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主动出行视角下祈福新邨住区道路空间优化探索

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Optimization Exploration of Residential Roads Space in Clifford Estates from the Perspective of Active Travel

A Dissertation Submitted for the Degree of Master

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摘　　要

建成环境与人群健康是人类社会发展关注的永恒话题。改革开放以来，中国经历了快速城镇化的过程，城镇化率从 1978 年的 17.92%上升到 2023 年的 66.16%。快速城镇化为经济与社会带来巨大成就的同时，也伴随着一系列快速建设对人群健康带来的影响，诸如，快节奏、高强度的现代生活和工作环境下人们体力活动的缺乏导致超重、肥胖等慢性疾病。不少研究表明体力活动和人体健康之间存在着紧密联系，适当增加体力活动量，有助于降低某些疾病的发病率或死亡率。

主动出行是指通过非机动的交通方式从一点到另一点的出行，通常是步行或骑行，并且在出行过程中必须涉及到体力的消耗，因此本质上也是一种体力活动。住区道路作为主动出行重要的空间载体，与居民日常的功能性出行活动息息相关，能够较为有效地作用于居民健康。祈福新邨是一个位于广州市番禺区的大型居住区，始建于上世纪九十年代，规划面积约四百公顷，常住人口达到二十多万。由于某些历史背景，原有的住区道路规划理念现今已不再适用，居民在主动出行时面临的问题较多，如道路空间多被车行交通占据，人车混行现象严重。基于此，本文尝试通过对祈福新邨住区道路空间的优化，达到促进居民主动出行的目的，进而增加居民日常的体力活动量，最终达到提升居民健康的效果。

本文分为三大部分：第一部分为研究背景以及相关理论和实践案例。首先介绍了本文的问题起源和相关背景，其次结合多学科视角下的行为理论模型，以及国外主动出行设计指导手册和道路改造案例，作为本文的理论与实证基础。第二部分为现状研究。首先根据理论模型和实践经验构建住区道路空间的评价框架，再依照该框架对祈福新邨住区道路进行评价，解析道路空间中存在的问题。第三部分为祈福新邨住区道路空间的优化方法与设计方案。基于前文的论述提出适宜主动出行的住区道路空间优化的原则与策略，其中“连续性、安全性、便捷性、舒适性、愉悦性”为设计原则，“确定主动出行范围、创造受保护的主动出行空间、缩短主动出行的距离和时间、改善道路空间配套设施、提高道路空间视觉多样性”为设计策略；并基于现状研究和设计方法提出设计目标和优化策略总图，并将设计策略落实于具体的住区道路中。最后是全文的结论以及展望。

关键词：主动出行；住区道路；祈福新邨

Abstract

Built environment and population health are eternal topics of concern for the development of human society. Since the reform and opening-up, China has experienced rapid urbanization, with the urbanization rate rising from 17.92% in 1978 to 66.16% in 2023. While rapid urbanization has brought great achievements to the economy and society, it has also been accompanied by a series of impacts of rapid construction on the health of the population, such as the lack of physical activity in the fast-paced, high-intensity modern living and working environments, leading to chronic diseases such as overweight and obesity. Many studies have shown that there is a close link between physical activity and human health, and that an appropriate increase in the amount of physical activity can help to reduce the morbidity and mortality rates of certain diseases.

Active travel refers to travel from one point to another by non-motorized means of transport, usually walking or cycling, and must involve the consumption of physical power in the process of travel, so it is essentially a kind of physical activity. As an important space for active travel, residential roads are closely related to the daily functional travel activities of residents and can effectively affect people' health. Clifford Estates is a large residential area located in Panyu District of Guangzhou City, built in the 1990s, with a planned area of about 400 hectares and population of over 200,000 people. Due to certain historical backgrounds, the original concept of residential roads planning is no longer applicable nowadays. Residents are facing many problems during the trips of active travel, such as the road space is mostly occupied by motorized traffic, people-vehicles mixing serious. Based on this, this thesis tries to optimize the residential roads space design in Clifford Estates, to achieve the purpose of promoting the residents' active travel, and then increase the amount of daily physical activity, and ultimately to achieve the effect of improving people' health.

This thesis could be mainly divided into three parts. The first part is the research background and related theoretical and practical basis. Firstly, it introduces the origin of the problem and

related background of this thesis; and secondly, it combines the behavioral theoretical models under the multidisciplinary perspectives, as well as active travel design guideline and road reconstruction cases in foreign countries, which serve as the theoretical and empirical basis of this thesis. The second part is the current condition research, which firstly constructs the evaluation framework of residential roads space based on the theoretical models and practical experiences, and then evaluates the residential roads in Clifford Estates in accordance with this framework to analyze the problems existing in the roads space. The third part is the optimization design methodology and specific design schemes of residential roads in Clifford Estates. Based on the analysis in previous two parts, putting forward the principles and strategies of residential roads optimization design, among which "coherent, safe, convenient, comfortable and enjoyable" are design principles, and "determine active travel range, create protected active travel space, shorten active travel distance and time, improve supporting facilities of roads space, and enhance visual diversity of roads space" are the design strategies. Based on current condition research and design methodology, propose design objectives and optimization strategic master plan and implement the design strategies in specific residential roads. Finally, the conclusions and prospects of the thesis are presented.

Keywords: active travel, residential road, Clifford Estates

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Chapter 1. Introduction

1.1 Research Background

Since the reform and opening up for more than 40 years, China's urbanization has experienced a rapid development process. According to the latest data released by the National Bureau of Statistics in February 2024, by the end of 2023, the urbanization rate of China's resident population had grown from 17.92% in 1978 to 66.16%[1]. The phenomenon of rapid urbanization has brought about the concentration of all kinds of factors, such as population, capital, information, and goods, in cities, which has brought the foundation and sustained momentum for urban development. However, this growth has been accompanied by the expansion of urban areas, the reliance on motorized transportation has become more common, and motorized travel has increased dramatically, leading to a series of negative consequences.

The first is the environmental impact, where vehicle emissions and concentrations of air pollutants lead to deterioration of air quality, posing serious health risks to urban residents. Vehicle exhaust has been shown to be a significant contributor to respiratory damage and a range of diseases[2]. In addition, these emissions contribute to the formation of smog and greenhouse gases, exacerbating climate change and its associated health consequences. Second, the dominance of motorized transportation has led to sedentary lifestyles and reduced levels of physical activity among urban residents. As people become more dependent on automobiles, the need for walking and bicycling decreases. This shift to a less active lifestyle has led to a rise in obesity, diabetes and other chronic diseases related to physical inactivity. The World Bank's Human Development Department has long pointed out the trend of chronic disease prevalence in China and called for the creation of a healthy and harmonious life[3].

The Report on Nutrition and Chronic Disease Status of Chinese Residents (2020) pointed out that the base of chronic disease patients in China will still continue to expand, while the proportion of deaths due to chronic diseases will continue to increase, and in 2019, deaths due

to chronic diseases in China accounted for 88.5% of the total deaths, of which the proportion of deaths due to cardio-cerebral and cerebral vascular diseases, cancer, and chronic respiratory diseases was 80.7%, and prevention and control efforts are still faced with enormous challenges. Mainly embodied in two aspects: first, the residents of unhealthy lifestyles are still prevalent; second, the residents of overweight and obesity problems continue to highlight, chronic disease prevalence and morbidity is still on the rise[4]. In addition, the sedentary nature of motorized transportation affects mental health by limiting opportunities for physical activity, social interaction, and exposure to the natural environment, all of which are critical to overall health.

In the rapid urban development, people have experienced the transition from the "walking/riding era" to the "motor vehicle era", the number of motor vehicles has increased dramatically, and the chances of individual residents owning cars and other motorized trips have also increased. According to the National Bureau of Statistics, as of the end of 2023, the number of civilian automobiles in the country was 336.18 million, an increase of 17.14 million compared to the end of the previous year, of which the number of private automobiles was 294.27 million, an increase of 15.53 million. The number of civilian cars was 186.68 million, an increase of 9.28 million, of which the number of private cars was 175.41 million, an increase of 8.56 million[1]. At the same time, the construction of existing residential roads was carried out in such a way that motorized vehicles were adequately secured, and after then the remaining space was allocated to non-motorized means of transport (walking, cycling).

Cycling lanes that were delineated in the 1970s and 1980s based on cycling travel considerations have mostly been eliminated in road reconstruction in recent years, and there are no planned cycling lanes in many older neighborhoods built in the 1990s, resulting in a situation where bicycles are forced to squeeze onto footpaths, often needing to use the same space as pedestrians, and some bicycles even risking mixing with motor vehicles that have large differences in speed. Bicycles in some areas are now faced with the awkward situation of having no space to ride and nowhere to park.

According to the results of a telephone and online survey conducted by the Guangzhou Municipal Bureau of Statistics in 2021 through a survey of 2,257 residents in the city, the contradiction between people, vehicles, and roads is the biggest nuisance for the public when traveling. The biggest problem faced by the public when traveling on foot is that "there are many bicycles or electric bicycles on the footpaths", which is reflected by 63.3% of the people, followed by "motor vehicles and pedestrians compete for road space or motor vehicles not yielding to pedestrians" and "motor vehicle parking spaces on the footpaths", reflected by 48.6% and 33.1% respectively. Among the main problems of people's cycling trip, the highest selection rate is "lack of non-motorized lanes", with 51.1% of people choosing it, followed by "illegal parking or parking of motor vehicles occupying non-motorized lanes", "large non-motorized traffic flow", "non-motorized route structure is unreasonable (such as difficulty in pushing bicycles onto pedestrian bridge)", the choice of people in about 40% respectively. In addition, more than 30% of the people chose "few centralized parking places for non-motorized vehicles" and "many road interruptions, damages and obstacles"[5]. All of the above factors have brought about a change in the structure of travel, i.e., an increase in motorized travel and a decrease in walking and bicycling trips.

In conclusion, on the one hand, in the process of rapid urban development, which brings about a fast-paced, high-intensity modern urban lifestyle, urban residents lack the necessary daily physical activities in this context, which triggers a serious situation of chronic diseases; on the other hand, the process of rapid urbanization, the rate of motorized travel has increased dramatically, and the proportion of walking and cycling has decreased, which to a certain extent reduces the residents' daily physical activities, and thus may bring about the exacerbation of chronic diseases[6].

Residential roads space is the key indicator of the walking and cycling environment in urban residential area. As an important part of public space, pleasant and vibrant road space is conducive to residents' lives and promotes their interactions[7]. Many elements of road space, such as road morphology and characteristics, have a significant impact on residents' walking

and cycling activities. Therefore, in modern urban living environments, there is an urgent need to optimize the design of residential roads in order to promote healthier mobility in urban residential area so as to contribute to the construction of China's healthy cities.

1.2 Explanation of Related Concepts

1.2.1 Active Travel

"Active travel" or "active transportation" refers to the use of any mode that requires using human physical power[8]. In other words, it refers to travel from one point to another by non-motorized means, usually walking or biking, though rollerblading, skateboarding, and non-motorized wheelchair use would also count (Figure 1-1). So active travel is often referred to as "non-motorized travel".

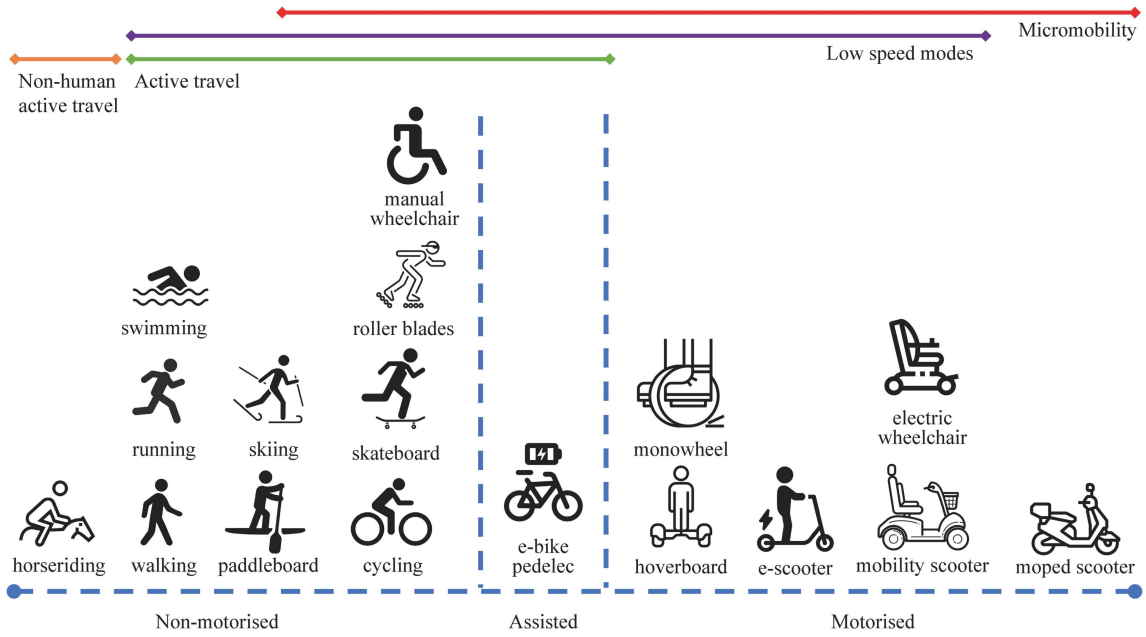


Figure 1-1: Taxonomy of active travel modes and related categories

Source: Self drawn by the author

Considering that walking and cycling are the two most common active modes of human travel, therefore, in the following part of this thesis, the optimization design of residential roads space will focus more on the travel needs and feelings of cyclists and pedestrians. Besides,

active travel is not simply a loop from starting point back to starting point, but rather involves a certain destination, a place where the traveler stops for some activity. Since it involves the consumption of human physical energy during travel, active travel might also be called “destination-oriented physical activity”, although it can be differentiated by the type of activity at the origin as well as at the destination: travel from home to work, travel from home to destinations other than work, travel from work to destinations other than home, and so on.

1.2.2 Residential Roads

"Residential roads" or "roads in the urban residential area" are part of the urban road transportation system and the main public space for urban life[7]. In other words, the residential roads has two parts of the function, firstly it is the urban infrastructure, for residents of active travel or motorized travel to provide the necessary physical support; at the same time to meet the basic function of access, but also social attributes, with the promotion of residents' interaction, recreational activities, and other daily life functions, to undertake to improve the quality of residents' outdoor daily lives. The travel activities of residents in their daily lives can be broadly divided into two categories, functional and recreational travel.

Functional travel mainly refers to residents' daily commuting to work, teenagers' schooling and residents' purchasing of necessary living goods, etc. Recreational travel refers to residents' play activities, such as aimless walks after tea and dinner. It is worth noting that recreational travel is not within the scope of research. This thesis only discusses residents' daily functional travel because it is an activity that residents need to do every day with high repeatability.

This thesis studies how residential roads space is suitable for residents' functional active travel needs, and therefore defines residential roads space as the space that provides a place for residents' active travel activities by enabling them to reach various types of functional travel destinations within a limited time and spatial range.

1.2.3 Clifford Estates

Clifford Estates is located in Panyu District, Guangzhou City, Guangdong Province, with a longitudinal length of about 1.7 kilometers from north to south and a width of about 2.9 kilometers from east to west, with a planned area of about 4 square kilometers[9], bordered by Shiguang Road and Zhongyun Road in the north, and about 3 kilometers from the central area of Shihqiao in the east, and the scenic Dafu Mountain Forest Park in the west. So far, the resident population of the residential area has reached more than 200,000, which is equivalent to the population scale of a Chinese county town[10]. Considering the main function of Clifford Estates is mainly residential, it currently contains 23 residential quarters and the whole area has a clear property management boundary with city. Therefore, Clifford Estates can be regarded as a mega urban residential area and the roads within this area can still be regarded as residential roads.

Figure 1-2: The location of Clifford Estates

Source: Self drawn by the author

Just as Rome was not built in one day, Clifford Estates construction since 1991, to the present has gone through more than 30 years of development, the former deserted place no one asked

for has long since ceased to exist, replaced by a large-scale modern urban residential area, the developer of this project, Clifford Group has become the pioneer in Chinese real estate "city-building movement". Due to the huge scale of construction of Clifford Estates, and the need for the real estate developer to take into account the policy environment, capital turnover, population movement and other factors, the development of Clifford Estates by Clifford Group is to break down the overall project into a number of independent sub-projects to be constructed in different time zones (as shown in Figure 1-3 below). Although this mode of development has improved the developer's risk-resistant ability, it has also brought about a problem, namely, the lack of systematic consideration of the overall planning of Clifford Estates, and residential roads seem to be only spaces set aside after the completion of the construction of various districts.

Figure 1-3: Old photos of Clifford Estates

Source: Reference[11]

During the 1990s when Clifford Estates was developed, Panyu City (at the county level) was in the process of being incorporated into Guangzhou City. After the completion of the administrative restructuring, Panyu District was a suburb far away from the city center. Because of the lower property prices in the suburbs and the proximity of Panyu District to Hong Kong SAR, China, most of the owners of Clifford Estates work in the center of Guangzhou and only use it as a place to rest during the night or on holidays, or they have settled in Hong Kong and only come to Guangzhou occasionally to visit their relatives or for fun. Therefore, the positioning of Clifford Estates by the Clifford Group is a real estate project located in the suburb of the city, and the creation of "car-based" residential roads has become

one of the selling points of Clifford Estates. However, along with the development of the city, nowadays, inside and outside Clifford Estates has a complete set of supporting functions for living, including education, commercial and medical functions, etc., so that the residents' travel activities have become diversified, and no longer just drive to this place to take a rest as they did 30 years ago. In this historical background, the new travel demand will certainly erupt into a sharp conflict with the old road planning concepts, reflecting the biggest problem is the lack of active travel space, that is, there is little space for residents to walk or ride on residential roads, which leads to the direct result of the lack of distinction between pedestrian and vehicular space on residential roads, and the phenomenon of mixed traffic is very serious.

Residents' short distance travel in the residential area should be a good opportunity for active travel to occur, yet faced with such chaotic and dangerous traffic conditions, residents may be forced to choose to motorize their trips. According to the results of investigation and research to Clifford Estates, in recent years, Clifford Group seems to be aware of the residents' demand for active travel, found this objective problem, and then paved the main roads in Clifford Estates with pedestrian pavement. However, due to the lack of consideration for people at the beginning of the planning and design, in order to avoid the existing trees and other obstacles such as road lamps, most of the routes for people to walk on are irregular and insufficiently wide zigzag lines, and the routes for automobile traffic, on the contrary, are unobstructed and wide straight lines.

Figure 1-4: Examples of footpaths in Clifford Estates

Source: Photographs by the author

The above problems are only one aspect of the difficulties faced by residents in active travel, the details of which will be elaborated in Chapter 4. The basic reason of these problems lies in the fact that the planning and design of residential roads did not take active travel into account from the very beginning, but only considered the smooth flow of motorized traffic. A residential area planned in the 1990s did not have a human-centered design concept, let alone residential roads designed before that, or those modeled after it.

1.3 Significance and Purpose

1.3.1 Research Significance

The research significance of this thesis mainly lies in the following two aspects:

(1) Theoretical Significance

China's national-level science and technology development strategies look at future development from a longer-term perspective and a forward-looking angle, proposing a blueprint for China's science and technology development in important fields in the next 50 years[12], clearly depicting the macro picture and eight systems that rely on science and technology to support China's modernization process by 2050, and among the eight systems, the "universal health protection system" is aimed at curbing the trend of early onset of major chronic diseases and significantly delaying the age of onset of major chronic diseases. One of the eight systems, "universal health protection system", aims to curb the trend of early onset of major chronic diseases and significantly delay the onset of major chronic diseases, and to realize the medical model from disease treatment oriented to prediction and prevention oriented direction change. Domestic scholars have begun to pay attention to the construction of residential environment based on active health interventions, and have pointed out that residential environment that attract people to active travel, and facilitate participation in fitness exercises and other opportunities to increase the physical activity of the population are an important way of effectively enhancing the health of the population and curbing the incidence of chronic diseases[13]. Coupled with urban sprawl and modern transportation's

reliance on mobility and the low priority given to the construction of walking and cycling environments and facilities in urban residential areas, there is also an urgent need to explore residential roads environments that attract people to active travel. Urban design is an important concept and method for creating a beautiful habitat and a pleasant spatial place. Thinking about how to build a physical space environment suitable for people's active travel from the perspective of urban design and attracting residents to carry out appropriate physical activities in their daily lives so as to achieve the purpose of curbing the occurrence of chronic diseases and promoting the health of the population can provide theoretical and technological support for the construction of the residential environment for active health interventions. It has important theoretical significance.

(2) Practical Significance

Active travel, as green and low-carbon transportation modes, is of great significance to ecology, society, economy, and population health. The value of residential roads construction under the perspective of active travel is mainly reflected in three aspects: ecological values, social values and health values (as shown in Figure 1-5).

Ecological value. The construction of residential roads suitable for active travel can improve the travel environment, attract people to active travel, reduce dependence on motor vehicles, and alleviate the environmental pollution caused by motor vehicle exhaust. People in residential roads suitable for active travel mostly use green transportation modes such as walking and cycling, which can not only reduce traffic congestion, but also save energy, reduce emissions and reduce noise.

Social value. Residential roads space suitable for active travel can attract people to walk and ride, increasing public contact between residents in spaces such as footpaths and bike lanes, and this small contact can lead to larger public activities and promote crowd interaction[14]. At the same time, such interactions can enrich community life and increase community vitality.

Health value. Residential roads space suitable for active travel can attract people to engage in appropriate physical activities such as walking and cycling in their daily lives. Effective physical activity is an important way to reduce the occurrence of chronic diseases such as obesity and enhance the health of the population[15], and there have been more and more studies proving that physical activity can reduce the incidence of chronic diseases such as coronary heart disease, hypertension, hyperlipidemia, diabetes mellitus type II, obesity, anxiety, depression, etc., and thus promote the physical and mental health of the population[16].

