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Strategies of Enhancing the Vitality of Pedestrian Spaces Based on Multi-factor Assessment

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Strategies of enhancing the vitality of pedestrian spaces based on multi-factor assessment

A Dissertation Submitted for the Degree of Master

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Abstract

Pedestrian space is the main place for people to move around and interact, and is closely related to the vitality of the city. However, with rapid urbanisation, pedestrian spaces are experiencing a loss of vitality, with the good urban public life disappearing. Since the end of the last century, valuing pedestrian space and enhancing public vitality has been a worldwide call. The question before us is how to create intimate and vibrant pedestrian spaces in a fast-moving modern city. It is of great practical importance to review the development of related theories, examine the current situation of urban pedestrian spaces, and study the methods of enhancing the pedestrian space vitality.

This research aims to establish a methodology for evaluating the vitality of pedestrian spaces, and to explore subsequent analysis and design tools to provide guidance for the construction and renovation of urban pedestrian spaces. Firstly, through the literature review study, the definition of pedestrian space vitality was clarified and the relevant principles behind it were elaborated, laying the foundation for the subsequent assessment. Secondly, the assessment factors were identified in conjunction with other related studies, and a multi-factor assessment method for the vitality of pedestrian space was established. The method was then applied to evaluate the vitality of the Ningbo Tianfeng Pagoda neighbourhood, obtaining the current status of the neighbourhood's vitality distribution and the problems existing in the area. Finally, based on the assessment results, a strategy for pedestrian space vitality enhancement was formulated and designed in detail.

This research divides the assessment of vitality into two dimensions: the assessment of the characteristics of public activities and the assessment of the environmental conditions behind them, unifies the results of each factor using a five-dimensional scale, and explores the interrelationships between the factors. It is hoped that a more scientific and accurate strategy for enhancing the vitality of public spaces can be derived from the mechanisms that generate public activities. As urban environments vary around the world, such locally adapted and realistic strategies for evaluating and

designing pedestrian spaces can be useful inspiration for old city regeneration, urban design, community creation, etc.

Key words: pedestrian space, urban vitality, multi-factor assessment, urban renewal, spatial design

摘要

步行空间是人们出行和交往的主要场所，与城市的活力息息相关。然而，随着城市化的快速发展，步行空间出现了关注度减弱、活力降低的问题，美好的城市公共生活正在消失。自上世纪末以来，重视步行空间、增强公共活力已是全世界的呼吁。摆在我们面前的问题是：如何在物质和人员高速流动的现代城市中塑造亲切、活力的步行空间。回顾相关理论的发展状况、审视城市步行空间的建设现状、研究步行空间活力的提升方法具有重要的现实意义。

本研究旨在建立步行空间活力的评价方法，并探索后续的分析与设计手段，为城市步行空间建设和改造提供指引。首先，本文通过文献综述研究，明确了步行空间活力的定义，阐述了其背后的相关原理，为后续评价打下了基础。其次，结合其他相关研究，确定了评价因子，并建立了步行空间活力的多因子评价方法。然后，运用该方法对宁波天封塔街区进行了活力评价，得到了街区的活力分布现状和环境条件存在的问题。最后，基于评价结果，制定了步行空间活力提升的策略，并进行了细节设计。

本研究将活力评价分为公共活动特征评价和其背后的环境条件评价两个维度，使用五度量表统一了各个因子的评价结果，并探索了各个因子间的相互关系。希望可以从公共活动产生的机制出发，更科学准确地得出公共空间活力提升的策略。世界各地的城市环境各不相同，这种因地制宜、实事求是的步行空间评价和设计策略对旧城更新、城市设计和社区营造都有有益的启示作用。

关键词：步行空间；城市活力；多因子评价；城市更新；空间设计

Contents

1.Introduction

1.1 Background and significance

1.1.1 Walking is essential for residents

As the most basic form of human transport, walking has had a profound impact on urban space. The ancient Romans called their city blocks *insulae* (islands), which reflects the relationship between pedestrian space and the city: in ancient times, urban pedestrian space both divided and connected the city. Streets and squares intertwined to form contiguous transport networks, while the plots of private land surrounded by public streets were like an archipelago of islands set in a sea of public space [1]. As a result, the pedestrian space became the central space in the city: it existed not only as a passage but also as a place for important public activities such as meeting, trading, selling, and lecturing. Generations of ancient European architects devoted themselves to designing and optimising streets and squares, leaving behind vibrant pedestrian cities that are still celebrated today.

During the industrial revolution, the automobile, a high-speed, stable mode of transport, was rapidly industrialised and popularised. Modernist city planners were keen to replace the inefficient and crowded streets with an efficient urban system dominated by a motorised transport system. Corbusier, the flagbearer of modernism, proposed the slogan of “eliminating the street” and promoted his concept of the *“Ville Radieuse”* internationally. In the context of the post-war worldwide recovery of the economy, there was a huge demand for new cities and urban renewal projects. Motor-led functionalist urban planning was then widely adopted around the world and had a disruptive effect on urban form: motor vehicles were designated as the main mode of transport, while the pedestrian space of the inhabitants was cut up by highways.

However, modernist planning practices have ignored the social interaction needs of urban residents. It not only destroyed the urban pedestrian space network, but also destroyed the urban environment for public activities, resulting in disastrous consequences - loss of neighbourhood vitality, rise of crime rate, loss of high-quality population, finally, the decline of the city and the abandonment of buildings. This acute urban contradiction led architects and planners to rethink. The Smithsons, the core members of Team X, were the first to recognise the importance of the everyday life of residents. They challenged the functionalist urban theory of the Athens Charter at the CIAM conference in 1953, using photographs by the artist Nigel Henderson as evidence of the importance of the neighbourhood environment in which people lives [2]. In 1961, after years of observing cities from the perspective of a pedestrian, the American writer Jane Jacobs pointed out that the root of the current urban problem was the destruction of street life by the functionalist city in her book *The Death and Life of Great American Cities*, which had a huge impact on the urban planning theory of the time [3]. Since then, more and more scholars have returned to advocating pedestrian-led urban design, seeking to harmonise motorised transport with urban pedestrian systems. Today, walking is still one of the main modes of transport for residents. And its importance continues to grow, led by a culture of green mobility and healthy cities.

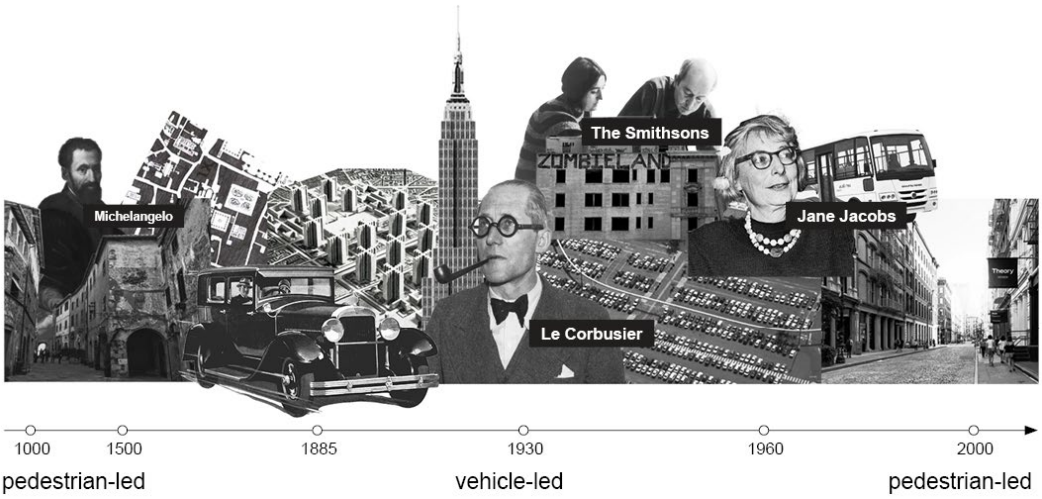


Figure 1-1. Urban pedestrian space history collage diagram

Source: own research

1.1.2 China's urban pedestrian space needs to be optimized

China has entered a phase of rapid urbanisation since the reform and opening-up. According to the information released by the National Bureau of statistics, China's urbanization rate has reached 64.72% in 2021, which is gradually approaching the average urbanization rate of 80% in developed countries. In 2021, *The Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Vision 2035* had for the first time proposed the “implementation of urban renewal action” at the national level, indicating the way forward for the innovation of urban construction and operation mode and the promotion of new urbanisation construction. It indicates that China has entered a new stage of development, with different development requirements, objectives, and modes. The importance of high-quality development has become a consensus. In the past, the rapid and sloppy construction of cities has created numerous low-quality urban spaces. The lack of consideration for pedestrian space has led to a decline in urban vitality, a problem that needs to be faced and solved today.

(1) The quality of the pedestrian environment in the old city is poor.

The lack of planning and control of early urban construction, the complexity of land tenure, the small size of the reserved space, and the poor quality of design and construction have combined to create a mismatch between the existing old city space and the rapidly expanding urban population.

On the one hand, the pedestrian space is insufficient and continuously compressed. Firstly, land ownership in old cities is complex and plot owners often use fences to enclose land, resulting in small areas and poor accessibility of pedestrian space. Secondly, the width of roads in the old city cannot meet the needs of today's large amount of motor vehicles, so many places choose to narrow the pavements or combine pavements and bicycle lanes to increase the number of lanes. Thirdly, the lack of underground development in the old city and the consequent difficulty in

parking makes it common for motor vehicles to occupy pedestrian space for parking. On the other hand, the existing pedestrian spaces are of poor design quality, which do not meet the needs of the residents. Many open spaces are left vacant or under inappropriate design and badly need humane renovation.

(2) The pedestrian space in new cities lacks vitality.

New cities lack the vitality of pedestrian space. In the process of urban development, modern planning concepts and city-building techniques were gradually introduced and developed in China. New cities built after the new century are often characterised by an abundance of space and high-quality infrastructure, but lack the vitality of old cities.

On the one hand, China's cities still follow the 'car-oriented' guidelines, building roads that are too wide and neighbourhoods that are too large, making the dimensions of urban space exceed a comfortable pedestrian scale. On the other hand, urban planning and design concepts are overly ambitious, pursuing macro-scale concepts and forms while neglecting the real psychological needs of residents. The lack of fine-grained urban design at the neighbourhood scale has resulted in many pedestrian spaces being left unattended despite excellent infrastructure.

Figure 1-2. Pedestrian space invaded by motor vehicles in the old city

Source: author’s own photograph

Figure1-3. Monotonous pedestrian space in the new city

Source: author’s own photograph

1.1.3 Absence of effective renovation guidance

In 2015, the Central Urban Work Conference put forward the concept of "Double Urban Repairs", which means using the concept of re-ecology to restore the damaged natural environment in cities and improve the quality of the ecological environment, and using the concept of renewal and weaving to restore urban facilities, spaces, and landscape, and enhance the characteristics and vitality of cities. Since then, governments across the country have been paying increasing attention to the transformation of pedestrian spaces. However, many renovation projects have often been hastily launched without a clear understanding of the problem, object, and method. As a result, some renovation projects do not have the effect of enhancing the vitality of the city, and even have a negative effect.

The reason behind these untargeted renovation projects is the absence of effective theoretical guidance. On the one hand, the values of renovation are not clear. The government and society have not yet recognised the definition, expression, and importance of urban vitality, leading to many renovation projects being superficial. On the other hand, the methodology of renovation is not clear. There is currently no consistent understanding of the principles and mechanisms behind pedestrian space vitality, and there is no scientific guidance on the methods and processes for evaluating the current situation, analysing problems and formulating strategies for pedestrian space vitality. As a result, the design of renovation projects often relies on the personal experience of designers or government leaders. It is not surprising that the quality of projects varies.

1.2 Purpose and methodology

The main purpose of this research is to explore a reproducible method of analysing existing problems in pedestrian spaces through vitality assessment and thus deriving renovation strategies. The specific process is described below.

The first step is to study the principles and mechanisms behind the vitality of pedestrian spaces, explore the relationship between vitality and spatial elements, and establish a multi-factor assessment system for the vitality of pedestrian spaces.

The second step is to take the Tianfeng Pagoda neighbourhood in Ningbo as an example, using the assessment system to present the distribution of local pedestrian space vitality and the environmental characteristics of the neighbourhood.

The final step is to propose a vitality enhancement strategy based on the evaluation results, to carry out the pedestrian space renovation design, and to summarise the process methodology for neighbourhood vitality evaluation and enhancement.

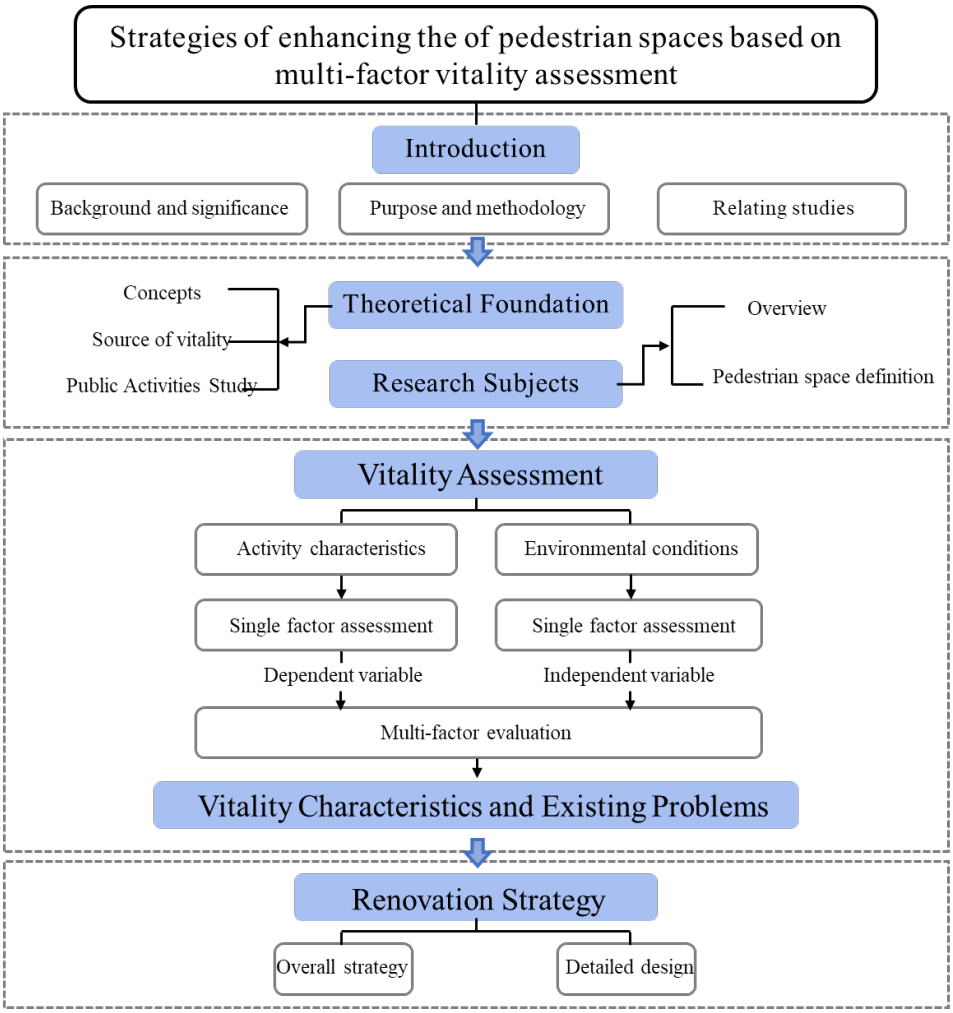


Figure 1-4. Research flow chart

Source: own research

1.3 Relevant studies

1.3.1 Theoretical studies

In the mid-nineteenth century, scholars began to study the theory of pedestrian space and realised the importance of pedestrian vitality to the city. In *The Death and Life of Great American Cities*, Jane Jacobs argued that the pavement was the dominant public activity space in the city, and that interaction in pedestrian space inspired the vitality of the city [3]. In *Great Streets*, Alan B. Jacobs examined memorable street spaces around the world and summarised the ways in which “great streets” were shaped [4]. In *Life between buildings*, Jan Gehl explained in detail the characteristics of public activity in pedestrian spaces and the factors that influenced it, emphasising the importance of public activity to urban vitality [5]. *In Finding lost space: theories of urban design*, Trancik R. pointed out that urban pedestrian space was the best place to carry the city's historical memory, and that the destruction of traditional urban street space by violent planning could result in the shrinkage and deactivation of regional social functions and networks [6]. Bosselmann Peter reviewed research related to street form in the nineteenth century in the United States and categorised the evaluation of urban form in terms of livability, sense of place and vitality, where vitality was measured by factors such as the diversity of activities and the density at which they occurred [7].

The above early theories mostly originated from the social observations and reflections of scholars, and later in the twentieth century, experimental and data-based studies of pedestrian space began to emerge. In 2001, Ewing R quantitatively studied urban vitality by means of photographic recording and manual assessment scoring. He examined the interrelationship between the transport environment and physical space, and analysed the elements of urban vitality in terms of accessibility, diversity of function and location of road intersections [8]. In 2010, Kamada and other scholars conducted an in-depth study of ten different types of pedestrian spaces in Japan. Firstly, they identified eight physical spatial elements that could influence

people's activities, including the width of vehicle lanes, the width of pavements, the height of buildings along the street, the density of building interfaces, etc. Based on this, they analysed the correlation between the spatial elements and the psychological feeling of people using them, and finally found that the shape of spaces formed by the layout of buildings along the street could affect the pedestrian's perception of “spaciousness” [9]. In 2012, Tsunematsu also found a strong correlation between the different arrangements of buildings along the street and the spatial perception of pedestrians [10]. In 2015, Corrado Zoppi used Cagliari as an example to investigate residents' satisfaction with the environment in the city centre and analysed it by a discrete model, suggesting that the provision of public space facilities such as parking pads and public green spaces could improve people's satisfaction, increase neighbourhood intimacy and enrich residents' social activities and sense of community [11].

In recent years, with technological developments in data acquisition and analysis, much research has begun to emerge in the direction of multi-source data analysis and big data analysis. Hyun-Gun Sunga used a multiple linear regression model to analyse pedestrian activity data from 9,571 streets in Seoul, showing that the physical environment measures proposed by Jacobs are an important factor in enhancing the overall vitality of the city, and verifying that Jacobs' theory is still applicable to Seoul in the 21st century [12]. Lei Jiang constructed a quantitative evaluation model of street vitality to evaluate Dalian's streets, and used inductive comparison and SPSS methods to summarise the factors that have a strong influence on vitality [13]. Shadi Zang Zarin et al. conducted a vitality survey of traditional and modern streets in Tehran and further evaluated the factors influencing vitality through multiple regression [14]. Xinhua Hao and Ying Long constructed three sets of indicators related to street vitality, and by regressing them on three functions of street vitality, they compared the strength of different types of indicator systems in explaining neighbourhood vitality, and compared the differences and commonalities in the factors influencing street vitality in Beijing and Chengdu [15]. Xavier Delclos-Alió

used a systematic approach to analyse Barcelona's urban dynamism through the perspective of Jacobs, questioning the nature of the new urban fabric, empirically testing the continued usefulness of Jacobs' ideas and methods, and proposing a methodological framework for dynamism creation based on this [16]. Jingyu Liang conducted a multi-source evaluation of Macau's street vitality based on spatial syntax, poi big data and automatic streetscape recognition [17]. In 2019, the School of Architecture at Tsinghua University and NRDC collaborated to release the Evaluation of Walkability in Chinese Cities, which visualised the walkability of 50 cities across China by using poi big data to count the density of public facilities in neighbourhoods.

In conclusion, there is a wide range of studies on the vitality of the walking system. However, there is no unified theory on the sources of pedestrian system vitality and the relationship between the relevant factors. At the same time, practical research which moved from theory and evaluation to design strategies is still in the exploratory stage.

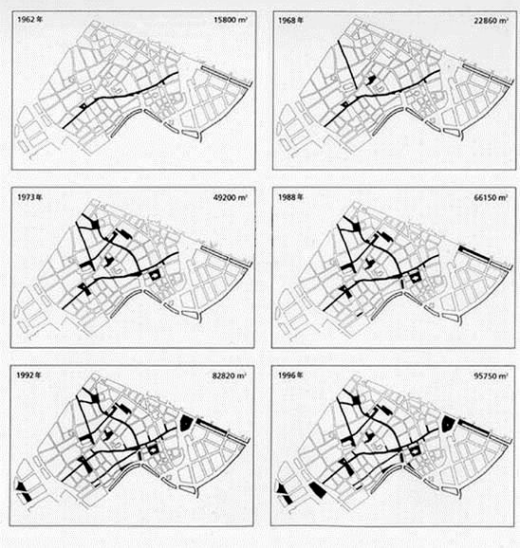
1.3.2 Practical studies

(1) Copenhagen city centre pedestrian system

The city of Copenhagen is renowned for its green transport and pedestrian environment and has been awarded the "Best City to Live In" and "Best Designed City" by UN-Habitat. The renovation and construction of its central pedestrian area is a process that has been ongoing for 50 years, with a focus on civic life as the basic starting point for the pedestrianisation of the area.

① Strengthening the pedestrian position

Copenhagen was one of the first cities in the world to introduce pedestrianised streets. As early as 1962 the main shopping street in the city centre, Stroeget, which is over 1km long, was transformed from a one-way carriageway into a pedestrianised street. Since then, Copenhagen has been systematically adding pedestrian streets, organising and transforming key pedestrian spaces such as waterfront spaces,



historic districts and city squares. From 1962 to 1995, Copenhagen's pedestrian space increased nearly six times. In addition, starting with the 1987 plan, Copenhagen used the TOD model to intensify the pedestrian city by building dense buildings near radially distributed public transport stations. A complete pedestrian network has now been developed in Copenhagen.

Figure 1-5. Changes in the range of pedestrian spacse in Copenhagen

Source: Gehl J, Gemzøe L. New city spaces[J]. 2001.

② Optimising pedestrian space

In 2005, Copenhagen implemented a new strategy - the Copenhagen Urban Spatial Action Plan (CUSAP). The plan divided the urban space into four different types: squares, pedestrian paths, shopping streets and linking nodes, and gave different strategies for them. CUSAP also introduced public participation and policy anchoring strategies, learning from the government's previous failed TOD development in Orestad. The strategies it has used on core streets include limiting traffic flow, reducing parking spaces and adapting spaces according to pedestrian crossing probabilities. Using the 2008 Norrebrogade Street as an example, the entire project was retrofitted with the CUSAP strategy, and it resulted in a 50% reduction in average vehicle movements, a 13Db reduction in noise, and a significant reduction in pedestrian-cyclist conflicts, with a significant improvement in the pedestrian experience and neighbourhood vitality [18].

③ Big data platform assisting urban design

In 2005, a design practice by Gehl Architects was carried out, which ran a public space analysis in to boost the attractiveness of Copenhagen. Then in 2016, the city of Copenhagen launched the world's first big data platform for cities called the City Data Exchange. With the launch of the City Data Exchange, it would bring together

data from both public and private data providers, turning the once fragmented data landscape into a one-stop shop for public and private data across the Copenhagen region. Thanks to the big data system, urban designers could take a fresh look at the city and quickly gain deeper insights into how citizens use the area, which would lead to more informed design decisions and public policy making.

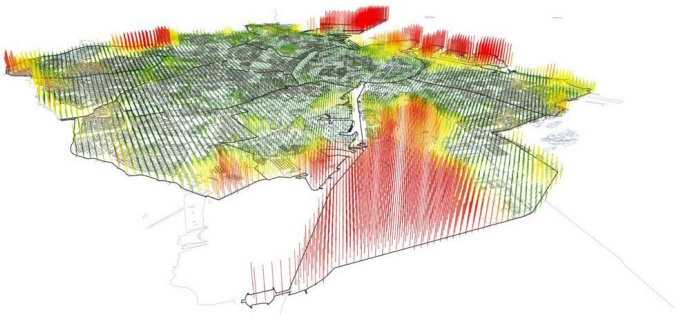


Figure 1-6. The compact city scores for all areas of Copenhagen

Source: Buro Happold

(2) Data Adaptive Urban Design of Shanghai Hengfu Historical District

In 2020, Long Zhang and other scholars proposed the Data Adaptive Design method (DAD) and used it in the study of the renovation of Shanghai Hengfu Historical District. This practice was a typical application of DAD to help better understand the design site through multiple data analysis. Based on the results, they proposed the concept of data adaptive urban design and its methods and applications to the renovation of the historical district [19].

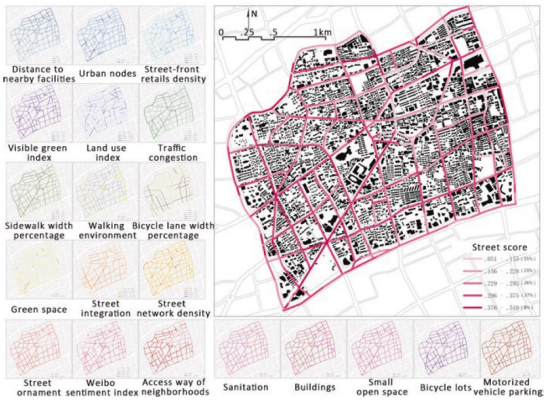


Figure 1-7. Street score results of Shanghai Hengfu Historical District

Source: Long Y, Zhang E. Data Augmented Design: Embracing New Data for Sustainable Urban Planning and Design[M]. Springer Nature, 2020.Design

Data Adaptive Urban Design integrated posterior spatial measurements and feedback into the urban planning and design process, which translated long-term planning assessments into short-term spatial interventions. By building a sensor infrastructure, they could gain feedback from accurate and customized big data that facilitated the interplay of urban design and spatial use. In this way, they could achieve DAD's goal of using data to enhance design throughout the process.

Finally, based on the results of the multi-data assessment, they further categorized the priority streets into A1 (streets with historical atmosphere), A2 (commercial streets with shared and public life), and A3 (streets with creative catalysts). These streets would be developed as major public spaces under targeted urban design guidelines.

