special Administrative Region Government and data from the citizens' physical fitness monitoring work conducted by the Sports Bureau in Macau in 2015 as basic empirical supporting data. It also used field research conducted in Santo António, one of the areas with a concentrated elderly population. As of December 2018, Macau had a population of 74,100 people over 65 years old, accounting for 11.1% of the total population, which is an increase of about 53.8% compared to the 39,900 elderly population in the 2011 census. As of 2018, the urban population aging index was 84.1%. According to the census data, the elderly population dependency index and aging index are higher in the following districts: Horta e Costa e Ouvidor Arriaga, Patane e São Paulo, Conselheiro Ferreira de Almeida, Guia, Baixa de Macau, Barra e Manduco, Praia Grande e Penha (as shown in Table 1).

Table 1. Regions with high dependency index and aging index of Macau’s elderly population.

Statistical Areas	Age Dependency Index	Aging Index
Horta e Costa e Ouvidor Arriaga	13.8	92.5
Patane e São Paulo	11.1	89.6
Conselheiro Ferreira de Almeida	13.8	100.6
Guia	14.1	81.8
Baixa de Macau	15.9	128.8
Barra e Manduco	10.4	84.2
Praia Grande e Penha	16.0	111.0

In the 2015 Macau Special Administrative Region Citizen’s Physical Fitness Monitoring Report (surveillance results for the elderly), a total of 638 valid samples were taken, including 201 males and 437 females. The survey results show that 13.3% of the average daily walking time is less than 30 min in daily life, 30.1% for 30–60 min, 33.2% for one to two hours, 23.4% for two hours and above, and, with age, the proportion of people who walk for a long time (more than two hours) increases, while the proportion of people who walk for less than two hours decreases [72]. With the increase of age, the physical functions of the elderly continue to decline, but their spare time increases, and the willingness of the elderly to go out (physical exercise, participate in social interactions, etc.) increases, and they expect to get healthy through outdoor activities.

The leisure time of the elderly is mainly used for sports activities (76.6%). In the comparison of men’s and women’s activities, women’s participation in sports activities is higher than men’s, and men’s activities are richer than women’s. The primary purpose of the elderly participating in physical exercise is to prevent and treat diseases (73.8%), and the others are in order to improve exercise capacity (38.2%), reduce stress, regulate emotions (27.1%), socialize (23.9%), etc., and with age growth, the proportion of the number of people for the purpose of “prevention and treatment of diseases” increased. The main places for the elderly to participate in physical exercise are: Parks (68.2%), stadiums (32.7%), roads or streets (10.8%), and open spaces (9.5%). Among them, the number of men who choose open spaces increases with age. Women’s choices do not change much.

Sickness: Among the surveyed population, 59.7% of the elderly suffer from hospital-diagnosed diseases. The diseases with the highest proportion of patients are: Hypertension (55.8%), and diabetes (18.3%), digestive system diseases (14.1%), cardiovascular and cerebrovascular diseases (9.2%), others (24.8%), and the number of patients increased with age.

2.3. Get Street View Data

The study is based on obtaining street view data of Macau (Peninsula) streets through Baidu maps on 16 December 2019. The area has a high population density, and at the same time, it has a high development intensity and is difficult to update. The investigation conducted in this environment can provide guidance for the research on the relationship between spatial quality and the health of the elderly in urban high-density areas, and the data sampling time was April 2018. In the study, sampling point lines were established along the road network. In order to ensure accurate data, the sampling points were 20 and 10 m apart. The street view images in the horizontal direction were queried through HTTP URLs and crawled by applying a Python programming program. In order to obtain a complete image for each sampling point, the street view contains six main directions (i.e., 0° , 60° , 120° , 180° , 240° , 300° , 360°) (Figure 2). The size of each street view image is: 999×512 pixels, and the vertical angle is 0° . Each picture contains information, such as the unique identifier of the location, latitude, and longitude, horizontal and vertical angles of sight. A total of nearly 18,669 pictures were crawled. The study was conducted in three steps (Figure 3). Then, based on machine learning-related algorithms for data cleaning and image segmentation, street view data were processed to eliminate invalid images such as pedestrian plazas and tunnels. Because Baidu’s street view pictures show various types of data regarding the angle of the roadway and do not consider the data generated by the perspective range of

people in the single-sided street interface. The average height that simulated elderly visual height was supplemented by street view evaluation tools (Figure 4).