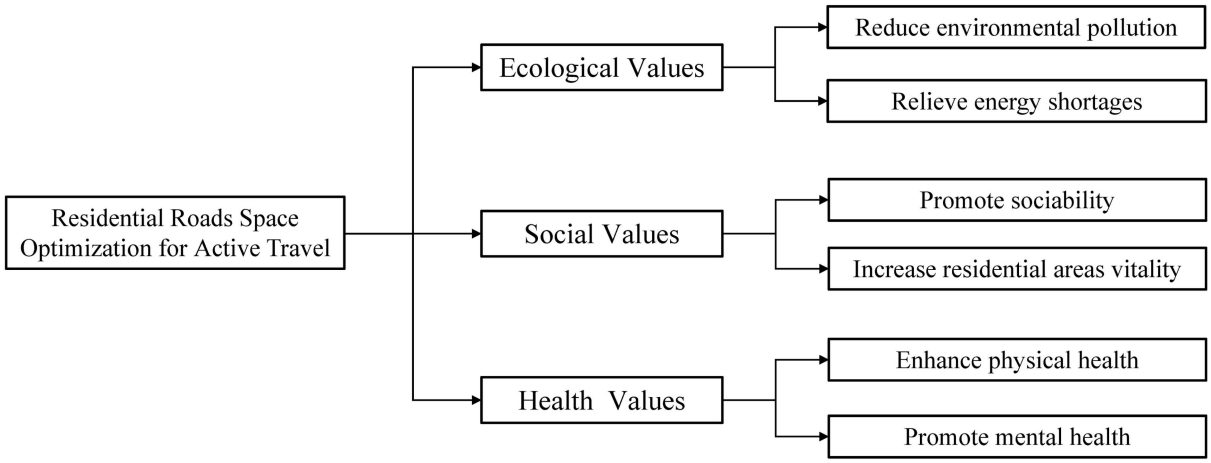


Figure 1-5: The values of residential roads space optimization for active travel

Source: Self drawn by the author

1.3.2 Research Purpose

In modern cities, the impact of fast-paced, high-intensity production and living environments on the space for active travel has resulted in physical inactivity for many residents, which has become an important factor in exacerbating their physical and mental health problems. Increased exercise is one of the most important ways to combat such health problems. And within residential areas, active travel such as walking and cycling are simple and efficient ways to travel due to the relatively low dependence on motorized vehicles. At the same time, moderate increases in active travel such as walking and cycling can be an effective way to improve the physical inactivity of residents. Since traveling is essentially a linear activity, the road is the spatial carrier to support this activity, so the construction of roads environment suitable for active travel has social and health value for residents, and the construction of

residential roads suitable for active travel can attract residents to travel actively, increase the frequency of active travel, increase the communication between people, increase physical activity, increase the pleasure of travel experience, and then enrich the life of the residential areas, increase the pleasure of travel experience. It can also increase mutual communication between people, increase physical activity, and increase the pleasure of traveling experience, which in turn can enrich the life and vitality of residential areas, and promote physical and mental health. This thesis researches the spatial environment of residential roads under the perspective of active travel, looks for the spatial environment factors affecting residents' active travel, and explores the spatial environment characteristics of residential roads space which is suitable for residents' active travel, with a view to providing valuable references for the optimization of roads space in urban residential areas.

1.4 Methods and Framework

1.4.1 Research Methods

(1) Literature Research Method

Through the domestic and international literature on the theory of active travel and residential roads design as well as on practical case studies, after sorting, analyzing and summarizing, we comprehensively understand the status quo and shortcomings of the existing research, find out the starting point and breakthrough of the research, and determine the content and methods of the research in this thesis.

(2) Field Survey Method

On-site investigation and research on a typical large-scale residential area in Guangzhou, Clifford Estates, the specific methods used include on-site observation and data statistics. The survey method is mainly used to study the residential roads space and residents' travel activities, observing, measuring and recording the selected roads space and all kinds of travel activities in the residential area under study, and then organizing the data into tables and graphs, and applying the software to visualize and analyze them.

(3) Perception Survey Method

On-site perception questionnaire distribution and interviews were conducted in the study area to understand the attitudes and needs of local residents towards active travel and the factors that influence their choice of active travel, and to find out the problematic aspects of residential roads from the road users' personal feelings, so as to provide a realistic basis and supplementary information for this study.

1.4.2 Research Framework

Chapter 1 is an introduction. It describes the origin of this thesis and the significance of this research. In view of the changes that have occurred in the travel mode of urban residents and the negative impacts of motorized travel on the ecological environment, urban transportation and human health, then the research content, objectives and research objects of this thesis are clarified.

Chapter 2 are theoretical studies. Several behavioral theoretical models from the perspectives of environmental psychology, social ecology and operations research are reviewed, and it is clear that human active travel behavior is influenced by many aspects, including personal factors, the physical environment and the social environment. These three factors are situated in the overall built environment of an urban residential area, which can be characterized by proximity, safety, connectivity, accessibility, comfort and aesthetics.

Chapter 3 are case studies. Firstly, design guideline related to active travel are reviewed, and it is found that the commonality is reflected in the improvement of infrastructure coherence, safety, directness, comfort and the creation of attractive travel space. Secondly, the Mini Holland Programme in London, UK is selected as a case study, in which the design measures are divided into two aspects: infrastructure improvement together with landscaping and public space improvement, and the specific program designs are listed one by one.

Chapter 4 is the current condition research of residential roads space in Clifford Estates. First,

according to the theoretical models and practical experiences to construct the evaluation framework of residential roads space from the perspective of active travel, and then evaluate the residential roads space in Clifford Estates from the five dimensions of coherence, safety, connectivity, comfort and aesthetics, and combined with the perception survey of residents' active travel behaviors (dimension of public engagement), to parse out the current problems of residential roads space.

Chapter 5 is the methodology of residential roads space optimization in Clifford Estates. On the basis of the previous theoretical studies, case studies and current situation research, optimization principles and strategies are proposed, each with five aspects. The optimization principles are coherence, safety, convenience, comfort and enjoyment of active travel routes; the optimization strategies are to determine active travel range, create protected active travel space, shorten active travel distance and time, improve supporting facilities of roads space and enhance visual diversity of roads space. There is a general correspondence between the principles and strategies, but at the same time, the strategies are complex, and a single optimization strategy can embody multiple optimization principles.

Chapter 6 is the residential roads space optimization design in Clifford Estates. The first step is to determine the scope of the optimization design research, followed by presenting the optimization design objectives and the optimization strategic master plan based on the discussion in the previous two Chapters, and then implementing the design strategies into specific residential roads space and resolving the various types of design elements separately.

The end are the conclusions and prospects of this thesis.

Chapter 2. Theoretical Studies

2.1 Related Travel Behavior Theory Research

Whether walking or cycling or other types of active travel, they are all important types of human behavior. When exploring travel environments that attract people to active travel, it is inevitable to return to the theoretical basis of behavior and environment for exploration. In the past studies, many scholars have explored theories of behavior and environment from psychological and social ecological perspectives, and several representative theories and models are selected in this section, which will be reviewed below. In addition, an operational theory will also be reviewed as a complement to the psychological and social ecological perspectives.

2.1.1 Perspective of Environmental Psychology

Behavior and environment research, including active travel research, has drawn largely on theories based in the field of psychology. These theories provide useful frameworks for understanding active travel, and might also be useful for understanding travel behavior more generally. These theories can be grouped into two categories, one surrounding the theory of planned behavior, and one surrounding social cognitive theory.

(1) The Theory of Planned Behavior

The Theory of Planned Behavior, developed by Ajzen in 1991 as an extension of the earlier Theory of Reasoned Action developed by Ajzen and Fishbein, focuses on the role of beliefs in explaining behavior. According to Azjen[17], “It is at the level of beliefs that we can learn about the unique factors that induce one person to engage in the behavior of interest and to prompt another to follow a different course of action.”

Azjen distinguishes between behavior beliefs, normative beliefs, and control beliefs, which respectively influence attitudes, subjective norms, and perceived behavioral control.

Behavioral beliefs are beliefs about the likelihood of possible outcomes of a behavior;

attitudes about a behavior depend on behavioral beliefs about each possible outcome weighted by an individual's evaluation of those outcomes, whether positive or negative. Normative beliefs are beliefs about whether important referent individuals (e.g., a friend, partner, parent, or boss) approve or disapprove of performing the behavior; subjective norms about a behavior depend on normative beliefs for different referent individuals weighted by an individual's motivation to comply with those referent individuals. Control beliefs are beliefs about the likelihood of possible factors that would facilitate or constrain a behavior; perceived behavioral control about a behavior depends on control beliefs for different factors weighted by the perceived power of each factor to facilitate or inhibit the behavior. These factors determine behavioral intention, which together with perceived behavioral control then determine behavior (Figure 2-1).

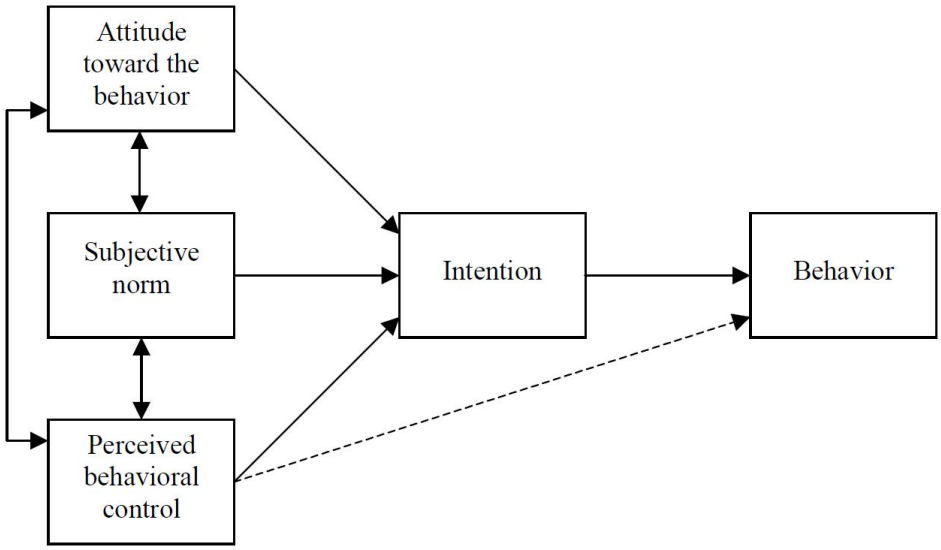


Figure 2-1: The theory of planned behavior

Source: Reference[17]

This theory has proved useful as a framework for conceptualizing, measuring, and identifying factors that determine behavior[18]. However, by focusing on beliefs, this theory does not posit a significant role for the built environment in explaining physical activity, including active travel. Where characteristics of the built environment might come into play is in control beliefs, the beliefs an individual holds about the likelihood of possible factors that facilitate or

constrain a behavior. For walking, such factors might include the presence or absence of footpaths or the presence or absence of automobile traffic. In this theory, it is an individual's beliefs or perceptions about the existence of these factors, rather than the objective existence of these factors, that explain behavior.

(2) Social Cognitive Theory

Social cognitive theory, developed by Bandura in 1986, explains behavior in terms of reciprocal relationships between the characteristics of a person, the behavior of a person, and the environment in which the behavior is performed[19]. Called "reciprocal determinism" (Figure 2-2), this concept suggests that a simple linear relationship in which characteristics of the person and the environment determine behavior is inadequate. Behavior also influences the environment and the person, and the person and the environment influence each other. The theory explains human activities in terms of the interrelationship between the individual's psychological and cognitive processes, the environment in which the behavior takes place, and human behavior, forming an analytical framework in which the environment, behavior, individual triad determines human activities. This concept does not mean perfect symmetry in the strength of the influences between each pair of components, nor does it mean that the interactions happen simultaneously[18].

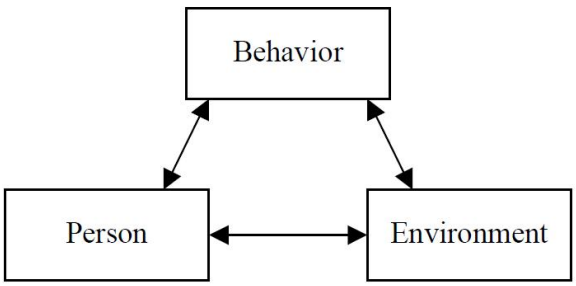


Figure 2-2: Reciprocal determinism

Source: Reference[19]

This theory also contributes other concepts potentially important to understanding active travel behavior[20]. One important distinction in this theory is between environments, the

objective factors external to a person that can affect his behavior, and situations, the mental representation or perceptions of the environment that may affect his behavior. Outcome expectations also play an important role in this theory: individuals learn that outcomes occur as a result of their behavior, then expect them to occur again. This learning can occur through one's own experience in similar situations and the rewards accrued, from observing others in similar situations and seeing what rewards they accrue, from hearing about situations from others, and from one's own emotional and physical responses to the behavior.

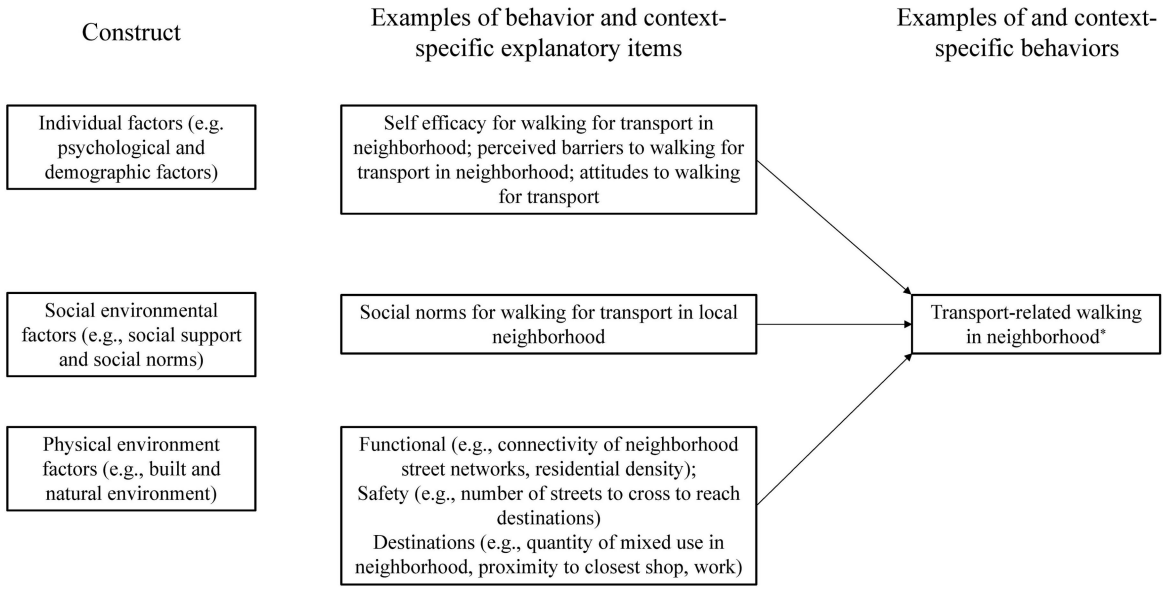
The concept of self-efficacy, developed by Bandura, is seen as tremendously important in efforts to understand health behavior. Self-efficacy refers to "the confidence that a person feels about performing a particular activity, including confidence in overcoming the barriers to performing that behavior"[20]. Bandura explains this concept as "people's sense of personal efficacy to exercise some control over events that affects their lives." According to Bandura, perceived self-efficacy is a significant determinant of performance and operates partially independently of underlying skills. In other words, whether one believes he can do something can matter as much as or even more than whether he actually can. An individual can come to know about his own efficacy through what he has attained in prior performances, observing what others have attained through their performances ("vicarious" learning), verbal persuasion and other social influences that convince his that he possesses the necessary capabilities, and through physical responses from which he judges his capabilities.

While social cognitive theory provides theoretical guidelines for the study of active travel and other physical activities, environment in this context refers to perceptions of the environment (mental representations that may influence behavior) rather than the external physical environment. The difference with social cognitive theory is that the social ecological models place more emphasis on the role of the external physical environment on behavior, rather than just individual factors and the social environment.

2.1.2 Perspective of Social Ecology

(1) Behavior-Specific and Environment-Specific Ecological Model

In 2005, Corti uses walking as an example to show that walking travel are influenced by individual factors, social environmental factors, and physical environmental factors (Figure 2-3). Individual factors mean psychological and demographic factors and others; social environmental factors include social support, social norms, and etc.; and the physical environmental factors include built and natural environment. Furthermore, he believes that recreational walking are different from transport-related walking in a neighborhood which is defined as a 10-15 minutes of walk from home, because different travel purposes will be determined by different individual, social environmental, and physical environmental factors. For example, transport-related walking will be affected more by functional items, such as connectivity of neighborhood street networks, residential density while recreational walking will be affected by aesthetics, such as attractiveness local streetscapes and local parks. But both of them would influenced by safety.



*Note: the neighborhood defined as a 10-15 mins walk from home.

Figure 2-3: Examples of behavior- and context-specific constructs for use

Source: Adapted from reference[21]

(2) The Hierarchy of Walking Needs Model

Alfonzo proposed the hierarchy of walking needs model in 2005 based on the social-ecological model, which further deepens the causal relationship between urban spatial form and walking activities. These needs range from the most basic feasibility (related to personal factors) to the higher levels of accessibility, safety, comfort, and pleasurability (related to urban form), which are also external environmental influences, among which feasibility is determined by individual factors such as socio-economic attributes and factors such as mobility, time, and ability, which are also determining factors. It is important to note that Alfonzo considers the lifestyle environment, which is constructed by the interaction of individual factors, group design factors and physical environment factors, as the internal process that determines walking behavior and is the mediator between environmental factors and walking behavior. In other words, the internal process is possible only when the external environmental factors are satisfied.

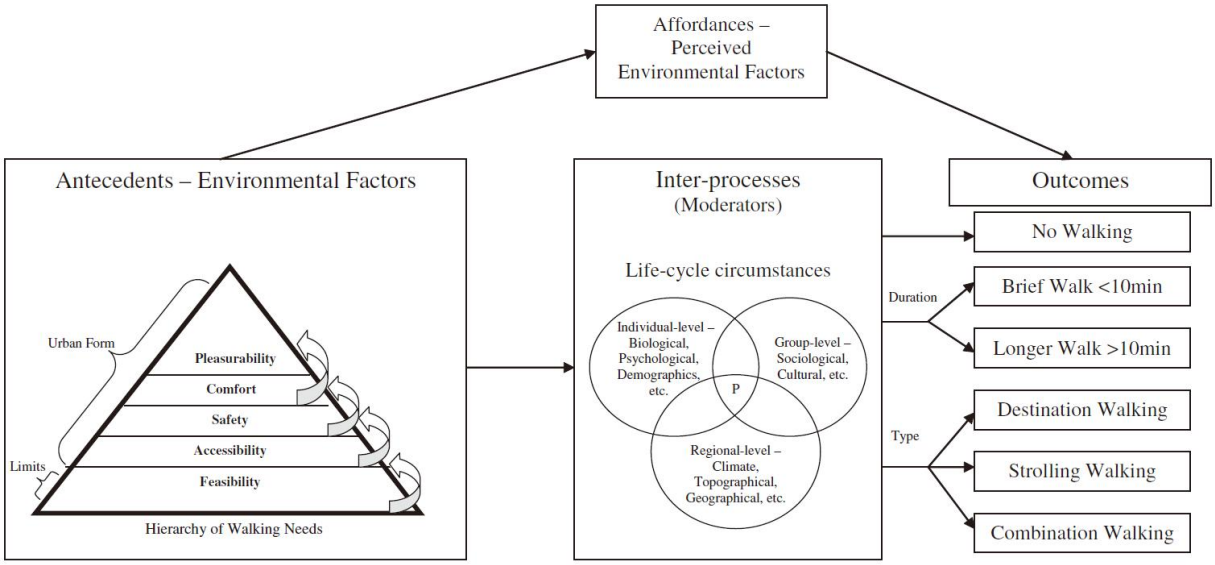


Figure 2-4: Hierarchy of Walking Needs within a social ecological framework

Source: Reference[22]

2.1.3 Perspective of Operation

Comparing with the environmental psychological and social ecological theories, operational theories are useful in some degree because they can provide concise, understandable

frameworks to summarize previous research for practical application.

Robert Schneider proposed an operational theory in 2013, called the Theory of Routine Mode Choice Decisions, to describe how people choose transportation modes for routine travel purposes, such as local shopping or other errands[23]. This theory suggests that there are five steps in the mode choice decision process (Figure 2-5). The first part, awareness and availability, determines which modes are viewed as possible choices for routine travel. The next three elements, basic safety and security, convenience and cost, and enjoyment, assess situational tradeoffs between modes in the choice set. Schneider claimed that the middle three steps may be considered simultaneously or in various sequences. The final part, habit, reinforces previous choices and closes the decision process loop. Socioeconomic characteristics, including age, gender, household size, employment status, income, household automobile ownership, and physical disabilities, explain differences in how individuals view each part of the process.

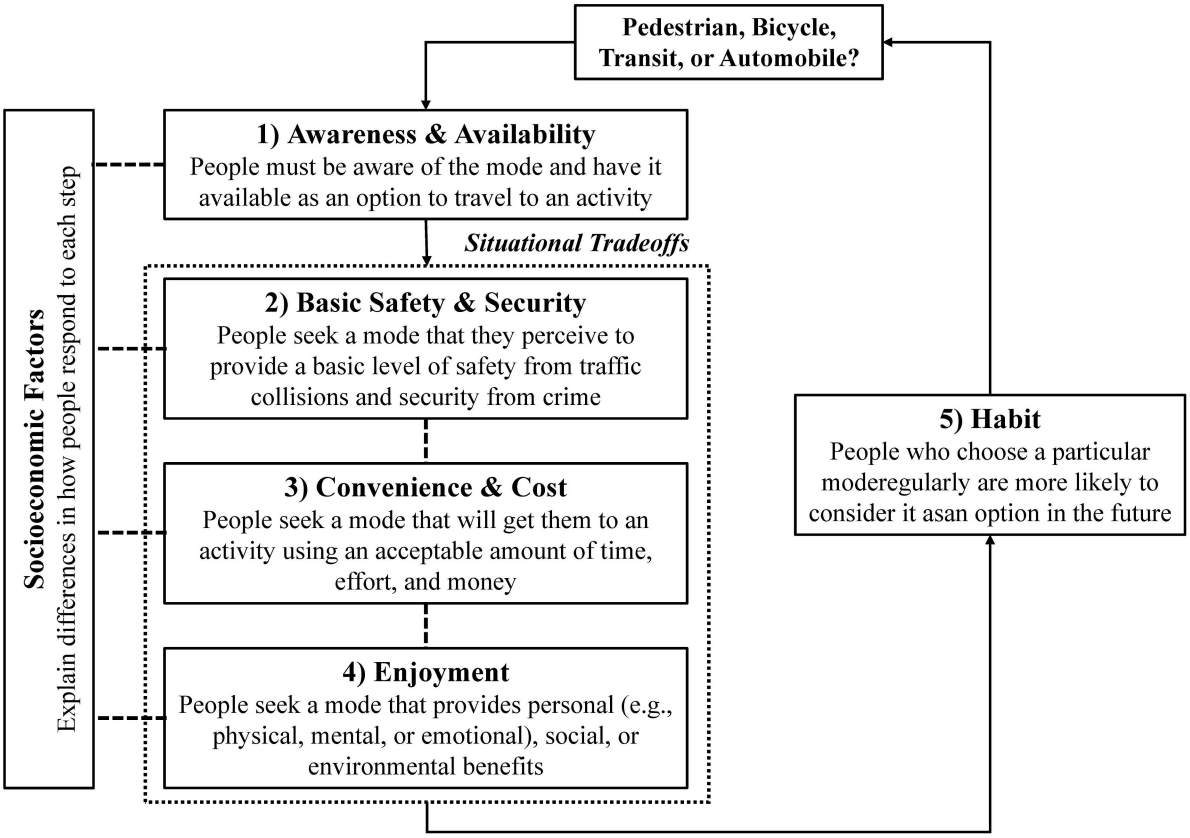


Figure 2-5: The Theory of Routine Mode Choice Decisions

Source: Adapted from reference[23]

2.2 The Spatial Connotation of Meeting Active Travel Needs

After the theoretical models of behavioral interventions from different perspectives above, it can be seen that behavioral change is the result of the joint action of the three levels of personal factors, physical environment, and social environment, but different theoretical models focus on behavioral intervention factors at different levels. In order to apply these theories in practice and understand the relevant factors of behavioral intervention comprehensively, domestic scholar Tan Shaohua in 2019 took walking as an example and divided the influencing factors of active travel into the three levels of predisposing factors, enabling factors, and reinforcing factors[24]. As can be seen from the conceptual Figure 2-6, although the physical environment mainly exists as a enabling factor, these three factors are influencing each other's role. Therefore, Tan Shaohua believes that the role of the physical environment and walking should be viewed in a connected way, and that predisposing factors, enabling factors, and reinforcing factors all have their physical significance (as shown in Figure 2-7). The following content are the physical explanation of the three factors.