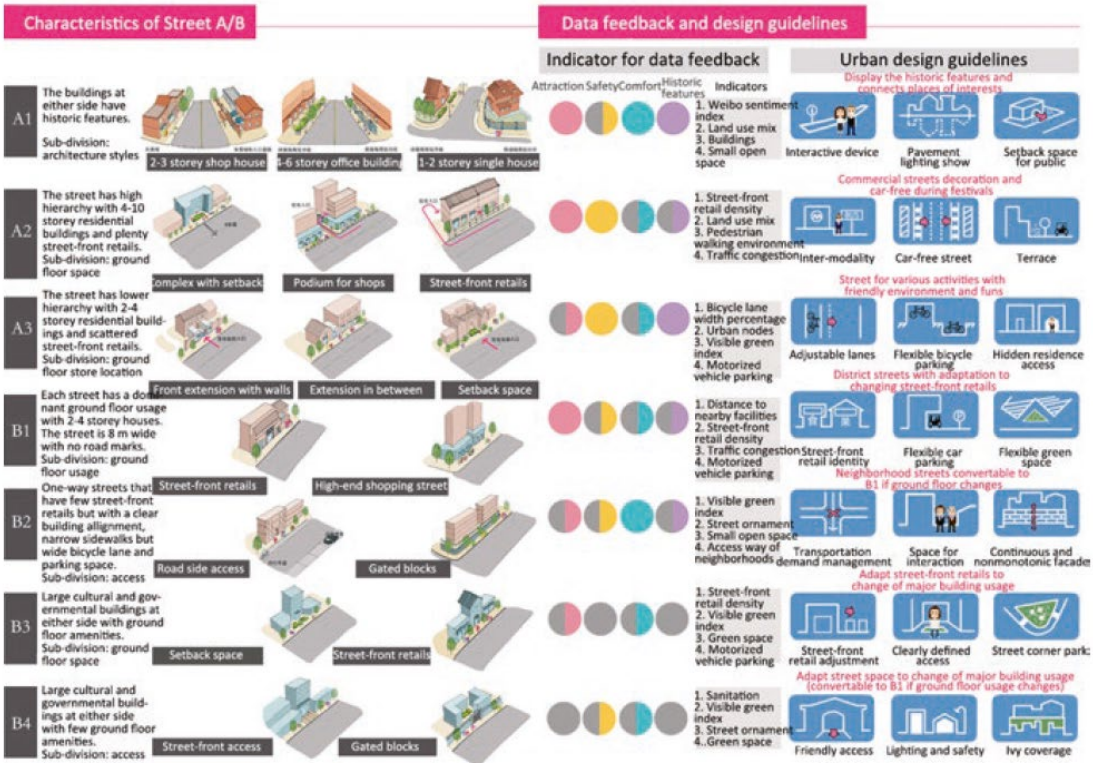


Figure 1-8. Design guidelines for different kind of streets

Source: Long Y, Zhang E. Data Augmented Design: Embracing New Data for Sustainable Urban Planning and Design[M]. Springer Nature, 2020.Design

1.4 Summary

Pedestrian spaces are the main places for public activities, making them an important part of urban vitality. Past motor vehicle-first urban construction has resulted in a variety of problems with pedestrian space in contemporary cities, inhibiting urban vitality. There’s a strong need to study pedestrian space to enhance urban vitality.

Research on the vitality of pedestrian spaces is moving away from researchers' own observations and judgements towards a multifactorial, comprehensive assessment that incorporates data. Related ideas and methods have been initially used in urban design practice. However, no authoritative criteria for evaluating vitality have yet emerged, and methods for transferring the results of vitality assessments to design outcomes are still in the exploratory stage. So, the main purpose of this research is to explore a reproducible method of analysing existing problems in pedestrian spaces through vitality assessment and thus deriving renovation strategies.

2. Relevant concepts

2.1 Pedestrian space

Pedestrian space in this research refers to the public space in a neighbourhood where walking is the main mode of travel. As the “capillaries” of the city, the first attribute of pedestrian space is to connect all parts of the city and to accommodate pedestrian traffic, while the second attribute is to carry public communication, leisure life and promote urban vitality.

The composition of pedestrian space in modern cities has changed dramatically from that of ancient times. In ancient times, when cities had a simple structure and a single mode of transport, pedestrian space was defined almost by the edges of buildings and the pedestrian system could be clearly and accurately represented and studied using architectural texture maps. In contrast, pedestrian space in modern

cities is more complex. On the one hand, the urban space is divided by motorised roads and urban landscapes, while many private and semi-private spaces enclosed by fences prevent pedestrian access. On the other hand, pedestrian crossings, footbridges, underpasses, and other facilities extend and connect pedestrian spaces in new ways.

The research of pedestrian activity in the pedestrian space of a neighbourhood is essentially the research of the public life of the neighbourhood. This is because pedestrian space is the primary public activity space of the street: street interaction, leisure and commercial activity can only be achieved through walking.

2.2 Vitality

The original meaning of “vitality” is energy and strength. "The term 'vitality' was first applied mainly in the fields of physics and biology, but has since been introduced into different fields and has taken on different meanings. In the field of urban design, vitality is used to describe a positive state of people and space. Throughout history, many scholars of architecture and planning have attempted to interpret urban vitality.

In 1961, Jane Jacobs first introduced the concept of 'urban vitality' into the field of urban planning, raising awareness of the importance of urban vitality to urban development. In her book *The Life and Death of Great American Cities*, Jane Jacobs stated that the vitality of cities came from the diversity of life within them. The process of human-spatial interaction constituted the diversity of life, and urban diversity itself led to the creation of more activities [3].

In *Good City Form*, Kevin Lynch outlined five indicators that influence urban spatial form: vitality, perception, suitability, accessibility and management, with vitality as the primary indicator of the quality of urban spatial form. He defined 'vitality' as the degree to which a settlement form supports vital functions, ecological requirements and human capabilities [20].

Bentley I. and five others of the Oxford Institute of Technology, in their book *Responsive environments: A manual for designers*, identified seven key issues such as accessibility, diversity, recognisability, viability, visual appropriateness, richness and personalisation. Vitality is defined as "the characteristic that influences the degree of diversity of a given place to accommodate different functions". That is, a place is vibrant if it offers its users a variety of functions and more possibilities for choice [21].

In his book *The Theory of Urban Vitality*, Difei Jiang proposed that urban vitality was the ability to provide a humane existence for the citizens, and the gathering and living of people gave the city the characteristics of a living body, which was the motive force for urban vitality. He argued that urban vitality consisted of economic vitality, social vitality, and cultural vitality [22].

Danish urban planner Gehl J. suggests that “in all cases, life inside and outside the building is more fundamental and meaningful than space and architecture.” He starts with human activity and feelings, and uses the presence of vibrant human activity as a criterion to determine whether a space is good or bad, stating that architecture and space are for people. The interaction and communication of people in urban spaces is what makes cities human and vibrant [5].

The Norwegian urban architect Norbert Schütz introduced the concept of “spirit of place” in 1979. He argued that “place” is somehow the spatialisation and objectification of the memories of people, and that the feeling of place arises from the link between space and “activities” of specific people or objects. Neighbourhood vitality is a sense of place. It means that people feel a sense of belonging and identification with the place [23].

A summary of the above theories reveals that the composition of urban vitality is a complex system, and the specific description of vitality differs in studies at different scales and from different perspectives. In brief, at the macro scale, vitality is expressed as the dynamics of economic, cultural and social development of a city; at the medium scale, vitality is expressed as the distribution and movements of people;

and at the micro scale, vitality is expressed as the positive interaction between people and space.

Therefore, for the pedestrian space in the neighbourhood, this paper describes vitality as a state of positive interaction between people and space in the pedestrian space. A state that creates a pleasant, lively feeling and a willingness for people to stay and engage activities.

Many cases show that the size, newness and beauty of pedestrian spaces are not directly representative of the vitality of a neighbourhood. The subject of vitality is people, and the direct source of vitality is also people's activity.

Delving deeper into the pedestrian spatial scale, vitality cannot be expressed without the public activities of people. When the neighbourhood environment interacts positively with the public activities of people, vitality is enhanced and released. The pedestrian space provides the necessary space for people to interact with each other, which satisfies material and spiritual needs of people and further increases the vitality of the neighbourhood.

2.3 Public activities

Public activity in pedestrian spaces is the direct source of vitality. The behaviour of people in public activities is diverse, motivated and influenced by many factors. Therefore, in order to optimise the pedestrian space and enhance the vitality of a neighbourhood, it is necessary to analyse the behavioural patterns, psychological needs and cognitive processes of the environment from the point of view of the active population, and to understand the interaction between people and the environment. Environmental behavior theories can be used as an important support for the study of the vitality of public activities in the neighbourhood.

As a cross-cutting field, environmental behaviour studies the environment-behaviour relationship as a whole, emphasising that when two or more environmental factors act together on behaviour, they have a very different effect on behaviour than when they act separately, i.e., an interaction. It argues that the perceptions of the user

arise from the appropriateness of the spatial form and material components, and that spatial qualities can be fed back through the subjective perceptions of the user. Furthermore, environmental behaviour is multidisciplinary in nature, with a focus on field research and a combination of qualitative and quantitative research methods, and this approach is also very applicable to the study of neighbourhood pedestrian systems [24].

2.2.1 Mental needs of the people involved in activities

Abraham H. Maslow, an American psychologist, proposed the famous Hierarchy of Needs in 1943. Maslow ranked human needs from lower to higher levels as physiological needs, safety needs, love and belonging needs , esteem needs and self-actualisation needs. He believed that physiological needs are the priority of all needs, and that after the lower needs are met, the higher needs appear [25]. The activity decisions of people in a pedestrian system can also be interpreted using the hierarchy of needs theory.

(1) Physiological needs

Physiological needs are the lowest and most urgent needs, such as food, water, air, sleep and sex. People need to move around in the pedestrian space to meet their most basic physiological needs. Examples include commuting to and from work, buying essential goods, etc.

(2) Safety needs

Safety needs, again at a lower level, include things related to one's sense of security such as personal safety, stability in life, physical health and having one's own possessions. Given multiple choices, people will inevitably choose the safer streets to travel on. At the same time, the various activities in pedestrian spaces are necessarily carried out on the basic premise that they receive protection for themselves. Spaces where people feel safe are more supportive for public activities.

(3) Love and belonging needs and esteem needs

Love and belonging needs and esteem needs are higher-level needs and are the main motivators of public activities. Walking space is important for people to meet with friends and family, or to meet strangers and to carry out social activities. In the process of transferring emotions and information to each other in interaction with different people, people gain a sense of respect and recognition, thus moving towards the highest level of human needs.

(4) Self-actualization needs

Self-actualisation needs are the highest level of needs and include needs for the highest realms of life. People pursue their self-actualisation needs in different ways and in different places, with some choosing to pursue their self-actualisation needs in pedestrian spaces. Examples include street artists, musicians, performers, speakers, etc. The public events surrounding them often attract large crowds and greatly enhance the vitality of the neighbourhood.

When lower level needs are met, higher level needs emerge, which makes people more open to activities that meet more and higher needs. In pedestrian spaces, people also tend to gather in places that are safer, more beautiful and more vibrant.

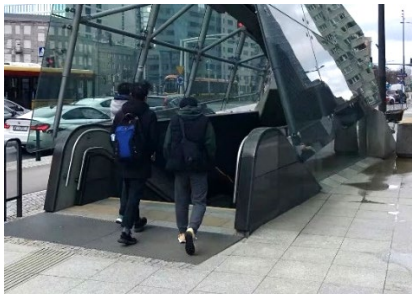
2.1.2 Types of public activities

There is a wide variety of activities in pedestrian spaces. In vitality research, activities can be classified according to the number of participants and their psychological needs. The Danish urban planner Gehl J. in *Life between buildings* divided outdoor activities in public spaces into three categories based on this idea: necessary activities, optional activities, and social activities [5].

(1) Necessary activities

Necessity activities are those in which people have to go out and participate, and generally include everyday work and life affairs. Examples include going to school,

going to work, waiting for people, waiting for the bus, etc. These activities are strongly purposeful and have minimal interaction with the people and environment around them. So, they are less communal and contribute little to the vitality of the neighbourhood. Because these activities are necessary, their occurrence is rarely influenced by the surrounding environment, and they must take place under all kinds of conditions. Therefore, they are not included in this research as a public activity for the purpose of vitality assessment.



Going to school

Queuing for vaccination

Figure 2-1. Necessary activities

Source: author's own photograph

(2) Optional activities

Optional activities are personal activities that people choose to engage in on their own, when time and place permit. Examples include resting, walking, jogging, stopping to watch, etc. This type of activity only occurs when external conditions are suitable and the weather and place are attractive.

Playing football

Jogging

Figure 2-2. Optional activities

Source: author's own photograph

(3) Social activities

Social activities are public events that involve many people, such as dinning, trading, gaming, performing, etc. They give people who know each other the opportunity to socialise, as well as giving strangers the possibility to meet each other and work together. Social activities are an important source of vitality for the pedestrian space.

Local concert

Playing with dogs

Figure 2-3. Social activities

Source: author's own photograph

In fact, the three types of activity are not separate, but co-exist in the walking space and may transform into each other. A person on his way to work will look forward to seeing something interesting on the way and, if time permits, may stop for a moment to look around and even say hello to the people around him. In this process, there is a transformation from necessary activity to optional activity and finally, to social activity. The more beautiful the environment and the more interesting the activities, the higher the likelihood that this conversion of activities will take place. This is the mechanism behind the activities in high vitality neighbourhoods.

2.2.3 Psychological effects of public activities

People are engaged in a variety of activities every day, and activities are behavioural expressions. Human behaviour is one of the most complex phenomena in the world and, like a kaleidoscope, can respond in the same way to different stimuli or in different ways to the same stimuli. But when measured in human groups, human

behaviour has similar characteristics [26]. Public activities in pedestrian spaces involve a large number of people and have uniform behavioural characteristics. These characteristics are important bases for the study of public activities and vitality.

(1) Behaviour environment

Italian architect Bruno Zevi says: "Although we may ignore space, it influences us and controls our mental activity [27]." Space can give people a sense of atmosphere. People can feel intimate or chilly, distant or close, enthusiastic or clam, spacious or crowded, moving or still.... These psychological feelings are very closely related to space, and different spatial forms can induce different psychological effects. Through cognitive processes, the spatial properties of the surroundings influence people's mental activities and shape their behavioural activities. In a pedestrian space, people use their surroundings consciously or unconsciously to carry out public activities. Similarly, if the pedestrian space is designed and controlled appropriately, it can lead to the generation of public activities and enhance the vitality of the neighbourhood.

There are many factors that influence the characteristics of pedestrian spaces, such as interfaces, materials, urban furniture, etc. American sociologist Herbert Gans says: "The artificial space is (and can only be) a potential environment, which can only become an effective environment if it is perceived on the basis of a cultural context [28]." The effective environment for inspiring public events is influenced by a variety of factors, and the dominant environmental attributes vary from place to place and from activity to activity. Therefore, specific issues need to be analysed in design to avoid empiricism.

(2) Personal space

Personal space is the space involved in activities around the individual. The requirements for personal space vary according to age, gender, ethnicity, activities performed and cultural practices.

The concept of personal space was first introduced by the psychologist R. Sommer and later summarised in his book *Personal Space. The behavioural basis of design*.

He argued that there is an invisible and indistinguishable spatial area around each person, the violation and disturbance of which causes anxiety. Personal space is the smallest space that the individual needs psychologically, which can also be called as the “bodily buffer zone [29]”.

In his book *The Hidden Dimension*, the American anthropologist Edward T. Hall suggests that individuals are surrounded by a “bubble” of vaguely personal space. In the book, Hall proposes four spatial distances: close distance (0~0.45m) is less than personal space and is the distance for the strongest emotional communication, which generally occurs in private spaces. Personal distance (0.45~1.30m) is basically the same as personal space and is suitable for contact and communication between relatives and close friends, such as the distance for sitting at the same table at a dinner. Social distance (1.30~ 3.75m) allows people to keep each other undisturbed and at the same time to observe each other's entire appearance and surroundings, and is the distance for daily communication with colleagues and neighbours. Public distance (over 3.75m) is more suitable for formal communication and one-way communication, allowing the other party not to respond, and is suitable for activities such as speeches and performances [30].

(3) Bandwagon effect

The Bandwagon effect is a psychological process whereby people consciously and unconsciously make judgements and form impressions based on the opinions of the majority. The Bandwagon effect has a strong influence on the choices people make in public activities, which are often characterised by a tendency to congregate. Jan Geiger concludes: "Living in outdoor spaces is a potentially self-reinforcing process. When someone starts doing something, other people express a clear tendency to participate, either by joining in themselves or by experiencing what others are doing [5]. "

Ongoing public activities can attract people to look, to stop, even to the point of joining or starting new public activities. The activities that are inspired tend to be more numerous and more varied than those that initially took place, giving a sense of

vitality. This attracts more people to the area. The Dutch architect F. van Klingeren described this positive feedback phenomenon in his research as "one plus one equals at least three [31]". In contrast, a pedestrian space without public activity is boring and lacks the incentive to stay. People prefer to stay at home watching TV and playing with their mobile phones because there is nothing to see outdoors, which further reduces the vitality of the area.

In addition to directing the generation of public activity, there are two other ways in which the positive effects of this characteristic can be exploited to enhance the vitality of the neighbourhood. On the one hand, the quality of the pedestrian environment can be enhanced, in order to extend the length of time that people spend in activity, which in turn increases the number of activities that exist in the neighbourhood at the same time. On the other hand, where the total amount of activity is limited, a rational planning scheme can be used to create vibrant central areas where public activity can first gather and then activate the whole area after it has played its role as a cluster.

2.4 Summary

Urban vitality is an abstract feeling. Historically, many scholars have interpreted vitality, but specific description of vitality differs in studies at different scales. For the pedestrian space in the neighbourhood, this paper describes vitality as a state of positive interaction between people and space in the pedestrian space. A state that creates a pleasant, lively feeling and a willingness for people to stay and engage activities.

The source of the vitality is the public activities of people. There are various types of public activities, and the driving force behind them is the psychological needs of people. At the same time, environmental psychology allows the study of the behavioural characteristics of public activities. These studies are the bases for the assessment of vitality.

3. Research subject

3.1 Overview of the Tianfeng Pagoda neighbourhood

The research on public activities needs to be implemented in the field. This research will observe the distribution of public activities and evaluate the vitality in the Tianfeng Pagoda neighbourhood.

3.1.1 Location

Tian Feng Pagoda neighbourhood is located within the western core of the eastern Chinese city of Ningbo, covering an area of approximately 0.8 square kilometres, made famous by the Tian Feng Pagoda, built in the Tang Dynasty. The neighbourhood is enclosed by two arterial roads and a river, with relatively independent pedestrian spaces. With a long history of construction, a high degree of functional mix and a diversity of crowd types, the neighbourhood presents a typical old city appearance, which is of good research value.

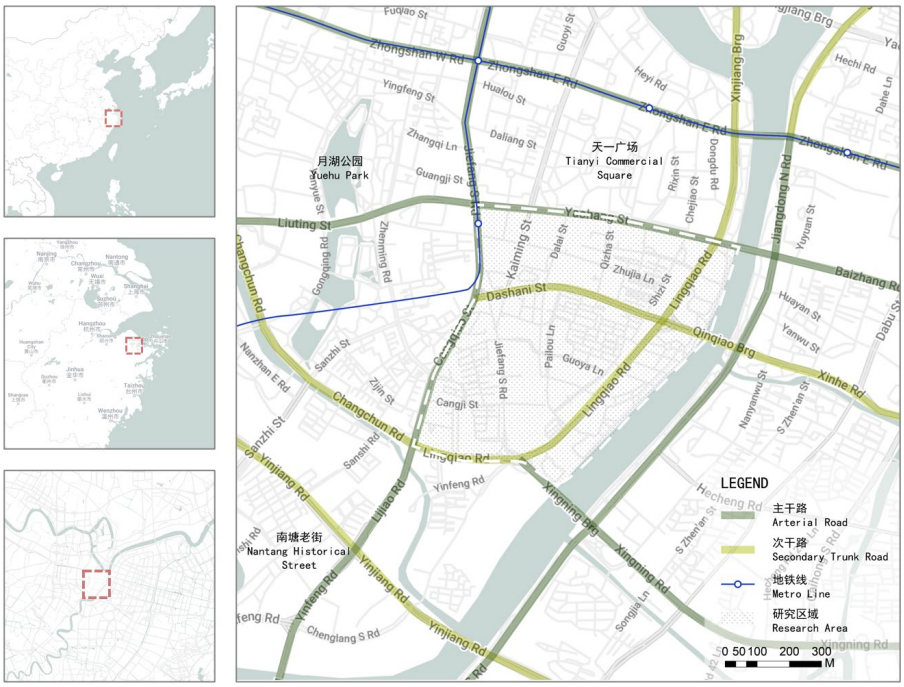


Figure 3-1. Location of Tianfeng Pagoda neighbourhood

Source: own research

3.1.2 Function of buildings

The Tianfeng Pagoda neighbourhood is rich in architectural functions and has a high density of uses. There are historical sights, commercial squares, old and new residential areas, offices and so on. Some of the building functions show a certain aggregated distribution. The residential areas are mainly located in the eastern and south-western parts of the area, while the commercial buildings and historical attractions are mainly concentrated in the central-northern part. The map below shows some of the important buildings by number.

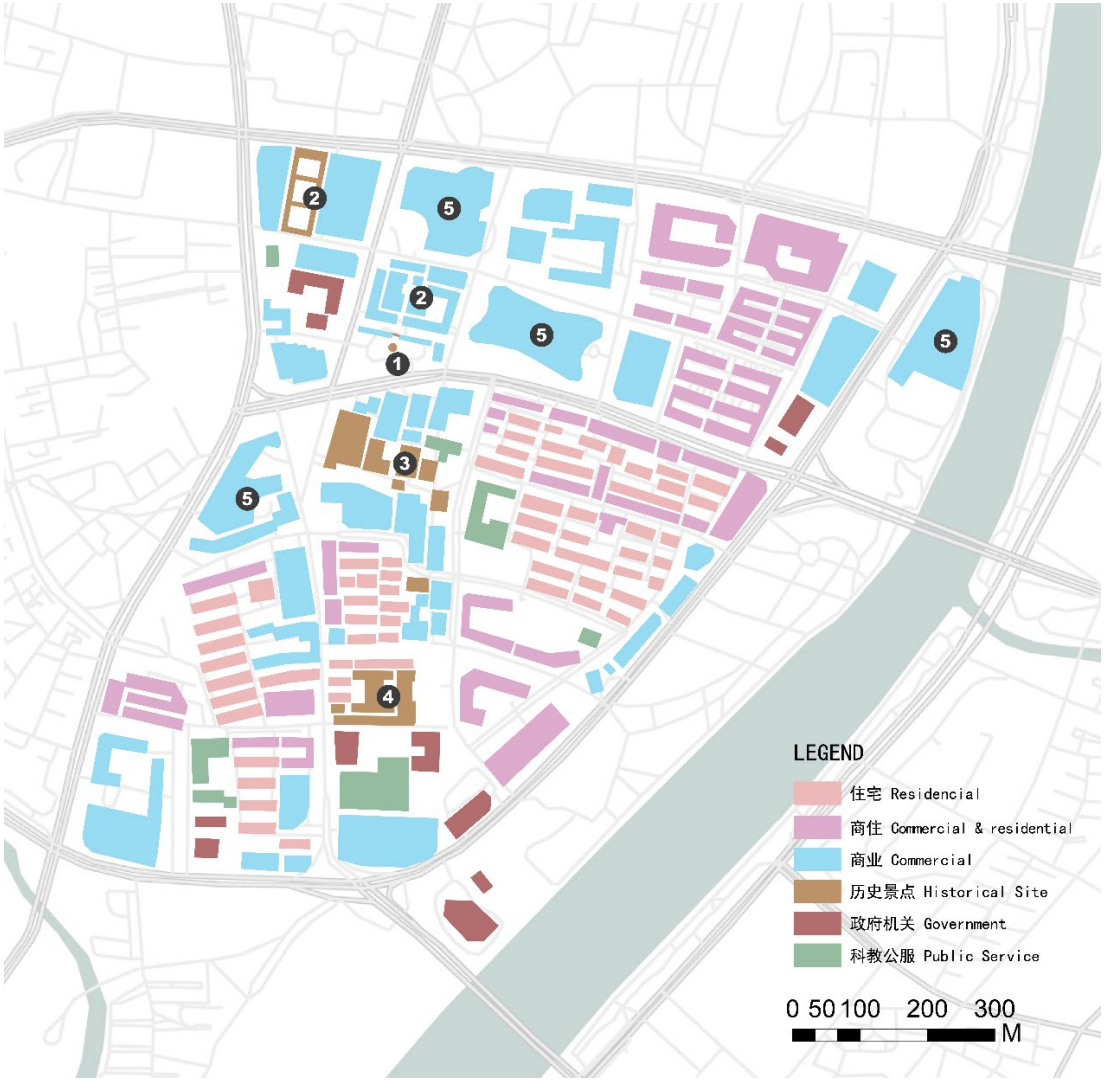


Figure 3-2. Functional distribution of Tianfeng Pagoda neighbourhood

Source: own research

Figure 3-3. Tianfeng Pagoda

Source: Baike.baidu.com

①Tianfeng Pagoda

The Tian Feng Pagoda is an important historical attraction in Ningbo. It was originally built during the Tang Dynasty (695-696) and has since undergone several restorations. Now it is a brick and timber pagoda in the style of a Song pavilion, with a hexagonal plan, 14 storeys and a height of about 51 metres.

Figure 3-4. Chenghuang Temple Commercial Street

Source: author's own photograph

②Chenghuang Temple Commercial Street

The Chenghuang Temple was built in the Liang Dynasty (916) and is one of the most important deities commonly worshipped in Chinese religious culture. Now it is converted into a commercial pedestrian street according to the Qing Dynasty form, which was once the liveliest commercial street in Ningbo. The plan of it is symmetrical in a central axis, forming a counterpoint to the Tian Feng Pagoda, creating a magnificent scenery.

Figure 3-5. Lianqiaodi Historical District

Source: author's own photograph

③Lianqiaodi Historical District

The historic district of Lianqiaodi was built during the Ming Dynasty (1368-1644).There're a large number of preserved historical buildings, making it one of Ningbo's important historic districts. in 2015, the district began to be relocated as a whole, preserving about 20 historical buildings, with the current commercial and cultural preservation operating together.

Figure 3-6. Guanzong Temple

Source: Baike.baidu.com

④Guanzong Temple

Guanzong Temple was built during the Song Dynasty (1078-1085) and is one of the most important Buddhist buildings in Ningbo. It is now undergoing a complete restoration and is not accessible for visits.

⑤Various commercial complexes

There are also four commercial complexes built at different times in the area, each positioned differently, adding to the commercial appeal of the area.

3.2 Definition of pedestrian space

An important basis for the evaluation of pedestrian space is the definition and mapping of pedestrian space within a neighbourhood. Historically architects have often used Figure-ground drawings to express the pedestrian system of cities. This method of representation was appropriate in the pedestrian-dominated medieval city, but is no longer relevant in the modern city, which incorporates a large number of motorised roads and fence walls.

This research defines a map of pedestrian space in the research area based on satellite maps and field research. After removing urban roads that require pedestrian crossings to cross, non-public spaces within walls and gates, enclosed car parks, and landscapes that are not generally accessible, the remaining urban spaces and pedestrian crossings make up the pedestrian space of the area.

After completing the scoping, the pedestrian space was extracted as the object of analysis. The whole area is divided into 20 zones (A-T) according to location and function, and then divided into a total of 223 segments, approximately 50-150m long

according to the spatial attributes of the pedestrian spaces, as the subject of research. At last, these segments are input into the gis software in preparation for the next step of assessment.

Figure-ground drawings　　Removal of inaccessible areas

Figure 3-7. The definition of pedestrian spaces

Source: own research

Figure 3-7. Segmentation and naming of walking spaces

Source: own research

4. Vitality assessment framework

Having defined the subject of the study, this chapter will construct the framework for the evaluation of vitality. The specific sequence will be to first distinguish the dimensions of the evaluation, then to select the evaluation factors and finally to develop a multi-factor evaluation method.