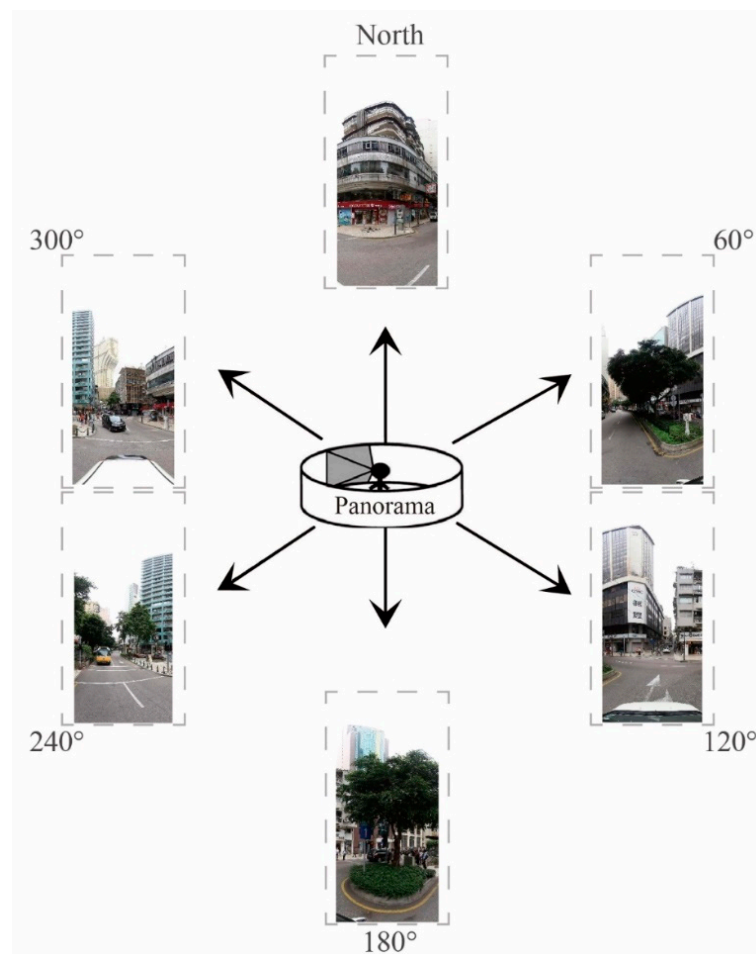


Figure 2. BSV(Baidu Street View) images captured in six directions at one of the sample sites.

2.4. Image Segmentation

In order to make the image more accurate in the study, the image was cropped, and the Baidu street scene collection vehicle was partially cropped. Kendall et al. [73] used pixel-level semantic segmentation of deep fully convolutional neural network architecture segmentation technology (Bayesian SegNet) to understand the visual scene-input image data, and the SegNet decoder to synthesize the characteristics of the environment, surrounding elements, and graphics to achieve an objective scene intelligent segmentation of features. After testing a variety of outdoor R (red) G (green) B (blue) (RGB color mode) images, this method is considered to be reliable [74]. In the study, a deep fully convolutional neural network architecture using pixel-level semantic segmentation was used for semantic segmentation (i.e., FCN-8). The input image was synthesized by the SegNet decoder to the environment, surrounding elements, and the characteristics of the graphic itself to achieve the objective elements of the scene smart segmentation [75] (Figure 5).

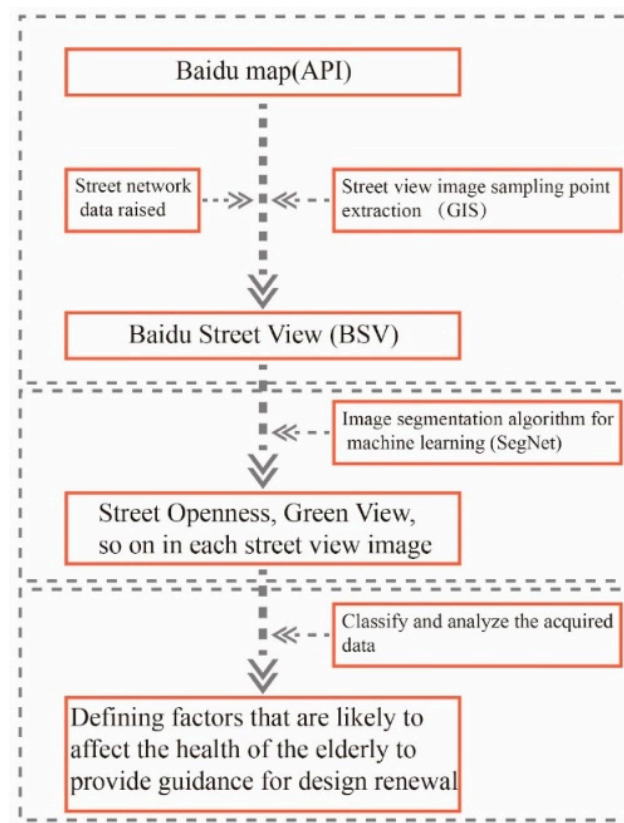


Figure 3. Research idea schematic.