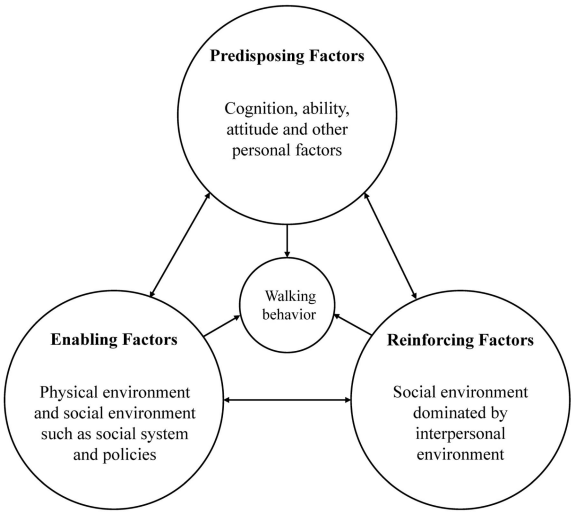


Figure 2-6: Relationship between the three factors of walking behavior change

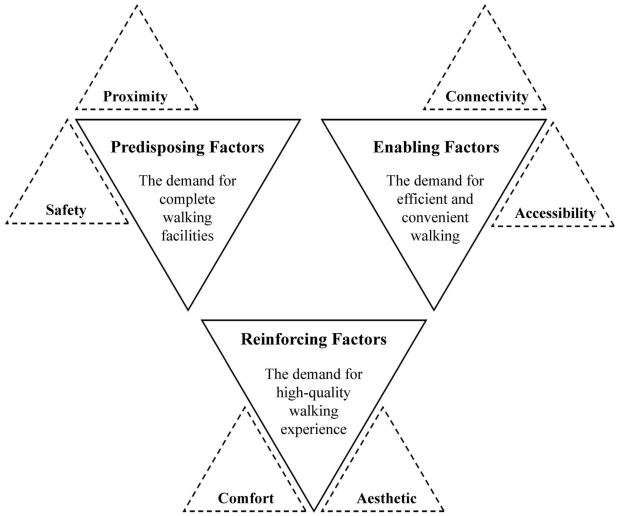


Figure 2-7: Spatial environments that promote walking travel

Source: Adapted from reference[24]

2.2.1 Predisposing Factors

Predisposing factors imply a definition of the adequacy of pedestrian facilities and determine what should be "there" in the space, and this level of spatial characterization is mainly reflected in the proximity and safety of the residential environment.

(1) Proximity

A mixed-use land layout pattern of shorter distances between residences and destinations (e.g., workplaces, businesses, parks, etc.) can promote active travel by residents. For example, mixed land use can lead to functional diversity, increase accessibility to transit facilities and employment sites, and enhance short-distance job opportunities and transit usage, which in turn promotes active travel[25]; distance to daily service facilities is also the most critical indicator of proximity because people generally tend to walk to their destinations when daily living facilities are located at a shorter distance from their residences. In a way, the layout of functions (including land use and layout of daily services) well reflects the requirement of "having" walking demand facilities in the predisposing factors.

(2) Safety

Safety is a guarantee condition to promote people's choice of walking travel behavior, including traffic safety and personal safety (security in residential area), which has an important impact on people's choice of walking travel. There are many factors affecting the safety of residential areas, and foreign countries have carried out theoretical exploration and practical research earlier.

In the 1820s, the pedestrian-vehicle separation model was proposed in Radburn, New Jersey, the United States. After the Second World War, Germany and the United Kingdom introduced transportation policies to improve walking safety; since 1960, many scholars have proposed traffic calming policies and theories of neighborhood sharing in order to realize the return of residential areas to a pedestrian environment and improve walking safety. In practice, scholars

such as Christopher S. Hanson, Robert B. Noland, Anne Verne Moudon, Dumbough E. Rae, and others have used examples of pedestrian accidents and individual characteristics, roadway environment, footpaths, number of lanes, road lighting, intersection traffic control, speed limit management and other factors, the safety of the neighborhood walking environment and the factors affecting it have become the focus of research in the industry. Domestic scholars research on pedestrian safety mainly focuses on the construction of humanized road space, pedestrian-vehicle coexistence road planning, pedestrian crossing safety, residential area defense space composition and other aspects.

2.2.2 Enabling Factors

Enabling factors emphasize the efficiency and convenience of walking demand, and focus on whether existing spatial elements are "usable" or "walkable". They determine the accessibility of complete facilities for active travel, and on the basis of complete pedestrian facilities, the accessibility of complete facilities becomes the key point of the enabling factors. Connectivity and accessibility, as important indicators of the convenience of travel paths and the absence of detours, reflect the status of the spatial layout of the residential area's amenities and the process of interaction with other amenities, and are important key factors in achieving the accessibility of amenities.

(1) Connectivity

The connectivity of residential roads reflects the degree of straightness or detouring of the walking path, and is an indicator of walking distance. It needs to reflect both the actual walking distance of the walking path and the straight-line distance of the walking path, as well as the ratio of the actual walking distance to the straight-line distance (i.e., the walking detour coefficient). Walking trips are only likely to occur if the actual walking distance and the walking detour coefficient are within a certain range. The higher the degree of road connectivity, the shorter the actual walking distance between the starting point and the destination, and the lower the walking detour coefficient (the closer the actual walking distance is to a straight line distance), i.e., from the perspective of the actual walking path to

shorten the walking distance, to reduce physical exertion for walking trips, and to promote the occurrence of walking travel.

(2) Accessibility

On the one hand, according to some foreign scholars, accessibility refers to the difficulty of overcoming spatial barriers. Specifically, if the spatial barrier from a certain location to other locations is large, then it means that the accessibility of that point is poor; on the contrary, it is considered that the accessibility of that point is good[26]. On the other hand, some Chinese scholars believe that accessibility expresses the degree of difficulty in reaching a destination from any point in space, reflecting the size of the spatial resistance that people overcome in the process of reaching a destination, and is commonly measured by indicators such as time, distance, and cost[27]. Besides, some domestic scholars believe that spatial accessibility reflects the ease or difficulty of overcoming distance barriers to communication between spatial entities and expresses the sparseness of the relationship between spatial entities, which is closely related to the concepts of location, spatial interaction and spatial scale[28].

2.2.3 Reinforcing Factors

Reinforcing factors correspond to the walking quality experience, which focuses on the spatial environment to promote the residents "persist walking". People's quality experience in the walking environment is reflected in two aspects, as shown in Figure 2-8. First of all, the comfort of people's body perception in the walking environment is the basic need for good walking experience, and the comfort of walking perception is mainly reflected in the comfort of walking facilities and the comfort of the walking environment. Secondly, after satisfying the basic comfort of body perception, better walking experience is closely related to the higher level of psychological aesthetic perception, and the walking environment with higher aesthetics is mainly manifested as the beauty of the form of the walking environment and the beauty of the connotation of the walking environment.

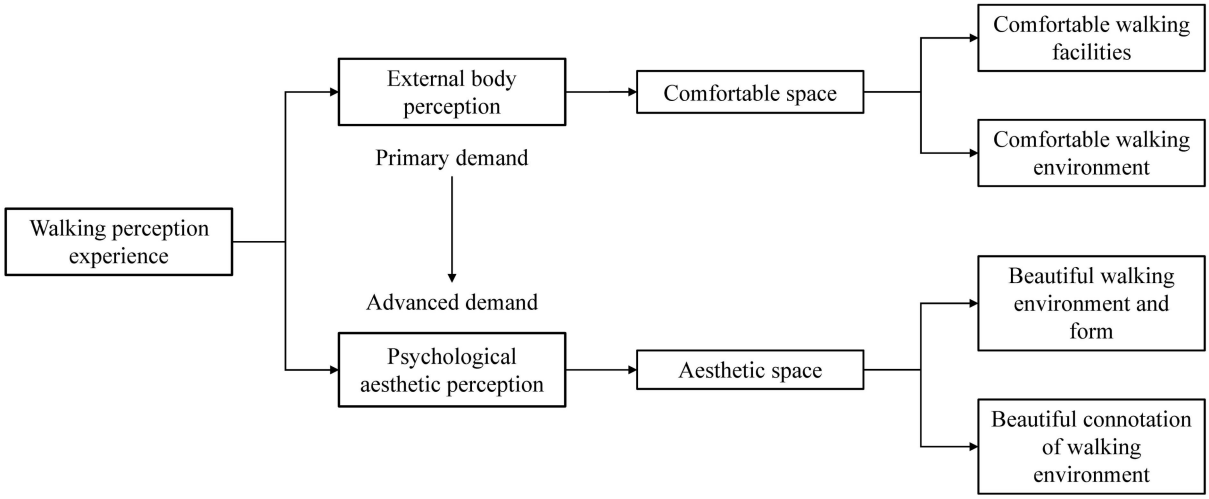


Figure 2-8: High-quality experience in walking space

Source: Adapted from reference[24]

(1) Comfort

Comfortable walking facilities and pleasant walking environment are important catalyst factors that attract people to active walking. Perfect walking facilities to a certain extent affect people's choice of walking behavior. At the same time, a quiet environment, low noise pollution, good environmental hygiene, and pleasant green landscape make walking activities more comfortable, thereby promoting the occurrence of walking activities.

In terms of the comfort of walking facilities, lots of scholars focus on the comfort of footpath use, arguing that there is a significant relationship between the comfort of the footpath and walking behavior. First of all, in terms of footpath width, the comprehensive consideration of pedestrian flow, and reduce the stacking of goods on the road surface, reduce motor vehicle parking, in order to meet the comfort of people walking scale. Usually, for ordinary people 400 to 500 meters is the walking distance that can be generally accepted, and the distance of 500 to 1,000 meters is the limit of comfortable walking distance, and people will seldom choose to walk when it exceeds 1,000 meters[14]. Secondly, studies have shown that people walk more frequently in neighborhoods with comfortable and accessible footpaths[29], the number of street furniture promotes walking comfort, and the location of the facilities affects ease of use. Studies have concluded that the width of footpaths, the pavement surfacing material of footpaths, the presence of steps and ramps on footpaths, and crossing facilities can

influence the comfort of people's walking experience[30]. In addition, urban furniture such as providing walkers with protection from inclement weather (e.g., canopies, arcades, etc.), roadside seating, and drinking water facilities can also affect the people's willingness to travel on foot[31].

In terms of the comfort of the walking environment, the comfort of streetscape is an important factor in determining how far people walk. The comfort of walking environment is related to the traffic environment of the roads, the richness of the green landscape, and the sanitary condition of the roads. Slower speed of motor vehicles, less on-street parking, pleasant and peaceful traffic environment will make the environment more suitable for walking, the richness of greenery and the diversity of plant species will also enhance the comfort of the walking environment, and to ensure that green plants, the sky and the building in the line of sight in a relatively balanced appearance, to maximize people's sense of comfortable walking. In addition, the spatial scale and quality perceived by people's bodies also have a decisive influence on walking comfort, and the walking environment with appropriate scale, spatial diversity and high spatial safety can stimulate people's interest in walking and lead to walking stay activities. Weather conditions, climate, air humidity and other micro-environmental factors also have a certain impact on walking comfort.

(2) Aesthetics

Aesthetic experience is a subjective process of mental activity, which is necessarily individual and may vary with people's personality, social and cultural background, goals, expectations and environmental elements. But at the same time, beauty is also subject to objective factors, and research has proved that the environment influences people's aesthetics more than personality. The aesthetics of the walking environment is mainly reflected in the two aspects of formal aesthetics and connotative aesthetics.

Formal aesthetics also known as direct aesthetics, refers to the feeling that people instinctively have for the color, shape, and type of the perceived object. The formal aesthetic elements

affecting the walking space are four aspects: complexity, enclosure, transparency and order. Complexity of the walking space is related to the number of significant differences in the environment felt by the observer in a unit of time, and it is the result of the combination and arrangement of various elements in the space with the common role of changing shapes, sizes, materials, architecture and decoration. Spaces with low complexity tend to give a monotonous and boring feeling; on the contrary, spaces with higher complexity can give a rich visual experience and attract more people to walk. Juts as Jan Gehl mentioned in Life Between Buildings, a abundant road makes the walking distance seem short.

Enclosure of walking space is defined and shaped by the vertical elements of the outdoor space and involves the characterization of the scale and height of the pedestrian space. Allan Jacobs has said, "Great streets have clear contours, and they all have their own well-defined boundaries, often a variety of fences, which define the edges of the road." Isaacs Raymond believes that enclosure is an important urban design quality and that varying degrees of street openness and enclosure can have a significant impact on the aesthetics of a street[32].

Transparency is the condition of perception of things or activities inside the street façade through doors, windows, fences and railings[33]. Alan B. Jacobs once said, "The quality of the finest streets is that they are transparent around the edges." A classic example of transparency is the graceful display of merchandise in a window attracting passersby to gather around and then enter the store to shop[34].

Order involves whether the walking space environment is coordinated and meaningful, and is related to the difficulty of people's understanding of the walking environment. Nasar demonstrates that the sense of order is an important component of spatial form beauty[35].

Connotative aesthetics refers to the observer's introspective grasp of their own psychological world. Tan Shaohua categorizes the connotation beauty of streets into the sense of culture, pleasure, and belonging.

The sense of culture refers to the material, spiritual and perceptual attributes provided to a place through the combined effect of environmental elements such as regional culture, social customs, local customs, national atmosphere, and socio-economic conditions, as Arnold Berleant puts forward in Environmental Aesthetics, "aesthetic values must be placed in their cultural and historical context", so the sense of culture is an important part of the inner beauty of walking space.

Pleasure is at the top of the walking needs hierarchy. It relates to the degree of attraction and interest of the environment to people's walking activities and the impact of crowd activities. People's pleasure in the roads space environment indicates that the physical environment of the walking space has a positive impact on people's mental health and shows the significance of the physical environment for individuals.

The sense of belonging is a place associated with the activities of people that creates feelings of recognition, fondness, and dependence[36]. A sense of belonging fulfills the ability to shape a sense of community and carry the crowd's memories of the past. Walking space with a sense of belonging makes it an indispensable place for people's daily lives, giving it a sense of place. Mehta Vikas identified the sense of belonging as the highest level of needs for people's walking activities[37].

In summary, under the two levels of people's aesthetic demand, the most common subjective factors about describing people's psychological response to the walking space are obtained, which include complexity, enclosure, transparency and order in terms of formal aesthetics; and the sense of culture, pleasure and belonging in terms of connotative aesthetics. These influencing factors basically summarize people's aesthetic perception of active travel space environment in a comprehensive way.

2.3 Chapter Summary

This Chapter discussed residential environments that promote active travel and increased physical activity as the purposeful needs of the population. First, based on multiple

perspectives such as environmental psychology, social ecology, and operational theory, it reviews the intervention theory of the environment on travel behavior, and makes it clear that travel behavior is the result of the joint intervention of personal factors, physical environment, and social environment at three levels. Second, it sorts out three types of influencing factors (predisposing factors, enabling factors and reinforcing factors) of the travel environment that influence human's travel behavior. And again, it further summarizes the three types of spatial connotations of meeting active travel, namely the demand for complete travel facilities, the demand for efficient and convenient travel, and the demand for high-quality travel experience. Finally, a preliminary summary of the environmental system of residential areas to promote active travel composed of six types of environmental features is presented at the level of residential areas, which serves as the theoretical basis of this thesis.

Chapter 3. Case Studies

3.1 Related Design Guidance for Active Travel

Given that active travel not only helps to alleviate traffic congestion and environmental pollution caused by motorized traffic, but also helps to improve people's physical activity and thus promote physical and mental health, some countries and regions have already developed local practices and formulated relevant design guidelines and acts to regulate the generation of designs. In this section, the active travel guidelines of Canberra, Australia and Wales, UK (Figure 3-1; Figure 3-2) are selected as references to extract their design principles with a view to providing guidance for subsequent strategy research and optimization design.

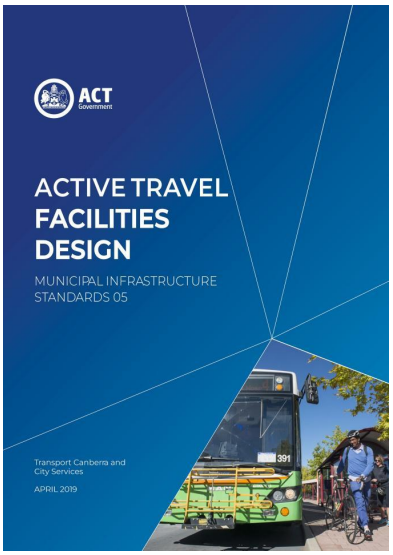


Figure 3-1: Active Travel Facilities Design

Source: ACT Government[38]

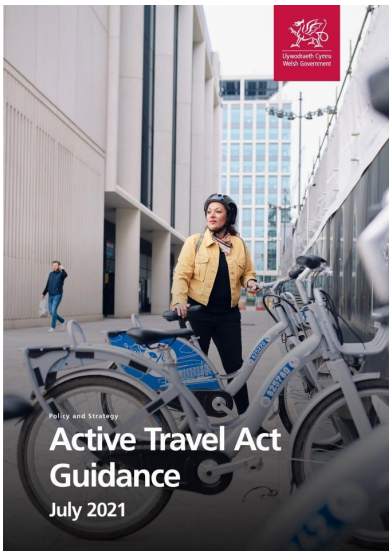


Figure 3-2: Active Travel Act Guidance

Source: Welsh Government[39]

The core principles of the two guidebooks are the same: they are coherence, directness, safety, comfort and attractiveness. These five core principles which represent the core requirements for people wishing to travel by cycle or on foot. Accessibility for all active travel users is a requirement that should always be considered in relation to each of the principles.

These design principles are further described below.

(1) Coherence

One the one hand, from the perspective of pedestrian needs, pedestrian routes must allow people to easily walk from residential areas to destinations including shops, schools, transport interchanges, bus stops and other community facilities in a way which is legible and easily navigable. Features that improve coherence include seamlessly connecting routes that form a logical and permeable network; and attractive features that overcome or reduce severance wherever possible, for example routes across busy roads, railway lines or watercourses. Where possible, underpasses or footbridges for pedestrians should be avoided in favour of at-grade crossings to avoid perceptions of danger and reduce deviation required.

One the other hand, from the perspective of cyclists' needs, cycle routes must form a coherent network. To achieve this, it must connect all the places cyclists want to start and finish their journeys with a route quality that is consistent and easy to navigate; abrupt changes in the level of provision for cyclists – such as a busy roundabout – will mean that a route becomes disjointed and is not suitable for all so will exclude some potential users.

(2) Directness

Directness is measured in both distance and time, and so active travel routes should provide the shortest and fastest way of travelling from place to place. Pedestrians are moving under their own efforts and therefore require routes and networks which are direct and follow natural desire lines. Features that improve a route's directness may include: reducing the distance required for pedestrians to travel between destinations, e.g. provision of cut-throughs within housing estates, retail and business parks; reducing corner radii at side road junctions to avoid deviation or crossing time. This also contributes to user safety by reducing vehicle speeds. Furthermore, narrowing the side junction radius also benefits blind and partially sighted pedestrians by reducing the distance needed to navigate in a straight line; providing continuous crossings over side road entrances, as well as dedicated crossing points that prioritize pedestrians where desire lines cross a feature of severance.

Routes for cyclists must provide the most direct and fastest route from origin to destination. In

order to make cycling preferable to driving, and reduce the risk that cyclists will choose unsuitable routes, there must be route options that are at least as direct as those available for motor vehicles. Consideration of directness must include delays caused by the need to stop and give way at junctions or crossings.

(3) Safety

Safety (both actual and perceived) is an essential user need for pedestrians, both in the form of preventing physical harm through collisions with vehicles, and minimizing threats to personal safety. Safety improvements can include: separating pedestrians from the routes of other faster modes vehicles or commuter cycle routes; reducing vehicle speeds and flows; increasing the build quality and maintenance of pedestrian routes; and promoting pedestrian routes that are overlooked by buildings or areas which are well-used.

Fears over personal safety can be a major barrier to walking. Road lighting is an important influence upon this. It should be ensured urban roads and paths are well lit at times they are likely to be used. Road lighting should provide an attractive environment which provides reassurance for pedestrians.

Cycle routes and networks must not only improve cyclists' - and other road users' - safety, but also their perception of how safe the environment is. To help achieve this: consideration must be given to reducing the volumes and speeds of motor vehicles to acceptable levels, particularly when cyclists are expected to share the carriageway; the need for cyclists to come into close proximity and conflict with motor traffic must be removed, particularly at junctions, where the majority of collisions occur; complex layouts which require users to process large amounts of information should be avoided. Good network design should be self-explanatory and self-evident to all road users; good quality surfaces are required, not least to prevent accidents and injuries.

(4) Comfort

Pedestrian comfort is influenced by a range of factors including the basic design of the route - its width as related to the number of users and the gradient and quality of the surface - as well as elements such as tactile paving, street furniture, drainage, cleanliness and lighting. Width is the key consideration for the comfort of pedestrian routes. Other features that can increase levels of comfort for pedestrians include: avoidance of permanent street furniture within the footpath (or if unavoidable away from the main pedestrian flows with appropriate clearance widths and lighting provided); enforcement or implementation of features that help to prevent (whilst being mindful of clearance width requirements) parking on footpaths. This may include features that contribute to other aims such as road trees, planters, or play.

To ensure acceptable levels of comfort for a cyclist, the following should be included: smooth surfaces; minimal stopping and starting (e.g. priority over minor side road junctions); avoiding of the need to ascend or descend steep gradients (or, where unavoidable, suitable mitigation features considered within route design); and use of design features which minimize risk of conflict with other users (e.g. separation of cyclists, pedestrians and motor vehicles with appropriate design widths for the route context).

(5) Attractiveness

The propensity to walk is influenced not only by distance, but also by the quality of the walking experience. A 20 minute walk alongside a busy highway can seem endless, yet in a rich and stimulating roads space, such as in a town center, it can pass without noticing. Residential areas can offer a pleasant walking experience if good quality landscaping, gardens or interesting architecture are present.

Attractive pedestrian routes not only encourage more people to walk but can also contribute to the overall quality of an area and help to create an improved sense of place through the creation of more accessible public spaces. Features that may improve attractiveness could include: effective use of environmental features that can both improve user experience, but

also act as environmental mitigation or sustainable drainage features; ensuring design considers future maintenance of a route, and that routes are regularly maintained to the appropriate levels; enhancing routes by the inclusion of formal or informal play-spaces and green infrastructure.