4.1 Assessment dimensions

As the basis for the assessment of pedestrian space, the assessment dimensions should be highly relevant. Combining the connotations of vitality and the characteristics of public activities summarised in the previous section, the assessment of vitality in this research will be carried out in two dimensions: on the one hand, the vitality characteristics, i.e., the factors that directly reflect the vitality of the crowd; on the other hand, the environmental conditions, i.e., the factors that reflect the ability of the pedestrian space to influence and promote public activities. The heat of public activity is a direct representation of vitality, while the environmental condition is the carrier of vitality.

4.2 Assessment factors

The selection of factors is key to the assessment process. This research focuses on pedestrian space vitality, and the selection of assessment factors needs to be targeted based on this perspective. For the vitality representation dimension, the evaluation factors need to accurately measure the vitality. And for the environmental condition dimension, the evaluation factors require relevance and breadth.

4.2.1 Activity characteristics

Vitality in this research refers to a state of healthy interaction between people and space in pedestrian spaces, which is directly characterised by the public activities of

crowds. For public activity, researchers often use factors such as pedestrian flow, number of participants in the activity, number of types of activity, and duration of activity to measure it.

(1) Pedestrian flow

Adequate pedestrian flow is the basis for vitality. In the age of mobile internet, the distribution of footfall in an area can be easily accessed using heat map data from map providers. However, it is not accurate to summarise vitality directly in terms of pedestrian flow. For example, when there is a queue for a nucleic acid test, when the underground is crowded of workers, or when tourist attractions are full, although there are also many people, people do not feel the vitality, but rather have the feeling of congestion and depression. The reason for this is the lack of public activity. It also inhibits the generation of activity when the flow of people exceeds the capacity of the space. Therefore, pedestrian flow can only be used as a supporting factor and still needs to be analysed in conjunction with other more direct and accurate factors for the characterisation of vibrancy.

(2) Number of participants in the activity

Number of participants in the activity is a direct indication of vitality. The number of activities observed within a certain time and place can reflect not only the frequency of public activities generated, but also the duration of public activities, in line with the impression of vitality obtained by normal people walking around the neighbourhood. In this paper, optional activities and social activities that contribute significantly to the vitality of the pedestrian space are counted, including sitting, chatting, buying and selling, exercising, walking dogs, etc.

(3) Number of types of activity

Number of types of activity is another important indication of vitality. Whereas areas with a single activity tend to be monotonous, while places where a variety of public activities take place can give rise to endless possibilities. Piazza San Marco, known as the living room of Venice, is a place where people come to chat, walk their dogs,

feed the birds, perform, pose for photographs, and do many other public activities, giving people an unforgettable experience.

(4) Duration of activity

The duration of activity, is also an important factor in the performance of vitality. The vitality that can be observed in a given space is a product of the quantity and duration of the various activities. [5] The longer the duration of a public activity in an area, the greater the number of people one can observe participating in the activity during a time period. The measurement of activity duration is difficult and time costly and is suitable for the assessment of vitality at a single small scale space. At larger scales, its usefulness will be reflected in the measurement of the number of people involved in the activity. As the subject of this research is a large neighbourhood, it is impossible to measure the duration of all public activities within a certain time period, and therefore it is not included within the vitality characterisation assessment factors of this research.

4.2.2 Environmental conditions

There is a wealth of research on the assessment of urban vitality, with many factors to choose from. Fifteen relevant studies from 2013 to 2022 were selected on CNKI and Google Scholar, and the Environmental condition factors used by them were counted in the following table.

Writer	Used factors
Lei Jiang [32]	Location, Density of uses, Shape of the space, Density of roads, Urban facilities, Quality of environment, Safety factors, Greening rate
Yanli Liu [33]	Integration, Shape of roads, Density of uses, Distribution of formats
Ying Zhang [34]	Shape of the space, Density of uses, Density of uses, Greening rate, Density of buildings, Age of buildings, Price of buildings, Urban facilities, Density of roads, Integration, Distribution of formats

Yanhong Wang [35]	Density of buildings, FAR, Density of uses, Density of uses, Greening rate, Density of roads, Urban facilities, Age of buildings
Guangchen Wang [36]	Integration, Shape of the space, Urban facilities, Quality of environment
Zhou Zhou [37]	Density of transport stations, Density of transport stations, Density of uses, Density of uses, Length of roads, Shape of the space, Greening rate
Yuanze Cheng [38]	Integration, Density of uses, Aggregation rate of uses, Shape of the space, Density of roads, Safety factors
Ye and Van Nes [39]	Integration, FAR, Density of uses
Delclòs-Alió and Miralles-Guasch [40]	Density of buildings, FAR, Density of uses, Size of blocks, Shape of the space, Age of buildings, Density of transport stations, Distance from border vacuums
Zhang et al. [41]	Density of transport stations, Density of roads, Size of blocks, Height of buildings, Density of uses, FAR, Price of buildings
Zumelzu and Barrientos-Trinanes [42]	Shape of the space, Density of buildings, Density of uses
Kim [43]	Density of roads, Size of blocks, Density of transport stations, Building Entrance Distance, FAR, Shape of the space, Density of uses
Lu et al. [44]	Price of buildings, Density of roads, Density of transport stations, FAR, Density of buildings, Density of uses, Shape of the space, Greening rate
Fuentes et al. [45]	Density of buildings, FAR, Density of uses, Size of blocks, Shape of the space, Age of buildings, Density of transport stations, Distance from border vacuums
Sulis et al. [46]	Density of uses, FAR, Integration, Shape of the space, Integration, Density of uses

Table 4-1 Environmental condition factors used by different studies

Source: own research

The frequency of each factor is shown in the table below.

Factors	Frequency
Density of uses	14
Shape of the space	11
FAR	8
Density of roads	7

Density of transport stations	7
Integration	7
Density of buildings	6
Greening rate	5
Density of uses	4
Urban facilities	4
Age of buildings	4
Size of blocks	4
Price of buildings	3
Quality of environment	2
Safety factors	2
Distribution of formats	2
Distance from border vacuums	2
Location	1
Shape of roads	1
Length of roads	1
Height of buildings	1
Building Entrance Distance	1
Aggregation rate of uses	1

Table 4-2 The frequency of each factor

Source: own research

As the scale of research varies from metropolitan area to neighbourhood scale, and the specific interpretation of urban vitality varies from study to study, the factors used are not uniform. Given the scale of the research in this paper, after excluding factors such as FAR, Density of roads and Density of buildings, which are applicable to large

scales, Density of uses, Shape of the space, Integration and Density of transport stations are generally considered to be correlated with urban vitality, being used six times or more. Based on these results, seven factors were selected for evaluation that have a significant impact on public activities. These are density of public centres, density of transport stations, integration, interface of pedestrian spaces and density of uses, which influence the gathering of people and generate activities, and size of pedestrian spaces and definition of pedestrian spaces, which provide the necessary conditions for public activities.

(1) Density of public centres

Public centres such as famous city attractions, large shopping malls and public buildings have a strong ability to attract people and, under the right conditions, can easily generate a large number of public activities, becoming a vibrant centre of the city and radiating vitality to the surrounding area. In Europe, major churches are important public buildings in the city, and their front squares can gather many people. In China, commercial centres and park squares are the most attractive for public events. Clearly, the higher the density of public centres, the greater the potential for pedestrian space vitality.

Commercial plaza with large crowds

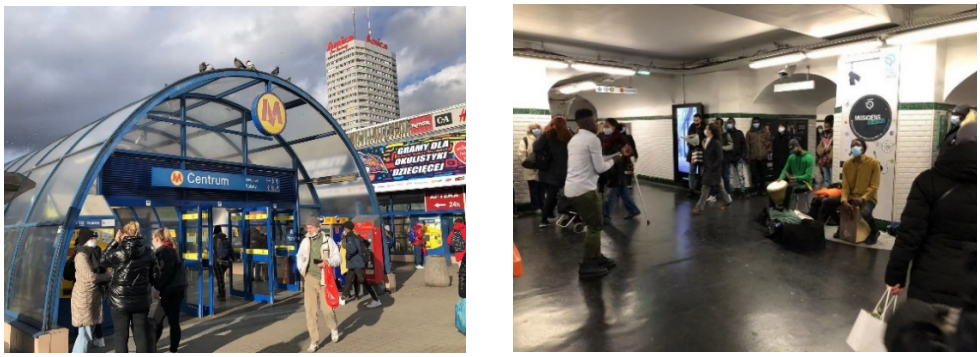
Stalls in front of the church

Figure 4-1 The pedestrian attraction of public centres

Source: author's own photograph

(2) Density of transport stations

Public transport is an important way for people to reach and leave an area. As such, transport stations are the starting or ending points of many people's walking paths and will be the nodes where people stop for a short period of time, attracting and gathering people and having a significant impact on the flow of people in the area.



People at the entrance to the station Performance events in the passageways

Figure 4-2 Crowd appeal of transport stations

Source: author's own photograph

(3) Integration of pedestrian spaces

The accessibility of a pedestrian space within an area will influence the motivation of people to travel and the likelihood of passing through it. It has been suggested that the main factor influencing people's walking decisions is not the distance, but the interconnectedness of the roads. The relationship between street network topologies allows for the study of spatial integration, with areas of high integration more likely to be populated. The most famous study of the topology of street networks is the Space Syntax theory proposed by Bill Hillyer in 1983. Spatial Syntax theory is a quantitative description of spatial structure patterns in order to perceive spatial patterns, and to explain the deconstructed spatial structure patterns in relation to human behavioural activities [47].

Through the abstraction and generalisation of space, the theory of spatial syntax has developed several mathematical models applicable to different scales, such as the

convex space model, the axis model, the line segment model and the visual field model. After years of experimental research, the axial model and line segment model have been proven to be quite accurate in predicting pedestrian activities at urban scale. The axial model uses axes to summarise the connections between spaces. The principle is to cover the entire spatial system with the fewest and longest axes, and to traverse each convex space. Each axis is then treated as a node, transformed into a relational diagram based on its intersection, and the parameters of the various spatial syntactic grouping variables can be calculated and analysed. The line segment model is a refined axial model, which adds a weighting option for spatial distance to the axial model, and also takes into account the topological paths between two elements, corners and other variables, making it more suitable for studying the movement of people under walking conditions.

Therefore, this research will use the integration parameter under the line segment model to measure the accessibility of the pedestrian space. Integration is the degree to which an element of a spatial system is clustered or discrete from other elements. It measures the ability of a space to attract arrival traffic as a destination, reflecting the centrality of the space in the overall system. The higher the degree of integration, the higher the accessibility, the more central the space is and the more likely it is to attract people.

(4) Interface of pedestrian spaces

The type of interface on both sides of a pedestrian path reflects the functions connected to the pedestrian space and determines what people see and hear in the pedestrian space, which has an important influence on the vitality of public activities. A study conducted by the Royal Danish Academy of Fine Arts School of Architecture in Trudgen, Copenhagen's main pedestrian street, showed that for architectural interfaces, the least number of people stayed at boring interfaces such as banks and office buildings, while a large number of people stopped to look at shops and galleries such as newsagents, clothing shops and toy shops [48]. Yong Chen analysed

the influence of building interfaces, street widths and shop densities on the pedestrian activity of seventeen sections of Huaihai Road in Shanghai, and found that continuous interfaces, a variety of shop densities and appropriate street scales had a positive impact on pedestrian activity [49]. This research classifies interfaces into five levels according to their influence on public activity.

① Interfaces that are good promoters of public activities and can lead to a wide range of activities, including natural interfaces, restaurant and commercial interfaces and famous attractions.

② Interfaces that have a catalytic effect on public activity, and under the right conditions can give rise to activity, including other open commercial interfaces, residential entrances and tree lawn interfaces.

③ Interfaces that attract people, but whose properties do not tend to support public activity, including most entrances to science and education buildings and office buildings.

④ Interfaces that inhibit public activity and generate less activity, including the non-public interface of the building and the entrance to government offices.

⑤ An interface that is a strong disincentive to public activity and where people are reluctant to stay, mainly in the form of fence walls.

Figure 4-3 Different types of pedestrian space interfaces

Source: own research

(5) Density of uses

The function of urban space is closely related to the vitality of pedestrian space. Not only does the function of a space affect the people who use it, but it also determines how it is used, how often it is used, how much it is carried, the value of its use and the types of activities it can generate, and these aspects have a huge impact on its vitality [33]. As Jacobs argues, the rich diversity of life in small-scale neighbourhoods is an important expression of urban vitality, and the mix of basic functions is one of the essential conditions for maintaining the vitality of cities. The diversity of spatial functions can meet the diverse needs of different people, providing a wide range of options for people to interact and engage in a wide range of activities, thus bringing vitality to the space. Therefore, the density of uses also affects the level of vitality of the pedestrian space.

(6) Size of pedestrian spaces

Adequate space is a necessary condition for public activities to take place. On the one hand, physical needs require a certain size of space for all kinds of activities to take place. On the other hand, in terms of psychological needs, the personal space effect causes people to feel that their space is invaded and crowded when the pedestrian spaces is narrow, and they are reluctant to engage in public activities.

The basic function of pedestrian space is walking. After the width required for walking is satisfied, the remaining space can support the occurrence of public activities. According to the Urban Road Engineering Design Code, the general width of a pavement on an ordinary urban road is 3 metres, with a minimum width of 2 metres; while the general width of a pavement on a road with a concentration of commercial or public places is 5 metres, with a minimum width of 4 metres. This paper uses this as the basis for the basic needs of pedestrian space, and combines Edward Hall's social distance theory (close distance (0~0.45m), personal distance (0.45~1.30m), social distance (1.30~3.75m), and public distance (over 3.75m)), to classify the size of walking space into five classes.

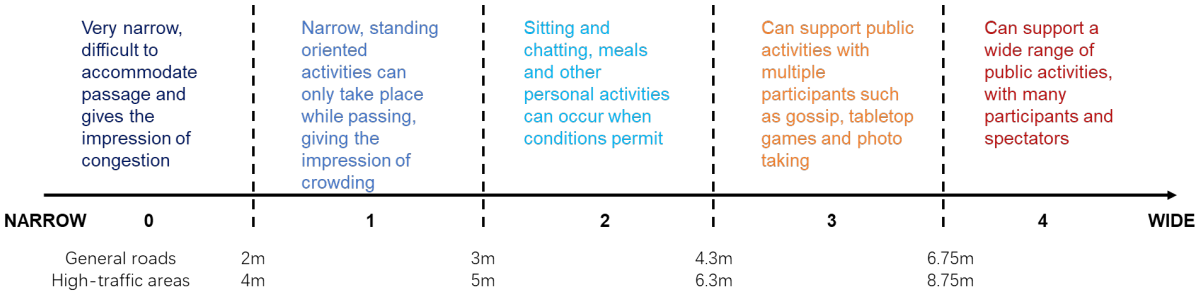


Figure 4-4 Different classes of pedestrian space sizes

Source: own research

(7) Definition of pedestrian spaces

The formation of any space requires boundaries to be defined. At the boundary one behavioural activity may end, while a new one may follow [50]. The basic function of a pedestrian space is movement, and its form is mostly linear. Without additional spatial definition, the movement of people would occupy the entire space, inhibiting the creation of public activities. On the other hand, some public activities require unique spatial conditions in order to take place. For example, benches are needed for relaxation and conversation, tables and chairs for outdoor dining, and equipment for fitness activities… Appropriate spatial definition can be effective in generating public activities.

Spatial definition can be created in a number of ways. On the one hand, space can be defined by changes in its own properties, such as significant changes in size, height and material. On the other hand, spatial entities that can carry activities can effectively define space. Examples include large trees, steps, low walls, urban furniture, etc. However, in the real urban environment, many pedestrian spaces are occupied, and their illogical spatial boundaries greatly reduce the scope of human activity and inhibit the production of public activities. This research classifies the boundaries of pedestrian spaces into five categories: fully occupied, partially occupied, no spatial definition, moderately effective definition and good spatial definition, based on their merits.

Appropriate definition Large space lacking definition

Figure 4-5 The impact of spatial definition on public activities

Source: author's own photograph

4.3 Assessment method summary

The assessment method is a decisive factor affecting the assessment results, and is also an important basis for subsequent problem analysis and strategy research. In this research, the assessment data is obtained through field research, digital maps and street maps, and the data is analysed mainly by using Arcgis and Excel software. Then, the evaluation is divided into two steps: single-factor assessment and multi-factor analysis.

For the single factor assessment, factors such as number of participants in the activity, number of types of activity, density of public centres, density of transport stations, density of uses and size of pedestrian spaces can be directly quantified, while factors such as integration of pedestrian spaces, interface of pedestrian spaces and definition of pedestrian spaces are not easily quantifiable. In order to unify the evaluation results, this research adopts a five-degree quantification method to classify the evaluation results into five classes for qualitative evaluation factors, and a natural breakpoint method to classify the quantitative evaluation results into five classes for quantitative evaluation factors.

For the multifactor analysis, the spatial heterogeneity of the neighbourhood dynamics distribution and the association with environmental conditions are assumed for the

purpose of this paper, with the activity characteristics factors set as the dependent variables and the environmental conditions factors set as the independent variables. A mathematical model of spatial heterogeneity is used to initially investigate the interactions, and then a specific cross-sectional analysis is conducted for the typical factors.

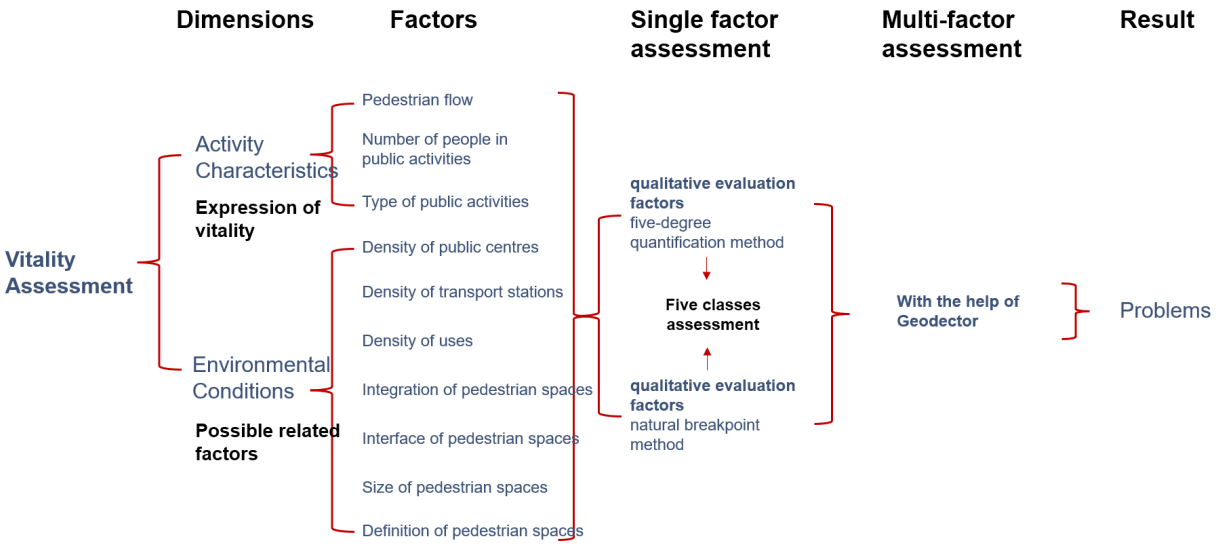


Figure 4-6 Assessment method

Source: own research

5. Vitality assessment results

The assessment methods described earlier were used in the field research. The results of the assessment are presented in this chapter.

5.1 Activity characteristic assessment

5.1.1 Heat map of pedestrian flow

The heat map data for this research was obtained from Baidu Maps and was collected from Monday, May 9 to Sunday, May 15, 2022, at two-hour intervals, covering a full week period. It was found that the heat map trends from Monday to Friday and Saturday to Sunday were very similar due to work and study time constraints. Therefore, the Thursday and Saturday heat map data were selected as a proxy for the thermal variation of footfall on weekdays and rest days.

(1) Weekday footfall

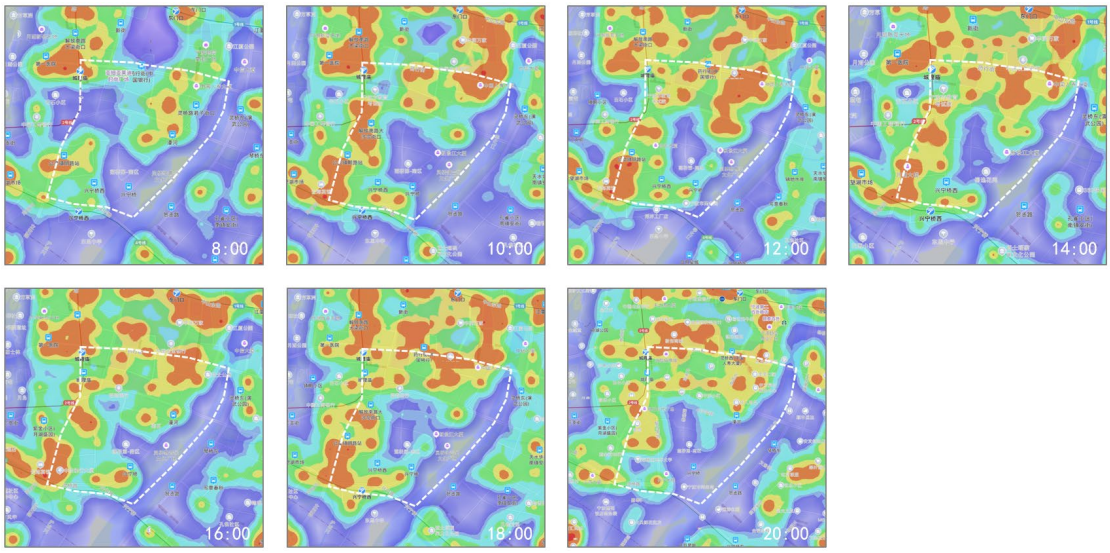


Figure 5-1 Heat map of footfall on working days

Source: own research

Crowd activity started early on working days. Crowds started to gather around the main office buildings in the neighbourhood from 08:00 onwards, as did the metro station in the north-west corner. At noon, density of people in the commercial and residential areas increased, reaching a maximum at 12:00 pm, after which the

hotspots returned to the office buildings. After 18:00 pm, the flow of people shifted again from the office buildings to the commercial areas and began to decrease throughout the area. This dynamic change was in line with the rhythm of the working weekday commuters in the neighbourhood: work - eat - work - eat - go home.

(2) Weekend footfall

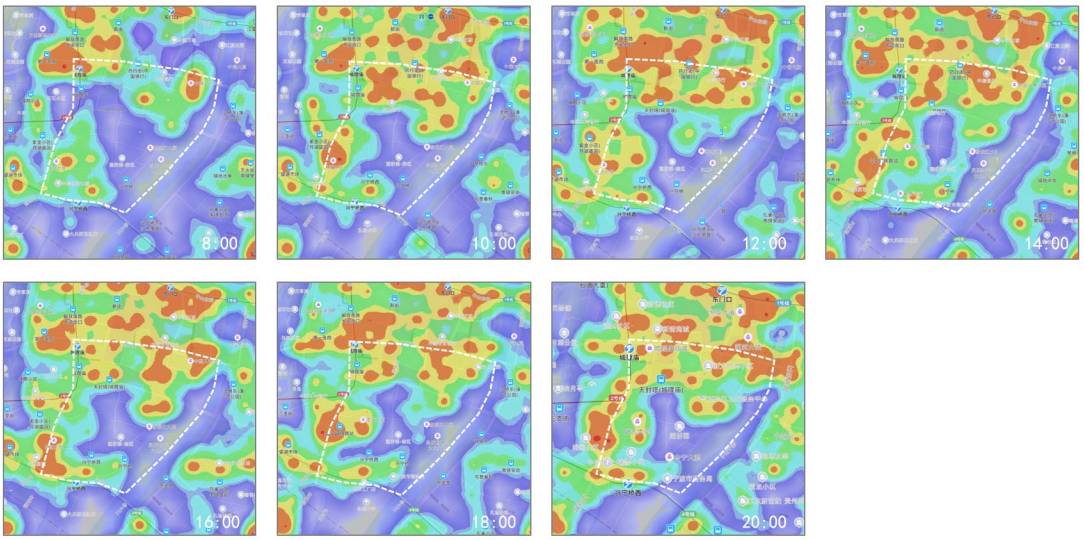


Figure 5-2 Heat map of footfall on rest days

Source: own research

Crowd activity on weekends showed a time shift backwards. After 10:00 a.m. there were clear hotspots of pedestrian activity. Crowds were mainly concentrated in the north-western commercial area, with several major commercial plazas and pedestrianised streets in the neighbourhood being stable hotspots.

In conclusion, the dynamics of pedestrian flow on weekdays and weekends showed that the distribution of pedestrian flow in the neighbourhood was high in the north-west and low in the south-east, with a steady dip in pedestrian flow in the south-east. On the one hand, this reflects the strong pedestrian attraction of the north-western part of the commercial agglomeration. On the other hand, it also reflects the fact that the recently renovated Lianqiaodi project in the south-east has not yet completed its investment and resident occupation, and its popularity is very low.

5.1.2 Public activity surveys and statistics

The author went to the site on Thursday morning (the 21st), Friday evening (the 22nd) and Saturday afternoon (the 23rd) to conduct a public activity survey, using these three representative days to summarise the dynamics in public activity over the week.

The research was carried out by walking around the whole neighbourhood, spending an average of 3-5 minutes in each street. The ipad was used to make timely notes on the map of public events encountered, supplemented by photographic records. The results are summarised below.