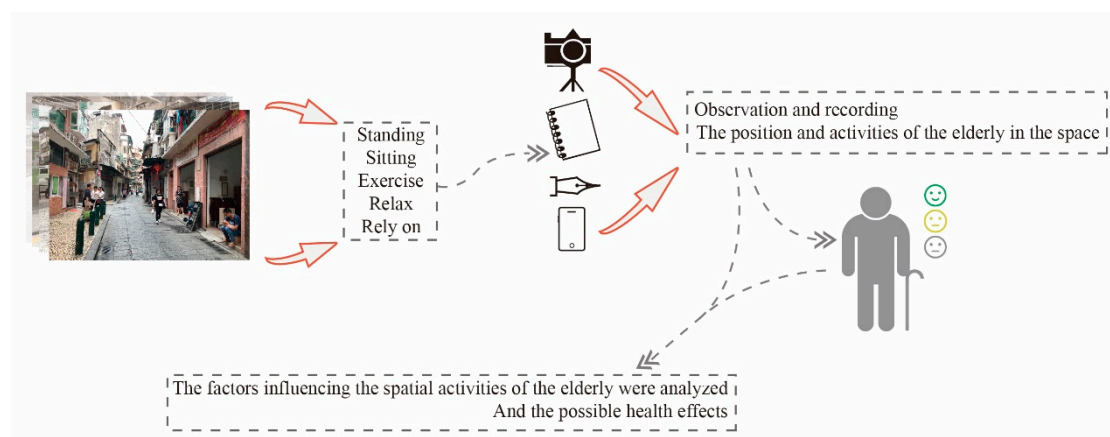


Figure 4. Methodological flow chart.

In this study, by interpreting the elements of the street space image of the island of Macau, inputting the image data of all points, and after obtaining the image segmentation from the trained network, we identified “sum_count”, “sidewalk”, “building”, “Wall”, “fence”, “pole”, “traffic_light”, “traffic_sign”, “vegetation”, “terrain”, “sky”, “person”, “rider”, “car”, “truck”. There are 20 types of elements: Bus, train, motorcycle, and bicycle. At the same time, according to the categories of factors that affect the health of the elderly, green view, street openness, street interface enclosure, and road area ratio are used.

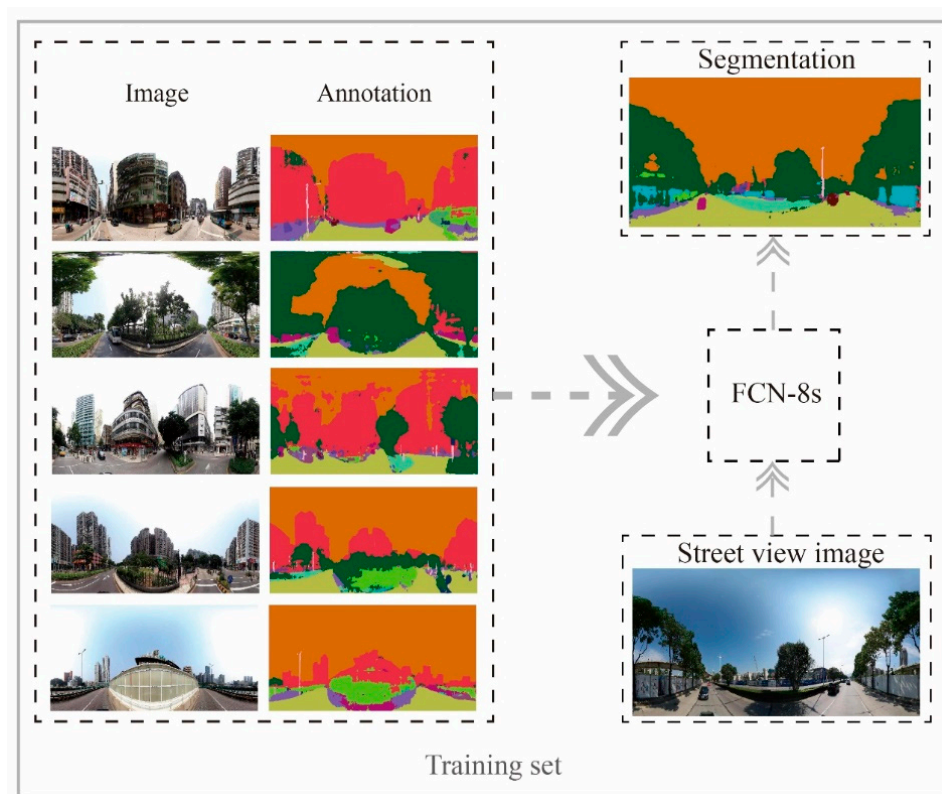


Figure 5. Street view image segmentation through the convolutional neural network (FCN-8s).

The next step is to classify them, and remove indicators that had unstable rates of cars, bicycles, and pedestrians were removed. Among them, the green viewing rate is the possibility of trees appearing on the city street, and the proportion of street greening in the street view image. The street openness indicates the degree of openness of the street, which is represented by the proportion of the sky. This range is defined by the interface on both sides of the street the top contour is determined. The degree of interface enclosure mainly describes the degree of enclosing the street on the sides of the interface, and the value is mainly determined by the proportion of the building and the wall, and the road area ratio is used to characterize the traffic of the point and to understand street layout, paving materials, and car presence are relevant.

3. Results

The study summarizes the indicators of each category after the image segmentation. From the distribution map of the interface enclosure (Figure 6), it can be seen that the average interface enclosure degree of Macau island is 60.21%. From the perspective of spatial distribution, the central district has a high degree of interface, with a large area ranging from 60.81% to 95.08%, and decreases from the central district and, then the central and western to the eastern and southwestern districts. The degree of enclosure is generally high. In the three districts (Conselheiro Ferreira de Almeida, Baixa de Macau, Praia Grande e Penha) in which the dependency index and aging index of the elderly population exceed 100, image data was not obtained in some regions due to road narrowness and other factors, but the data distribution shows the values of 45.72%–60.8%, 80.81%–95.06% which are relatively high.