In suitable locations, incorporating formal or informal opportunities for play through hard and soft landscaping or small items of equipment, can increase the enjoyment and with it the likely use of a route.

People cycling are more aware of the environment they are moving through than those in cars or other motor vehicles. The attractiveness of the route itself will therefore affect whether users choose to cycle. Routes should be appealing and be perceived as safe and usable, with the impact on pedestrians, considered at all stages of development. Often routes can be improved via implementation of measures that contribute to other aims, e.g. provision of planting that both increases attractiveness and acts as a form of sustainable drainage.

3.2 Mini-Holland Programme, London

The Mini-Holland Programme was introduced in March 2014 by Boris Johnson, then Mayor of London (2008-2016), made to better protect vulnerable road users, learning from Dutch cycling provision[40]. The Mini-Holland programme formed part of the Transport for London Vision for Cycling (2013). It has now evolved to be part of the more holistic Healthy Streets approach, aimed to encourage travel modal shift from car to bike and walk for short journeys, thereby improving people's health.

It took the form of a competition among outer London boroughs for a £100-million fund. Because compared to inner London, outer London has low levels of cycling and low levels of walking, and is relatively car dependent. Three outer London boroughs – Waltham Forest, Enfield and Kingston – won £30 million each, and the remaining £10 million was shared by several other boroughs. Enfield and Waltham Forest are neighbouring boroughs in North and

East London, while Kingston is in the southwest (see Figure 3-3 below).

102 separate schemes have been proposed within the three boroughs, comprised of 97 infrastructure schemes and 5 "supporting measures"[31]. The infrastructure changes include redesigned town centers, with cycle hubs at tube and rail stations; measures to reduce and calm motor traffic in residential areas; physically protected cycle lanes along main roads; and safety measures at junctions. Many schemes also seek to improve walking environment and public realm quality.

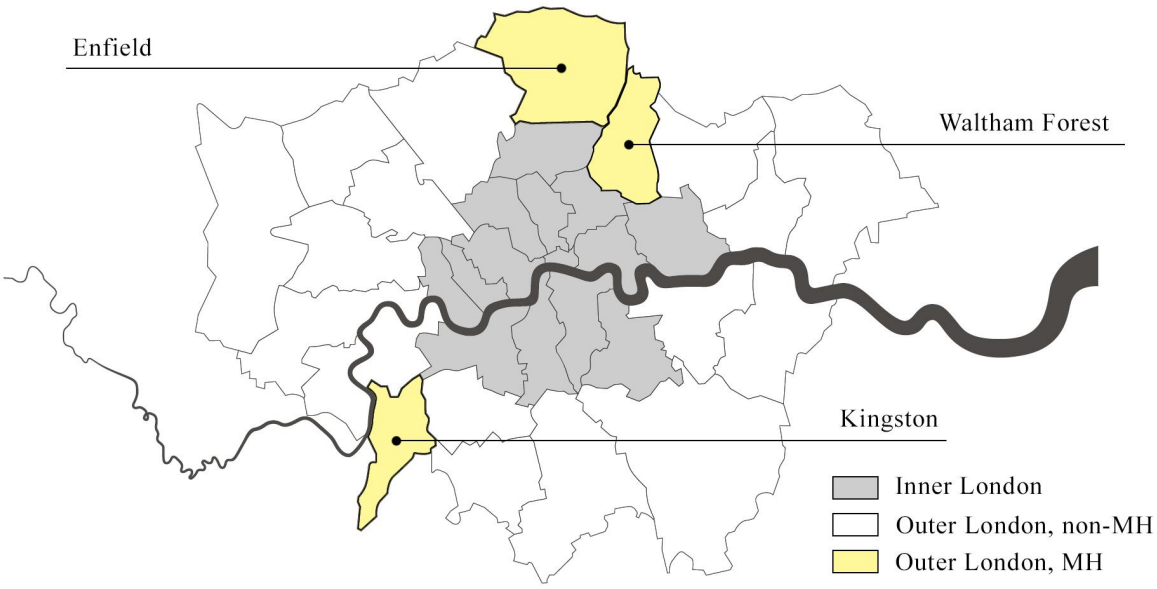


Figure 3-3: Map showing Mini-Holland boroughs

Source: Self drawn by the author

Waltham Forest Council was one of three boroughs to be awarded 30 million pounds of funding from Transport for London for the Mini-Holland Programme to make significant improvements to the borough and encourage more local people to walk and cycle. As a result, the Waltham Forest Mini-Holland is the most advanced of the three awarded schemes in London. It has been awarded London Cycling Award 2015, the Sustainable City Awards 2016 and the 2017 London Transport Award for "Transport Borough of the Year"[41]. In this section, the specific schemes measures in Waltham Forest will be discussed separately through the following three projects.

3.2.1 Lea Bridge Road, Waltham Forest

The Mini Holland Programme in Lea Bridge Road is a part of a broader initiative in London that seeks to transform urban spaces to prioritize cycling and walking, aiming to create more sustainable and active modes of transportation. This program, which originated in Waltham Forest, is inspired by the Dutch approach to urban design and transportation, where cycling and walking are integral components of the urban fabric.

In the context of Lea Bridge Road, the initiative involves comprehensive changes to the infrastructure and streetscape. It includes the creation of dedicated cycling lanes, improved pedestrian crossings, and the development of public spaces to encourage community engagement. The overall goal is to make the area more conducive to active transportation, reduce reliance on cars, and enhance the overall quality of life for residents. The regeneration of Lea Bridge Road is divided into six sections: A, B, C, DEF, G and H (see Figure 3-4).

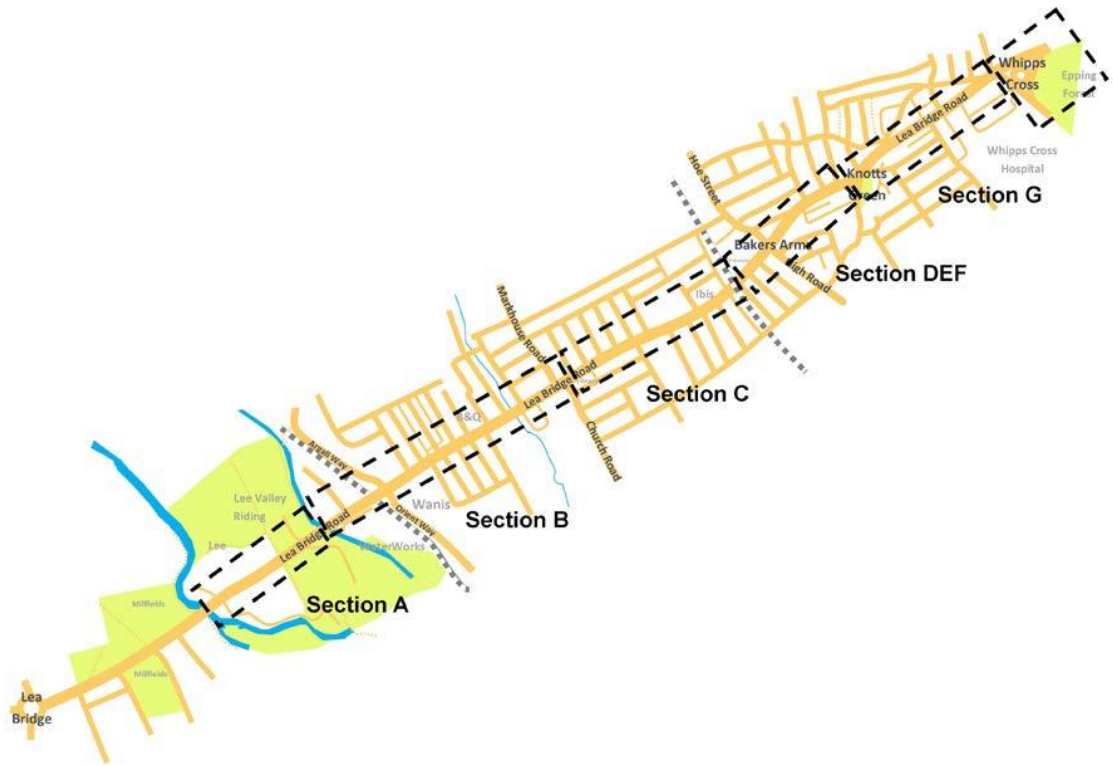


Figure 3-4: All sections of Lea Bridge Road

Source: Reference[42]

The design scheme measures in all sections of Lea Bridge Road can mainly be divided into two aspects, one is infrastructure regeneration, and the other is the improvement of landscaping and public spaces. The specific scheme proposals in Lea Bridge Road will be introduced in detail below.

Form the aspect of infrastructure regeneration:

(1) Introduce Fully Segregated Cycling Tracks

Two segregated cycling tracks were introduced into Lea Bridge Road, one on each side of the road, to transform this key route for people who cycle. It provided a safe space for people to cycle on, separated from motorized traffic. This type of cycling lane also reduced confusion and conflict among all road users by creating the cycling track on a slightly lower level to the footpaths, and making the cycling track a different color and material to footpaths.

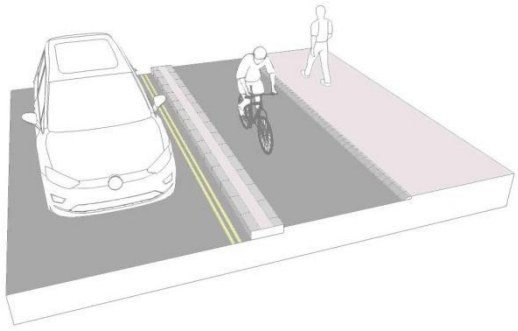


Figure 3-5: Fully segregated cycling tracks

Source: Reference[43]

Figure 3-6: Cycling lanes on Lea Bridge Road

Source: Google Map screenshot

(2) Upgrade Junctions

Junctions are where most serious and fatal collisions involving those walking and cycling happen. One of the main risks is a vehicle turning across the path of a cyclist going ahead or turning. This far too common “hook” risk is also one of the reasons why junctions are the points en route which are most stressful for those who do cycle and why most people do not cycle. So getting junctions right for cycling will not just save lives of those who already cycle,

but represents one of the best ways to get more people cycling. The way to deal with these issues is to ensure that cyclists are separated from turning motor traffic in time or space.

One of the best junctions in London for this so far is the Lea Bridge Road junction with Argall Way and Orient Way. Here, more space is provided for pedestrians and cyclists by way of changes to the road layout at the junction. Increasing the width of the footpath around the junction and introducing new segregated cycle lanes provides more space for pedestrians and cyclists. Also, shorten the distance of crosswalks at intersections to reduce the time it takes for people to cross the road. And connect existing and planned bike lanes to provide continuous protected space for cyclists.

Figure 3-7: Illustration of Orient Way and Argall Way junction new layout

Source: Reference[44]

Figure 3-8: Aerial photo of Orient Way and Argall Way junction

Source: Google Map screenshot

(3) Upgrade Side Road Junctions

Introducing a new style of crossing called blended “Copenhagen” crossings (shown in Figure 3-9 below), which prioritize pedestrians at side road junctions open to traffic. The specific proposals are that widen the footpath and introduce a raised junction to slow vehicle speeds when turning. They are popular in Europe and extend the pavement across side roads at junctions, giving pedestrians a continuous pavement rather than a traditional kerb that they need to wait at before crossing the side road. This encourages vehicles to slow down when entering or exiting the side road, ensuring that pedestrians and people cycling have right of

way. At the same time, the trees at the side road entrances squeeze the space in the carriageway and carry out a step to reduce the speed of vehicles.

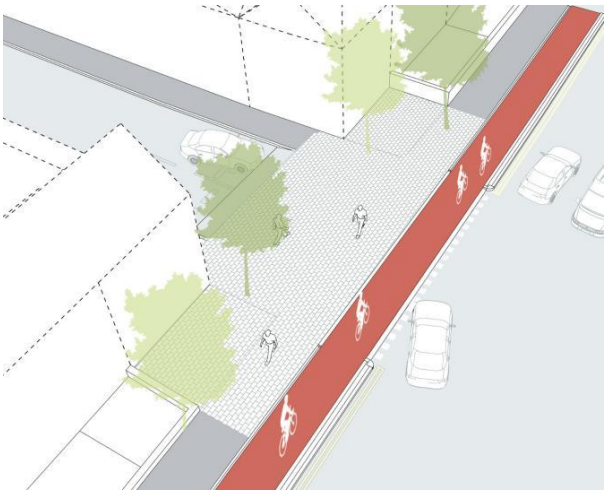


Figure 3-9: Blended "Copenhagen" crossings

Source: Reference[43]

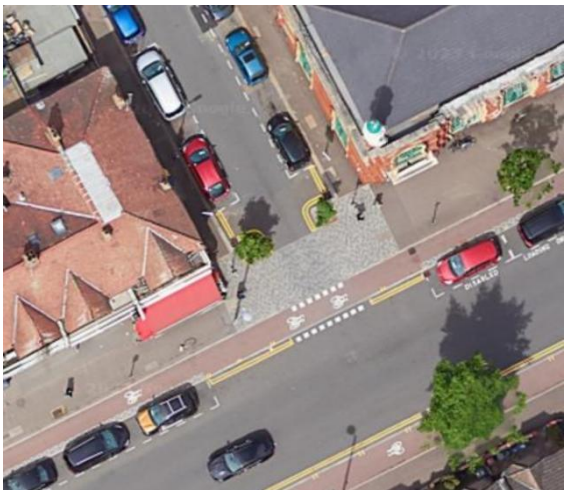


Figure 3-10: Example of Copenhagen crossings

Source: Google Map screenshot

(4) Add New Road Crossings

The proposal shown in Figure 3-11 below made significant improvements to crossing points on the busy stretch of Lea Bridge Road. The new and improved crossings benefits both cyclists and pedestrians, by creating an additional crossing near the junction, and through upgrading existing crossings to the latest standards of traffic signals that accommodate both people walking and cycling. The crossings used new "elephant footprint" road markings which have been endorsed by the Department for Transport of London which indicate where cycles can cross the road. The new and improved pedestrian and cycle crossings allow the users to cross directly without the need to wait at an island.

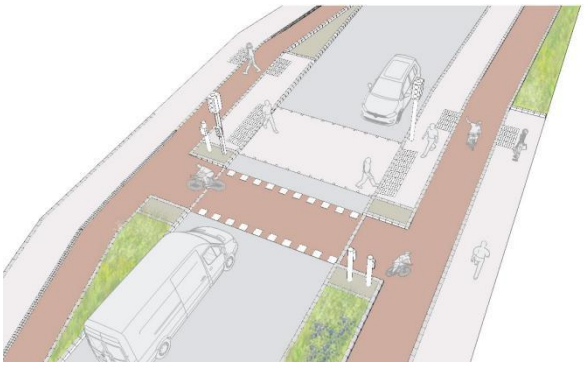


Figure 3-11: New and improved crossings

Source: Reference[43]

Figure 3-12: Example of a improved crossing

Source: Google Map screenshot

(5) Introduce Floating Bus Stops

Floating bus stop also known as a “bus stop bypass”, this is an arrangement that involves a cycling lane running behind the passenger boarding area at a bus stop, between an island and the footpath. It efficiently reduces interaction between cyclists and passengers when boarding and exiting buses. Floating bus stops enhance pedestrian safety by physically separating bus passengers from the footpath. This reduces the risk of accidents and collisions between pedestrians and buses. Besides, these stops provide dedicated spaces for cyclists, making it safer and more convenient for them to navigate through the area. Separating cyclists from vehicular traffic improves overall road safety. By eliminating the need for buses to merge in and out of traffic lanes for stops, floating bus stops contribute to smoother traffic flow. This can result in reduced congestion and improved overall transportation efficiency.

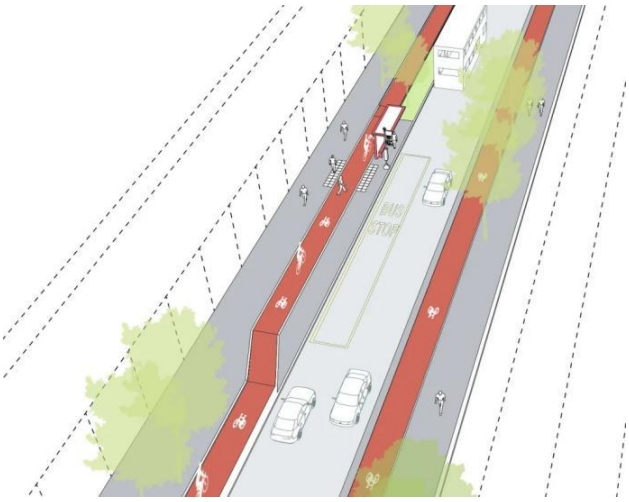


Figure 3-13: Illustration of floating bus stops

Source: Reference[43]

Figure 3-14: Example of a floating bus stop

Source: Google Map screenshot

(6) Modal Filters (roads accessible to pedestrians and cyclists only)

Collisions involving people on cycles often occur when vehicles turn into and out of minor side roads. To reduce collisions in this area, permanent road filters were introduced at special locations. The modal filters help to improve safety for the local community, in particular children and the elderly, whilst creating more attractive residential roads, providing a place suitable for people to play out, relax and spend time with neighbors. These filters will affect

motorized vehicles, and only people who walk and cycle will be able to pass through the road. Where a filter is installed, space will be provided to allow vehicles to turn around (on side roads) where possible, access for other vehicles such as for deliveries and bin collections will be maintained and residents will still have access to their roads.

Figure 3-15: Modal filter on Kettlebaston Road

Source: Reference[45]

Figure 3-16: Modal filter on Browning Road

Source: Reference[46]

Form the aspect of landscaping and public spaces improvement:

(1) Enhance Identity of Public Entrance Spaces

In Lee Valley Park, the new access ramp into the park , connecting with the former aqueduct and key regional cycle route becomes a clearer and more visible entrance area, increasing awareness of the Lee Valley Park and encouraging more people to use the park and walking and cycling routes within it. The ramp entrance is marked with new signage, which would be visible to all road users from a distance. Wayfinding and historical information is incorporated within the signage structure, and a small seated area to enable people to stop and rest.

Key features include: new signage to mark the entrance to Lee Valley Park; wayfinding information and graphics provided to increase awareness and aid legibility of the area; and new seating area (see Figure 3-17).

The entrance area to Lee Valley Riding Center becomes a new meadow planted green area with horse figures to make an interesting and attractive space that shows people what the area is used for. More tree and wildflower meadow planting make the area greener and more pleasant, while the sculptural horses will create an eye-catching feature on Lea Bridge Road that celebrates the Lee Valley Park and family attractions present in the area.

Key features include: increased greenery including tree and wildflower meadow planting; and new horse figures that take inspiration from the Lee Valley Riding Center (see Figure 3-18).

Figure 3-17: Lee Valley aqueduct entrance

Source: Reference[47]

Figure 3-18: Lee Valley Riding Center entrance

Source: Reference[48]

(2) Improve Negative Urban Interfaces

The proposals seek to improve the frontages of Rigg Approach and Thames Water, which currently are industrial fencing. Exciting graphics which provide information about what businesses in the area do, as well as local information would help to make the fencing more attractive and interesting. Information would encourage interest and ensure that children as well as adults can be engaged to find out more about what happens in these industrial areas.

Key features include:new boundary treatments; and new wayfinding and information graphics providing interesting information on industrial activities taking place within the site.

Figure 3-19: Improved industrial frontages

Source: Reference[49]

(3) Add New Public Spaces

The addition of new public space helps to instil a sense of pride in a neighbourhood, whilst encouraging people to spent time in the area and shop locally. For instance, create a new entrance to the Library Park off Lea Bridge Road, improving planting and adding new seating and cycle parking, to encourage more people to use the space, and create opportunities for its future use as an events space like an outdoor cinema and children's play-space. Transform the unused green space into a play area between the road and properties with a new fence, signage, seating and easy access from Lea Bridge Road.

Figure 3-20: New entrance to Library Park

Figure 3-21: Transform unused green spaces

Source: Reference[50]

(4) Enhance Vegetation Types in Green Spaces

Landscaping and new planting forms a key part of public space proposals, and helps to create a more attractive to reduce the impact of the highway, and provide sustainable urban drainage systems (SUDS) to absorb surface water and reduce the risk of flooding. New and enhanced green spaces introduced planting such as wildflower meadows and orchard trees as well as shrubs and trees. Tree planting was increased throughout the scheme and low maintenance wildflower meadows create changing visual displays throughout the year.

Figure 3-22: New vegetation types

Source: Reference[51]

(5) Change Surface and Materials

The new cycle tracks and pavements will be surfaced to distinguish between them and help pedestrians and cyclists. The change in surface continues across road crossings and junctions, making it clear to motorists that pedestrians and cyclists are present and making the junction easy to navigate for those walking and cycling. Bespoke feature paving will be used in key public space areas that is inspired by William Morris floral patterns, who was born and lived in Walthamstow.

Figure 3-23: New pavement materials

Figure 3-24: Feature pavement

Source: Reference[51]

Bus stops are one of the key public areas with feature paving, as part of upgrading existing bus stops, the proposal seeks to create feature bus stops where there is space to do so. Feature bus stops seek to create more attractive and interesting places to wait, whilst introducing some of the borough's culture and history.

Figure 3-25: Example of a feature bus stop with new cycling tracks and pavement surface

Source: Reference[52]

Section A of Lea Bridge Road runs from the borough boundary with Hackney to the junction of Lammas Road, shown in Figure 3-26 below. To varying degrees, the new road layout of Section A reflects, the measures to optimize infrastructure and public space mentioned above, improving the original environment and making it an ideal space for people to better enjoy their travels. New and improved road crossings will help pedestrians to cross the road easily and safely. Transit facilities will also be upgraded to improve accessibility for cycling traffic

and waiting areas for passengers. Improvements to the side road intersections will greatly improve access for road users using the intersections. Fully segregated cycle tracks mean that the safety for cyclists and other road users will be greatly improved. The proposed public realm improvements mean that already green parts of this road become even greener, creating pleasant and interesting places.

Key features include: two fully segregated cycle tracks to improve safety for cyclists; existing pedestrian crossing points to improve safety for pedestrians; new pedestrian crossing point east of Lammas Road to allow better crossing; existing bus stop facilities upgraded to improve accessibility and waiting for bus passengers; side road junction redesign to improve access and safety for all road users; enhanced public space at a number of locations to improve the environment and encourage more people to use and enjoy the area.

Figure 3-26: The new road layout of Section A

Source: Reference[53]

3.2.2 Blackhorse Village

Blackhorse Village is one of a series of residential areas in this borough invested in as part of the programme to create places that are great to live, work and travel around. For the purpose of the programme this scheme has been named Blackhorse Village and forms part of the Mini-Holland Villages scheme in Waltham Forest.

The Blackhorse Village scheme is the area framed by Forest Road, Hoe Street, Selbourne

Road and Blackhorse Road. The Blackhorse Village scheme aims to reduce the amount of non-local traffic using the area; improve the look, feel and safety of the roads space for all road users; improve routes to and from local schools and other places of interest in the area; and encourage people to use healthy modes of transport.

The proposal in Blackhorse Village combines a mix of road closures, traffic direction changes, creation of shared public spaces and safety improvements. The key elements of the proposal are shown on the map and outlined below.