Figure 5-3 Location of activities recorded on Thursday, Friday and Saturday

Source: own research

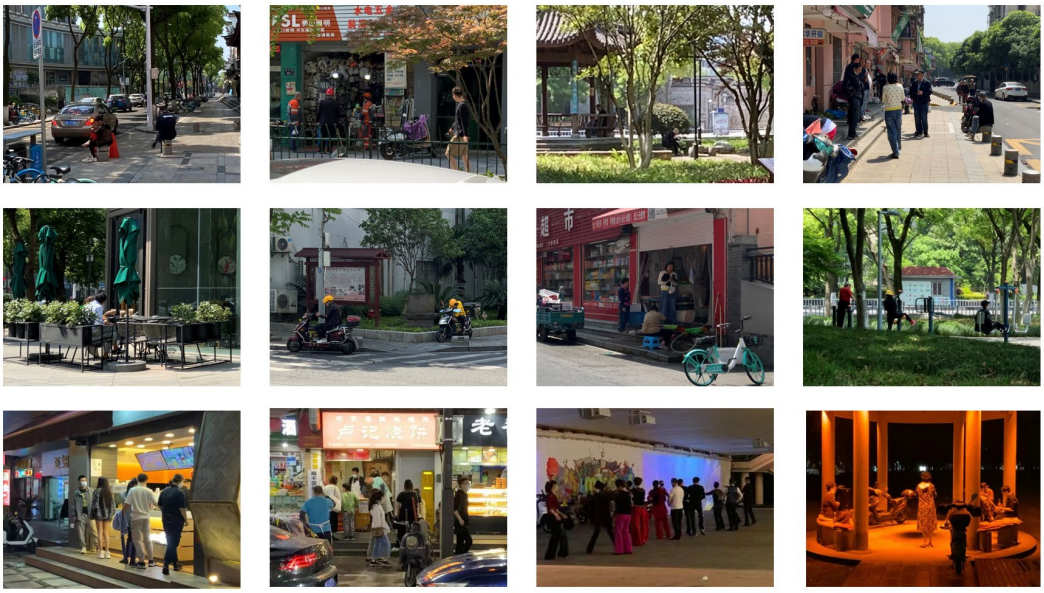


Figure 5-4 Photographs of recorded activities

Source: author's own photograph

(1) Public activities on Thursday

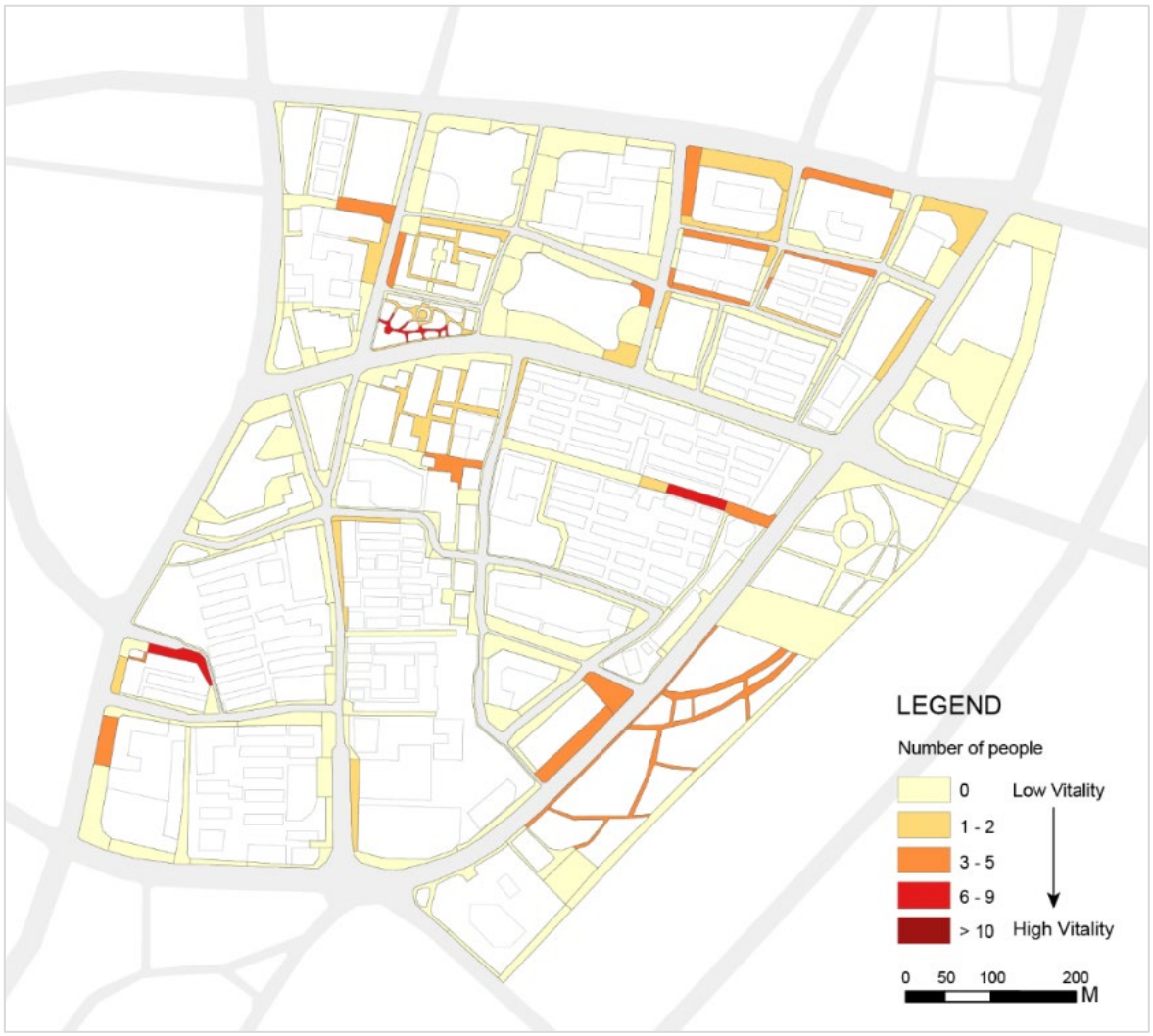


Figure 5-5 Number of participants in the activity on Thursday

Source: own research

The neighbourhood was quiet on weekday mornings. A total of 128 people were recorded participating in public activities, mainly retired elderly people and delivery workers. The elderlies were mainly found in the living areas and vegetable markets, while many of the delivery workers were relaxing and chatting around the restaurant and commercial areas waiting to take orders.

The type of public activity was relatively homogeneous. A total of seven types of activity were recorded, mainly stationary, with more than half of the people resting and chatting in situ. The heat distribution of activity types was generally consistent with the number of people engaged in them.

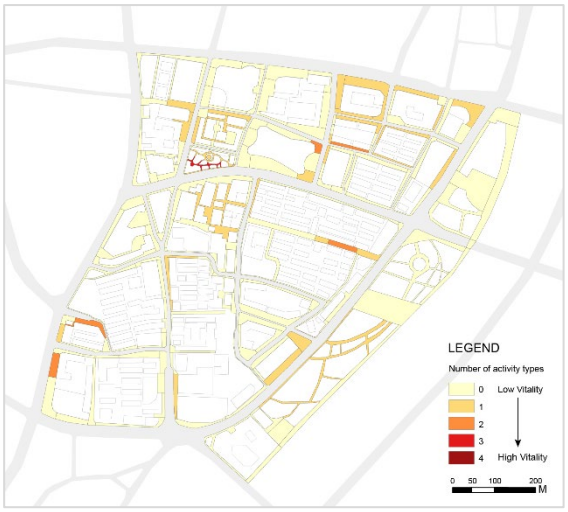


Figure 5-6 Number of activity types on Thursday

Source: own research

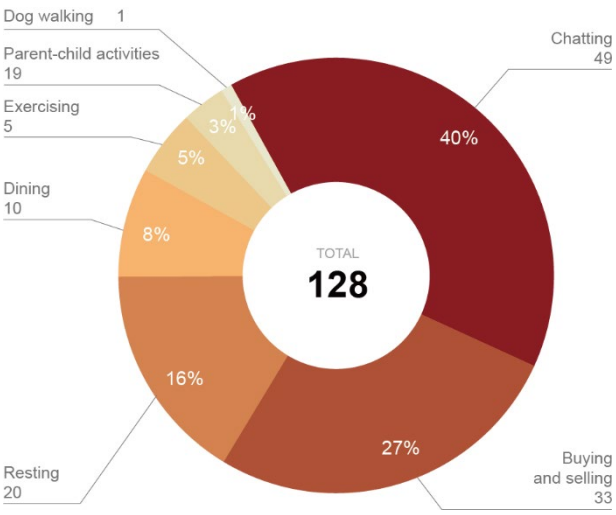


Figure 5-7 Thursday's participation in different activities

Source: own research

(2) Public activities on Friday

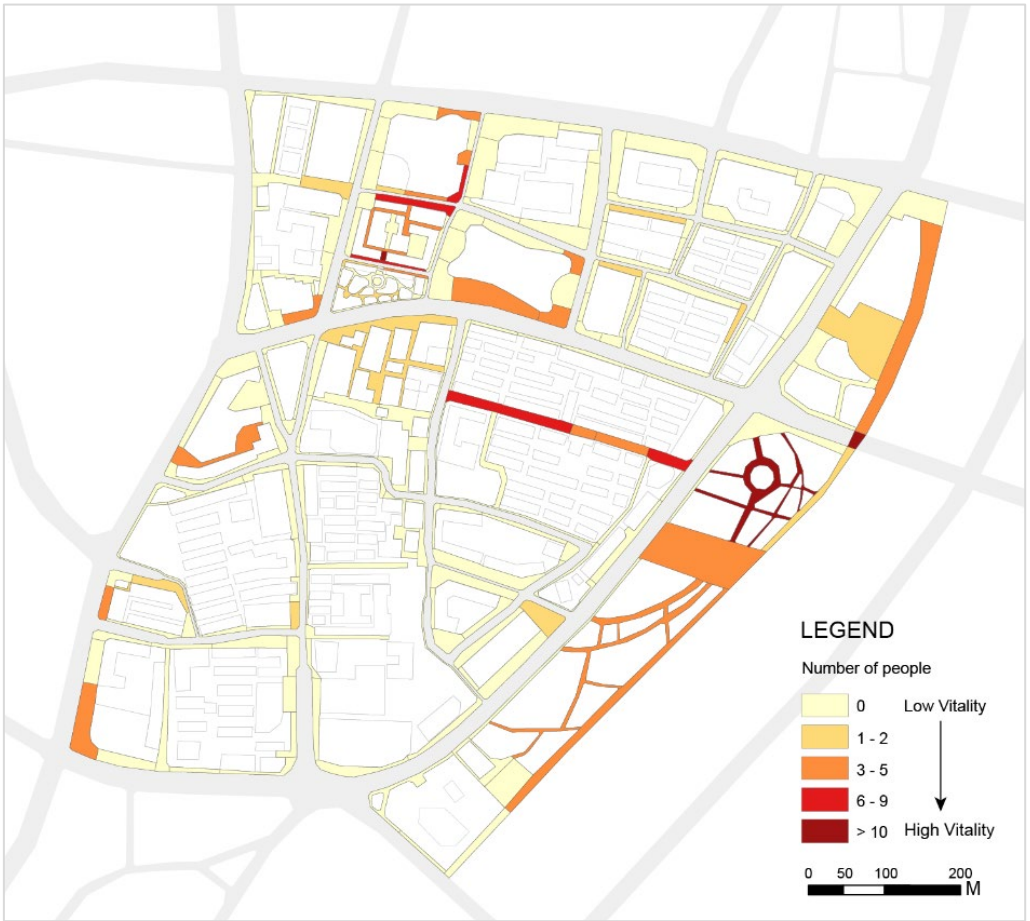


Figure 5-8 Number of participants in the activity on Friday

Source: own research

There was a significant increase in activity on Friday evenings, with a total of 178 people recorded as participating in public activities. Young people leaving work dominated public activity, followed by older people. There was a significant increase in the number of public activities in the commercial and waterfront areas compared to weekday mornings.

There was also a significant increase in the richness of the week's activities, with a total of 11 events recorded. Buying and selling was the most attended activity, reflecting the vitality of Friday night business. The heat distribution of activity types was generally in line with the number of participants.

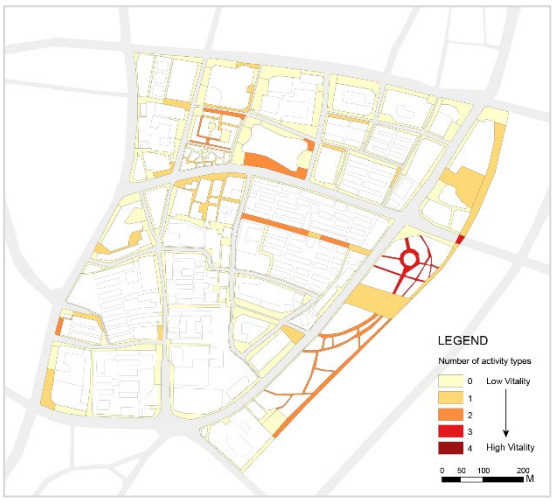


Figure 5-9 Number of activity types on Friday

Source: own research

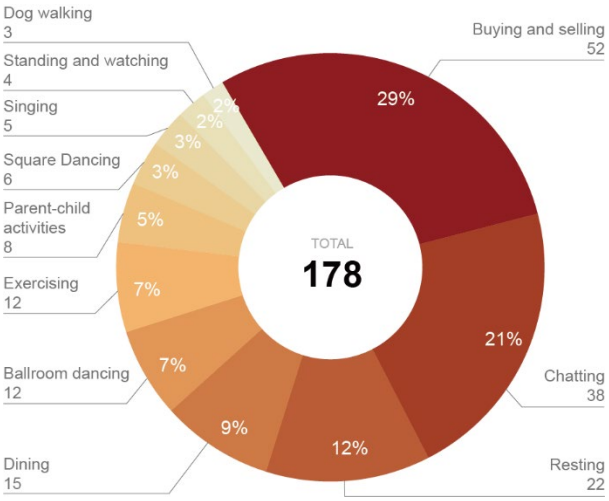


Figure 5-10 Friday's participation in different activities

Source: own research

(2) Public activities on Saturday

Saturday saw a further increase in activity numbers, with a total of 217 people recorded as participating in public events. There was a significant increase in the number of people attending activities at large shopping centres and amusement facilities.

Saturday saw an even greater variety of public events, with 13 public events recorded. The most distinctive point is the presence of parent-child activities. The weekend is a time when children have a break from school and they become

important users of the public space in the city. The heat distribution of activity types was generally consistent with the number of activities.

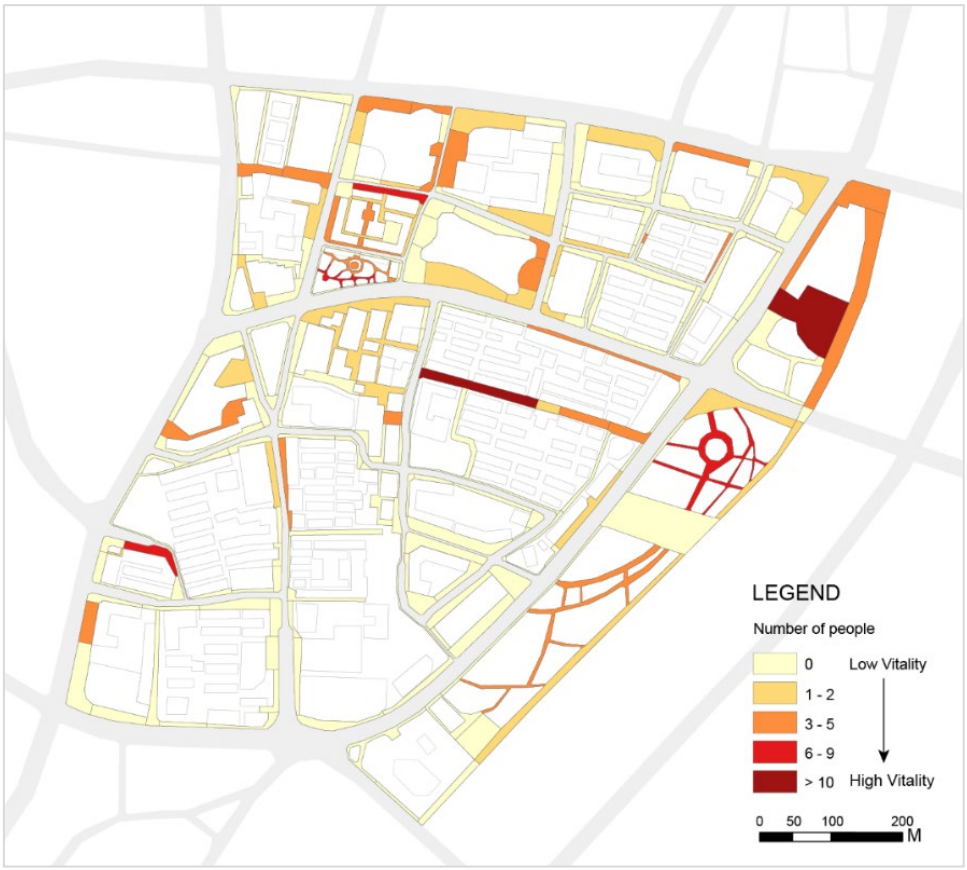


Figure 5-11 Number of participants in the activity on Saturday

Source: own research

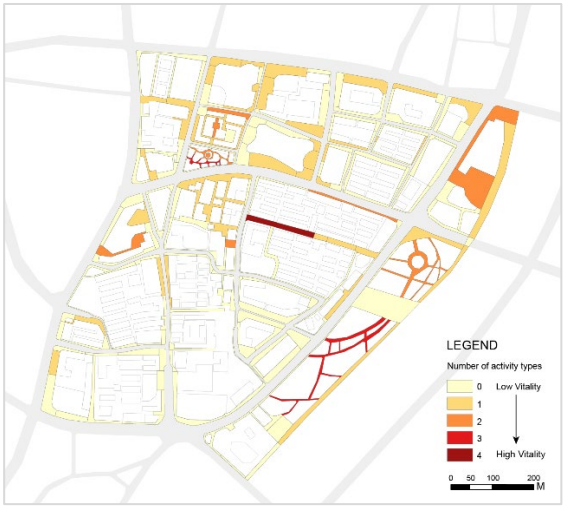


Figure 5-12 Number of activity types on Saturday

Source: own research

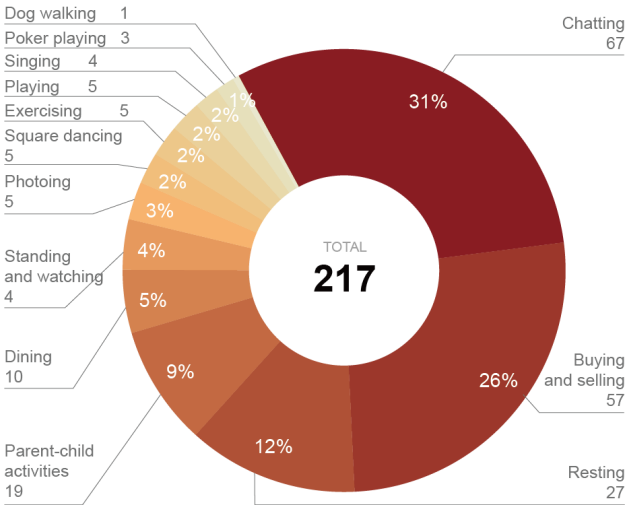


Figure 5-13 Saturday's participation in different activities

Source: own research

5.1.3 Summary of activity characteristics

The three-day data was combined to create a heat map of vitality in the neighbourhood. The north-eastern part of the neighbourhood has high heat levels, while the southern part of the neighbourhood has very low heat levels, with almost no public activity observed. The distribution of activity numbers is generally consistent with the distribution of pedestrian flows, but there are some segments with high pedestrian flow heat and low activity heat, indicating a low incidence of public activity. At the same time, the waterfront has a low level of pedestrian flow, but many public events occur, suggesting that it is effective in generating public activities.

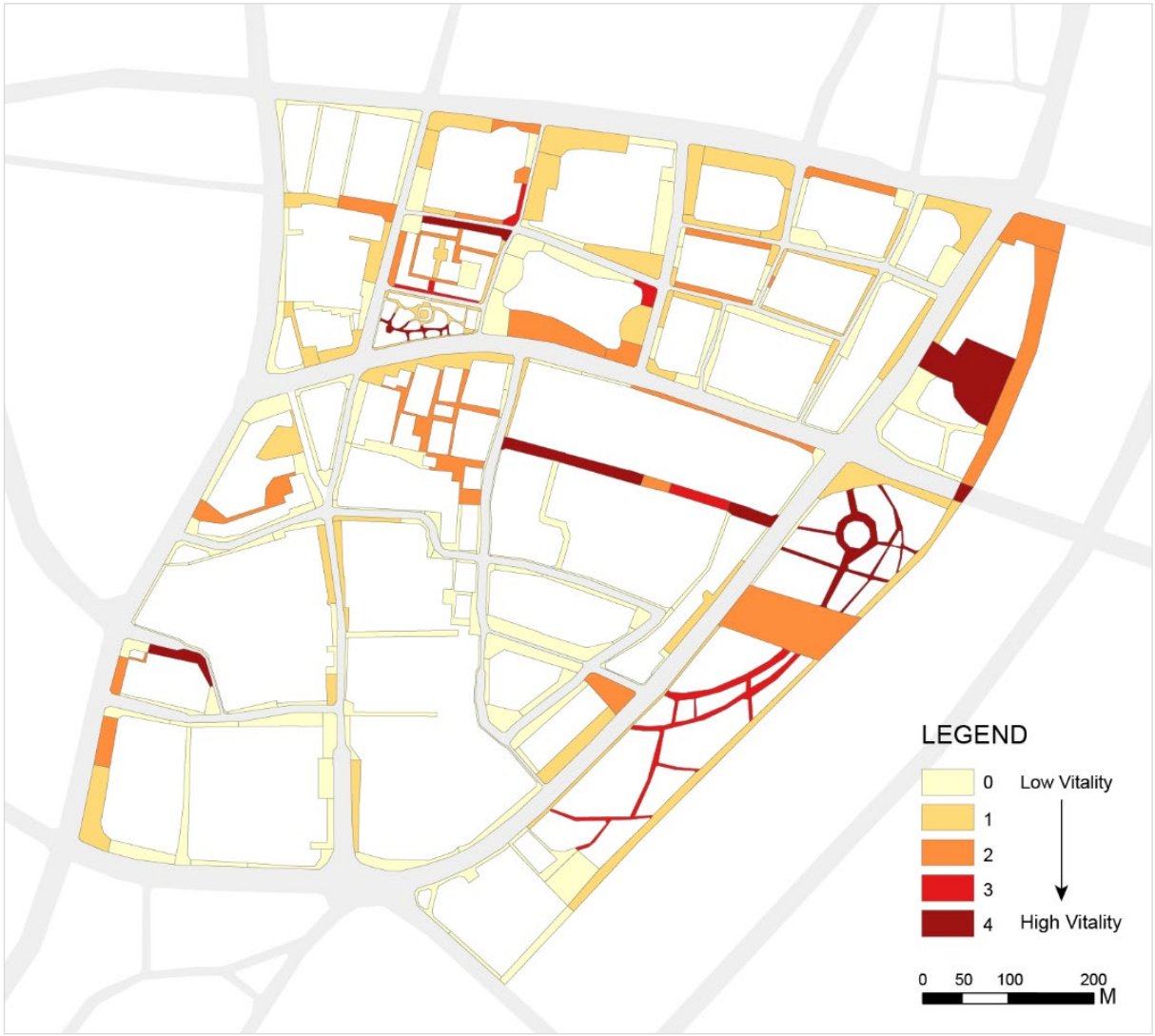


Figure 5-14 heat map of vitality

Source: own research

The variety of activities in the neighbourhood remains inadequate. Chatting, buying and selling, and resting activities are the main public activities in the neighbourhood, accounting for 71% of the total. All three are characterised by the small number of participants and the small amount of space required.

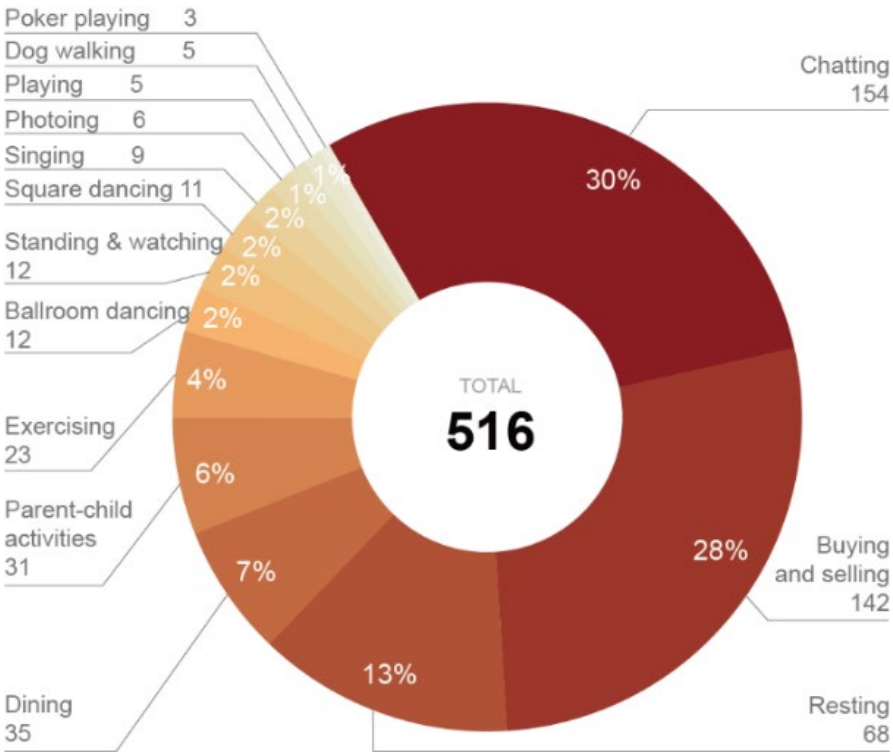


Figure 5-15 Participation in different activities

Source: own research

5.1.4 Analysis of activity characteristics

In order to verify the value of the distribution of public activities in the above study, a spatial autocorrelation analysis (Global Moran's I) was carried out using arcgis software.

The Global Moran's I tool measures spatial autocorrelation based on both element location and element value. Given a set of elements and associated attributes, the tool assesses whether the pattern expressed is a clustered, discrete or random pattern. A global Moran's I analysis yields three parameters: the Moran's I index,

which ranges from -1.0 to +1.0. P-value: probability. Z-score: multiple of standard deviation.

A Moran's I greater than 0 indicates a positive spatial correlation, the larger the value the more significant the spatial correlation; a Moran's I less than 0 indicates a negative spatial correlation, the smaller the value the greater the spatial variation; a Moran's I of 0 indicates a random spatial correlation. Z-score and p-value are measures of statistical significance and are used to determine whether the null hypothesis is rejected. For this tool, the null hypothesis represents the random distribution of values associated with the factors. The closer the p-value is to zero, and the more the z-value deviates from zero, the less likely it is that the spatial patterns of the study elements are generated randomly.

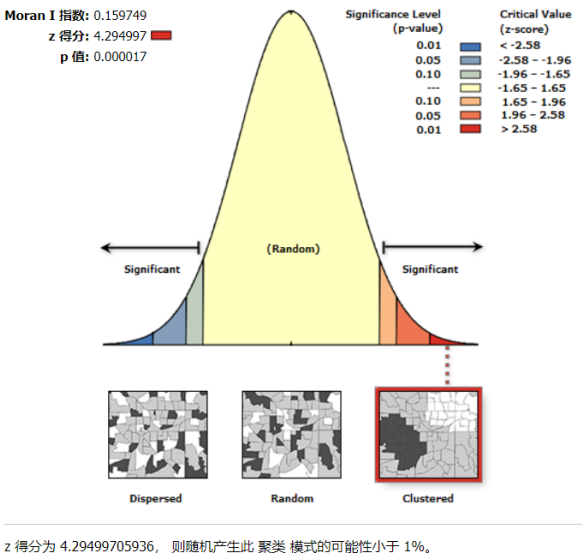


Figure 5-16 Global Moran's I Result

Source: own research

The z-score obtained from the analysis is about 4.295, with a p-value equal to 0, indicating that the spatial clustering pattern is less than 1% likely to be randomly generated. The Moran's I index is 0.16, which indicates that the distribution of public activities is clustered and polycentric.