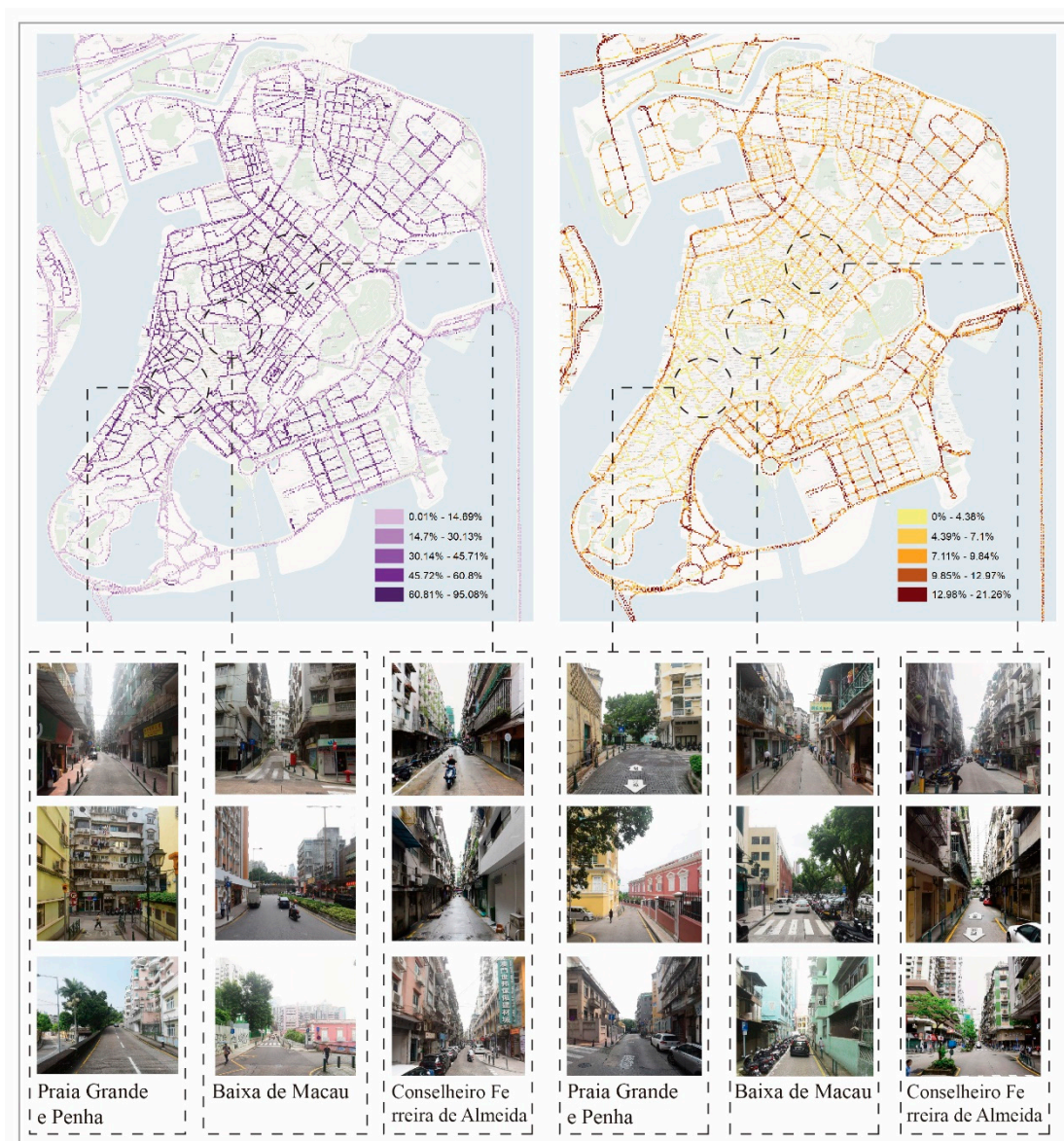


Figure 6. Display of results of segmentation.

In the road area ratio distribution chart (Figure 6), from the perspective of the overall regional distribution, the average road area ratio is 8.69%. The area of peripheral roads accounts for a relatively high area, with 12.9%–21.26% of numerical values concentrated in the northeast and southeast regions. In urban central areas, the numerical distribution is mainly 0%–4.38%, 4.39%–7.1%. This situation is caused by the high-density space environment of the city. The central urban area belongs to the old urban area, with narrow road space and small building spacing, which may cause unhealthy factors to the daily life of the elderly residents such as small street area, car exhaust pollution, heavy traffic, traffic accidents, etc.

As can be seen from the distribution map of street openness (Figure 7), the average street openness of the street space in the island of Macau is 0.96%, and the street openness in the central region is relatively low, ranging from 0% to 0.81% and from 0.82% to 2.42%. More, 2.43%–4.56%, 4.57%–7.72%, 7.73%–19.13% are distributed in the northeast, east, south, southwest of the region, and the distribution is relatively small. The icon clearly reflects the real situation in the area, reflecting the high density and low permeability of the central area, but there will be a small amount of more transparent space due to the undulating terrain. The outer space of the city will be affected by the ocean and high

permeability. The situation in the three regions with a higher dependency index and aging index is also not optimistic.