Figure 3-27: Blackhorse Village Final Design

Source: Reference[54]

(1) Road Closures (modal filters)

To encourage traffic reduction and traffic evaporation throughout this area, permanent road closures at the key locations to address the issues surrounding non-local traffic driving through the area. In the meantime, a number of innovative solutions that combine closures

with greening, a place to rest such as benches or functions such as cycle parking would also be introduced. The road closures also improve safety for local residents in particular children and the elderly, whilst providing a place suitable for play-streets and boosting community interaction. The closures only affect motorized vehicles, and pedestrians and cyclists are able to pass through the closures, so this proposal could also be called modal filters. Where a closure is installed, space will be provided to allow vehicles to turn around, access for other vehicles such as for deliveries and bin collections will be maintained and residents will still have access to their roads.

Figure 3-28: Residential roads with modal filter

Source: Reference[55]

(2) Speed Limitation and Traffic Calming Measures

By the time the Mini-Holland Programme commences all roads within the Blackhorse Village will be subject to 20mph speed limits and traffic calming introduced. As a part of the implementation of the village, the design team reviewed existing traffic calming features, replacing measures that are not cycle friendly and introducing new measures such as sinusoidal (cycle friendly) speed humps and tables. Sinusoidal ramps have a smooth transition profile on both sides of the hump as shown in Figure 3-29. They are more comfortable for cyclists and should normally be used where on-carriageway cycling is anticipated.

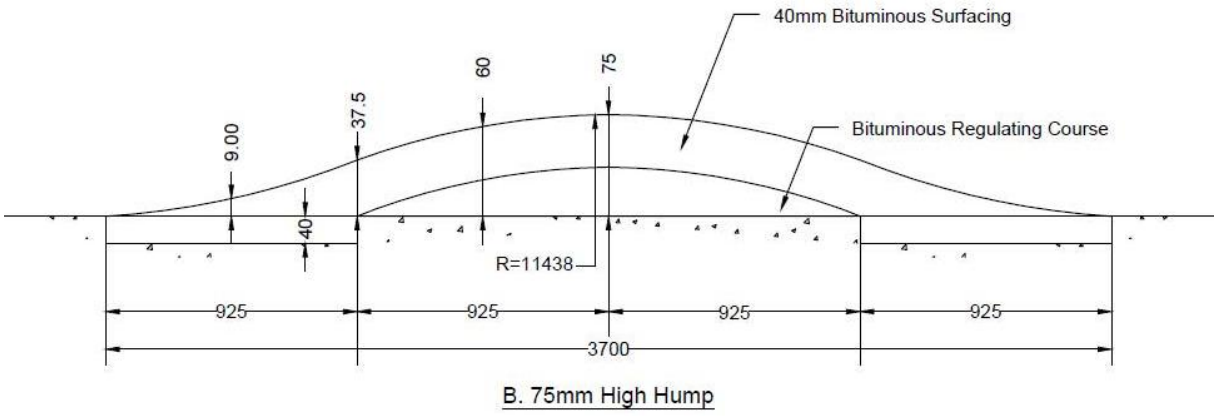


Figure 3-29: Sinusoidal Ramps (Hump may be round or flat-top)

Source: Reference[56]

(3) Traffic Direction Changes

The main purpose of traffic direction change is to improve accessibility in the area, and the specific change depends on the local traffic conditions. There are a number of existing one-way systems/roads within Blackhorse Village, and due to the reduction of possible conflicts with opposing traffic flow and the reduction of mutual interference, the road capacity will be significantly improved. But precisely because of this, implementing one-way traffic can make drivers relax their vigilance and increase their driving speed, which may become an obstacle for residents to walk and cycle. At the same time, it should also be noted that in residential areas, some roads have narrower widths and parking lots are relatively scarce. Achieving one-way traffic can effectively solve the problems of parking difficulties and traffic congestion on narrow roads. Therefore, one-way traffic and two-way traffic are not better or worse than each other, and improvement measures need to be proposed based on the actual traffic situation of the road. For example, changing the original one-way traffic to two-way traffic on Coleridge Road and Gaywood Road, and vice versa on Longfield Street and Pretoria Street.

(4) Pocket Parks

The introduction of modal filters and road closures provides an opportunity to enhance the public realm through the introduction of complementary greening. There are many examples

of such uses of greening in neighboring boroughs. As part of the creation of the village, the design schemes introduced pocket parks, trees and planting where feasible.

(5) Play Streets

Play Streets provide an opportunity for children to reclaim the streets from vehicles and traffic for a few hours on selected streets on agreed days. This allows children who do not live near to a park or playground to safely play in their street, which is vital for their physical and emotional development and for their social learning. Children are far more likely to get a good daily dose of physical activity if allowed to play outside which helps address many social, environmental and health issues.This also supports the view that roads are not there purely for the movement and parking of cars.

Here are three examples showing some specific improvement measures.

Table 3-1: Specific proposals in several examples

Names	Proposals	Images
Ruby Road	• Improved pedestrian access; • Improved route for people who cycle and new cycle parking; • Signage information to places of local interest; • Road trees, planting and places to sit; • Terrace spaces for local businesses • Creating a gateway to the William Morris Gallery and Lloyd Park.	
Buxton Road	• Improved entrance space to school; • Safer crossing for pedestrians; • New cycle parking; • New local pocket park and meeting place to include trees, planting and playful elements.	

(continued Table 3-1)

Greenleaf Road	• Safer crossing locations for pedestrians, including raising the level for pedestrian access; • Traffic calming measures to help slow traffic; • footpaths widened creating generous and more sociable access to the school and local play space; • Additional road trees, planting and bicycles parking.	

Source: Adapted from reference[57]

3.2.3 Hoe Street, Walthamstow

Walthamstow is a dynamic and vibrant town center and destination in Waltham Forest, boasting a diverse community, with excellent shopping and public transport links. It's the busiest transport interchange in Waltham Forest, serving both journeys into the town center area and outward trips to key destinations such as Central London.

In recent years, Walthamstow has gone from strength to strength with an ambitious programme of regeneration, including a number of new developments as well as a range of independent restaurants, cafes and businesses opening. To support and compliment these changes, Walthamstow Town Center and the former Walthamstow Gyratory have undergone major transformation, making it an even more accessible, attractive, and popular destination for people living in Waltham Forest, as well as those travelling from further afield. With more exciting development and regeneration planned in the future, more visitors will come to the town center, and more people will generally travel to, from and through Walthamstow Central every day. The schemes in Walthamstow try to continue improving Hoe Street and the town center so it is a safer, more accessible and convenient place to travel to, particularly by active and sustainable forms of transport.

The plans focus on the section of Hoe Street between Orford Road and Lea Bridge Road and

aim to build upon the existing network of safe and direct walking and cycling routes in the borough. The following are improvement measures for pedestrians and cyclists in Hoe Street between Orford Road and Lea Bridge Road.

(1) Improvements for Pedestrians

Raise the junction at Queen's Road/ Orford Road to encourage drivers to slow down when approaching the junction and to reinforce the 20mph speed limit. Introduce two raised pedestrian and cycle crossings near Grosvenor Park Road and Boundary Road to provide more safer places for people to cross the road. Widen the pavements at key pinch points and remove obstructions such as street furniture and historically poorly sited trees (which are in the center of footpaths) to make Hoe Street more accessible for people with pushchairs, wheelchairs, and mobility scooters. Introduce continuous footpaths also known as blended "Copenhagen" crossings, at all junctions with Hoe Street to prioritize pedestrians wishing to cross the junction, making travelling by foot safer and more direct.

Figure 3-30: Improvements for pedestrians

Source: Reference[58]

(2) Improvements for Cycling

Introduce new fully segregated cycle tracks on both sides of Hoe Street between Orford Road and Lea Bridge Road. A fully segregated cycle track is when the cycle lane is higher than the

carriageway but separated from the pavement. Introduce two raised pedestrian and cycle crossings near Grosvenor Park Road and Boundary Road to provide a safe place for people cycling to cross the road when moving between cycle tracks.

Figure 3-31: Improvements for cycling

Source: Reference[59]

(3) Improvements to the Look and Feel

Improve the footpath with high quality materials that have a pronounced color contrast with the cycle tracks to aid the visually impaired and to improve the overall aesthetics of the area. Identify locations along Hoe Street, and in surrounding streets, for new trees and plants, and introduce sustainable urban drainage at key locations (such as at side road junction treatments) to help address ponding and flooding during heavy rainfall. Furthermore, improving the lighting along the highway to make people feel safer when travelling or spending time in the area.

3.3 Chapter Summary

This Chapter reviewed the design guideline for active travel in Wales, UK and Canberra, Australia, and learned that active travelers have the need for travel spaces with coherence, directness, safety, comfort and attractiveness. Meanwhile, through the study of the London Mini Holland Programme, it is known from the specific improvement measures of Lea Bridge

Road, Blackhorse Village and Hoe Street that the road space transformation suitable for active travel can be divided into two aspects, namely the optimization of infrastructure construction and the enhancement of landscape and public space. On the one hand, from the perspective of infrastructure, most of the improvement measures include adding fully segregated cycling tracks, introducing traffic calming measures, optimizing people's and motorized traffic flow, and upgrading the existing intersections and crossings. On the other hand, from the perspective of landscape and public space enhancement, most measures are to improve the identity of key public space, improve negative urban interfaces, incorporate new activity spaces, and optimize the landscaping configuration on both sides of the road. The review of the above guideline and the three improvement cases will play a constructive role in the study of the current condition of residential roads space in Clifford Estates in Chapter 4 and the optimization design strategies for residential roads space in Chapter 5.

Chapter 4. Current Condition Research of Residential Roads Space in Clifford Estates

4.1 Evaluation Framework of Residential Roads in Clifford Estates

According to the theoretical review related to active travel in Chapter 2, the factors affecting active travel can be categorized into: proximity, safety, connectivity, accessibility, comfort and aesthetics at the level of the whole built environment of urban residential areas. From the foreign design guidance related to active travel in Chapter 3, it can be concluded that roads' infrastructure suitable for active travel should have coherence, directness, safety, comfort and attractiveness. In order to better explore the problems faced by residents during the trips of active travel on residential roads in Clifford Estates, this section will construct an evaluation framework for residential roads from the perspective of active travel on the basis of previous two Chapters, in order to objectively and comprehensively identify the existing problems of road space.

(1) Coherence

The coherence of residential roads is reflected in whether the routes for walking and cycling form a seamless network that connects all the places where pedestrians and cyclists wish to start and finish their journeys. Specifically, the first concern is whether footpaths and cycling lanes exist, and if so whether they are two-way or one-way. The second concern is the width of the footpaths and cycling lanes; if they are less than one meter wide, they will not be usable by the majority of people, and will be psychologically imperceptible and non-existent. In general, the presence and width of footpaths and cycling lanes together determine whether residential roads form a coherent network of active travel spaces.

(2) Safety

Safety as the basic need for residents' active travel is reflected, first, in the measurement of whether the motorized traffic flow on commuter roads is excessive, whether motorized

vehicles comply with the speed limit management of the residential area, and whether traffic calming measures are in place to limit the flow or speed of motorized vehicles; second, the number of marked crossings on the roads and the safety of passing through them. Third, whether there is a potential risk of collision on the roadway. Fourth, whether road lighting is adequate to ensure visibility and personal safety when walking or cycling at nighttime. Fifth, whether there have been any collisions involving pedestrians or cyclists in residential roads.

(3) Connectivity

The connectivity of residential roads is reflected in the degree of directness of walking and cycling routes, or the degree of detouring, and is often analyzed in detour ratio, namely the ratio of the actual walking or cycling distance between two points to the straight-line distance. Determining reasonable detour ratio domain for pedestrians and cyclists requires consideration of a variety of factors, such as the quality of infrastructure, safety, comfort, and and people's preferences, so there is no absolutely reasonable domain of detour ratio. For example, in 2007, Frank Witlox found that the detour ratio for short trips were higher than those for long trips, with detour ratio of 1.45 for very short-distance trips and 1.12 for trips of more than 22.5 km[60]. In conclusion, the smaller detour ratio proves that the residential roads network is more connected, and this principle also provides a theoretical reference for estimating the willingness of pedestrians and cyclists to deviate from the shortest route.

(4) Comfort

The perceived comfort of active travel is mainly reflected in the comfort of supporting facilities and the comfort of travel environment. Considering that the latter is more concerned with the traffic environment with slower speeds and the richness of green landscaping, which duplicates the analyses of safety and aesthetics, respectively. Therefore, the comfort analysis of residential roads in the following section will focus only on the comfort of supporting facilities. On the one hand, the quality of walking and cycling surfaces is concerned with the hardness, smoothness and water permeability of the surfaces, and whether they can still support travel activities nowadays; on the other hand, it is the ability of the road's supporting

facilities to provide pedestrians and cyclists with adequate resting space and other facilities, such as the presence of signage facilities in the road space that provide guidance of the area.

(5) Aesthetics

Since the aesthetic experience of travel environment is a subjective process of psychological activity, it is individual depending on many factors such as the actor's personality, social and cultural background. The content of Chapter 2 has already divided the aesthetics of active travel environments into two aspects: formal aesthetics and connotative aesthetics. Comparing with formal aesthetics, the latter emphasizes human psychological activities more. Therefore, the aesthetics of residential roads will focus only on formal aesthetics in following content, with the influencing elements of complexity, enclosure, transparency and order.

(6) Public Engagement

Public engagement refers to gathering the past experiences of local residents, pedestrians and cyclists as road users and their needs for future residential roads planning and design. They have valuable insights into the current condition of residential roads and the challenges they face. Incorporating these local knowledge into the implementation of active travel initiatives can help to rationalize decision-making and finalize the residential roads design.

Table 4-1: Evaluation framework of residential roads space in Clifford Estates

Dimensions	Dimension descriptions
Coherence	Presence and width of footpaths and cycling lanes
Safety	Traffic speed and volume, marked crossing, potential crash risk, road lighting, historical crashes
Connectivity	Detour ratio
Comfort	Rest facilities, signage facilities, quality of walking and riding surfaces
Aesthetics	Complexity, enclosure, transparency and order of road space
Public Engagement	Past experiences of local road users and their needs for future residential roads

Source: Self edited by the author

4.2 Clifford Estates Site Overview

Prior to the systematic analysis of existing problems of residential roads in Clifford Estates, this section will introduce the holistic elements related to residents' active travel. In terms of the spatial structure of the residential area, Clifford Estates has a number of artery and sub-artery roads, which are dispersed in all directions with the central roundabout in the residential area as the center, and divide the whole area into a number of residential quarters and other functional groups. The buildings within each functional group are mostly arranged in rows and columns, which generally show a checkerboard grid-like urban texture with good order and unity, reducing the possibility of getting lost when traveling. In the terrain conditions, except for the west side and east side of the local area has the terrain of the ups and downs, the whole site is relatively flat, the ground ups and downs is not big, which is conducive to reduce the active travel when the physical energy consumption. In addition to the basic residential function, Clifford Estates also contains other functions such as education, commerce and medical care, which are all ideal catalysts for active travel behavior to occur. Therefore, it should be appropriate to carry out this optimization exploration of the residential roads space in Clifford Estates from the perspective of active travel.

Figure 4-1: Clifford Estates partial aerial view

Source: Reference[61]

4.2.1 Travel Origins and Destinations

(1) The Distribution of Travel Origins

Residential quarters are the main origins of daily travel for residents. As mentioned earlier,

there are currently 23 residential quarters in Clifford Estates (as shown in Figure 4-2). Based on the criteria of "whether there is access control", these 23 residential quarters can be divided into 8 open quarters and 15 closed quarters. Open residential quarters are all multi-storey residential buildings with no underground parking space or access control, allowing any resident to enter and exit freely (such as Zone A). Among the 15 enclosed residential quarters, there are 7 high-rise residential quarters, all of which are equipped with underground parking lots (such as Tianhu Ju).

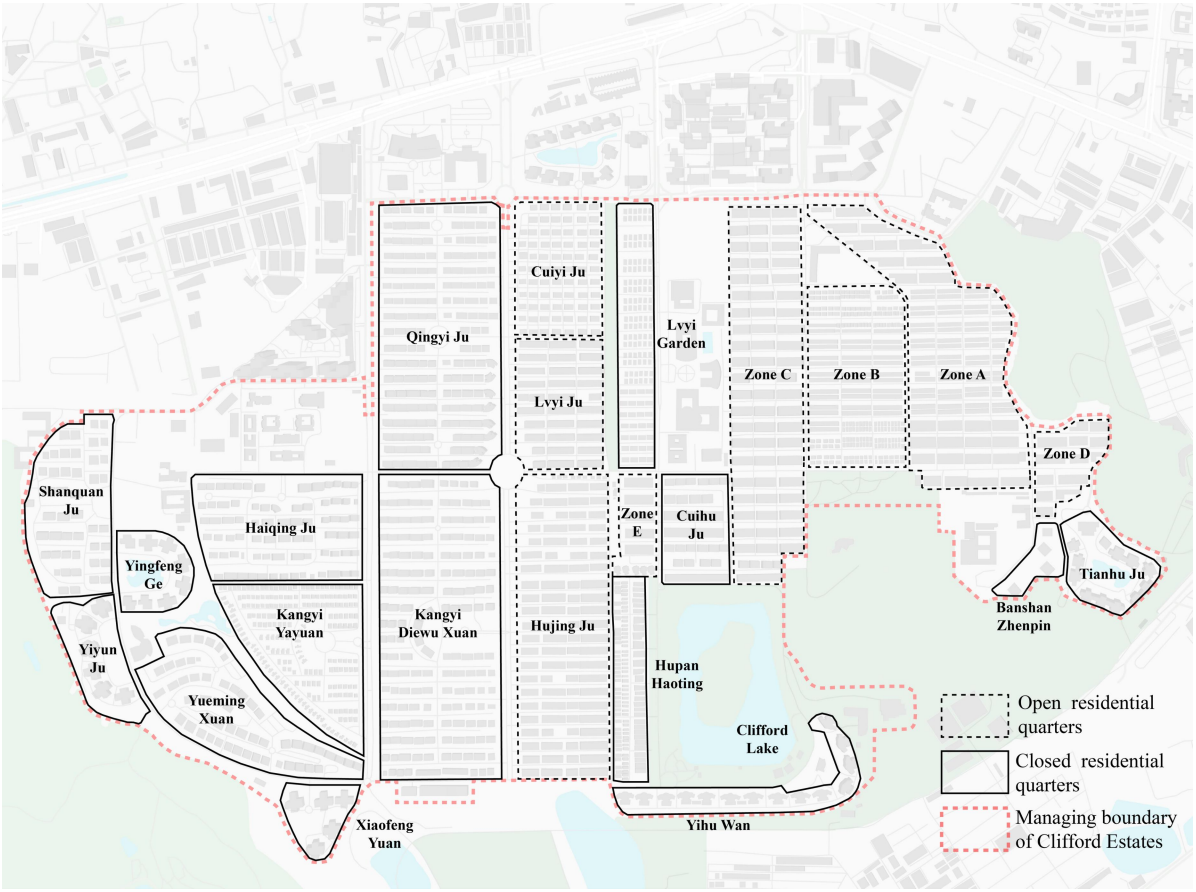


Figure 4-2: Residential quarters in Clifford Estates

Source: Self drawn by the author

Most of the open residential quarters in Clifford Estates were built at the beginning of the development, in the 1990s, by learning from the construction of foreign neighborhoods. These quarters are all multi-storey buildings, with Zone A, B, C, D, and E being single or row villas with two to three floors; Cuiyi Ju, Lvyi Ju, and Hujing Ju are multi-storey residential quarters

with four or five floors. The ground floor of the building, except for a small number of residents who have privately converted from residential to commercial, does not have service formats such as retail and catering, and the environmental quality is relatively good. The internal roads mainly serve the houses on both sides, providing certain free parking services, and almost all house roads allow transit traffic to pass through.

Figure 4-3: Open residential quarters—Zone B (left) and Zone C (right)

Source: Reference[61]

The buildings in closed residential quarters retreat behind the fences and are equipped with property security personnel. The unit buildings are arranged in a row layout, and the public spaces are mostly located in the center of the quarter, connected by linear roads. There are two types of residential buildings in the quarters: multi-storey and high-rise. Multi-story buildings include small villas with three to three floors, as well as point-style residences with three to six floors. After investigation, it was found that the ground floor of the closed residential quarter only has residential function, and there is no commercial activity inside, nor is there a situation of "residential to commercial" conversion. The internal roads are divided into two levels: group roads and house roads. Most residents use them as parking spaces, but some house roads have set up roadblocks to prohibit the passage of motorized vehicles.

Figure 4-4: Closed residential quarters—Kangyi Yayuan (left) and Yingfeng Ge (right)

Source: Reference[61]

(2) The Distribution of Travel Destinations

The occurrence of travel behavior requires the support of activities, and the travel activities of residents can be roughly divided into two categories: functional travel and recreational travel. Functional travel mainly refers to the daily commuting and work of residents, the school travel of teenagers, and the daily shopping activities of residents; recreational travel refers to the leisure activities. It is worth noting that recreational travel is not within the discussion of this thesis. This thesis only discusses the daily functional travel of residents, as it is an activity that residents need to engage in every day, and has strong repeatability. The active travel destinations discussed in this thesis only involve educational, commercial, and medical groups both inside and outside of Clifford Estates, as well as urban bus and metro stations, Clifford Estates Neighborhood Committee, and Clifford Estates Library.