Based on this finding, the Getis-Ord Gi* tool was used to analyse the exact location of the vitality hotspots in the neighbourhood. The hotspot analysis tool calculates Getis-Ord Gi* statistics for each element in the dataset. The z-scores and p-values obtained give an indication of where the high or low value elements are clustered in space. The tool works by looking at each element in the immediate environment. To be a statistically significant hotspot, an element should have a high value and be surrounded by other elements that also have a high value. The local sum of an element and its neighbouring elements is compared to the sum of all elements; when

the local sum is so different from the expected local sum that it cannot be a randomly generated result, a statistically significant z-score is generated and the element is judged to be a hotspot.

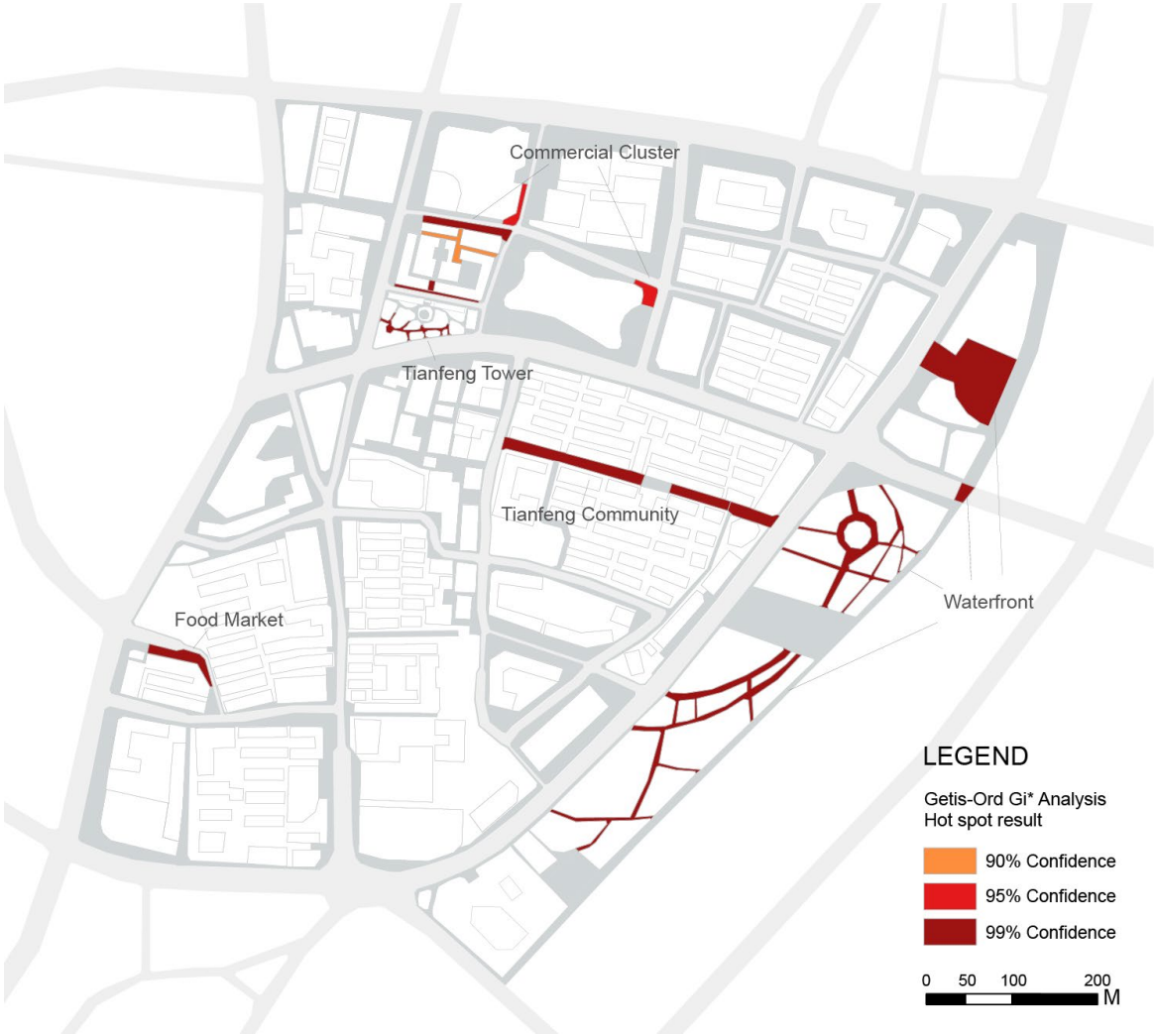


Figure 5-16 Getis-Ord Gi* Results

Source: own research

Based on the results of the analysis, there are a number of existing vitality hotspots in the research area, which can be divided into five vitality centres. These are the commercial cluster in the north, the Tianfeng Pagoda, the internal streets of the Tianfeng community, the food market in the south and the waterfront in the east. However, in the central part of the area, there are still large areas with low levels of activity. The centres of vitality have not yet been linked together to form a system.

5.2 Environmental condition assessment

5.2.1 Density of public centres

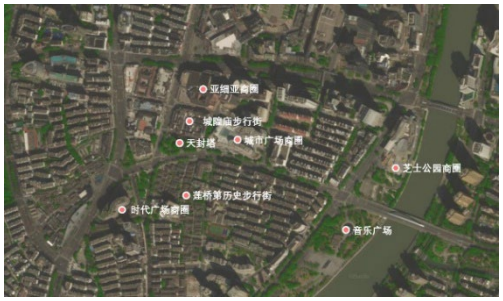


Figure 5-17 Selected public centres

Source: own research

Based on the current situation, eight functioning public centres in the neighbourhood were selected. The number of existing points of interest within a straight-line distance of 200m of each study segment was counted to obtain the map below.

A high density of public centres is evident in the north-western part of the region, while the southern part currently lacks a public centre.

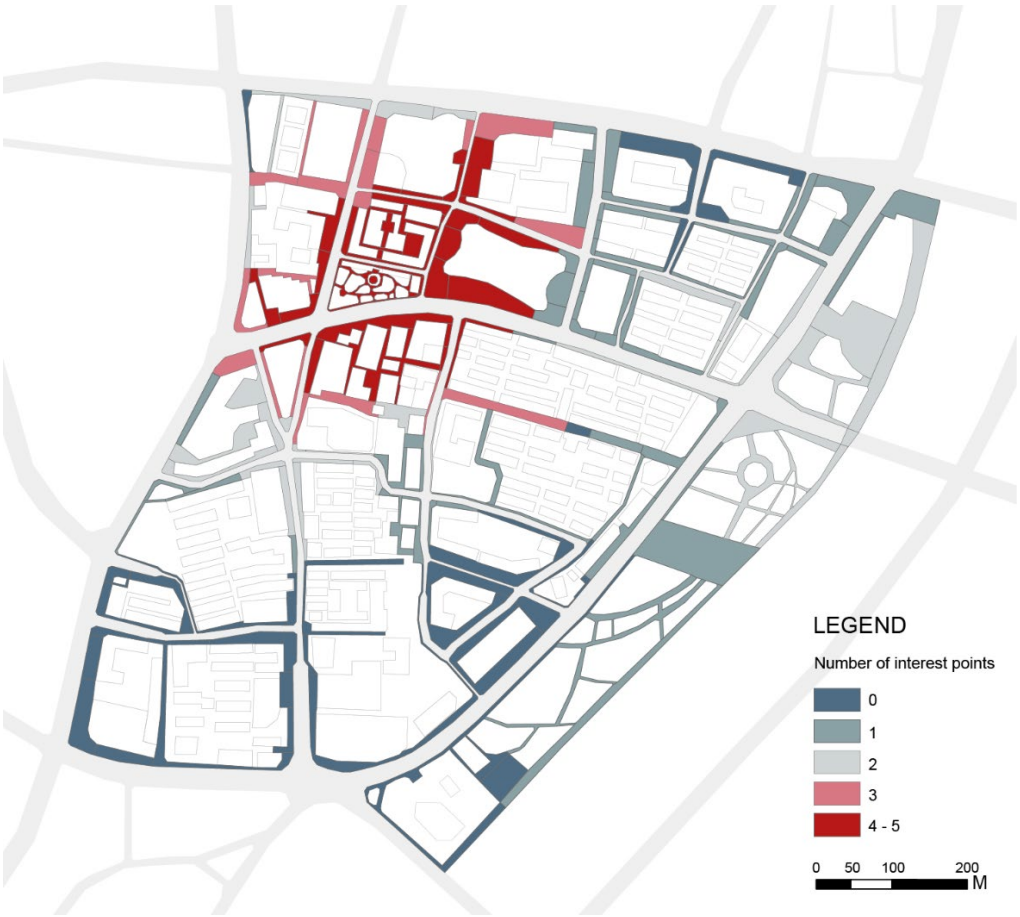


Figure 5-18 Density of public centres

Source: own research

5.2.2 Density of transport stations

There is one metro station and 13 bus stops in the research area. The bus stops within a straight-line distance of 200m of each study segment were counted and the following map was obtained.

The distribution of the density of transport stations matches well with the heat distribution of pedestrian flow in the previous section. This suggests that transport stations bring a high level of pedestrian traffic to the surrounding area.

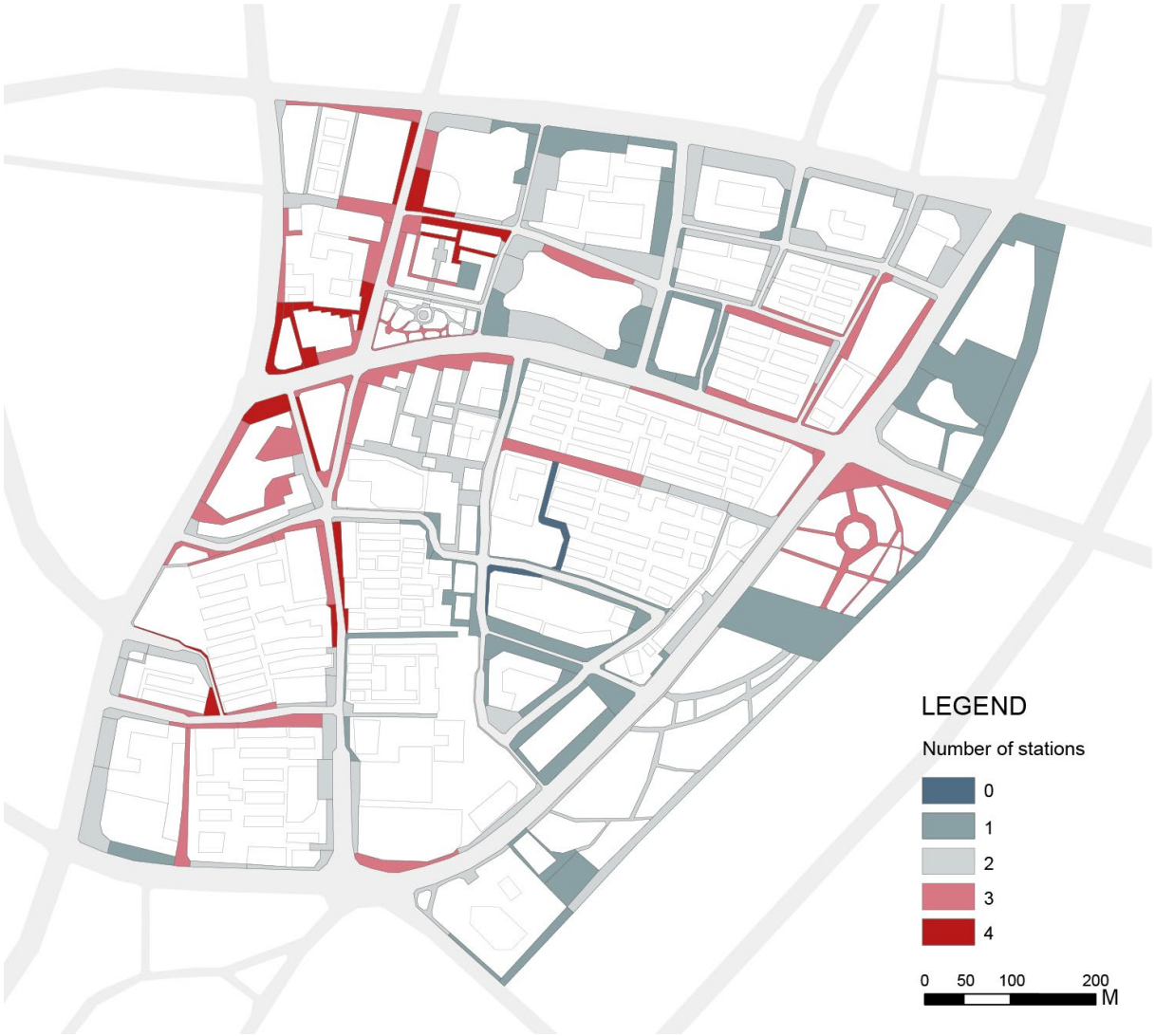


Figure 5-19 Density of transport stations

Source: own research

5.2.3 Density of uses

The buildings in the area with actual functions such as government, offices, science, education and public services, residential areas, restaurants, and other commercial locations were extracted. Then, the number of functional categories within a 200m linear distance of each study area was counted and plotted on a heat map.

It can be seen that the density of uses is high and evenly distributed within the study area. Most of the areas can be counted for 5 or more functions. The density at the boundary is low due to the extent of the study.

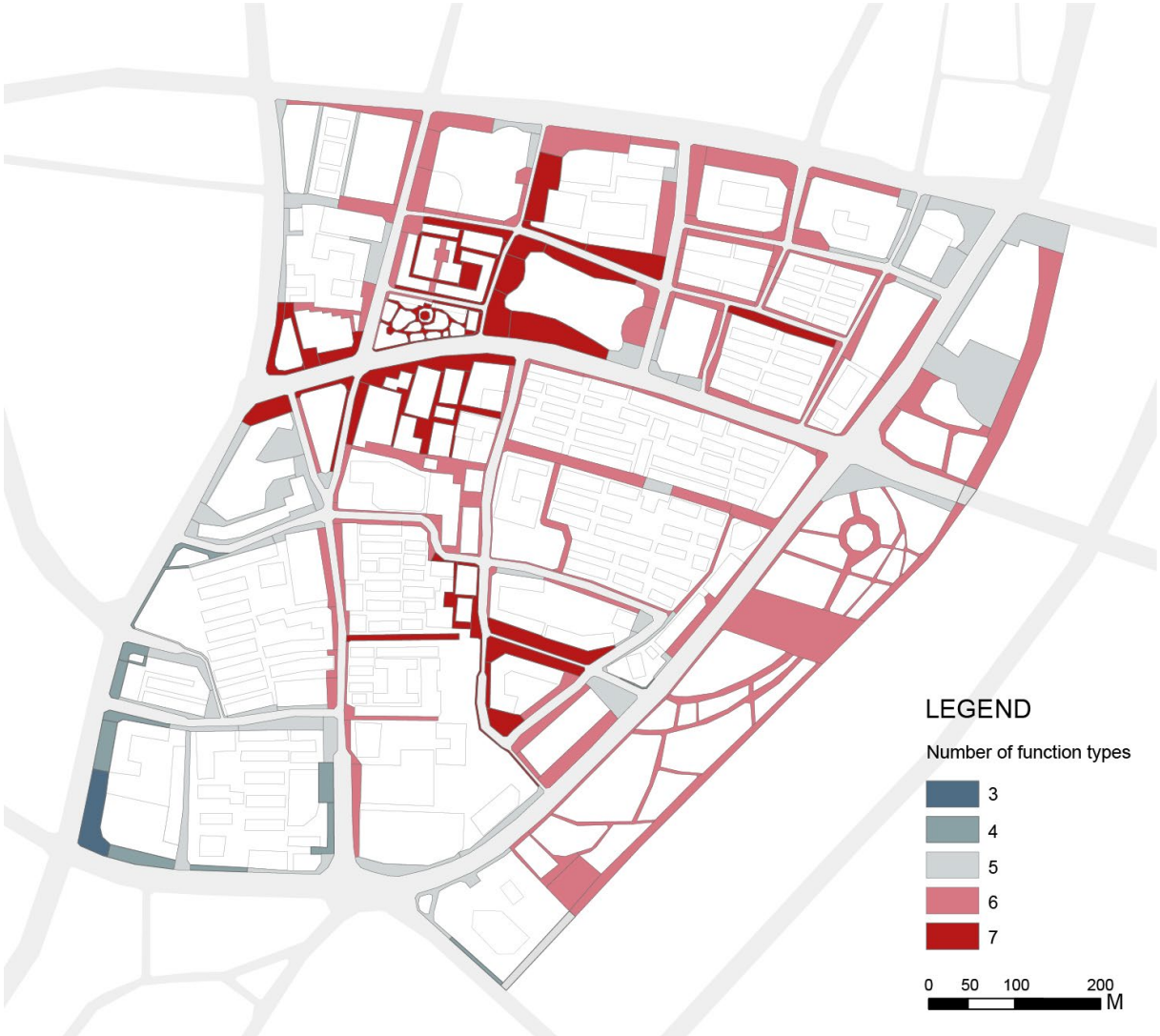


Figure 5-20 Density of uses

Source: own research

5.2.4 Integration of pedestrian spaces

Before carrying out the syntactic integration analysis, it is necessary to model the pedestrian space of the neighbourhood in line with the current situation. There are two main points. Point 1: Establish a hierarchy of roads in the neighbourhood, with pavements on each side of the road being mapped separately. It is important to focus on the side streets where pedestrians are allowed to cross freely, and these should be mapped as a line segment. Field research shows that there are few such roads in the area, as most of the branch roads have a central guardrail. Point 2: Each pedestrian crossing is a separate line that intersects with other paths to simulate the human decision to cross the road and to wait for the traffic lights. The resulting line segment model is shown below.

Figure 5-21 Hierarchy of roads in the research area

Source: own research

Figure 5-22 The line segment model

Source: own research

Figure 5-23 Integration in 400m

Source: own research

A comfortable walking distance of 400m was chosen as the radius of calculation to calculate the degree of integration. The results are shown in the top right diagram, with high integration paths in red and low integration paths in blue. The data was transferred to the gis software to obtain a heat map of the integration of the walking space, and it can be seen that the highest integration of the neighbourhood is located in the central-northern area, while the southern integration is poor.

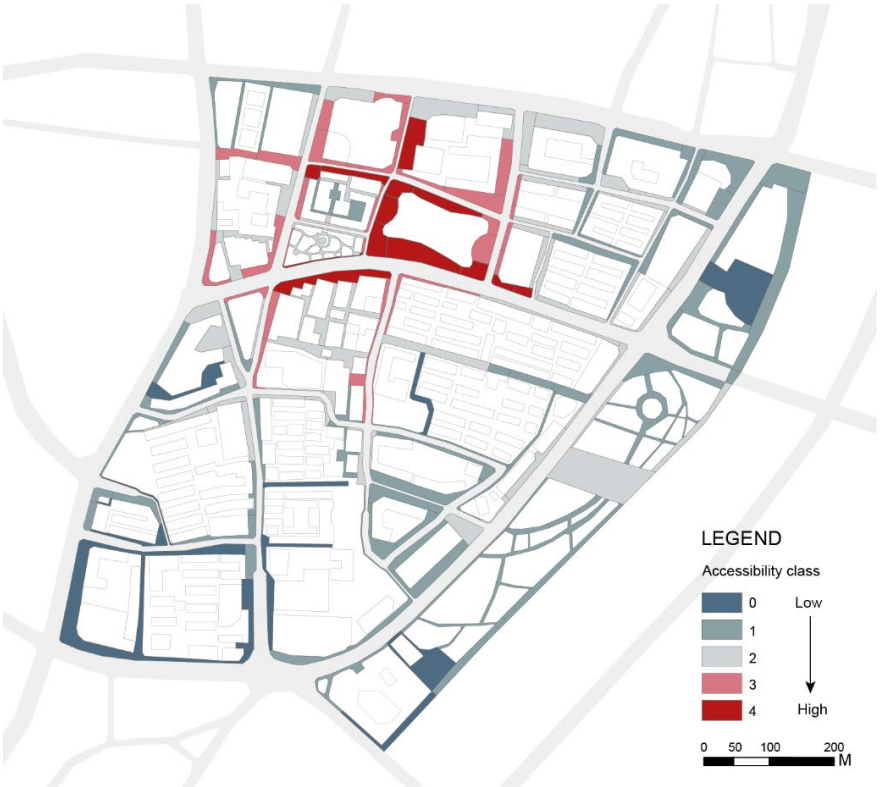


Figure 5-24 Integration of pedestrian spaces

Source: own research

5.2.5 Interface of pedestrian spaces

A 10m*10m grid was used to cover the neighbourhood, combining streetscape maps and field research to classify the types of pedestrian paths along their boundaries. A total of 2048 points were taken. It can be seen that the commercial interface is the most dominant in the neighbourhood, followed by the tree lawn interface. However, a large proportion of negative wall interfaces and non-public building interfaces are also present.

Figure 5-25 Types of pedestrian paths

Source: own research

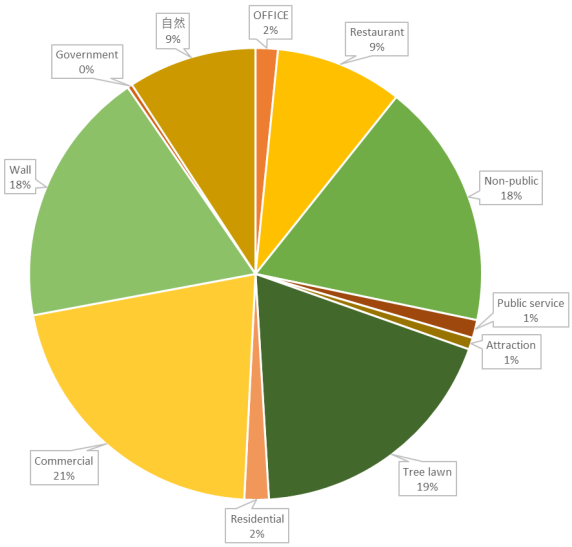


Figure 5-26 Percentage of different types of interfaces

Source: own research

The previous classification of the different types of interfaces was transformed into five levels from 0-4. A weighted average of the interface data within each research segment was calculated to obtain its pedestrian path interface rating, again divided into five levels.

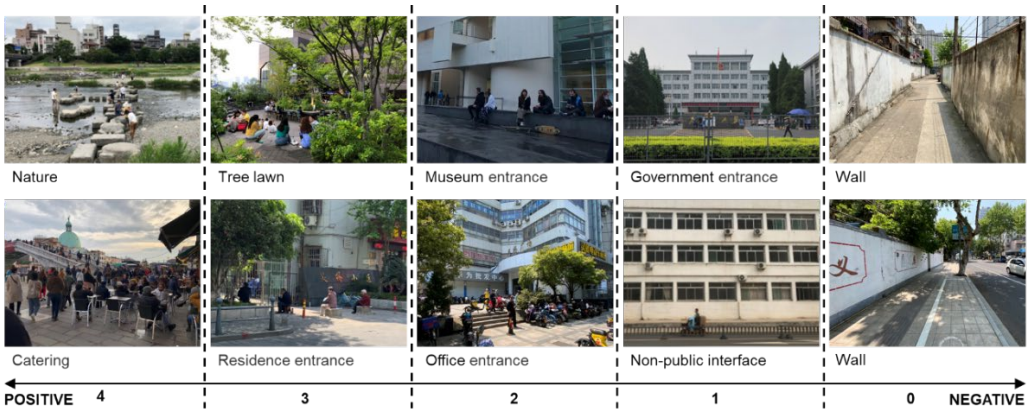


Figure 5-27 Classification of different types of interfaces

Source: own research

It can be seen that the waterfront space has a high score. There are no significant areas of high scores in other areas and the southern part scores lower. In terms of interface, there is no active and coherent system within the neighbourhood.

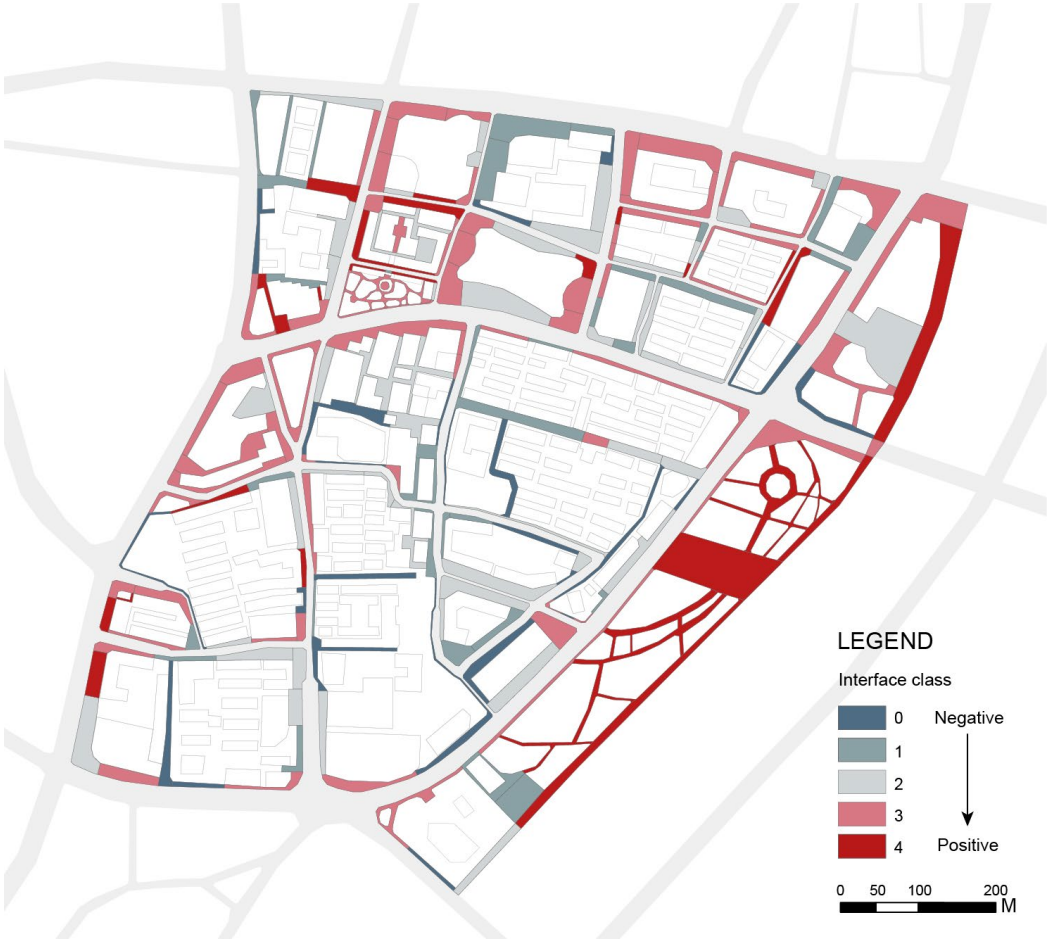


Figure 5-28 Interface assessment of pedestrian spaces

Source: own research

5.2.6 Size of pedestrian spaces

Adequate space is a necessary condition for public activities. The previous classification of the different sizes of the pedestrian space was transformed into a rating of five levels from 0-4, and the results are shown in the figure. It can be seen that the neighbourhood as a whole is not narrow, and that the majority of spaces are of a size that allows for basic access. In many areas there is space available to support public activities.