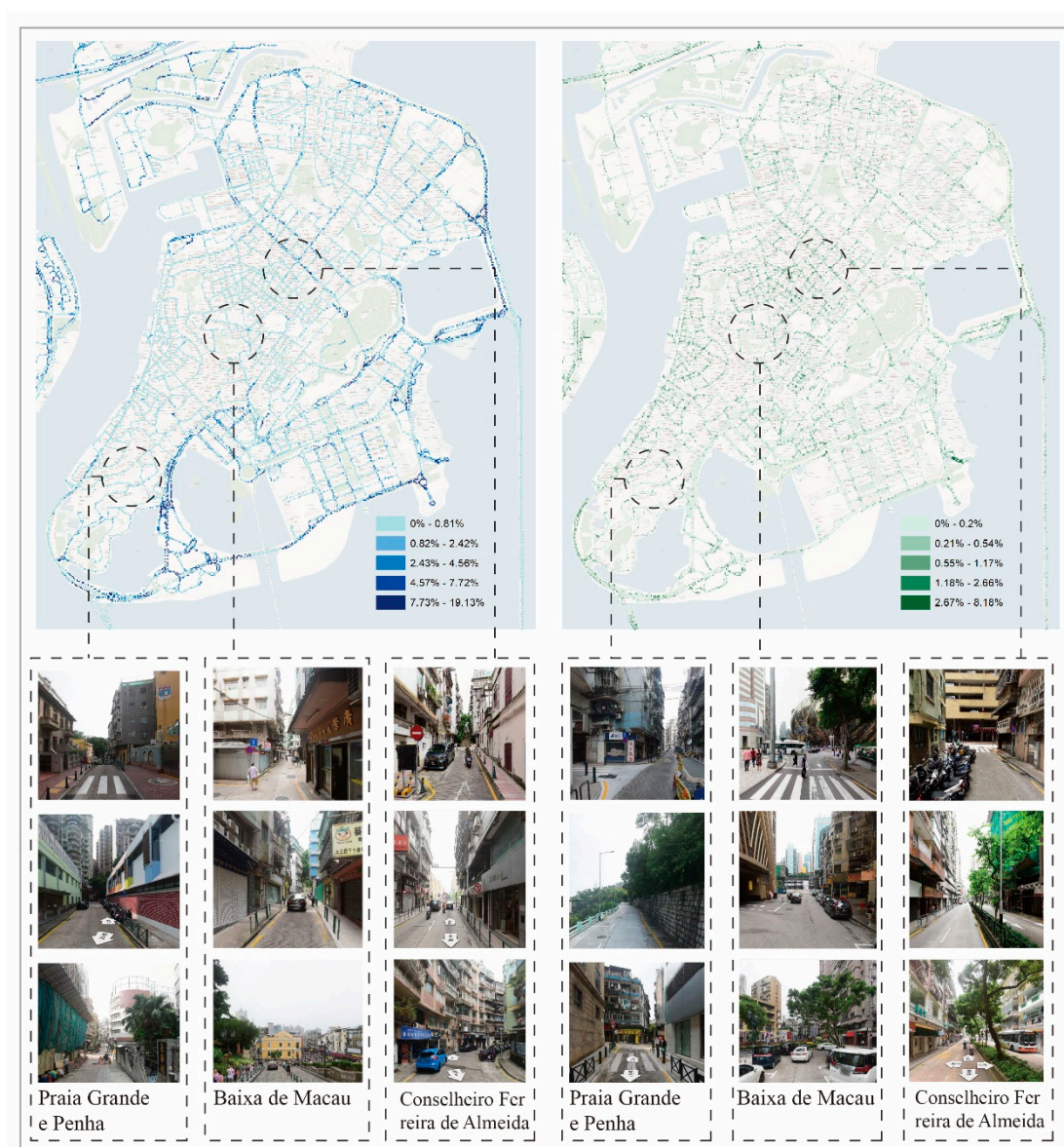


Figure 7. Display of results of segmentation.

Studies have shown that a space with a higher green vision can bring a more comfortable space experience and can have a soothing healing effect on people. In the green vision rate distribution chart, the average street openness is 0.65% from the overall area, and the distribution of each value is relatively scattered. In Conselheiro Ferreira de Almeida, Baixa de Macau, Praia Grande e Penha, the green vision of the three regional spaces the rates are mostly 0%–0.2%, 0.21%–0.54%, and 0.55%–1.17%.

This study selects public street spaces where the daily activities of elderly residents are concentrated and have no street view data as an in-depth study. The street and its surrounding area of 500 m (including 21 public spaces in 1 block) are used as the street view image data acquisition area. The in-depth analysis and research are made on four aspects: Road area ratio, street interface enclosure, green view, and street openness.

(The openness of the street refers to the proportion of the sky area viewed from the perspective of the human eye in the global picture, and the street view image represents the sky picture from the perspective of the roadway, and does not fully consider the sidewalk on the side of the street. The

influence of the difference between the green area and different buildings on the sky area under the perspective of human eyes, taking into account the above factors, the sky area conversion coefficient of the single-sided interface is introduced in this study [76], which is represented by letter A.)