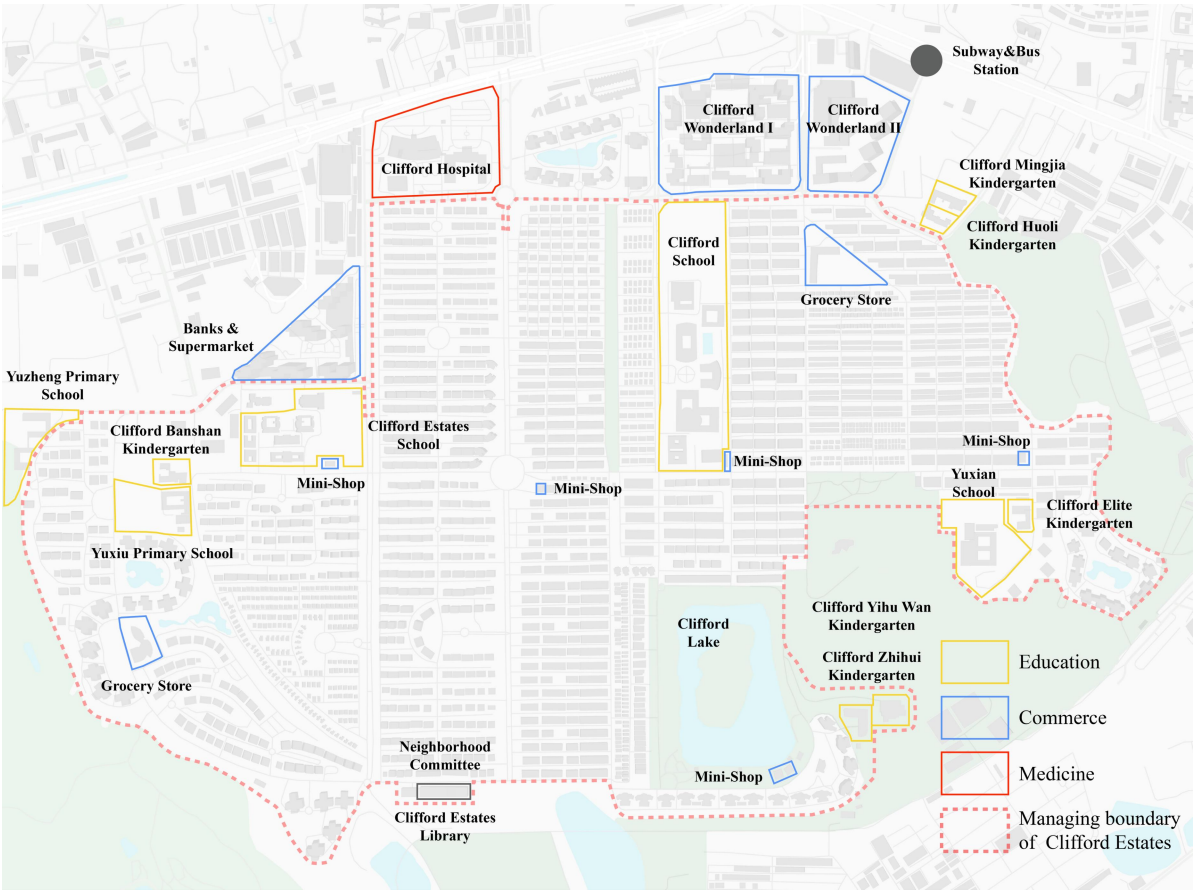


Figure 4-5: Residents' functional travel destinations

Source: Self drawn by the author

In terms of educational functions, Clifford Estates is one of residential areas in Panyu District where educational resources are relatively concentrated, providing children with a one-stop high-quality education service from kindergarten to high school. The education services of Clifford School cover kindergartens, primary schools, junior high schools, and senior high schools, and offer Chinese Canadian American classes, Hong Kong and Macao classes, bilingual classes, etc. to meet the needs of various families. Similarly, Clifford Estates School is not only a nine-year consistent school where children can complete their studies from primary to junior high school, but also has a kindergarten, laying a solid foundation for the lifelong development of young children. Yuxian School, Yuxiu Primary School, and Yuzheng Primary School are three public primary schools. Except for Yuzheng Primary School, the other two schools are all located within the property management boundary of Clifford Estates. After research, it was found that most teenagers have the habit of walking and cycling

to school, making them a rational group to practice active travel. In addition, there are six high-quality kindergartens inside and outside Clifford Estates. Through on-site investigations, it was found that although children's activities require adult companionship, parents often choose active transportation for traveling when picking up and dropping off children. Therefore, in Clifford Estates, travel for the purpose of education is an important component of functional travel activities for residents.

Clifford School

Clifford Estates School

Clifford Elite Kindergarten

Figure 4-6: Educational groups in Clifford Estates

Source: Photographs by the author and from Clifford Estates WeChat Account

In terms of commercial functions, there are already two grocery stores located in the northeast and southwest of Clifford Estates. Residents mainly engage in activities such as purchasing daily necessities such as vegetables, fruits, meat, and other daily necessities. There are also multiple mini-shops within Clifford Estates that can provide residents with sales services such as beverages and snacks. Outside of Clifford Estates, the supermarket in the northwest covers a wide range of categories, and residents also consider it as their daily travel destination. In addition, as part of the commercial high-rise podium, there are also service functions such as finance and catering near the supermarket. Clifford Wonderland in the northern part of the residential area is a large commercial complex composed of two parts. It was built by Clifford Group at a cost of billions of RMB and opened grandly in 2017. The total construction area of the first and second phases that have been completed is about 147,000 square meters, integrating various business formats such as catering, clothing, fitness, and cinema. These rich commercial functions constitute every aspect of residents' lives, and they are important places

for residents to active travel.

Grocery store

Banks

Clifford Wonderland

Figure 4-7: Commercial and financial groups in Clifford Estates

Source: Photographs by the author

Clifford Estates Neighborhood Committee and Library are both located at the southernmost end of Clifford Estates. The Library is located on the third floor of the Neighborhood Committee office building and is a community library that connects with the Guangzhou City Library and the Panyu District Library, with a building area of 200 square meters and a collection of 12000 books. The library will also regularly hold a variety of activities such as book sharing sessions, book clubs, and art exhibitions to enrich the daily lives of residents.

Figure 4-8: Clifford Estates Neighborhood Committee & Library

Source: Photographs by the author

In terms of medical and health care, Clifford Estates is equipped with a large comprehensive tertiary integrated traditional Chinese and Western medicine hospital, with a construction area of nearly 300,000 square meters. It has a large modern outpatient and inpatient department, and complete medical functions. The first phase of the hospital was completed and put into use in 2001, and the new second phase of Clifford Hospital was officially put into use in 2017.

Currently, it can open up to 3,000 beds. In addition to offering basic outpatient services, Clifford Hospital also provides services such as elderly care, medical beauty, and pharmacy to safeguard the health of residents in the residential area and surrounding areas.

In terms of urban transportation, Shiguang Road Metro Station located northeast of Clifford Estates is one of the four stations of the currently operating Guangzhou Metro Line 22, which was officially opened in March 2022. It, together with the nearby Clifford Estates Bus Terminal, connects Clifford Estates with the central urban area of Guangzhou and is an important travel point for residents in their daily lives.

Figure 4-9: Clifford Hospital and Shiguang Road Metro Station

Source: Reference[61]

Source: Photograph by the author

4.2.2 Roads and Non-motorized Traffic Routes

(1) Roads Condition in Clifford Estates

The roads in Clifford Estates can be divided into four levels, namely, artery roads, sub-artery roads, group roads and house roads, and the roads of each level are articulated at different levels to form a good transportation system and a sense of spatial domains with distinctive hierarchies. The artery roads are used to divide the whole residential area and solve the internal and external traffic connection between the residential area and the city, forming a road network together with urban roads, but it must be emphasized that their function is to serve the traffic of Clifford Estates only, and outside vehicles can not enter the residential area without permission, so it can not be mixed with the urban roads. The sub-artery roads are also

the main roads connecting the inside and outside of the residential area, playing the role of dividing the land and connecting the residential groups, connecting the public buildings and recreational places. In general, the artery and sub-artery roads together form the transportation artery of the residential area, transporting people and vehicles to the various plots of the residential area. The group roads are the roads that connect the artery and sub-artery roads and the house roads, namely the roads that branch out from the artery roads and lead to the inner part of the residence or the groups. The house roads are small roads leading to the doors of each houses or units, which serve to connect residential units with each other, and connect residential units with group roads or other grades of roads, and are the end of the road system in residential areas.

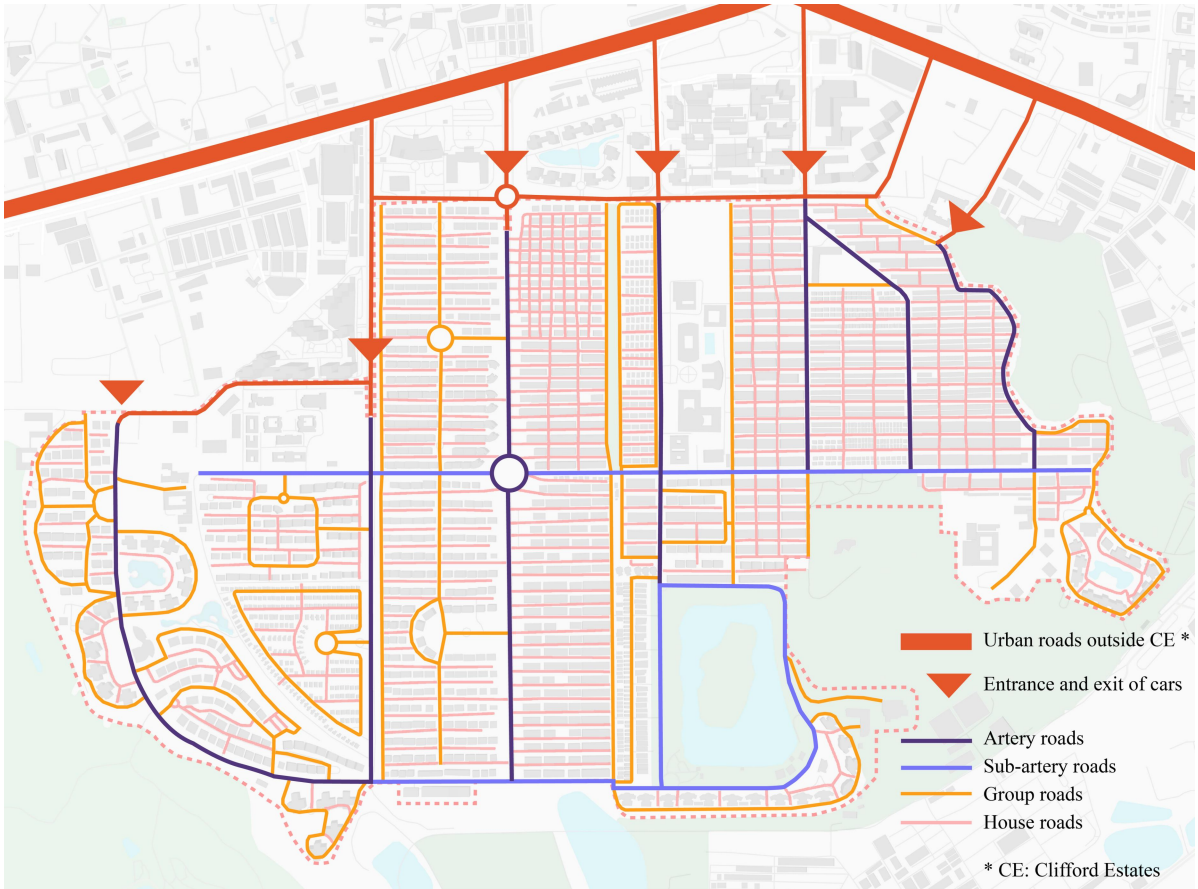


Figure 4-10: Residential roads hierarchy in Clifford Estates

Source: Self drawn by the author

As mentioned above, artery roads are used to solve the problem of connecting the residential area with the inner and outer urban transportation. As Clifford Estates is surrounded by hills

on three sides and the six main vehicular entrances are located on the north side of the property management boundary, seven artery roads run through the whole residential area from north to south, namely Peak Road, Fuyi Road, Clifford Avenue, Xueyuan Road, Fuhua Road, Fulin Road and Fuxiang Road from west to east. Clifford Avenue is the highest grade of these seven artery roads, for two-way four lanes and the road is arranged in the middle of the green belt. Fuyi Road is the second highest grade among these seven artery roads, with two lanes in both directions and a green belt in the middle of the road like Clifford Avenue. Both roads mentioned above have a number of openings in the central green belt for residents to cross horizontally. The remaining five artery roads are all two-way two lanes with no central divider, allowing residents to cross at will. It was found that the artery roads in Clifford Estates are equipped with footpaths to varying degrees, but no dedicated cycling lanes were found, the details of which will be discussed in the next section.

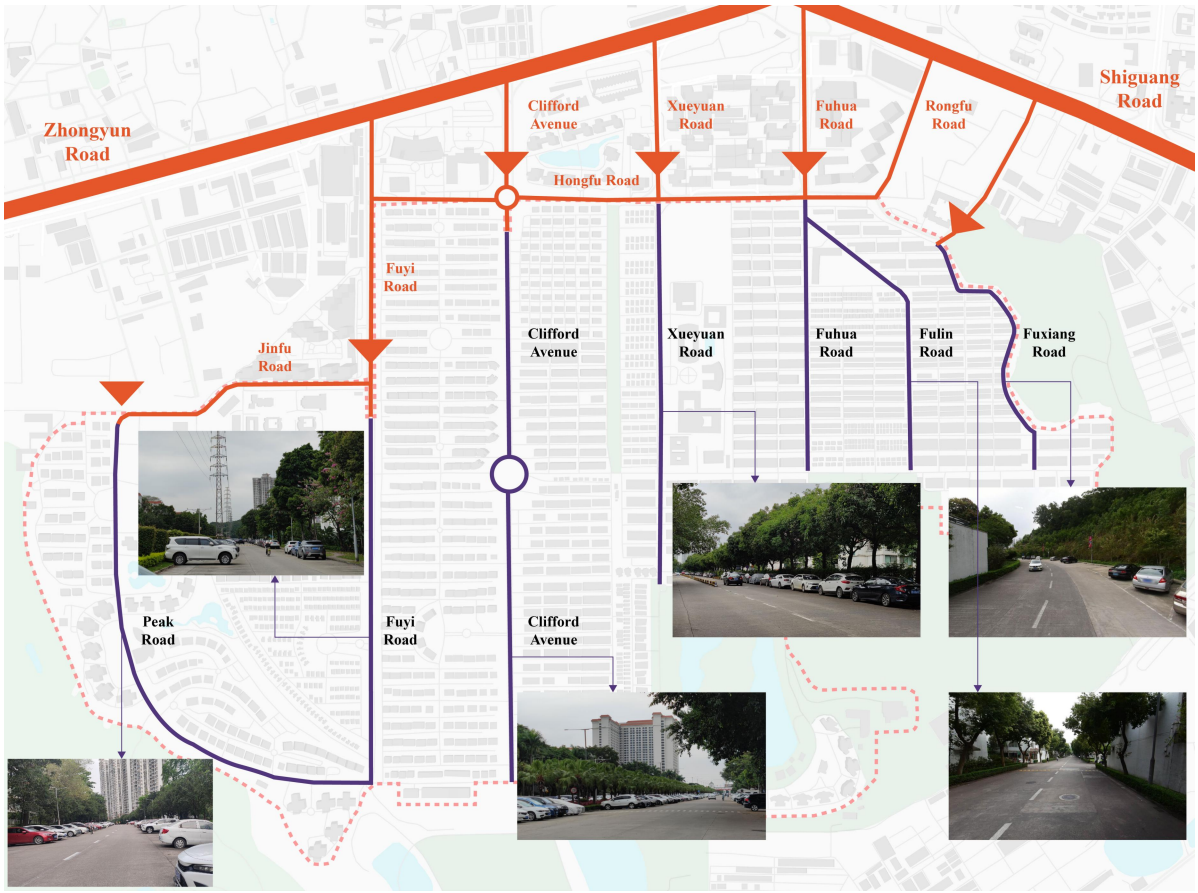


Figure 4-11: Residential artery roads in Clifford Estates

Source: Self drawn by the author

Sub-artery roads are used to solve the transportation links within the residential area. Located in the center of the residential area, Lvyi South Road and 19th Street together form the most important sub-artery road in Clifford Estates. It is the only road that runs directly east-west and roughly divides the whole residential area into north and south parts. It is connected with residential, educational, commercial and recreational functional groups, and it is a road with high pedestrian and vehicular flows. Apart from these, the sub-artery roads include Hujing 1st Street at the southernmost part of the site and the Huanhu Road (comprising Huanhu North Road, South Road, East Road and West Road), which encircles the Clifford Lake. Of these roads, all of the sub-artery roads are configured to varying degrees with footpaths dedicated to walking, with the exception of Huanhu Road, which has no footpaths. Dedicated cycling lanes are in the same state of absence as the artery roads.

Figure 4-12: Residential sub-artery roads in Clifford Estates

Source: Self drawn by the author

The next level of sub-artery roads is the group roads, which serve to solve the internal and external transportation links of residential quarters. The group roads in open residential quarters are mostly north-south through type, connecting to each residential quarter with the highest efficiency; the group roads in the closed residential quarters are mostly encircling type, namely, around the center of the quarter to form an inward-looking center, and then with the house road to form a common "fishbone" road structure. The width of the group roads within different residential quarters varies, with most being 10 to 12 meters and a few being 14 to 16 meters wide. As shown in the Figure 4-13 below, both sides of the roads are mostly used for parking. In Clifford Estates, group roads do not only exist in the residential quarters, there are also two group roads connecting educational functional groups, Yuxin School, Yuxian Primary School and two kindergartens. However, due to the location of schools and the surrounding terrain restrictions, these two group roads are cul-de-sac.

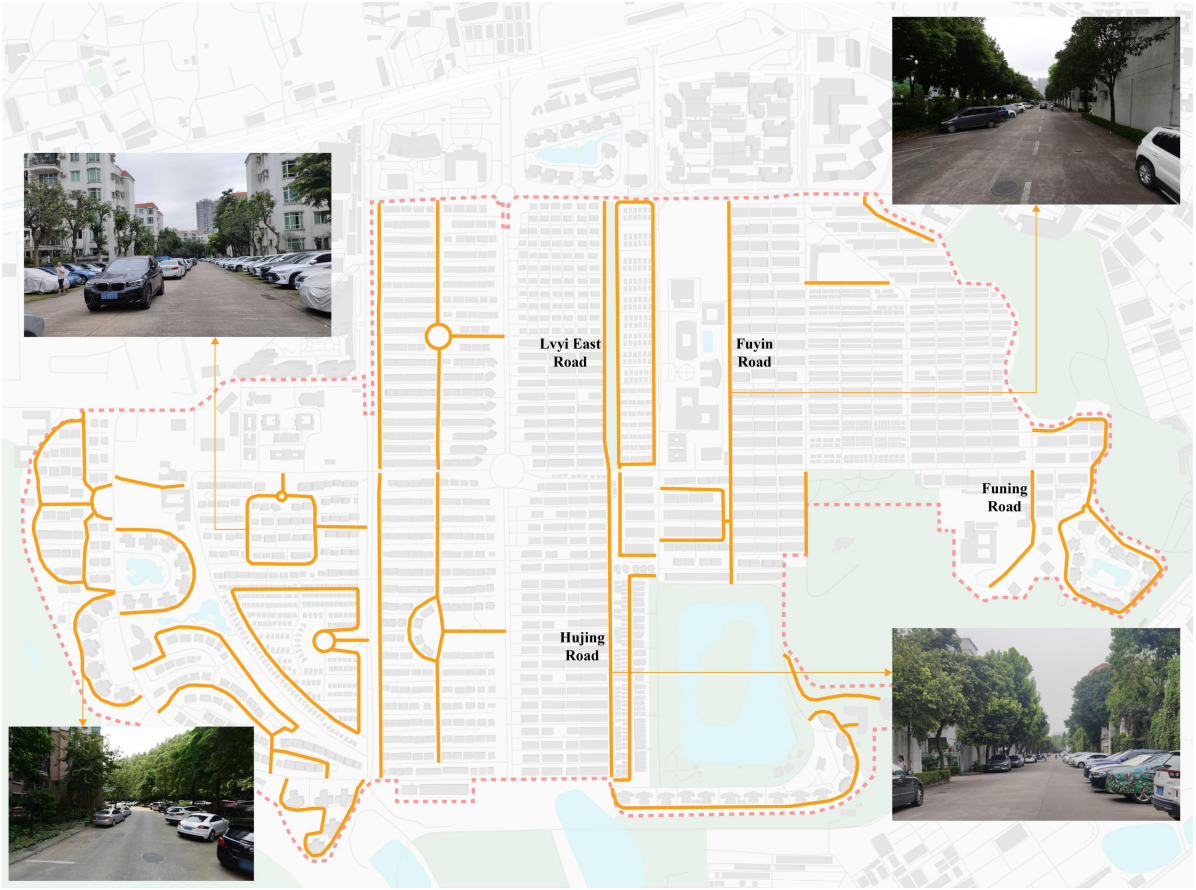


Figure 4-13: Group roads in Clifford Estates

Source: Self drawn by the author

The house roads are paths leading to the doors of each houses or units, and they are the "capillaries" of the road system, spreading to all corners of residential areas. In Clifford Estates, there are three forms of connection between house roads and other types of roads, namely, connection with artery roads, connection with sub-artery roads and connection with group roads. Depending on the type of residential quarters, if the quarter is an open one, then the house roads are directly connected to the artery or sub-artery roads; if the quarter is closed, then the house roads are connected to the group roads. In addition, in open quarters such as Zones A, B and C, there are house paths located between the walls of the two houses. As the paths are mostly only 120 centimeters wide and have a height difference of more than 10 centimeters from the paths between the house roads, they can only be used by pedestrians. At the same time, the lush vegetation on both sides of the paths and the absence of motorized traffic make them ideal for active travel.

Figure 4-14: House roads and paths in Clifford Estates

Source: Self drawn by the author

(2) Non-Motorized Traffic Routes

In Clifford Estates, in addition to vehicular roads, there are several non-motorized traffic routes which are exclusively for pedestrians and cyclists. They are the existing greenway, and the trails around several closed residential quarters. The greenway is designed and built for the general residents of health sports and leisure trails, can run sports, can also be leisurely slow walk. The greenway circumference of about 1.38 km, by a 4-meter-wide healthy trail and a 2-meter-wide one-way cycling lane. Trail around the beautiful scenery, attracting many residents to use. The trails around Haiqing Ju and Kangyi·Yayuan are located between several closed residential quarters, with no motorized vehicles passing through, and shaded by trees on both sides of trails. Residents often take walks with their dogs after dinners, and children can be seen chasing and playing, which is a very strong life style.

Figure 4-15: Non-motorized traffic routes in Clifford Estates

Source: Self drawn by the author

4.3 Spatial Analysis of Residential roads in Clifford Estates

The following spatial analysis of residential roads in Clifford Estates will pay more attention to the coherence, safety, connectivity, comfort and aesthetics of the artery and sub-artery roads in Clifford Estates. Firstly, as the artery and sub-artery roads are the backbone of the spatial structure of the residential area, they connect the various functional groups of Clifford Estates; secondly, as the artery and sub-artery roads are public roads in the whole residential area, they are open to all the residents, whereas the group roads and house roads in residential quarters emphasize more on privacy; thirdly, as they bear the main people and vehicular traffic flow and are the roads that residents must use to active travel and motorized travel.

4.3.1 Coherence of Active Travel Routes

As can be seen from the preceding on-site photos of Clifford Estates, most of the space on both sides of the artery and sub-artery roads in the residential area is occupied by parking, and it is difficult to find any signs of the existence of footpaths and cycling lanes. This has led to pedestrians and cyclists in Clifford Estates taking to the carriageway, where walking and cycling with cars is very common. The main reason for this contradiction is the lack of coherence of active travel routes, which is manifested in two ways: the lack of effective width of footpaths and the absence of dedicated cycling lanes.

Regarding the coherence of the dedicated cycling paths, there is no coherence of the cycling routes as there are no cycling lanes on any of artery and sub-artery roads. Cyclists in Clifford Estates are already in a state of "no way to ride" and are forced to share the road with other road users. As for the coherence of walking routes, Figure 4-16 below shows that, except for the Huanhu Road, all other artery and sub-artery roads are equipped with footpaths, but some of them only have one-way footpaths. In addition, most of the footpaths are one meter or less in width on one side, with the exception of Peak Road, which has two-meter wide footpaths in both directions, and the northern section of Xueyuan Road, which has a three-meter wide one-way footpath. The basic reason of this problem is the lack of systematic design at the

beginning of the planning of Clifford Estates. The construction of residential areas was carried out in zones and plots at different times of years, which also resulted in the failure of the walking routes to form a coherent network.