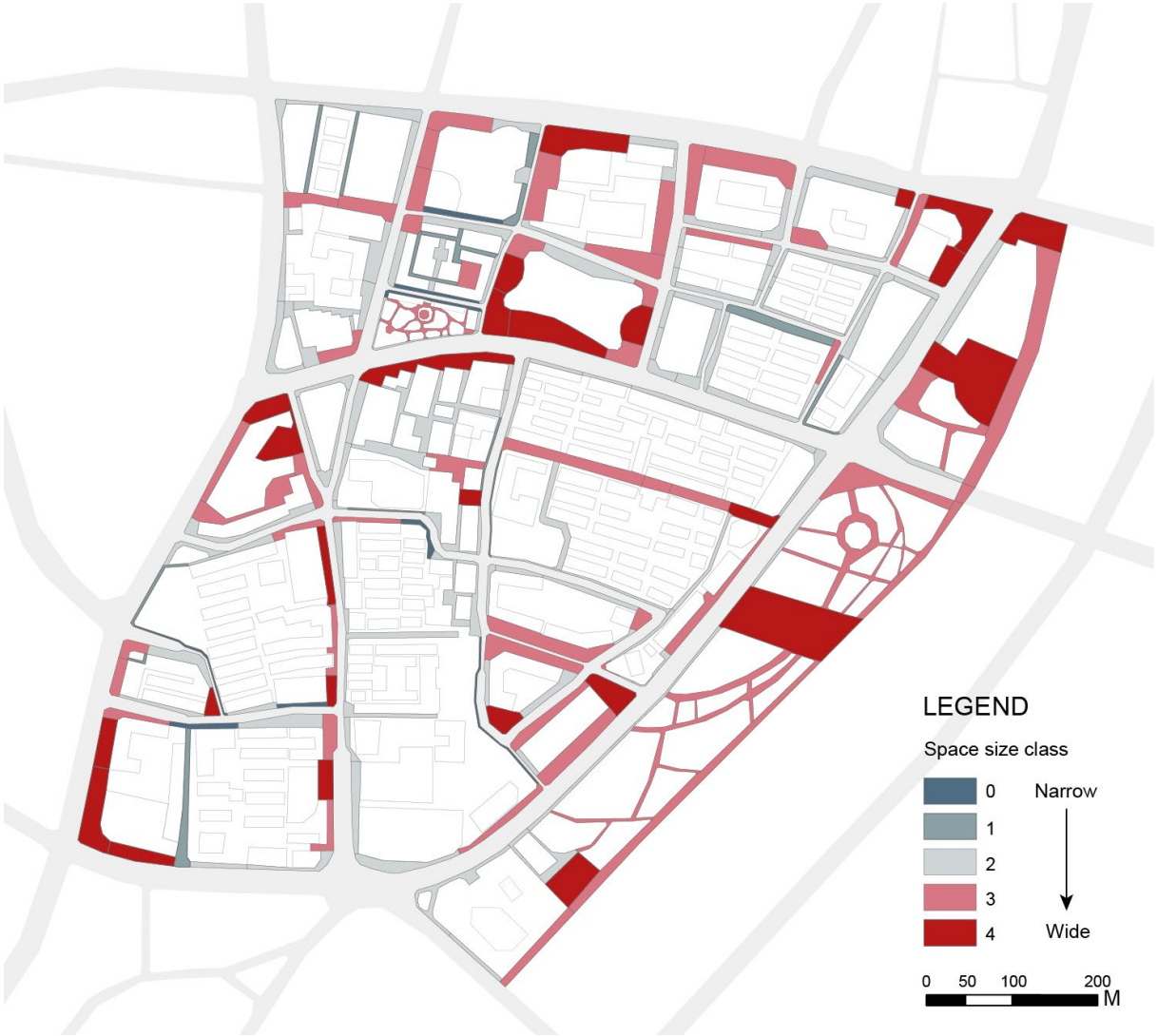


Figure 5-29 Size assessment of pedestrian spaces

Source: own research

5.2.7 Definition of pedestrian spaces

According to the current spatial situation, the research fragments were classified into five levels (0-4): fully occupied, partially occupied, not spatially defined, somewhat defined (moderately effective), and with good spatial design, as shown in the figure.

It is evident that most areas of the neighbourhood are not well defined, and that many spaces are even occupied. Parking by motor vehicles is the main reason for the occupation of pedestrian space.

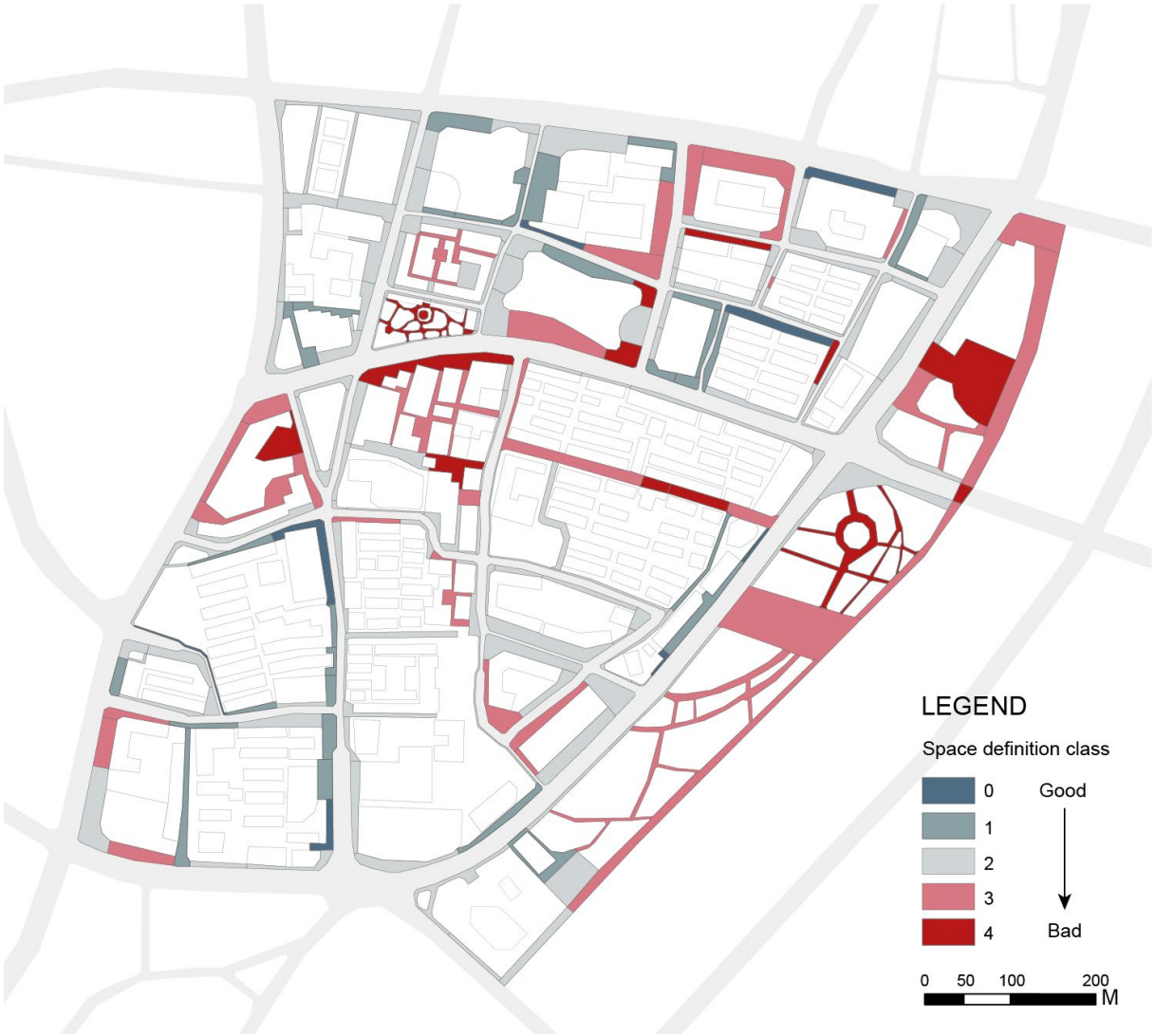


Figure 5-30 Definition assessment of pedestrian spaces

Source: own research

5.3 Multi-factor assessment

5.3.1 Spatial heterogeneity analysis based on Geodetector

The spatial autocorrelation analysis in the previous section demonstrates the spatial heterogeneity of the distribution of vitality in the research area. The decision-making mechanism of public activities is complex, and the factors that play a key role in the vitality of pedestrian spaces may be completely different for different neighbourhoods with different functions and characteristics. Therefore, a mathematical model for spatial heterogeneity can be used to effectively analyse the role of each factor in the study area and to filter out the key factors.

The Geodetector model is a set of statistical methods proposed by Jinfeng Wang and other scholars to explore spatial heterogeneity and reveal the driving forces behind it. The basic idea is that the study area is assumed to be divided into sub-regions, and if the sum of the variance of the sub-regions is smaller than the total variance of the area, then there is spatial heterogeneity [51]. It has obvious advantages over other models: it can detect both numerical and qualitative data, and it can detect interactions between factors and relationships between dependent variables. Whatever the type of relationship of the factor superposition, the relationship can be detected if it exists. Since it was first proposed in 2010, some 2,600 studies have used the geodetector model for correlation analysis and its accuracy has been tested.

The Geodetector include four types of analysis: factor detection, interaction detection, risk detection and ecological detection. This research focuses on the use of factor detection to analyse the role of each environmental substrate factor in the characterisation of vitality. The principle is to detect the extent to which the spatial variation in the dependent variable is explained by the interaction between the factors and the factors, and the explanatory power is measured by the q-value. q-value is calculated as

$$q = 1 - \frac{\sum_{h=1}^{L} N_h {\sigma_h}^2}{N\sigma^2}$$

In this research, N is the number of block segments in the study area. σ^2 is the discrete variance of all block vitality in the study area. h is the partition of each factor. L is the number of segments of each factor. h is an integer of 1,2,3,4...L. The value of q characterises the explanatory power of each factor on the variance of block vitality. The larger the q value, the better the explanatory power of the factor on the block vigour, and the weaker the opposite. The q-value can be interpreted as the independent variable X explaining 100*q% of the dependent variable Y. Also, as with Moran's I, the model calculates a p-value as a test of the significance of the q-value. When the p-value is less than 0.05, it means that the result is significant and has reference value; on the contrary, the larger the p-value, the less significant the result is and has no reference value.

The Geodetector application requires the independent variable to be a type quantity, and the results of the evaluation of each factor in this paper have been transformed into a five-level type result, which meets the requirements. The results are presented in the table below, using the total distribution of vitality as the dependent variable Y and the six factors of environmental conditions as independent variables X1, X2, ..., X6.

	Density of public centres	Density of transport stations	Density of uses	Integration	Interface	Size	Definition
q statistic	0.0518	0.0193	0.0268	0.0128	0.1687	0.0752	0.2716
p value	0.0319	0.3899	0.4487	0.6318	0.0000	0.0069	0.0000

Table 5-1 Results of the factor detection analysis

Source: own research

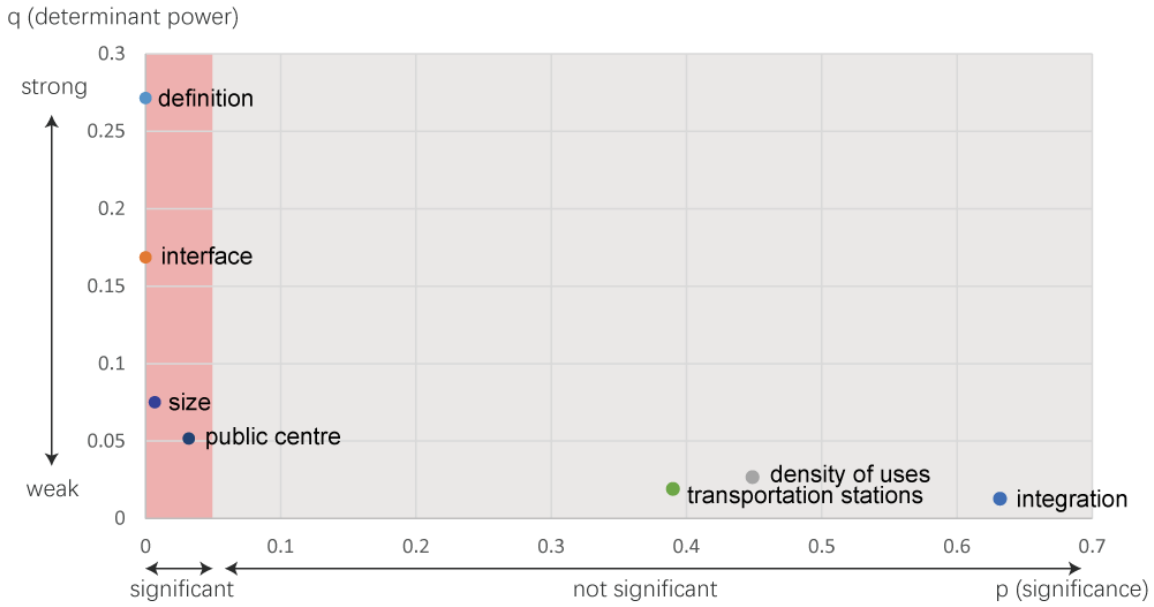


Figure 5-31 Results of the factor detection analysis

Source: own research

The p-value of the significance test shows that Interface of pedestrian spaces and Definition of pedestrian spaces have the highest significance on the distribution of vitality, while Density of public centres, Size of pedestrian spaces The significance of Density of public centres and Size of pedestrian spaces is also within the range of confidence. The factors Density of uses, Integration and Density of transport stations have no significant effect on the distribution of vibrancy within the study area and have no reference value. The Density of uses factor is generally high in the study area, which means that it is not an influence on the distribution of internal vitality. The factor of Integration and Density of transport stations directly affects the distribution of the number of people, which is in line with the heat of pedestrian flow in the neighbourhood, but has no significant effect on the distribution of public activities. This suggests that there is a problem in the research area in which pedestrian heat does not translate into public activity heat.

Among the factors with significant p-value results, Definition of pedestrian spaces and Interface of pedestrian spaces had the strongest explanatory power for the distribution of vitality, with q-values of 0.2716 and 0.1687, indicating that pedestrian spaces with good spatial design and positive interfaces are the most likely to

stimulate vitality in the area. At the same time, it can be observed that the q-values of the explanatory power of all factors are low. This suggests that the distribution of vitality within a neighbourhood is influenced by a combination of factors, with the strengths and weaknesses of each factor interacting with each other. No single factor can fully explain the distribution of public activity. Further comprehensive analysis of these four important factors is needed in the research.

5.3.2 Analysis of spatial conditions

Size of pedestrian spaces and Definition of pedestrian spaces are both essential spatial conditions for pedestrian spaces to support public activities. The analysis shows that Size of pedestrian spaces has a relatively low explanatory value for the distribution of vitality, with a q-value of 0.0752, which is in line with the findings of the public activity study that 71% of activities have a small number of participants and require little space. Further analysis combining the two evaluations provides a clearer picture of the potential impact of spatial conditions on public events. The results can also be graded on a five-degree scale.

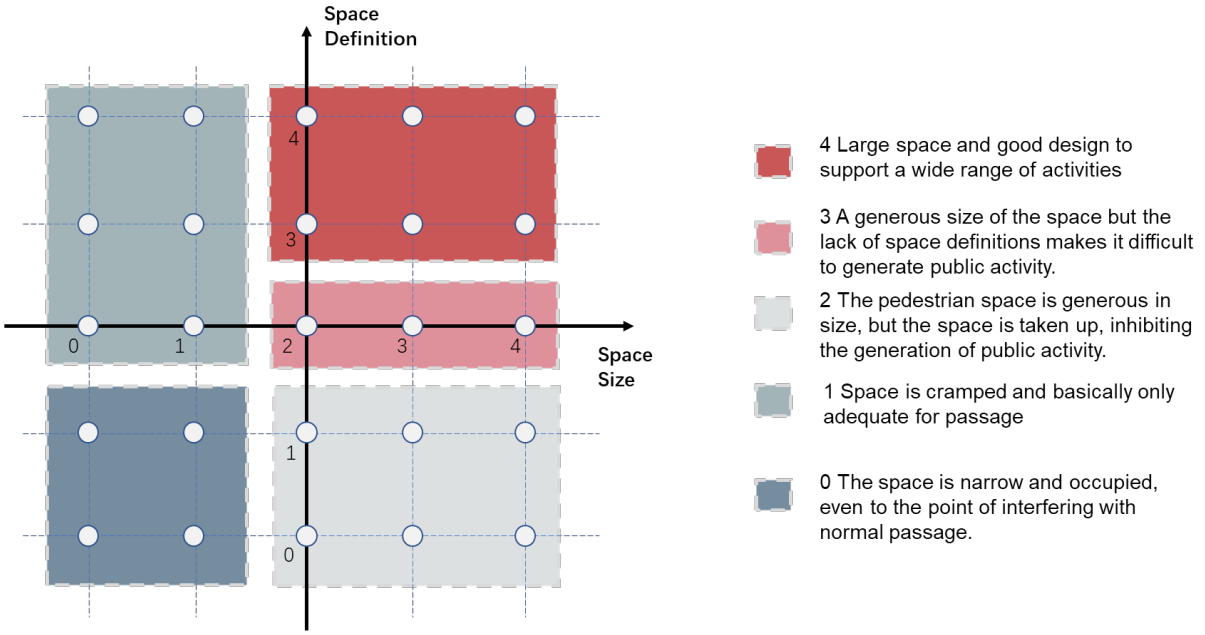


Figure 5-32 Cross analysis of size and definition

Source: own research

The cross-assessment results are shown below.

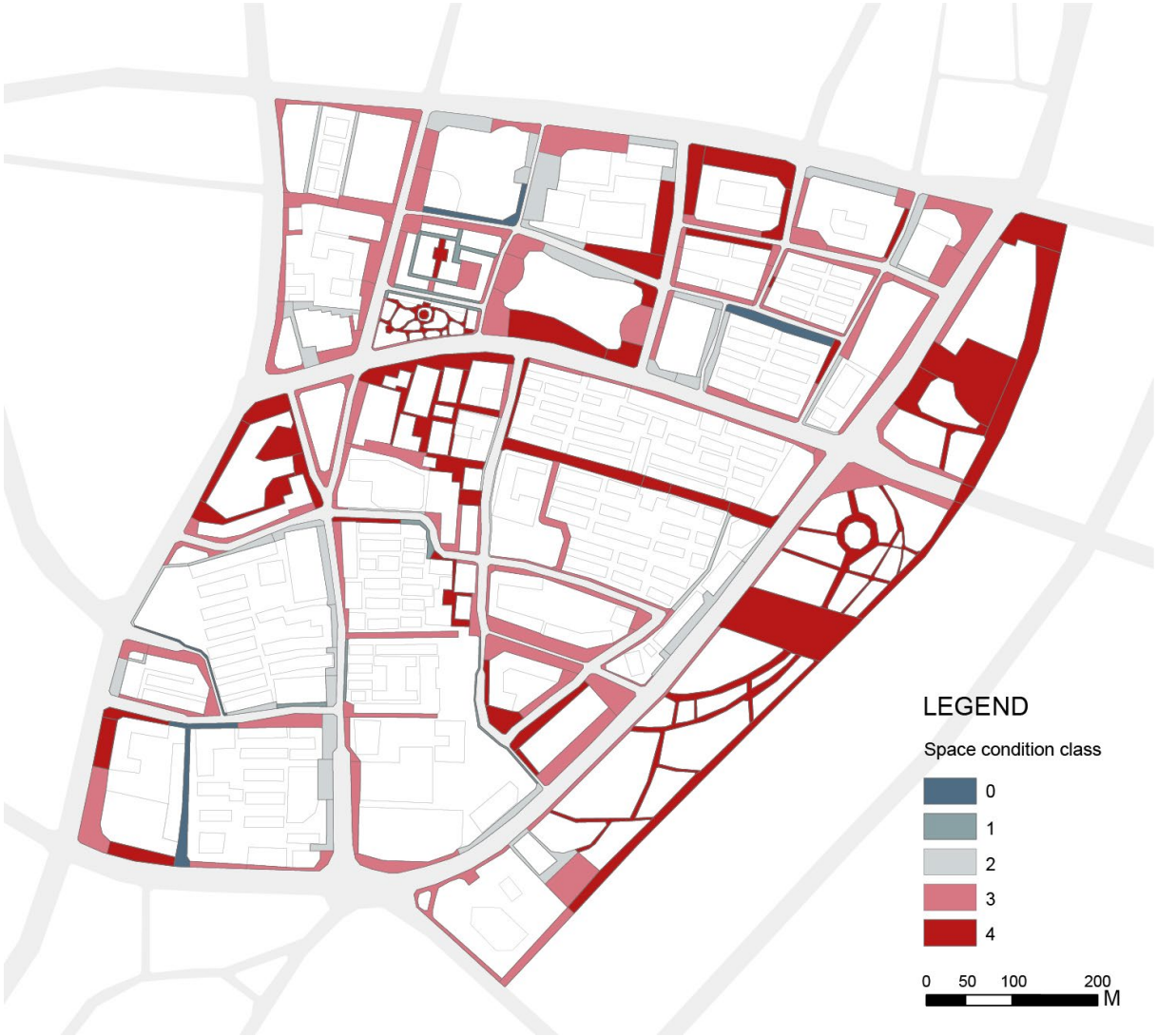


Figure 5-33 Cross analysis of spatial conditions

Source: own research

Of the five classes of spatial conditions, the second (large space, lack of definition) and the third (large space, occupied) are the segments where spatial size advantages are difficult to translate into public activity vitality, and these segments also have the greatest potential for transformation. A total of 159 segments, or 71% of the total 223 segments, met these two spatial conditions. It can be observed that there are still a large number of pedestrian spaces in the research area that have the potential to be transformed, and they offer possibilities for future pedestrian system renovation.

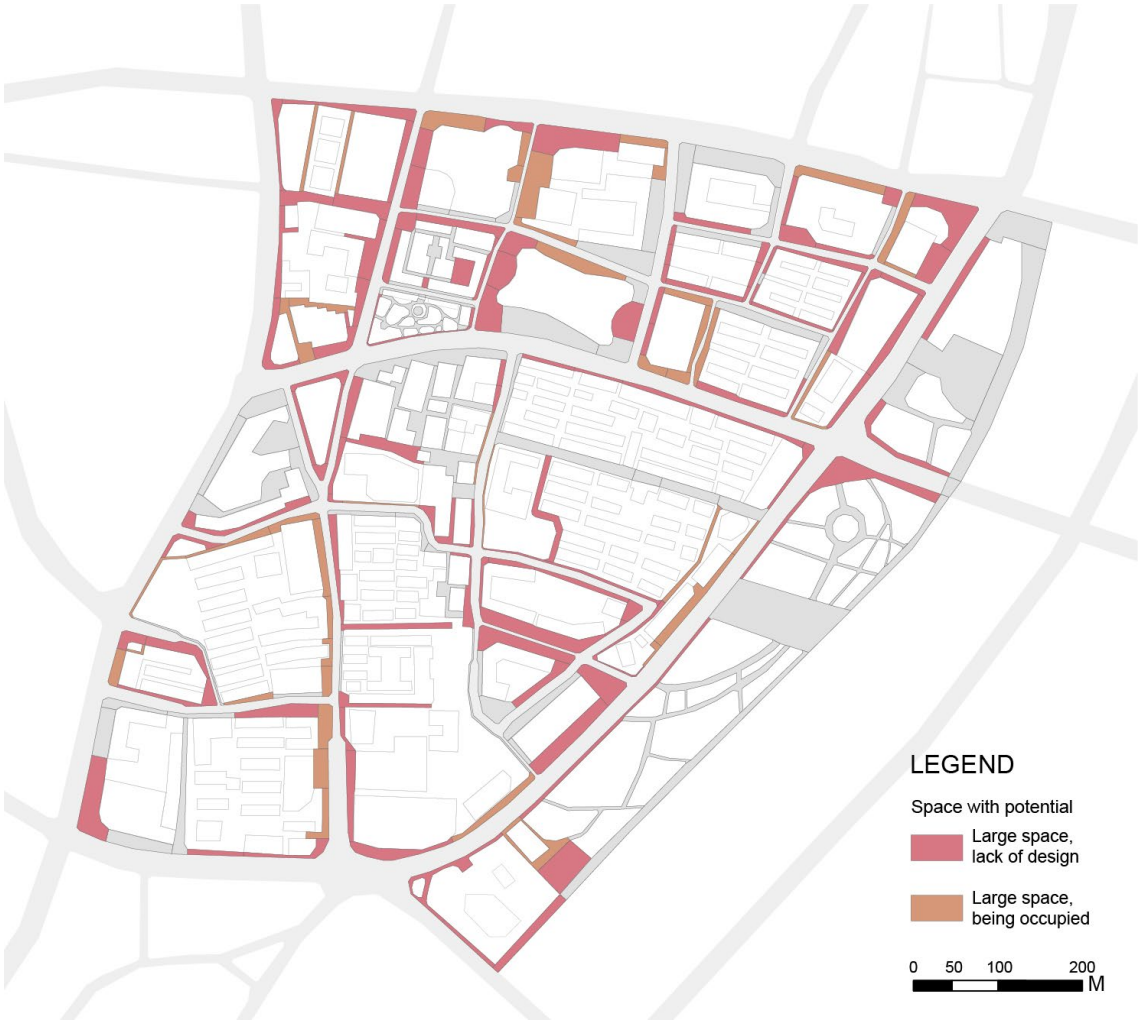


Figure 5-34 Space with potential of renovation

Source: own research

5.3.3 Analysis of interfaces

The interface of pedestrian spaces is one of the most important drivers of neighbourhood vitality. The explanatory power of the interface of pedestrian spaces factor on the distribution of vitality was only 0.1687, indicating that some of the interface vitality was not transformed into public activity vitality for other reasons. By superimposing the interface and activity ratings, 38 segments were extracted from the study with an interface rating higher than or equal to 3 (positive expectation of the interface) and a vitality rating of 0 (no public activity). That is, the interface of these fragments is not in play. The motivations of people for public activities are complex, and there are various reasons why the vitality of the interface is not being exploited.

However, based on data comparison and field observations, the author found that the vitality of the pedestrian spaces dominated by tree lawn interfaces within the study area was often lower than expected. A total of 27 segments were extracted from the study area, and it was observed that 21 of these segments did not have an interface effect, with a 77.8% overlap. This is the evidence that the tree lawn interface in the study area is not functioning as it should.