It can be seen from the analysis (Figure 8) and calculations (Table 2), that in the areas where the elderly live and work relatively concentratedly, the street interface has always occupied the highest proportion, the green vision rate is higher than the street openness, and the road area ratio accounts for five groups of data. The proportions are low, and the data can confirm the situation in the area (Figure 9). In a narrow street space, how to use a relatively high street interface enclosure area should be one of the key considerations for city managers and designers.

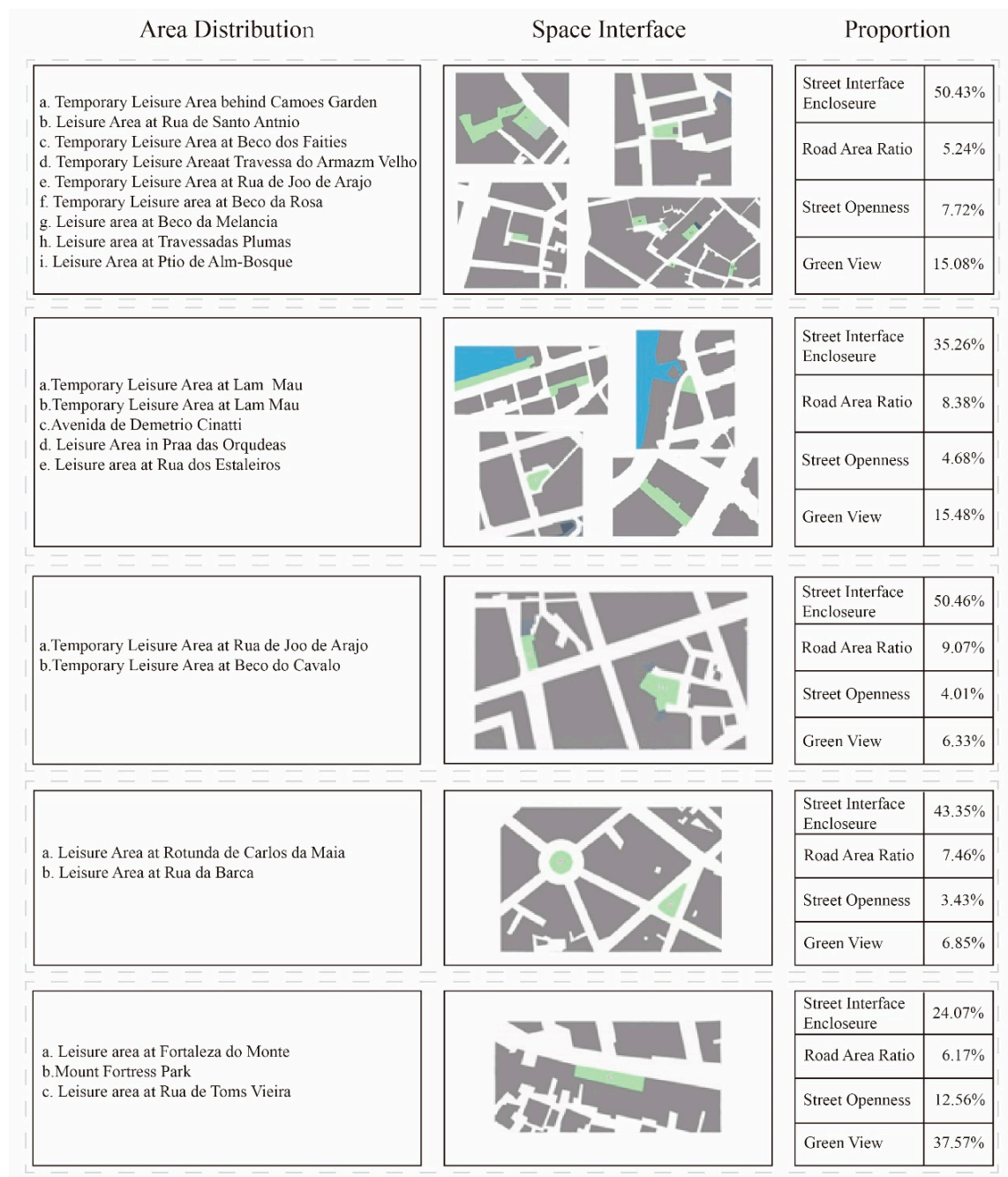
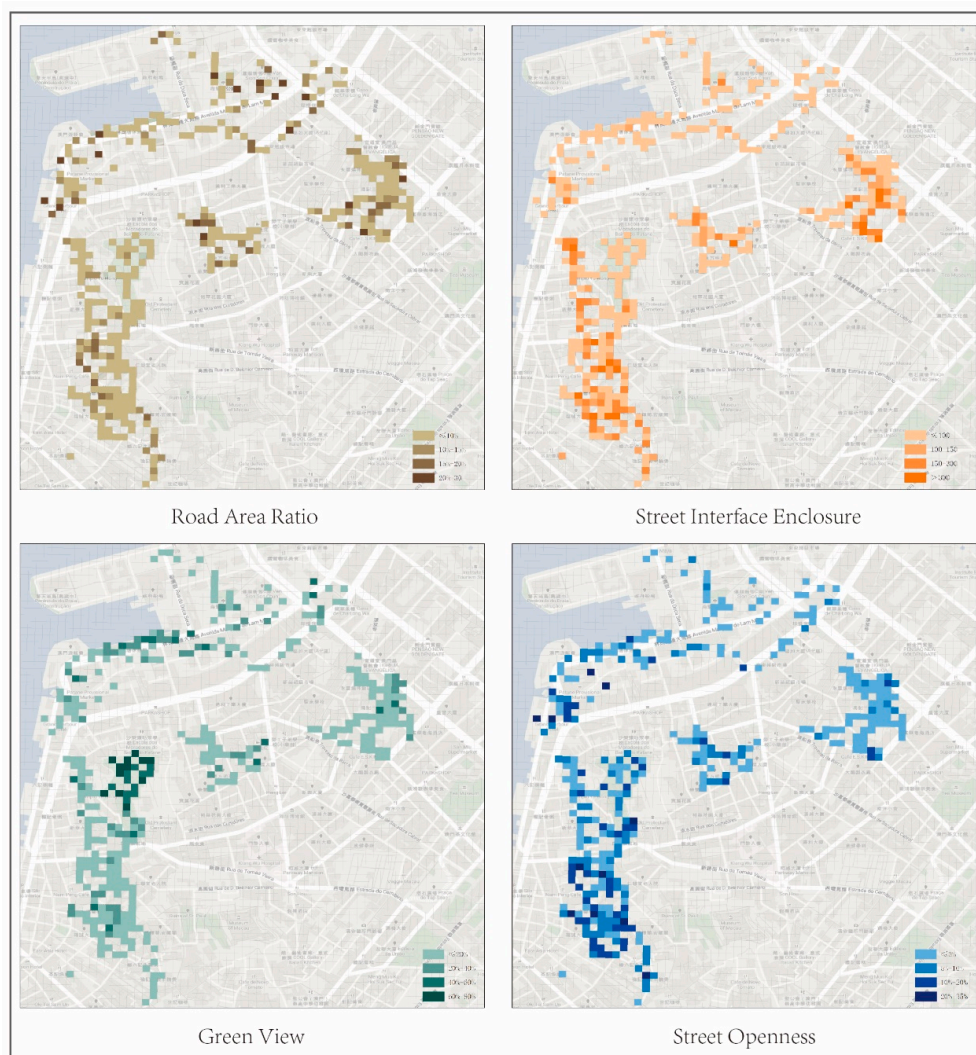