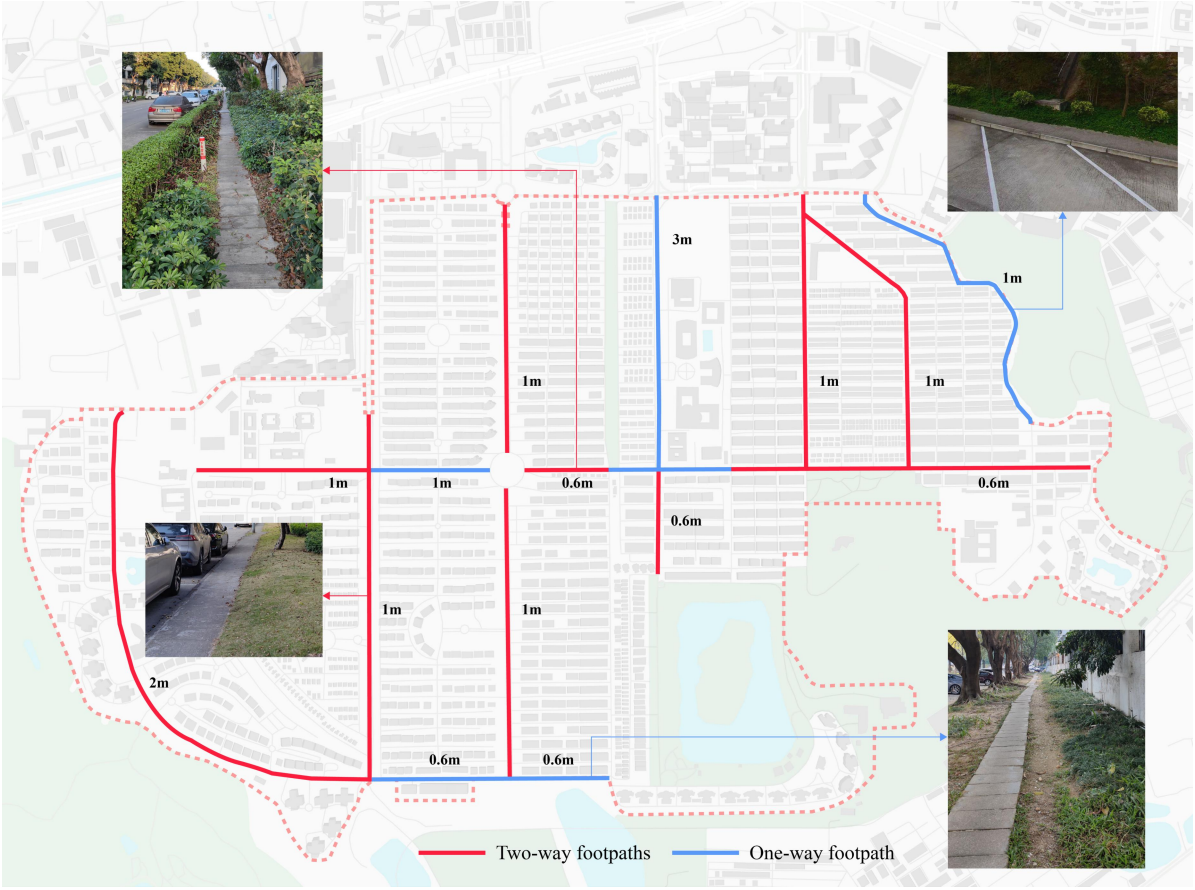


Figure 4-16: Distribution and width of footpaths in Clifford Estates

Source: Self drawn by the author

From the photos above, it can also be seen that the footpaths are often obstructed by plants and vehicles, which makes them difficult to detect visually. At the same time, the growing trees also often conflict with the pavement of the footpaths, on the one hand, encroaching on the originally little walking space, on the other hand, the broken pavement is prone to stagnant water in the rainy days, which also causes a nuisance to pedestrians traveling. All these make the footpaths almost better than nothing in Clifford Estates, and people mostly walk on the carriageways.

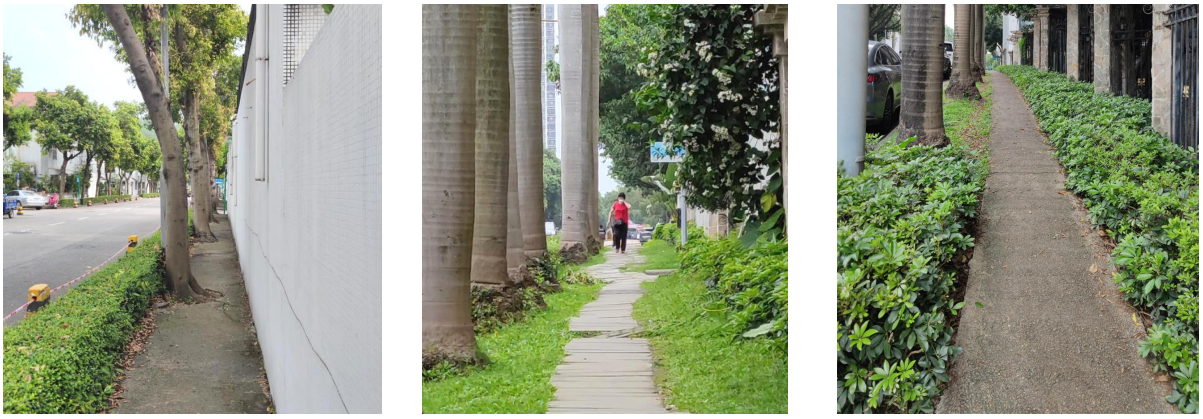


Figure 4-17: Trees encroach on road space

Source: Photographs by the author

The following photos all reflect the actual conditions in residential roads. The photos show primary school children walking home from school on the carriageway sharing the space with motorized vehicles, and one adolescent on a bicycle traveling in the carriageway and then riding into the footpath to share the same travel space with the children returning home from school. It is important to note that the road the youth was riding on was Peak Road, which has two-meter wide, well-maintained footpaths on both sides of the road, making it possible for pedestrians and cyclists to share the footpath. Had he been riding on another road, the cyclist would have been forced to share the carriageway with cars.

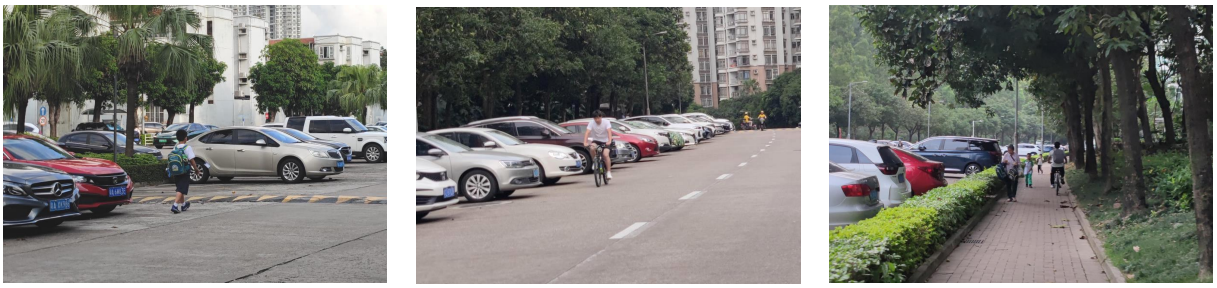


Figure 4-18: Serious mixing of people and vehicles

Source: Photographs by the author

In fact, most of the artery and sub-artery roads have ample road resources in Clifford Estates, but the reality is that a large amount of road space is reserved for motorized vehicles rather than people. This, coupled with the fact that active travelers are inherently disadvantaged in the competition for right of way with motorized vehicles, results in a situation where residents

are more likely to choose to travel by motorized means, and where the desire for active travel is difficult to be realized. Table 4-2 and Figure 4-19 below illustrate the specific allocations for the motorized vehicles space and pedestrian space of the artery and sub-artery roads in Clifford Estates.

In response to the data in Table 4-2, it should be additionally noted that since the residential roads are not urban roads, so there is no legal boundary line of roads, and the following road widths refer to the spacing between the buildings on both sides of the road, the spacing between the buildings and the fences, or the spacing between the fences and the fences.

Table 4-2: Motorized space allocations in artery and sub-artery roads

Road name	Road width	Carriageway number	Carriageway width	Parking lane number	Parking lane width
Clifford Avenue	61m	4	4.5m	4	5m
Fuyi Road	39m	2	5m	4	5m & 2.5m
Peak Road	29m	2	3.5m	2	5m
Xueyuan Road North Section	24m	2	6m	2	5m & 2.5m
Xueyuan Road South Section	24m	2	4m	2	2.5m
Fuhua Road	15m	2	6m	0	/
Fulin Road	15m	2	6m	0	/
Fuxiang Road	18m	2	5m	1	5m
19th Street	28m	2	6m	2	5m
Lvyi South Road	32m	2	6m	2	5m
Huing 1st Street	23m	2	5m	2	5m
Huanhu Road	10m	2	5m	0	/

Source: Self edited by the author

The analysis and data in this subsection all point to the lack of coherence of active travel routes on residential roads in Clifford Estates to form a network which is suitable for walking and cycling. The consequence of this is that pedestrians and cyclists are forced to mix with motorized vehicles, thus posing risks in terms of safety that will be analyzed below. This negative impact from the external environment also saps residents' motivation to choose active travel in the first place.

Figure 4-19: Cross sections of artery and sub-artery roads

Source: Self drawn by the author

4.3.2 Safety of Active Travel Routes

(1) High Traffic Volume and Speed

The safety of active travel routes has a great relationship with the speed of motorized traffic, the higher the speed the higher the threat to people. When the speed is reduced to a certain level, people and cars can use the street together harmoniously, as exemplified by the shared streets in the Holland. After observation, motorized traffic speed traveling on the artery and sub-artery roads is generally high, visual inspection has exceeded 40 kilometers per hour, higher than the Clifford Estates property management regulations of 20 kilometers per hour speed limit.

In addition to the impact of excessive speed on human safety, traffic volume is another important factor affecting safety. High traffic volume means a high density of vehicles on the road, and the reduced distance between vehicles can easily lead to traffic accidents and increase the risk of pedestrian-vehicle collisions. Furthermore, pedestrians and cyclists need to compete with a large number of vehicles for road space when crossing the road, making them prone to accidents.

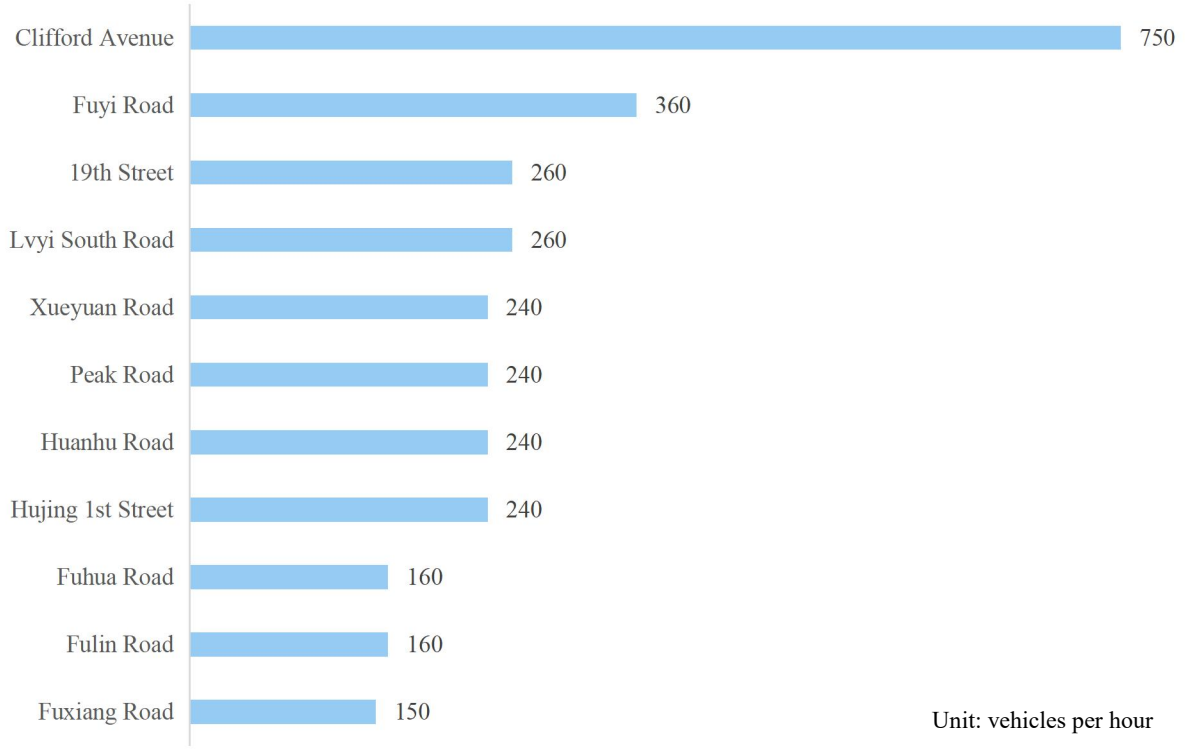


Figure 4-20: One-way motorized traffic flow in artery and sub-artery roads

Source: Self edited by the author

The above traffic flow monitoring data of the artery and sub-artery roads in Clifford Estates were collected by the author, and the sample data were obtained from 2:00 p.m. to 7:00 p.m. on a certain Monday, which was a normal working day with hot temperature and sunny weather, so that the data results are indicative. Specifically, as Clifford Avenue is located in the center of the residential area and is the only road with two lanes in both directions, its traffic volume is unsurprisingly at the top of the list, reaching 750 vehicles per hour in one direction during the off-peak period from 6:00 p.m. to 7:00 p.m., with the direction of the

traffic flow entering Clifford Estates from the outside to the inside. Fuyi Road came next, and compared with Clifford Avenue, due to the lanes into a single lane, the traffic flow is also approximate to reduce by half correspondingly, 360 vehicles per hour. Fuhua Road, Fulin Road and Fuxiang Road are the three artery roads with the lowest traffic volume of about 150 vehicles per hour. The rest of the artery and sub-artery roads have traffic flows in the region of 250 vehicles per hour.

In addition, as there are no traffic signals within Clifford Estates, in order to cross these roads during peak hours, residents have to stop and wait patiently for the traffic signals outside the residential area to change, which in turn brings about an instantaneous stoppage of the traffic flow within Clifford Estates. The added waiting time for pedestrians and the additional braking and restarting of bicycles in this process increase the amount of time and physical effort residents spend on active travel inevitably.

(2) Inadequate Protection for People at Crossings

The crossings at road junctions are the main points where people cross the roads in Clifford Estates. Whether the design is reasonable or not is directly related to the safety of active travelers crossing the roads. As mentioned above, some of the artery and sub-artery roads in Clifford Estates have huge traffic flow during the peak commuting hours. In the face of such a high traffic flow, the poorly designed and considered crossings are daunting to the oncoming vehicular traffic, which not only causes inconvenience to pedestrians and cyclists crossing the roads, but also affects road safety.

According to incomplete statistics, there are 58 marked crossings inside and outside Clifford Estates, mainly on roads on Clifford Avenue, Fuyi Road, Lvyi South Road, 19th Street and the residential roads on the north property management boundary. These road crossings do not have any measures to restrict the speed of vehicles other than marked crosswalks, resulting in pedestrian flow being impeded here and even causing conflicts.

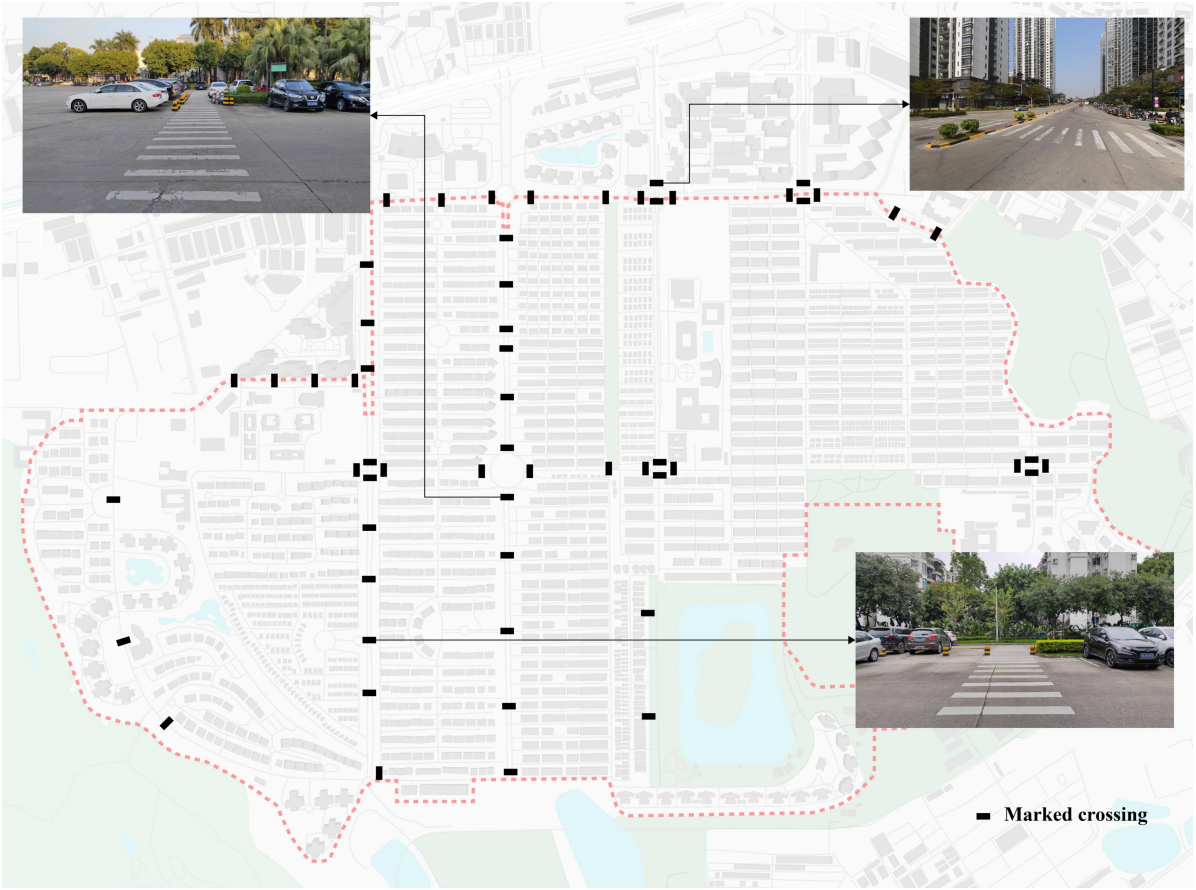


Figure 4-21: Marked crossings inside and outside Clifford Estates

Source: Self drawn by the author

(3) Potential Conflicts between Cyclists and Buses

At present, Clifford Estates is served by eight estate bus routes, namely, Line A, Line C, Line 1, Line 2, Line 3, Line 5, Line 6 and Line 8, which run vertically and horizontally through the entire residential area. The operating hours of all estate bus routes are from 6:00 a.m. to 11:30 p.m. Except for Route 8, whose departure and terminus are both inside Clifford Estates, the departure stations of all other estate buses are located at the Clifford Transportation Center outside the property management boundary of Clifford Estates.

Figure 4-22: Bus route maps in Clifford Estates

Source: Self drawn by the author

It was found that all bus stops in Clifford Estates are simply placed on one side of the road, and passengers usually stand in the gap between the parking spaces on both sides of the road waiting for the bus, or, in a slightly better case, on the footpaths waiting for the bus. The consequence of this bus parking is that when bicycles ride to a bus stop, they must cross an area that intersects with the flow of buses, potentially creating conflicts with parked buses, passengers waiting to get on and off, and other pedestrians, leading to chaotic and unsafe traffic conditions. In addition, as a result of the conflict, cycling travel is impeded and cyclists are forced to wait for or go around stopped buses, which on one hand slows down cycling travel, and on the other hand increases the risk of collisions with vehicles traveling on the left side, posing a potential safety threat.

Figure 4-23: Bus stops in Clifford Estates

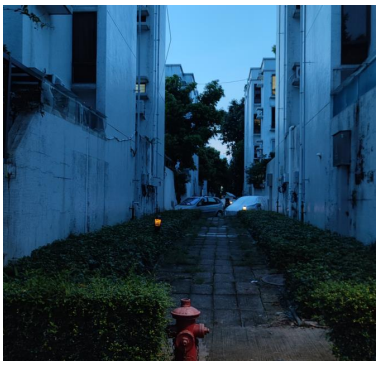
Source: Photographs by the author

(4) Insufficient Nighttime Lighting

Good nighttime lighting can significantly enhance road safety and reduce the risk of nighttime accidents, such as falls and collisions, making it safer and easier for residents to walk or ride at night. In addition, good lighting can also safeguard the personal safety of residents and reduce the occurrence of criminal activities. It has been observed that the lighting facilities on both sides of the artery and sub-artery roads are mostly high-pole road lamps with single-arm. The light emitted by such road lamps can cover the carriageway well, but the light is already weak when it is received by the human eye after many times of diffuse reflection on the road surface, so that the light environment on the footpaths is poor. In the group and house roads, the overall light environment is maintained only by the hanging lamps on the walls of the houses, the spherical road lamps at the roadside and the low-post road lamps, which are generally dim. This shows that the lighting facilities in the residential roads of Clifford Estates have not taken into account the walking and cycling activities at night.

Road lights in a artery road

Road lights in a group road



Road lights in a house road

Figure 4-24: Nighttime lighting in Clifford Estates

Source: Photographs by the author

(5) Historical Crashes

According to the report from the Clifford News Center, a car accident occurred in Clifford Estates on May 20, 2023 at about 7:10 pm. A student riding a bicycle was knocked to the ground without warning by a motorized vehicle that suddenly appeared. The boy was nearly caught under the motorized vehicle, and passers-by watched as the car crashed into the

bicycle. Fortunately, the vehicle was not at a high speed, and the boy only suffered soft tissue contusions on his legs and was not seriously injured.

Figure 4-25: Example of a certain car accident involving a cyclist and a vehicle

Source: Reference[62]

Regrettably, it is also clear from the report of the Clifford News Center in July 2023 that this case is not an isolated one, and that such accidents involving cyclists occur from time to time in Clifford Estates. For example, a man was hit and fell on his bike. The black man lying on the ground in the photo below was riding his electric bicycle through the section in front of Kangyi·Yayuan when he was knocked to the ground by a motorized vehicle that was coming out of the group and preparing to make a right turn. In addition, there are other non-motorized vehicles and motor vehicles collision accident, limited to the length of this thesis can not be listed one by one.

Figure 4-26: Multiple examples of historical traffic accidents

Source: Reference[63]

Facing such frequent occurrences of traffic accidents, news reports in the common statement is "residents need to raise awareness of traffic safety", but never to face up to the existing

problems lying in residential roads such as active travel routes are not coherent, high traffic volume and speed, no protection measures for crossings and other problems. Even the news has issued a warning that "non-motorized vehicles should not race the lanes with motorized vehicles", which raises the question of whether non-motorized vehicles have a way to go in Clifford Estates?