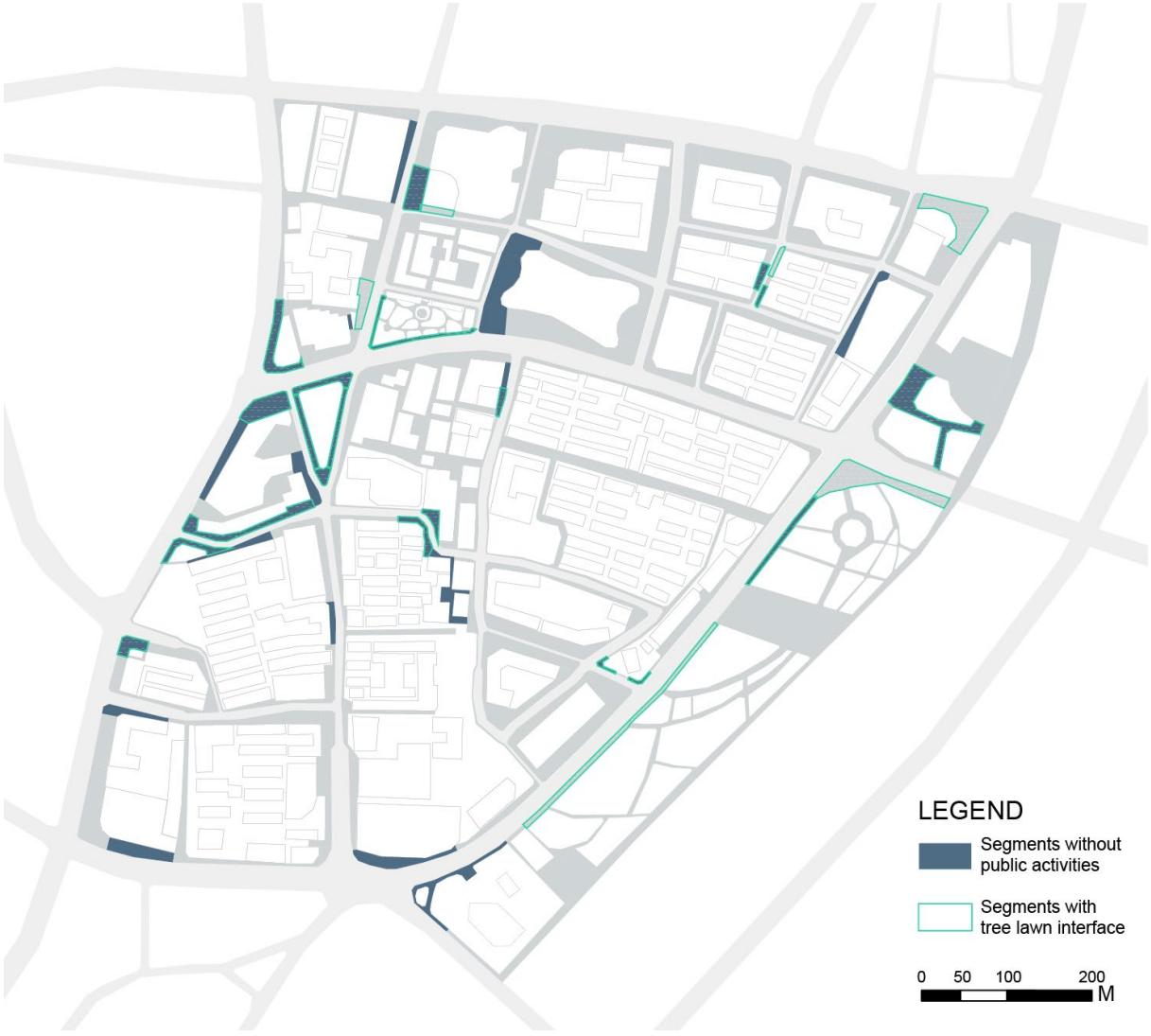


Figure 5-35 Analysis of interfaces

Source: own research

Field research has shown that the tree lawn in the research area is generally designed as a combination of shrubs and trees. This combination, although visually hierarchical, does not allow for crowd access and does not accommodate urban furniture. As a result, it serves as a practical fence, but takes up pedestrian space and inhibits public activity.

Figure 5-36 Tree lawns in the research area

Source: author's own photo

5.3.4 Analysis of public centres

Public centres such as attractions and shopping malls attract many people from outside the area and have a high footfall. Due to the herding effect of public activities, areas with a high density of public centres are more likely to stimulate public activities and show high neighbourhood vitality. According to the statistics presented in the previous section, the north-western part of the study area has a high density of public centres, with many attractions and commercial plazas. However, during the field research, the writer found that the pedestrian space in this part is not fully activated. That is to say, people have low willingness to stay and few public activities can be saw.

Comparing the density of public centres with the public activity fever gives a clearer and more accurate picture of these segments. The figure below summarises the segments where there is a significant difference between the public centre density rating and the activity fever rating (dark blue is a rating difference of 4 levels, light blue is a difference of 3 levels). These segments account for 29 segments, or 46% of

the total of 63 segments with high point-of-interest density (point-of-interest density rating of 4 or above). In the light of the actual research situation, these areas mainly suffer from two kinds of problems: inappropriate spatial design and negative interface.

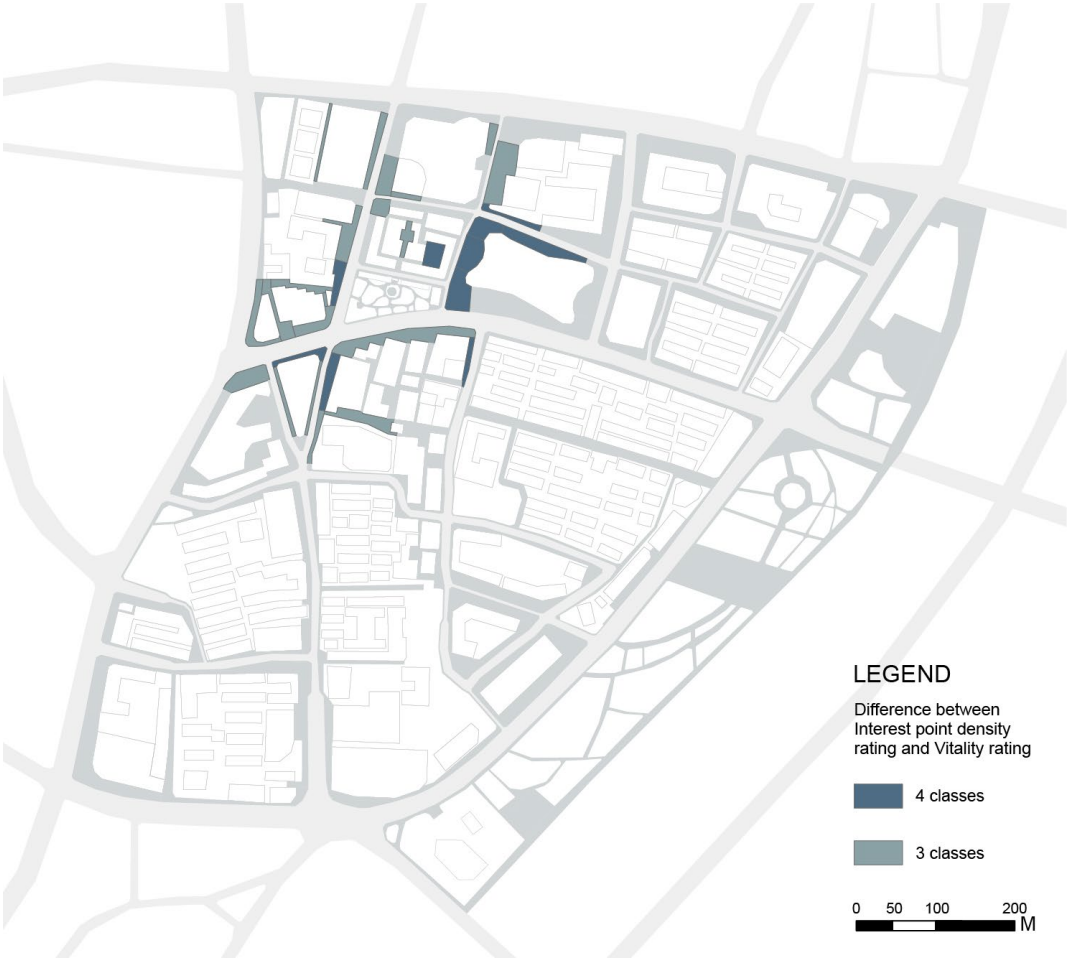


Figure 5-37 Analysis of public centres

Source: own research

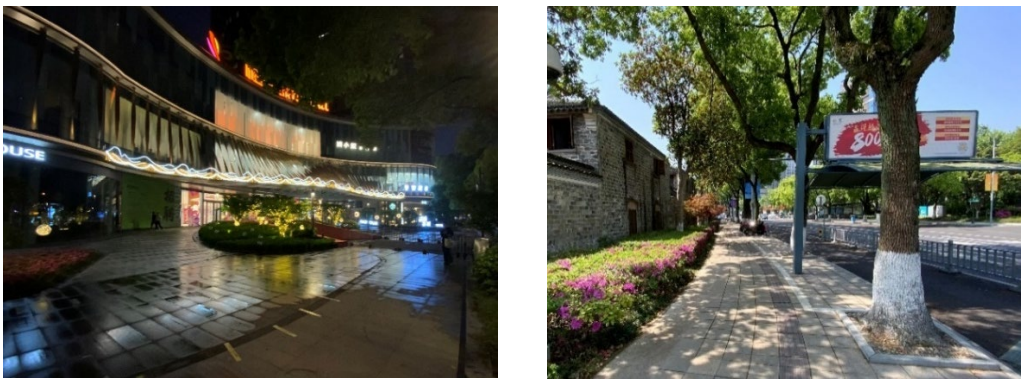


Figure 5-38 Negative spaces near public centres

Source: author's own photograph

5.4 Summary of the assessment

The research area is in the core area of Ningbo old city, with a full range of internal commercial, office, residential and waterfront leisure functions. A comprehensive assessment shows that the research area has a high road network density and is suitable for walking. Attractions such as Tian Feng Pagoda and commercial centres in the area can attract a large number of people from outside the area to visit. At the same time, the region has a good base of vitality with a wide variety of functions, abundant commercial buildings and generally generous dimensions of walking space. The area is suitable for developing into a highly dynamic and mixed neighbourhood with good liability, business and fun.

However, the current situation of the area shows a block-like aggregated distribution of various functions, which can be roughly divided into commercial, office, residential and waterfront areas.

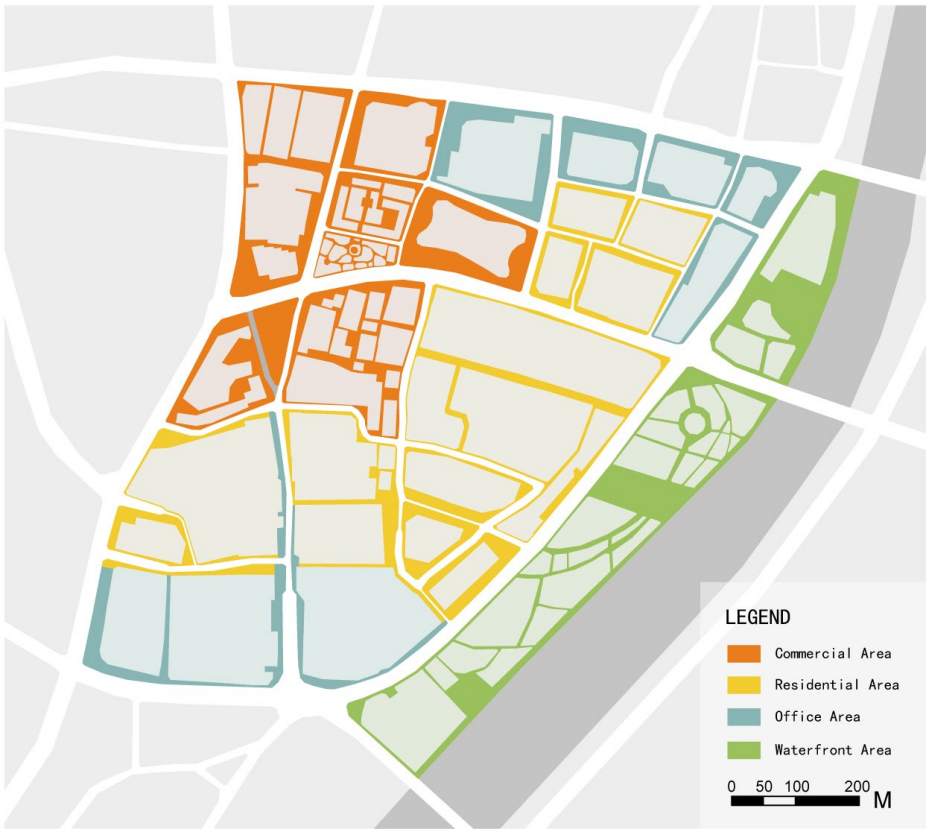


Figure 5-39 Existing zoning of pedestrian spaces

Source: own research

The spatial form and the use of space in each area differ greatly, which affects the distribution of public activity vitality. The research shows that there is a certain amount of public activity vitality in the area, and the distribution of vitality shows a multi-point distribution pattern, which has not yet formed a dynamic and coherent pedestrian system. The existing hot spots are concentrated in the commercial clusters in the northwest and the waterfront recreation area in the east, while the southern area lacks vitality.

Blurring functional boundaries, opening up various areas, and activating diverse vitality are the main directions for neighbourhood vitality enhancement. However, there are some design and management problems in all parts of the area. These problems especially affect the assessment results of the three factors of Integration of pedestrian spaces, Interface of pedestrian spaces and Definition of pedestrian spaces, which ultimately inhibit the generation of public activities and weaken the vitality of the neighbourhood. The prevalent problems can be summarized as the following three points.

(1) Motor vehicles affecting walking space

The conflict between motor vehicles and pedestrians is common in modern cities, and there are some instances of motor vehicles encroaching on pedestrian space in the research area. Firstly, there is a lack of planning for parking space, with many vehicles parked on the pavement taking up pedestrian space. Secondly, the existing surface car parks are often bounded by walls, making them a poorly perceived space. Thirdly, there are many unnecessary barriers in community-level side streets, which not only discourage pedestrians from crossing the street, but also prevent cars from making way for others, reducing the accessibility of the street.

Figure 5-40 Problems about motor vehicles

Source: own research

(2) Commercial vitality not fully released

The research area is located in the core of Ningbo's old city, with a variety of commercial squares and a high proportion of street-level shops. The commercial function is effective in attracting people, generating public activities such as buying and selling, dining, sitting and chatting, and enhancing the vitality of the neighbourhood. However, the research found that the commercial vitality of some of these areas has not been released. On the one hand, the design of the external space of some commercial plazas is bad, resulting in a lack of public activity. On the other hand, there are still many shops in the area that have not yet completed their investment or are in a state of closure, presenting a state of non-public building interface, which inhibits the vitality of the neighbourhood.

Figure 5-41 Problems about commercial vitality

Source: own research

(3) Lacking of proper design of public spaces

The road infrastructure in the research area is well developed and the pedestrian space is generally generous. However, the lack of spatial design at the appropriate scale is a key reason for the lack of public activity. Most of the pedestrian spaces are still designed to serve the needs of access, with monotonous paving, boring landscaping, a lack of interaction spaces and urban furniture, and very little interaction with shops. The dullness of the space leaves no desire to linger, inhibits the emergence of public activity and reduces the attractiveness of the neighbourhood.

Figure 5-42 Problems about the design of public spaces

Source: own research

In conclusion, the results of the multi-factor vibrancy assessment effectively reveal the existing problems within the neighbourhood. The renovation design of the neighbourhood will aim to solve these problems and enhance vitality.

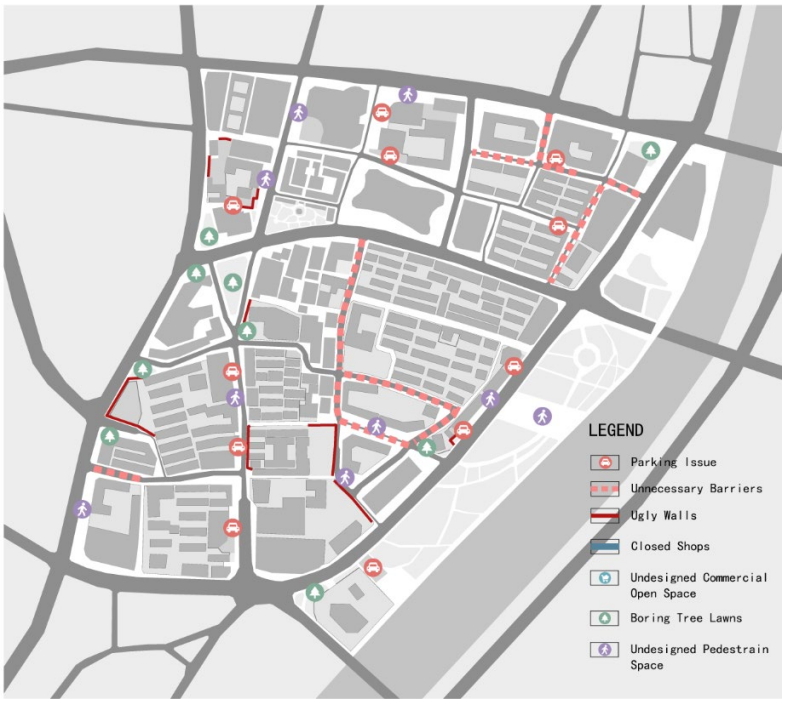


Figure 5-42 Summary of problems in the research area

Source: own research

6. Strategies and designs

This chapter will develop a design for the renovation of the pedestrian spaces in the research area based on the results of the previous assessment, with the aim of enhancing the vitality of the neighbourhood. The specific design will be developed at three scales: overall strategy, detailed sections and spatial nodes.

6.1 Overall strategies

6.1.1 Scope of renovation

Based on the results of the previous research, the pedestrian spaces identified in the figure were selected for renovation, considering their potential for transformation and the demand for public activities. The purpose of the renovation is to connect the existing vitality centres and enhance the diversity of the area. A total of 12 new or renovated public space nodes and 19 sections of core streets have been renovated. These transformed spaces will complement the existing vitality hotspots, improve the pedestrian system of the neighbourhood and stimulate the vitality of the area.

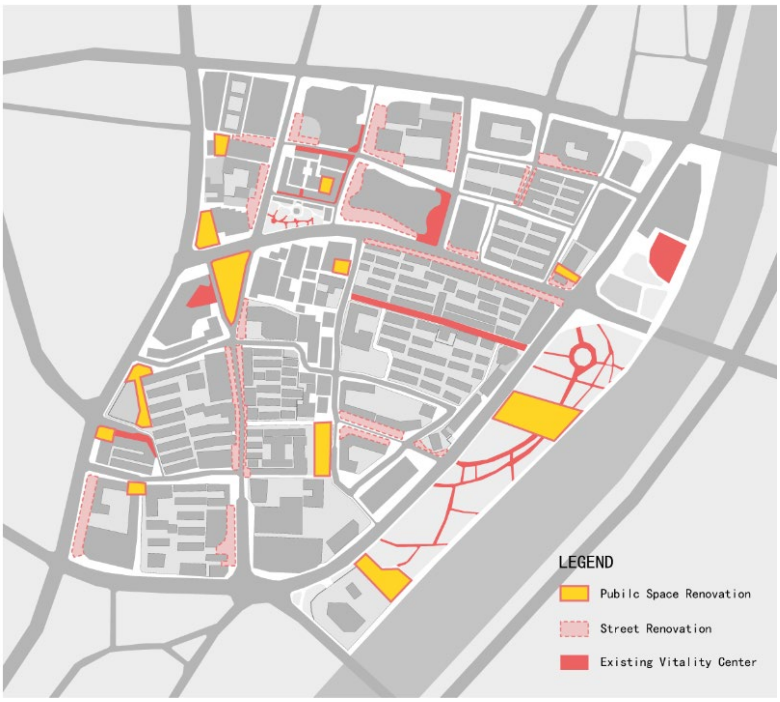


Figure 6-1 Scope of renovation

Source: own research

6.1.2 Guidelines for different spaces

The research shows that there is a certain agglomeration in the distribution of building functions and spatial characteristics in the area. At the same time, the current public activities also have a certain agglomeration and several vibrant centres are formed. The future neighbourhood transformation will focus on eliminating the boundaries of the area and enhancing the integrity and diversity of the neighbourhood. Therefore, in establishing guidelines for pedestrian space renovation, this research will classify pedestrian spaces through the attributes of the space itself, rather than functional zoning. Based on this principle, the spaces are classified into three types: squares, sidewalks, and pedestrian paths, based on their dimensions and attributes. For each type of space, guidelines are used to guide the design.

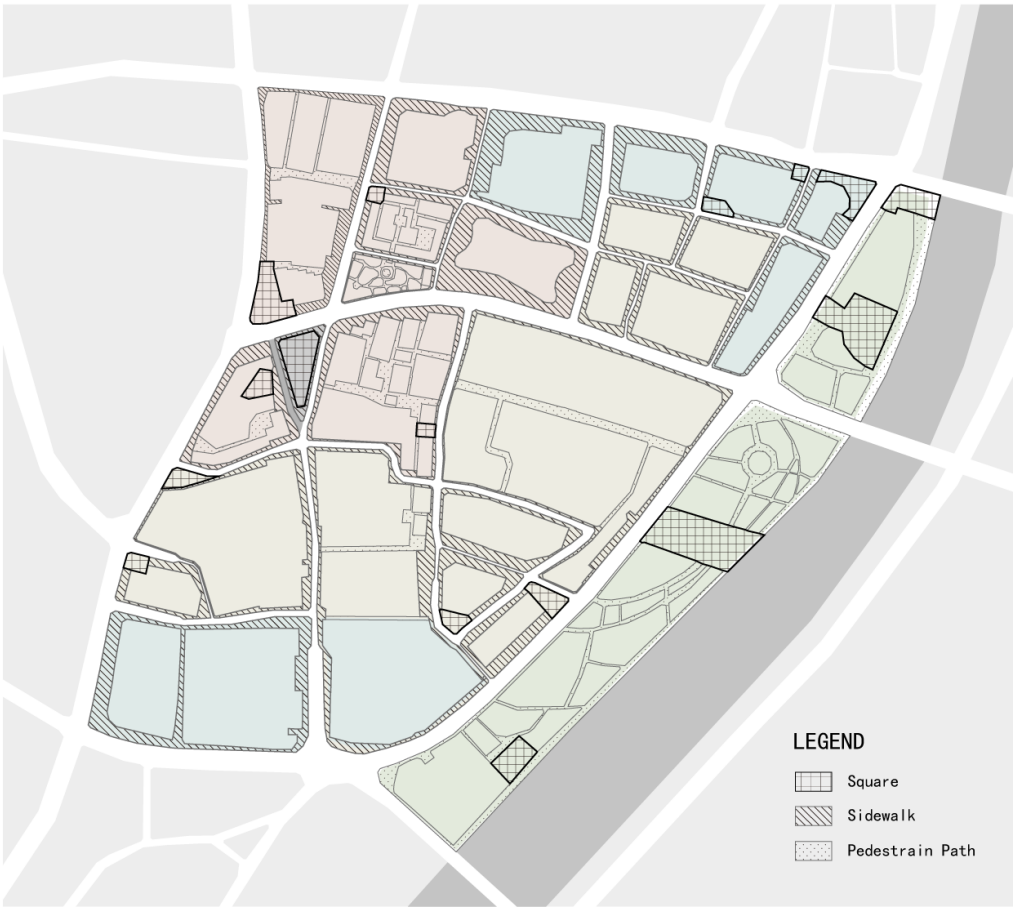


Figure 6-2 Type of spaces

Source: own research

(1) Square

The square is an important place for people to gather and disperse, and it is also the place where public activities are concentrated. In the design, it is appropriate to select an influential public activity (such as performance, photo-taking, parent-child activity, etc.) as the main activity organization space, and set up viewing and resting space around it. The square should be highly accessible and form a good interactive relationship with the surrounding buildings. Sculptures, fountains, interactive devices, etc. should be installed in the plaza to provide attraction.

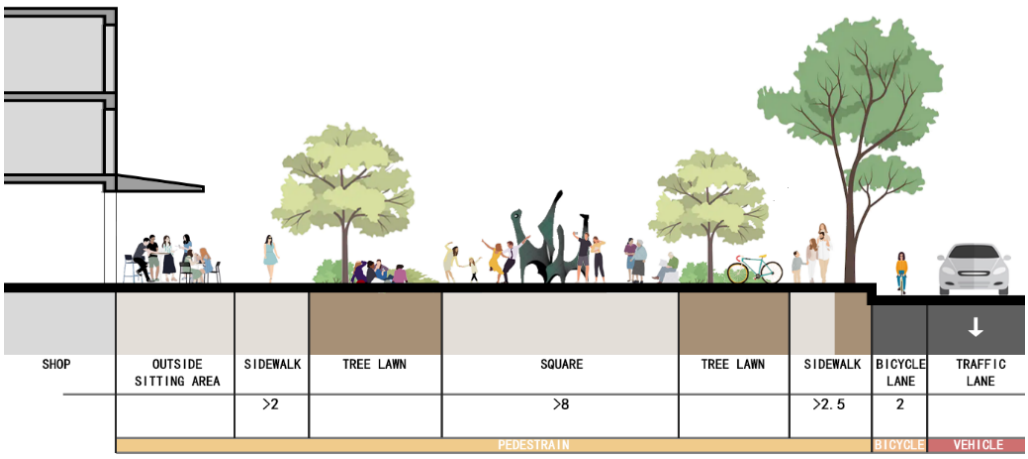


Figure 6-3 An example of the section of squares

Source: own research

(2) Sidewalk

Sidewalks need to have a basic width of passage based on pedestrian flow. For core areas, the width must be greater than four meters. For other areas, the width must be greater than two meters. Adequate space should be reserved at the entrance of stores for people to line up and stay, and sidewalks with a width of 6 meters or more should be designed with space nodes for dining, sitting, performing and other activities. Except for pre-designed parking spaces, cars are strictly prohibited to stay on the sidewalk.

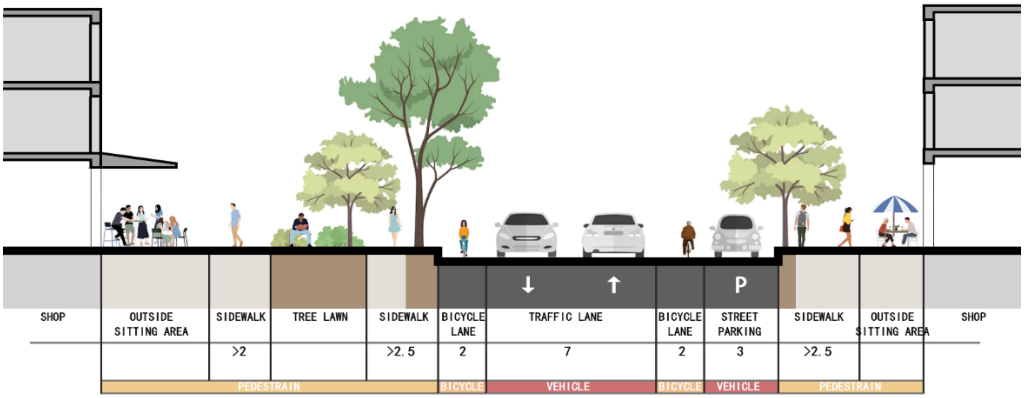


Figure 6-4 An example of the section of sidewalks

Source: own research

(3) Pedestrian path

Pedestrian paths are positioned as commercial pedestrian streets, community streets, or waterfront trails. Pedestrian paths are purely " spaces for people" and should be as dynamic as possible for public activities. The width of a pedestrian path should be greater than 3 meters. When it is wider than 8 meters, it should be divided into two paths by spatial division. The middle of the pedestrian path should be designed as a space node for resting, dining and entertainment. The pedestrian street should consider shading, and trees, structures and rides can be used to create a comfortable walking environment.