Figure 8. Survey spatial distribution and data graph.

Table 2. Relevant indicators and their contents, formulas and explanations.

Indicators	Definition	Formula	Explanation
Street Interface Enclosure	The enclosure of street interface, the proportion of buildings and walls in the image.	$SIE = \frac{\sum_{i=1}^4 (Area_{build_{ij}} + Area_{wall_{ij}})}{\sum_{i=1}^4 (Area_{sum_{ij}})} \times 100\%$	$Area_{build}$: The number of build pixels; Sum is the total pixel number.
Road Area Ratio	Proportion of roads in street image, Pedestrians, automobiles, motorcycles and other means of transportation are not counted, and they have certain uncertainties.	$RAR = \frac{\sum_{i=1}^4 (Area_{road_{ij}})}{\sum_{i=1}^4 (Area_{sum_{ij}})} \times 100\%$	$Area_{road}$: The number of build pixels; Sum is the total pixel number.
Street Openness	Proportion of sky in street image.	$D_{0left} = D_0 \times A_{left}$ $D_{0right} = D_0 \times A_{right}$	A_{left} : Left interface coefficient; A_{right} : Right interface coefficient; D_{0left} : Openness under pedestrian space on the left interface; D_{0right} : Openness under pedestrian space on the right interface. A_0 : Single-sided interface conversion coefficient; W_p : Sidewalk width; w_v : Motorway width; v_{green} : Corresponding green view rate; v_{build} : Architectural proportions corresponding to perspective pictures; n : Total number of unilateral (left or right) road sections.
Green View	The area of the sky in human eyes is inversely proportional to the area occupied by vegetation and the height of the building. Proportion of plants in street image.	$A_0 = \frac{\sum_{i=1}^n \left[\left(\frac{W_p}{w_v} \times \frac{1}{(v_{green} + v_{build})} \right) \right]}{n}$ $GV = \frac{\sum_{i=1}^4 (Area_{tree_{ij}})}{\sum_{i=1}^4 (Area_{sum_{ij}})} \times 100\%$	$Area_{tree}$: The number of tree pixels; Sum : The total pixel number.

**Figure 9.** Distribution of various indexes.

4. Discussion

This study is the first to study the relationship between streetscapes in Macau and health gains for the elderly. During the research, street view data was acquired through machine learning and field surveys, and a comprehensive assessment of the current state of street view in Macau.

The results of the study indicate that the overall urban street space quality of the local island of Macau, which is representative of high-density cities, is generally in need of improvement. Previous studies have demonstrated [70,77]: Positive perceptions of urban street spatial quality (e.g., street openness, green vision) have potentially positive effects on the health of older people, as well as negative spatial perceptions (e.g., street interface potential negative effects on the health of the elderly).