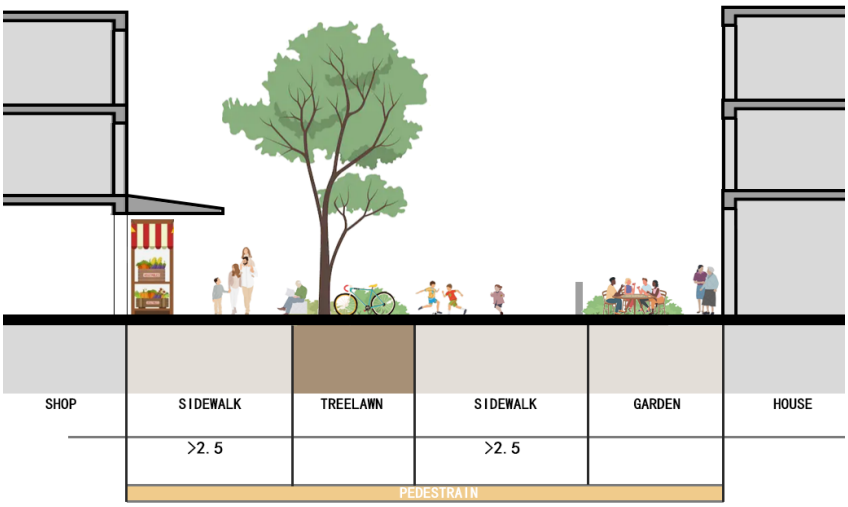


Figure 6-5 An example of the section of pedestrian paths

Source: own research

6.1.3 Planning for parking space

Research has shown that "parking difficulties" are the main reason for the occupation of pedestrian space by motor vehicles in the neighbourhood. The existing parking space in the neighbourhood was analysed, and new surface and street parking areas were created according to the current road and space conditions, and parking areas in front of buildings were planned and designed. Motor vehicle parking is strictly controlled in the core vitality zone and is not allowed to affect pedestrians. Street parking should be provided as required in residential zones, and parking on pavements should be prohibited. Street parking should be provided as required in office areas, and pavement parking may be designed in areas where space is available, to prevent indiscriminate parking.

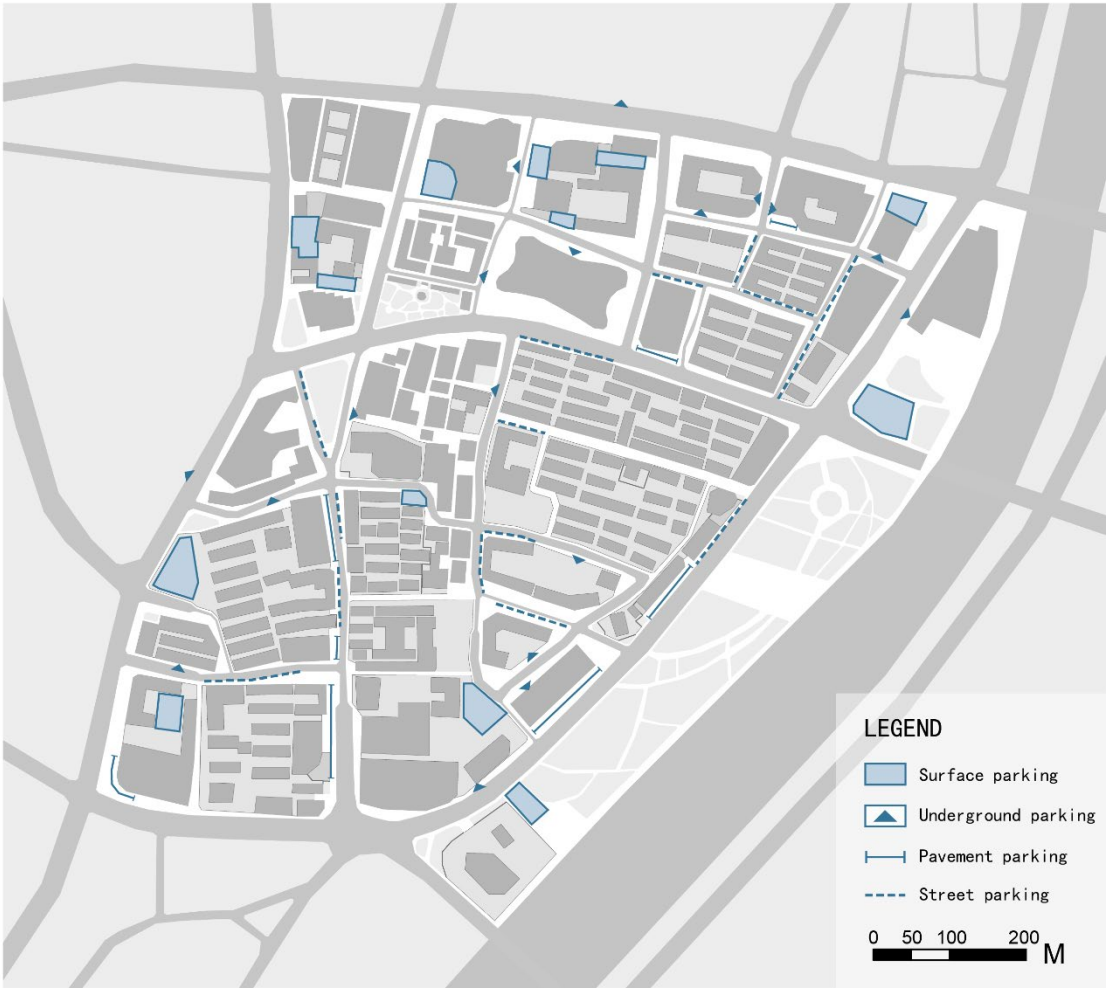


Figure 6-6 Planning for parking space

Source: own research

6.2 Detailed design

6.2.1 Basic information

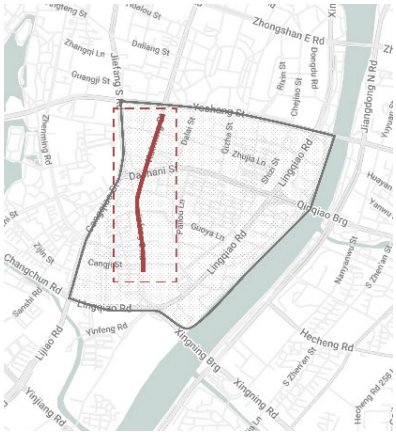


Figure 6-7 Location of detailed design area

Source: own research

The section between Kaiming Street and Jiefang South Road, to the west of the area, was selected for detailed design. This section runs north-south through the research area and contains the core area, residential area, and commercial area of the guidelines, covering most of the problems of pedestrian space in the area. Most of the section is spacious and has great potential for renovation, resulting in a variety of designs including small pocket park designs, a medium-sized children's square, and street spaces, covering a wide range of areas.

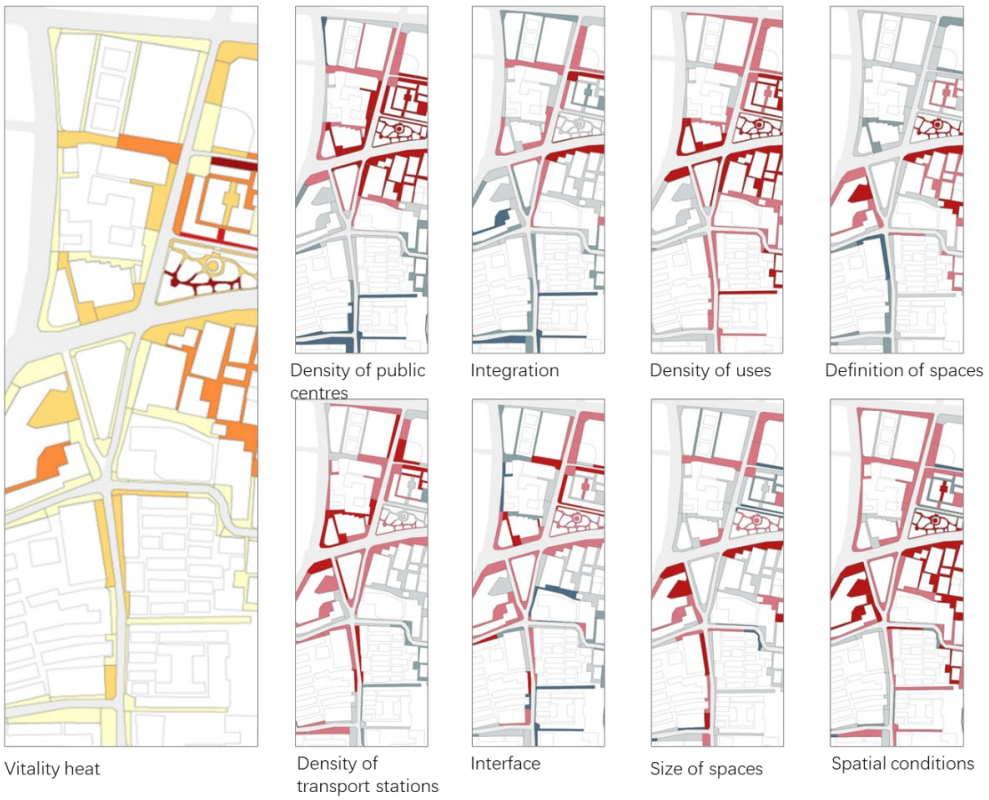


Figure 6-8 Assessment results of detailed design area

Source: own research

How to fully unleash the commercial vitality in the north and spread its influence to the south is the main issue to be considered in the design. The site contains several undesigned open spaces and discordant elements that need to be rectified, and they are the main targets for the renovation of the pedestrian space.

Figure 6-9 Typical problems in detailed design area

Source: own research

6.2.2 Master plan design

Figure 6-10 Master plan of detailed design

Source: own research

The main objective of the design is to reinforce the vitality of the commercial core to the north and to eliminate the negative areas in the centre, so that the vitality of the core can radiate to the south. The triangular area in the middle of the section is the largest area that can be transformed into a new vitality centre.

The main tool for the design of the renovation is the use of greenery, paving and the addition of urban furniture to divide the existing pedestrian space into appropriate scales and to increase the public space for activities. Particular attention is paid to the integration of the pedestrian space with the surrounding functions. For the spaces in front of the commercial shops, the design complements the external spaces for dining and sitting to create a commercial atmosphere. For spaces in front of office and government buildings, spaces are shaped for rest and interaction, while harmonising the relationship between motor vehicle parking and pedestrians. For the negative walled spaces, they are transformed into urban landscapes or new public space nodes, making them new active nodes. The design allocates space for static and dynamic activities, and adds a range of public services and bicycle parking points.

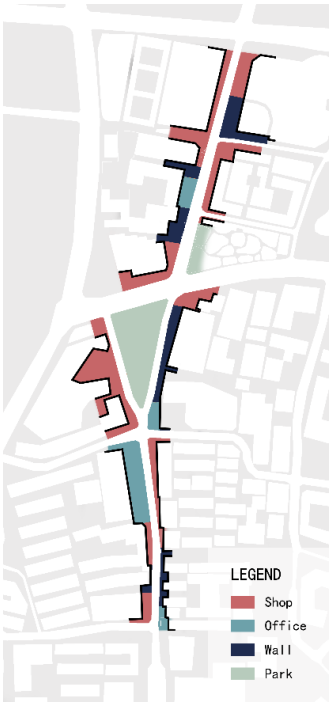


Figure 6-11 Analysis of interfaces

Source: own research

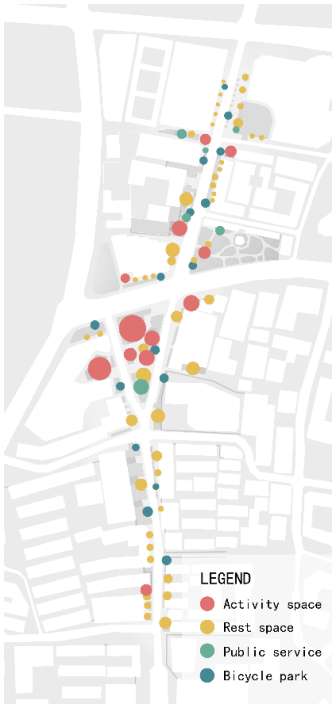


Figure 6-12 Analysis of functions

Source: own research

6.2.3 Node design 1 - pedestrian path

Node 1 is an entrance of one pedestrian path, which located in the northern part of the section. It is a spacious pedestrian walkway with an average width of 10-15 metres between several major commercial centres. On one side of the pavement are government offices, parking walls and small shops. In its current state, it is lacking in design and greenery, being a depression in the vitality of the neighbourhood.

The main objective of the design is to turn this node into an extension of the commercial vitality and to activate the shops in the south. To this end, the main functions of the pedestrian space have been defined according to the function of the surrounding buildings. The central part of the node is well aligned with the Tianfeng Pagoda, which is designed as a public stage for gatherings, events and performances, serving as a small vitality point to attract people. All the existing trees have been retained as the basis of the landscape design.

Figure 6-13 Location of node 1

Source: own research

Figure 6-14 Design analysis of node 1

Source: own research

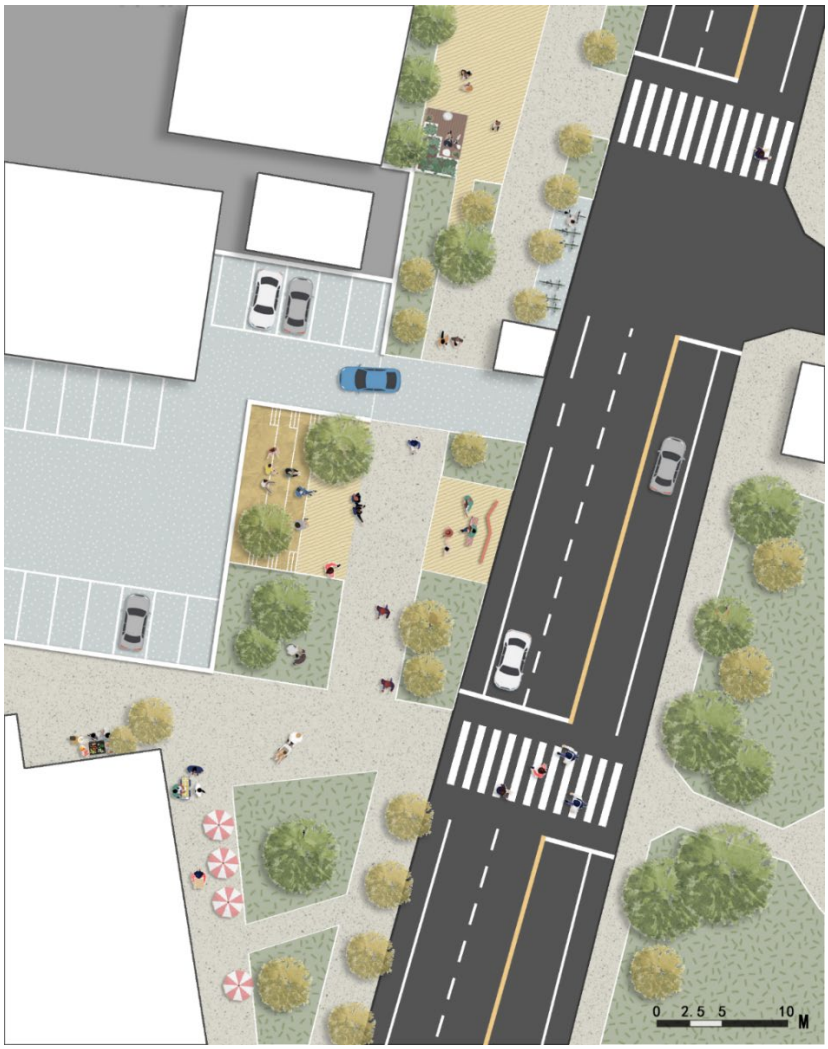


Figure 6-15 Master plan of node 1

Source: own research

Figure 6-16 The public stage and Tianfeng Pagoda

Source: own research

6.2.4 Node design 2 - square

Figure 6-17 Location of node 2

Source: own research

Node 2 is a triangle square in the middle of the road section and is a triangular area formed by three roads. To the west of the site is a commercial square, to the east is a historic commercial area, and to the east there is a kindergarten and a primary school within approximately 250m. The site is currently an inaccessible landscaped green area, which does not allow for public activities and blocks the communication between the two sides of the site. It is therefore planned to transform it into an accessible children's square, providing a means of communication between the two plots and complementing the children's play space in the western part of the neighbourhood.

Firstly, the access road is designed to connect the two sides of the site, which will divide the site into two parts, north and south. The larger northern part will be used for children's activities and the smaller southern part will be used to provide resting space and public services. A strip of trees surrounds the children's area, acting as a barrier between the square and the road, separating it from danger and noise. In the division of the internal space, particular attention is paid to the relationship between the parents' resting area and the children's activity area, so that parents can see the children's activities when they are resting nearby.

Figure 6-18 Design analysis of node 1

Source: own research

The design of the site is based on the theme of the universe, using circles and curves to divide the five large activity areas, which can be used for all kinds of children's play and parent-child activities. The children's square is also equipped with bicycle parking and public toilets to ensure the provision of public services.

Figure 6-19 Axonometric view of node 2

Source: own research

6.2.5 Node design 3 - sidewalk

Figure 6-20 Location of node 3

Source: own research

Node 3 is located in the southern part of the section. The theme of this node is street transformation. To the west of the section is an area of office buildings, the ground floor of which is dominated by the entrance to the bank and office buildings, with a large demand for parking. Due to the early construction of the building, no underground parking is provided. As a result, a large number of cars occupy the entire pavement, making this pedestrian space congested and chaotic. The main objective of the design is to respect the parking requirements, to provide a reasonable parking plan, to reduce the impact of motor vehicles on pedestrians, and to provide some public space for leisure and commercial activities.

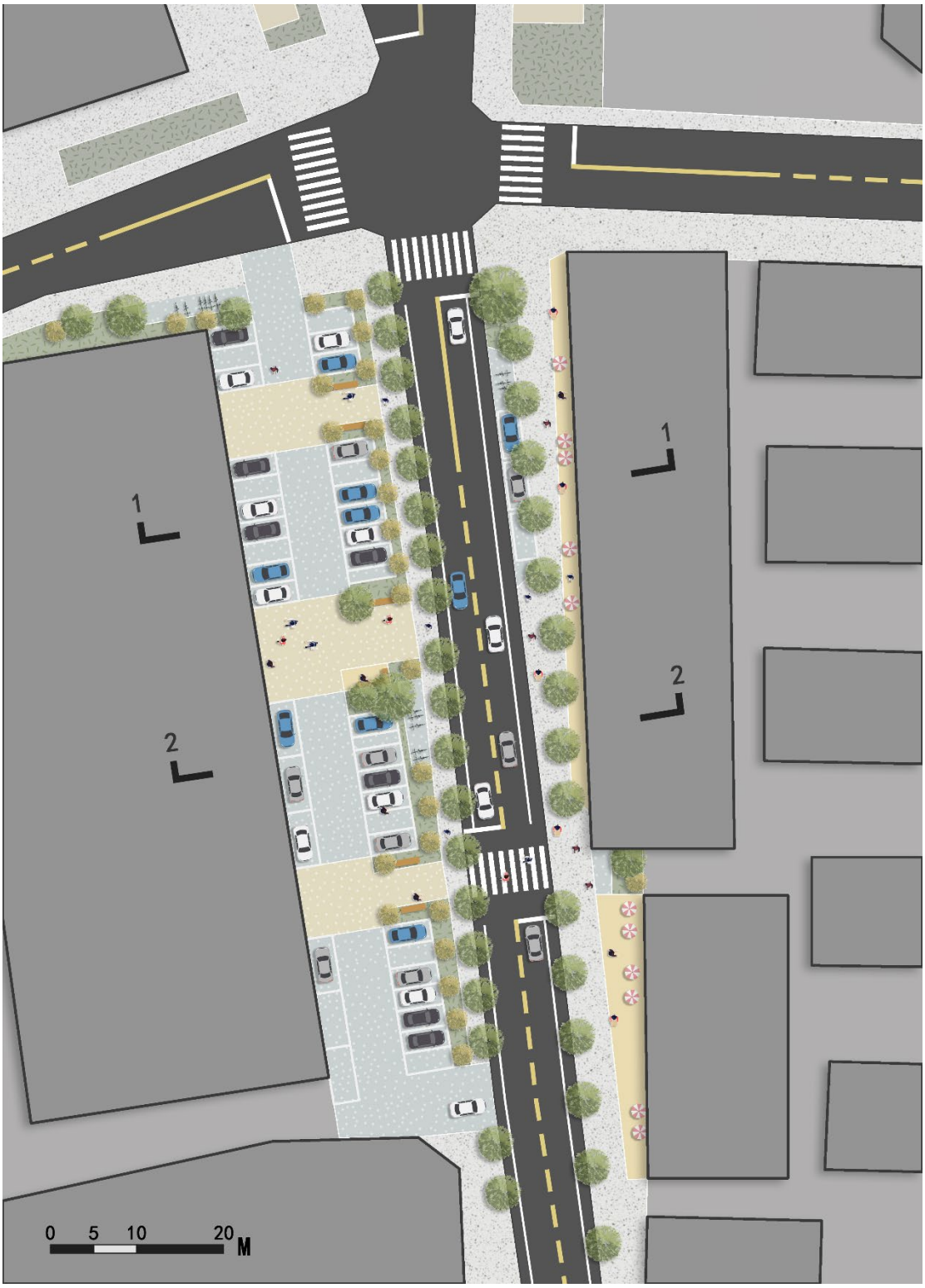


Figure 6-21 Master plan of node 3

Source: own research

The paths at the nodes tend to narrow from south to north, showing how different pavement widths can be used to design the pedestrian space.

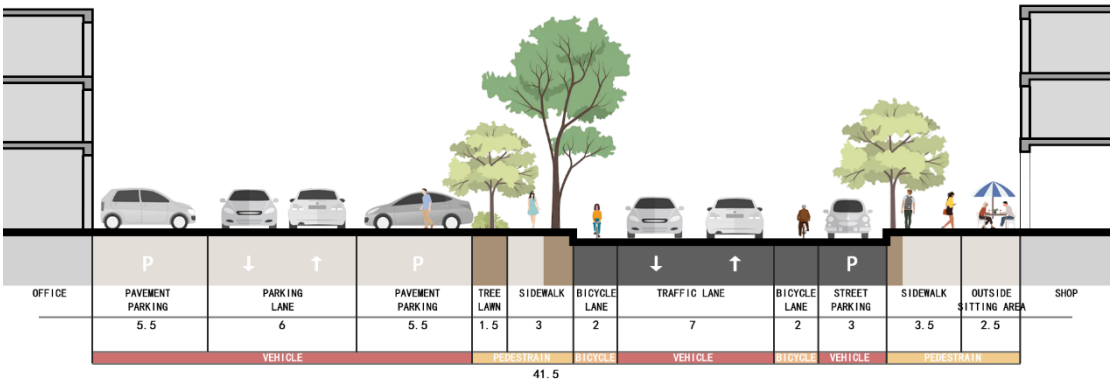


Figure 6-22 1-1 section

Source: own research

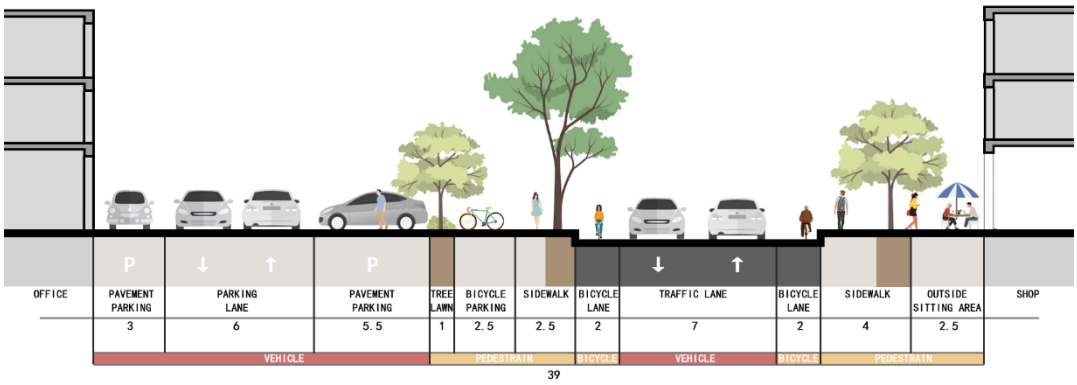


Figure 6-23 2-2 section

Source: own research

6.3 Summary

The wholesale renovation of public pedestrian spaces in the research area is an effective way to address existing problems. This chapter identifies the priority areas for pedestrian space renovation based on the analysis in the previous section. In order to better guide the renovation, the pedestrian spaces are divided into three types: square, sidewalk and pedestrian path, for which guidelines are developed

separately. Subsequently, The section between Kaiming Street and Jiefang South Road was chosen as a demonstration area for the detailed design. The renovation of this area addresses the various issues prevalent in the research area. Finally, exemplary node designs are given for each type of pedestrian space.

7. Conclusion

Pedestrian spaces are the main places for public activities, making them an important part of urban vitality. This research explored the interpretation of vitality at various scales through a literature review, and defined pedestrian space vitality as a state of positive interaction between people and space in the pedestrian space. Through further analysis, this research concluded that the source of pedestrian space vitality was the public activities of the crowd, and analysed the attributes and characteristics of public activities, laying the foundation for vitality assessment.

Subsequently, this research constructed a method for evaluating the vitality of pedestrian spaces by summarising recent vitality studies. The method distinguished between the assessment of vitality performance and the assessment of potential influencing factors, and specified the evaluation method for 10 factors. Taking Tianfeng Pagoda neighbourhood as an example, the vitality assessment was carried out. A multi-factor analysis was also conducted using the geodector model. And it was obtained that the density of public centres, interface of pedestrian spaces, size of pedestrian spaces and definition of pedestrian spaces were the most important factors for local vitality. Through further analysis of these four factors, the research summarised the basic problems that existed in the pedestrian spaces within the study area. Based on these problems, a strategy for enhancing the vitality of pedestrian spaces was developed and designed in detail.

This research is an attempt to standardise the assessment of the vitality of pedestrian spaces and to apply the results to renovation practice. It is expected that a more efficient and accurate design can be obtained by applying a standardised process. However, there are still many aspects of the research need to be improved. On the one hand, the amount of data from the public activity research was not large enough, due to manpower and time constraints, so that chance in the data cannot be ruled out. It could affect the accuracy of the vitality performance assessment and have an impact on the subsequent multi-factor analysis. On the other hand, vitality is a subjective feeling, and public activities are also influenced by subjective factors.

Therefore, more practical research is needed to verify the accuracy of objective vitality assessment results and the validity of the resulting designs. To test, validate and extend this research, we still need to carry it out in more cities and regions.

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