First, most of the research on the relationship between streetscape and health is concentrated in Western countries, but related research in China is gradually increasing. However, due to the small urban area of Macau, researchers tend to ignore it, which is not consistent with the fact that Macau is the fifth largest population density in the world, and the city is facing the arrival of an aging society. Second, ensure the matching of the training data set and the test data set are ensured. The datasets in the study are collected through Baidu Street View. With free street view images and machine learning methods, we can effectively obtain the perception of large learning areas (such as entire cities). This is one of the first studies using Baidu Street View to investigate the relationship between street view image perception and various health outcomes for a large sample of elderly people in Macau. A large number of training data samples and advanced machine learning methods ensure the accuracy of the perceptual data. The acquisition time of street view was selected in April 2018, so the accuracy and timeliness of the dataset can be tested. Third, due to the special nature of the urban space environment in Macau, the research sample is insufficiently representative, which makes it impossible to collect valid street view data in some areas. But these areas with difficulty in collecting valid data are still places where the elderly live that are even more dense. In areas without Baidu Street View, manual field surveys were used to obtain data to fill the gaps in the data. At the same time, Street View data obtained from the sidewalk and the perspective of the elderly can complement Baidu Street View data, further enhancing the validity of the data and improving the accuracy of the data results. Fourth, in the study, we also found that the street enclosure interface accounts for the largest proportion, and the elements contained therein will have a significant impact on the perception of the elderly. Buildings and the sky will affect the visual effect [61], green space can reduce the sense of stress, and streets and roads are narrow, and the impact of noise on residents' health [78], so they will all affect the mental state of the elderly. The elderly's perception of urban space is reflected in the perception of various elements in the space. The negative perception of urban space may increase psychological stress, which may become a source of long-term stress and lead to endocrine disorders and long-term health problems [79,80]. Knowledge of the spatial environment may also affect health-related behaviors in older people, including physical activity and social interactions. This phenomenon can be explained by Mehrabian–Russell model theory, which believes that human perception of the urban environment may affect our emotions and feelings, which in turn may affect our behavior choices [25]. Positive urban concepts may encourage residents to participate in more health-related activities and promote their health, while negative urban concepts may reduce residents' health-related activities and have a negative impact on their health [81]. Therefore, as a city manager and designer, attention should be paid to the visual proportion of different ground objects.

At last, an explanation of whether the selection of the elderly as a research group is fair. Elderly people may have limited mobility and stay at home most of the time. In contrast, the daily environmental exposures of young people include their neighborhood, workplaces, and leisure places [82,83]. As a result, older people are more susceptible to the surrounding environment than young people. Second, older people have a stronger attachment to their neighbors than younger people, because this is their most important social space [12,84]. Therefore, the perception of the spatial environment may have more influence on the elderly than the young. Compared with young people, older people have a restricted radius of activity, so they are more constrained.

The further development of this study will help provide relevant support for the ongoing urban renewal, aging society, and healthy city construction in Macau. Research on using Baidu Street View to investigate the relationship between street view image perception and various health outcomes has developed a lot in recent years. A large number of training data samples and advanced machine learning methods have ensured the accuracy of the perception data. However, some limitations should be noted. Firstly, in some circumstances, the use of street view data to assess factors related to the health of the elderly in urban streets has to eliminate the non-objectivity of subjective evaluation. After comparison, the analysis of objective factors and the evaluation and analysis of users' subjective feelings, the use of deep learning methods enables the research process to be more effective and accurate in identifying relevant content. Secondly, a large number of research tests have confirmed that Street View can promote the physical and mental health of the elderly. However, the research process is also subject to certain restrictions. The accuracy of the objective component analysis of the research elements still needs to be further improved. The four indicators of the element analysis could be expanded continuously. The subsequent subjective evaluation part can also combine with traditional survey methods on trying to build a regression model of objective elements' contribution to subjective feelings.

5. Conclusions

This study provides a better understanding of the extent to which streetscapes in Macau are related to the health of the elderly, by using street view data and deep learning to extract factor indicators related to spatial perception. Although some problems still need to be solved, the combination of street view data and deep learning provides a valuable tool for the automated environmental assessment of street space. In the related evaluation of the study, the factors that influence the degree of street enclosure in the space are more influential, while the degree of openness and road area ratio in the space have less influence on the quality of the space (poor remodeling). Therefore, in the future optimization of Macau's urban street space, the fusion relationship between the "hard" interface of the street enclosure and the "soft" interface of the environmental interface should be dealt with. For example, the building wall needs to be improved by greening and color beautification to improve its ability to shape the building interface. Without affecting the continuity of the interface, vertical greening, curtain wall renovation, and wall decoration can be used to shape the changing building interface space, meanwhile, the related environmental interface feeling and spatial scale feeling will be improved to varying degrees. In future research, we will make good use of street view and obtain the evaluation of street view through the questionnaire of the elderly's perception of space aiming to build a healthy ecosystem related to Macau's elderly health, and make a positive contribution to supporting the construction of healthy aging in Macau.

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