4.3.3 Connectivity of Active Travel Routes

The initial function of road is transportation, and the convenience and efficiency of the route is the first element to satisfy transportation function, and an important dimension to measure whether the road is convenient and efficient is the connectivity of the route. As mentioned above, active travel involves physical exertion, and after clarifying the direction and location of the destination, people always want to reach the end of the trip in the shortest possible time and distance, so the idea of "taking shortcuts" arises naturally.

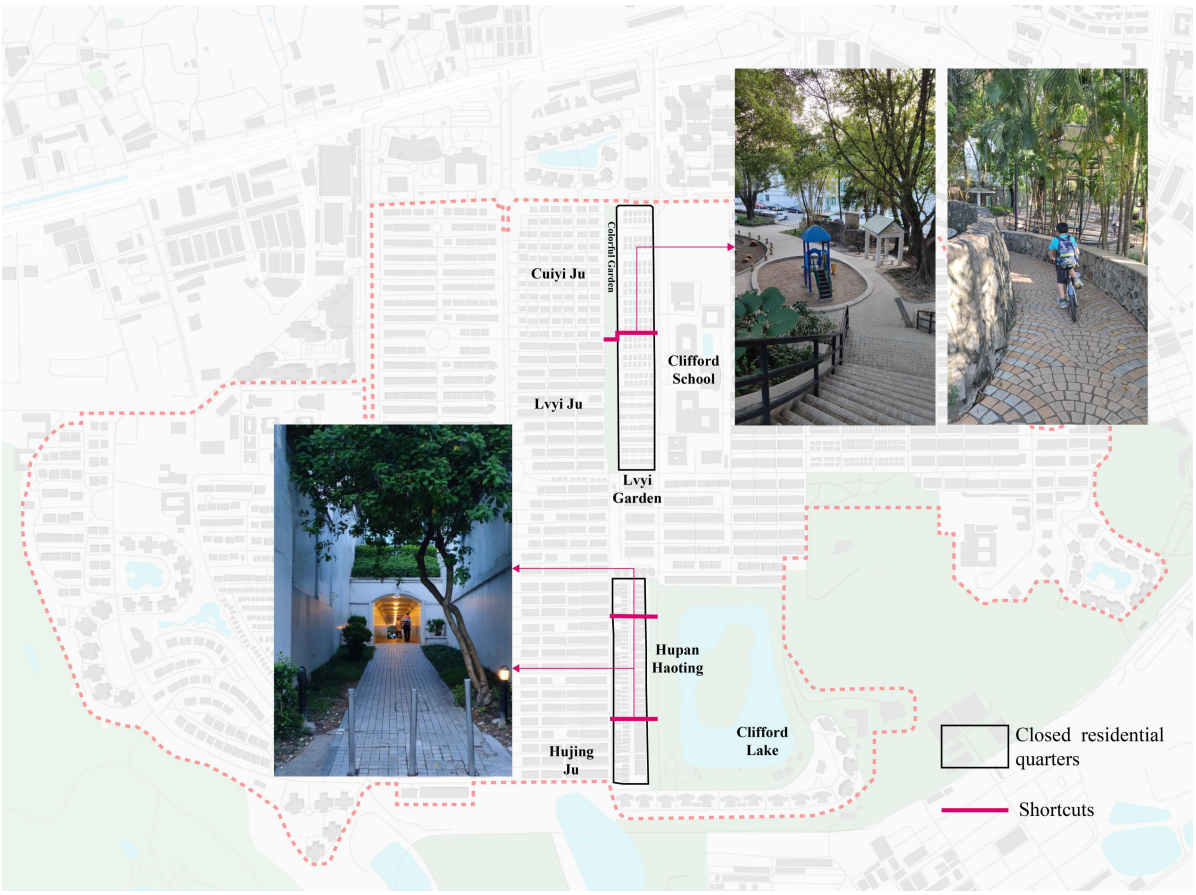


Figure 4-27: Existing shortcuts in Clifford Estates

Source: Self drawn by the author

However, closed residential quarters have strict access control, if the scale is too large, it will form an artificial barrier that is difficult to cross during the trips of active travel. At the same time, due to the topography of the residential area, some roads have differences in elevation, which further reduces the connectivity of roads. Faced with topographical differences, closed gates and cumbersome access procedures, residents often choose to travel longer distances, which not only reduces the efficiency of road access but also causes time delays and wasted physical effort.

Clifford Estates currently has two shortcuts limited to active travel (Figure 4-27), and their presence greatly improves the connectivity of the surrounding road network. One is the two tunnels located between Hujing Ju and Clifford Lake, through which one can easily pass through Hupan Haoting, a closed residential quarter, to reach Clifford Lake or other locations. The other is located on the east side of Cuiyi Ju and Lvyi Ju, through the steps or ramps can easily overcome the obstacles of the terrain, through the Colorful Garden and Lvyi Garden, the former is a recreational place, the latter is also a closed residential quarter, and finally to Clifford School or other destinations. It has been observed that both shortcuts are highly utilized, with residents often seen crossing the tunnel to the Clifford Lake for recreational activities, and students walking or cycling along the other shortcut during school hours.

Unfortunately, only two closed residential quarters could be overcome by shortcuts at present. In other words, the road systems within the other closed residential quarters are independently networked and fragmented, and cannot be shared by all residents in Clifford Estates. Figure 4-28 below illustrates the distribution of closed residential quarters that affect residents' active travel. Closed residential quarters located at the property management boundary are excluded first, because they do not have the destination or the value to pass through; secondly, the two quarters, Cuihu Ju and Yingfeng Ge, are excluded given that they are not large in scale themselves, and at the same time do not significantly conflict with the desired routes for active travel. Negative impacts of the remaining closed quarters on road connectivity are described in more detail below.

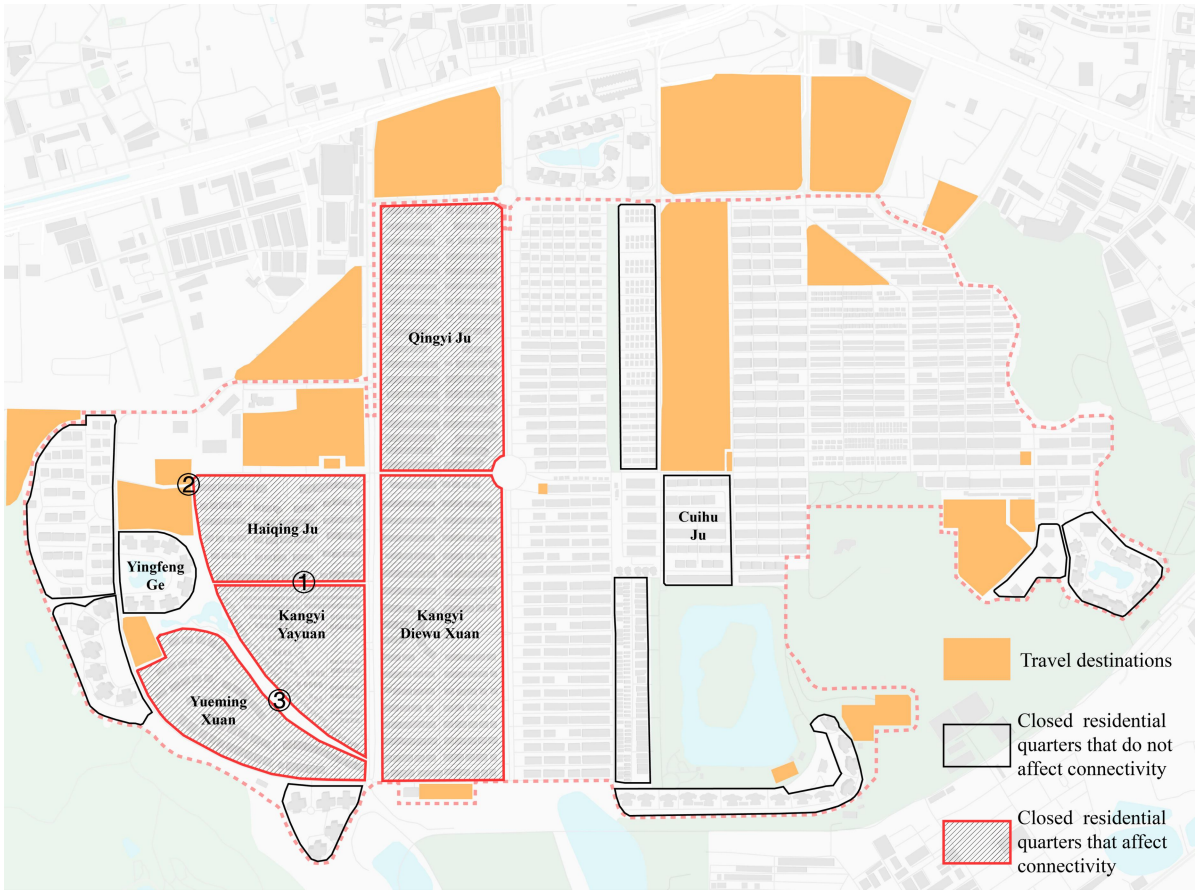


Figure 4-28: Closed quarters affecting connectivity

Source: Self drawn by the author

At Location ①, that is, from the north gate of Kangyi·Yayuan to the entrance of Clifford Estates School, the straight-line distance between the two is 320 meters. Right now the north gate of Kangyi·Yayuan and the south gate of Haiqing Ju are closed, a person needs to walk 1,000 meters, with a detour ratio of 3.1; if the gates are open, a person only needs to walk 500 meters, with a detour ratio of 1.6. A significant reduction in detour ratios can be seen in the comparison of the two different cases.

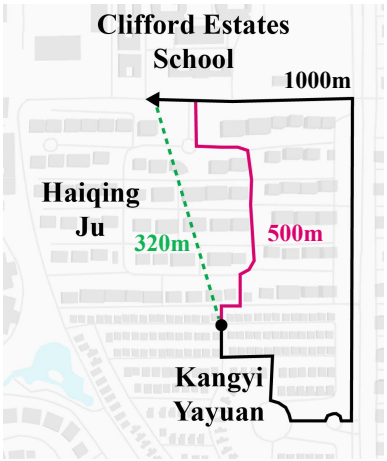


Figure 4-29: Detour analysis to Location ①

Figure 4-30: Closed gates of Kangyi·Yayuan (left) and Haiqing Ju (right)

Source: Self drawn by the author and photographs by the author

In the analyzed Location ②, from a residential unit of Haiqing Ju to Yuxiu Primary School and Clifford Banshan Kindergarten, the straight-line distance is less than 100 meters, but due to the restriction of the terrain elevation difference on the direct route, people need to walk for 2,500 meters, with a detour ratio of as high as 27.8. In the face of such a huge psychological gap, it is hard to imagine that students will choose to go to school on foot. At the same time, the topographical constraints of the site greatly affect the connectivity of the residential roads network, hindering the interaction between people.

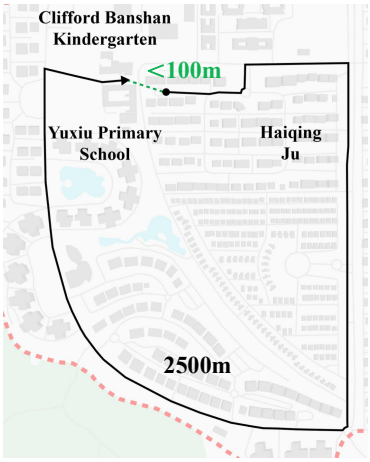


Figure 4-31: Detour analysis to Location ②

Figure 4-32: Elevation restrictions between the two parcels

Source: Self drawn by the author and photographs by the author

Location ③ is a shortcut for walking formed under the residents' spontaneous behavioral activities, from which it can also see the strong demand for active travel from residents, even though it is very risky and challenging to pass through this place, but following people's natural idea of "seeking the nearer for the farther," the neighboring residents will choose to borrow this road to reach the target place. Because the number of people climbing the steep slope is too large, Clifford Estates Property Management Company set up a warning sign in this place, but so far has not solved the actual problem of traveling.

According to the analysis of the detour at this location, it can be seen that the straight-line distance between the two points is 330 meters, if a person do not go through this shortcut to reach the nearby grocery store need to walk 1200 meters, the detour ratio of 3.6; but through this shortcut only need to walk 450 meters, the detour ratio of 1.4.

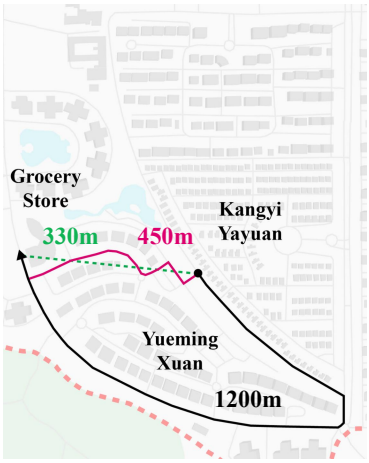


Figure 4-33: Detour analysis to Location ③

Figure 4-34: Walking shortcuts formed by people's activity

Source: Self drawn by the author and photographs by the author

Qingyi Ju and Kangyi·Diewu Xuan are the two largest closed residential quarters in Clifford Estates, and their access control systems are only open to the residents of their own quarters. In addition to this, some of the entrances of the two quarters are currently closed, losing their external connectivity. All of these factors make them huge barriers for residents on their way to active travel. For example, if one person goes from the location between Cuiyi Ju and Lviyi

Ju to the bank and supermarket on the west side, the original walking distance of less than 500 meters has to be detoured 1,200 meters because of the access control to reach the destination, and the walking detour coefficient has increased from 1.2 to 2.9.

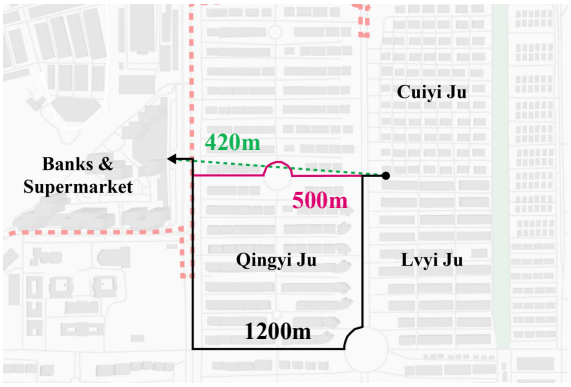


Figure 4-35: Detour analysis to Qingyi Ju

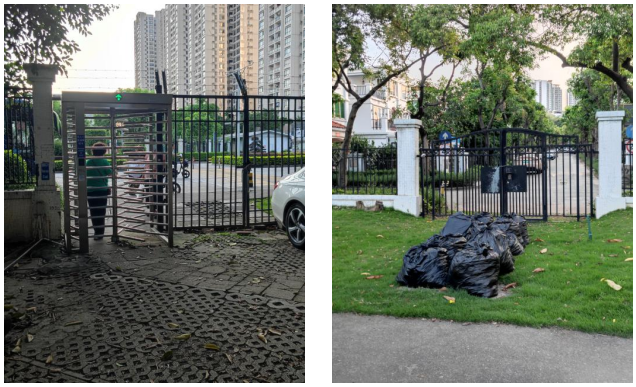


Figure 4-36: Access control of Qingyi Ju and the closed gate of Diewu Xuan

Source: Self drawn by the author and photographs by the author

Longer distances mean longer travel times and more physical exertion, and the superposition of these travel costs all have an impact on the choice of travel mode and decision-making at the outset. It is clear that the access control of closed residential quarters and the topographic elevation differences are negative factors that constrain residents' active travel.

4.3.4 Comfort of Active Travel Routes

The poor comfort of active travel routes in Clifford Estates is reflected in the lack of roadside rest facilities, inadequacy of signage facilities and poor quality of footpath surfaces.

(1) Lack of Rest Facilities

Rest facilities in residential areas usually include squares, parks, courtyards, benches and so on. These facilities are intended to provide a relaxing and pleasant environment for residents to actively participate in their lives and engage in leisure activities and social interactions. The absence of these rest facilities may have a negative impact on active travel in a number of ways, the most immediate impact being that it makes it difficult for residents to find appropriate resting places when they are walking or cycling. People usually need short breaks

to relax, and the lack of rest facilities may make residents feel tired and uncomfortable, affecting their motivation for active travel. It may also limit residents' opportunities to engage in various activities outdoors, such as walking, cycling and jogging. This may reduce the quality of life for residents, making them more inclined to indoor activities and reducing the diversity of active travel.

It was found that only two artery roads in Clifford Estates, namely Fuyi Road and the northern section of Xueyuan Road, have scattered seats, and the arrangement of the seats is not regular. There is insufficient space for footpaths on other roads, let alone reserving space for resting seats. Moreover, the seats lack humanization. Most of the existing seats are made of marble, which makes it difficult to sit on the seats in winter when the temperature of the seats is low. The lack of greenery around some of the seats to protect them from the hot sun and cold wind makes it difficult to attract residents to stop by.

Figure 4-37: Scattered seats in Clifford Estates

Source: Photographs by the author

(2) Inadequacy of Signage Facilities

Signage facilities are facilities that provide residents with specific information services in residential areas, which are important for guiding residents to choose activity places according to the type of activity. The research found that the number of signage facilities in residential roads is relatively small, and most of them are mainly to inform the name of specific roads and remind drivers of the speed limit, which is not able to guide the residents to carry out

healthy behaviors. On the one hand, the installation of road signs is inadequate, especially the lack of overall orientation and route navigation information, and residents may face problems such as getting lost, detouring, wasting time, etc., which affects the efficiency of travel when they are actively traveling. On the other hand, not enough has been done to remind drivers to drive slowly. Although speed limit signs have been erected on both sides of the road, most drivers turn a blind eye to them because they are not eye-catching enough.

Figure 4-38: Signage facilities in Clifford Estates

Source: Photographs by the author

(3) Poor Footpath Surface

The vast majority of footpaths are made of concrete in Clifford Estates, most of which are no longer smooth under the effect of time, and footpath surfaces are prone to water accumulation and slippery phenomenon. Such surfaces are obviously not suitable for people to walk, in addition to the above mentioned insufficient width, under normal circumstances, pedestrians in the face of such footpath surfaces more often choose to walk directly on the carriageways with motorized vehicles.

There are only a small number of pedestrian pavements made of brick collages, such as those on both sides of Peak Road, which are well maintained and level enough to support walking activities. This is one of the few footpaths in Clifford Estates that is suitable for walking in terms of width and the level of the surface.

Table 4-3: Footpath surfaces in Clifford Estates

Fuyi Road	19th Street	Xueyuan Road-South	Peak Road
			
Moderate hardness	Moderate hardness	Moderate hardness	Moderate hardness
Low flatness	Low flatness	Average flatness	High flatness
Poor permeability Slippery	Average permeability Slippery	Poor permeability Slippery	High permeability Not slippery

Source: Self edited by the author

4.3.5 Aesthetics of Active Travel Routes

(1) Complexity

Clifford Estates generally has a high greening rate, which is directly reflected in the road interface. It has been observed that both sides of the road are surrounded by green trees, which makes the scenery pleasant. However, this has also brought about the aesthetic homogeneity of residential roads. Apart from green trees, the roads are lined with residential buildings and cars parked by the roadside, coupled with the fact that most of the roads in the residential area use concrete pavement, the overall color of the roads shows green plants, gray road surfaces and white buildings as the three dominant tones, with a lack of vibrancy in the atmosphere. The green space on both sides of the road, except for plants, also did not find traces of the existence of landscaping sketches. Some unused green space around the road is also abandoned and does not have public space with activity. Although recreational travel is not within the research of this thesis, vibrant roads can also add an extra dimension to active travel. As a result, residential roads provide a low level of sophistication and the longer the distance traveled the more likely the idea of boredom will arise.

Figure 4-39: Homogenized road spaces

Source: Photographs by the author

(2) Enclosure

As mentioned above, the widths of the artery and sub-artery roads in Clifford Estates are large, in particular, the width of Clifford Avenue is more than 60 meters. Such wide roads will result in buildings on both sides of the roads being relatively far away from each other, thus weakening the sense of enclosure of the road space. Walking in a road space with a low sense of enclosure, people may feel isolated or insecure as they have to cross a relatively long distance to reach the opposite footpath or building. In addition to the width of the roadway as a factor, tall, dense road trees can form a good visual barrier and can have a positive impact on creating spaces with a strong sense of enclosure. However, based on observations of residential areas, the vast majority of footpaths are lined with road trees on only one side, which further diminishes the sense of enclosure of the road space.

(3) Transparency

The transparency of the residential roads in Clifford Estates is mainly derived from the openwork design of the fences of the closed residential quarters and schools, through which public activities within the groups can be observed, providing a certain visual connectivity for passing pedestrians. This also has the potential to promote people's interaction between the road and the quarters or schools, as people can communicate visually through the fence and even talk to pedestrians or neighbors outside through the fence, which helps to break down the closed nature of the boundary. However, since there is no additional pattern or molding added to the fence, it is not a landscaping feature and is slightly less aesthetically pleasing.


Figure 4-40: Fences of closed residential quarters and schools

Source: Photographs by the author

(4) Order

The overall spatial layout of Clifford Estates is like a checkerboard, which brings the benefit of a network of roads intersecting at right angles, and the regular spatial layout makes the roads have a clear sense of visual order. As the intersections of the roads are mostly at right angles, the land is divided into regular square or rectangular blocks, coupled with the similarity of the plans of residence and their heights are relatively uniform, a strong sense of order can be felt when walking in the residential roads. Of course, along with the deepening of familiarity with Clifford Estates, the sense of order may also evolve into a sense of boredom. Therefore, when necessary, it also need to break the dull order and consider the influence of complexity, enclosure and transparency on the aesthetic of the roads space.

4.4 Summary of Active Travel Perception Survey

Perception survey as one part of this site study in Clifford Estates, can help to understand the problems that residents face during the trips of active traveling and why they not do so, as well as to know what vision residents have for the future of the residential roads, with a view to providing a realistic basis for the development of design strategies in Chapter 5. Specific questions can be found in the appendix at the end of thesis.

There are two forms of survey data collection: one is to distribute paper questionnaires and invite students, parents and other residents to fill them at the main entrances of schools, supermarkets and residential quarters; the other is to forward the electronic questionnaires to

the owners' WeChat groups of residential quarters in Clifford Estates through the respondents who filled in the paper questionnaires, so as to encourage more residents to take part in this online perception survey.

Results are calculated from the number of respondents who answered the specific question and not the overall number of respondents of the survey. Finally, 1706 valid questionnaires were collected, of which the number of questionnaires filled out by minors totaled 549, and the number of questionnaires filled out by adults totaled 1157, with the ratio of the number of the two groups of people approximating 1:2. By collating the information from the data, the overall situation of the residents interviewed is as follows:

(1) Frequency of Active Travel

Of the minors interviewed, 54% often chose active travel, 26% chose "occasionally", and 15% and 5% each chose "never" and "always". Among the adult respondents, 53% considered that they occasionally chose active travel for their daily activities, 35% often active travel, and 6% each chose "never" or "always". This shows that residents in Clifford Estates generally have a greater demand for active travel, and this is particularly evident among the adolescent groups. Although the majority of adult respondents chose "occasionally" to active travel, it can be assumed from the interviews that some of them believe that the residential roads environment restricts them from choosing to walk or cycle, and so that they can be considered as potential active travelers.

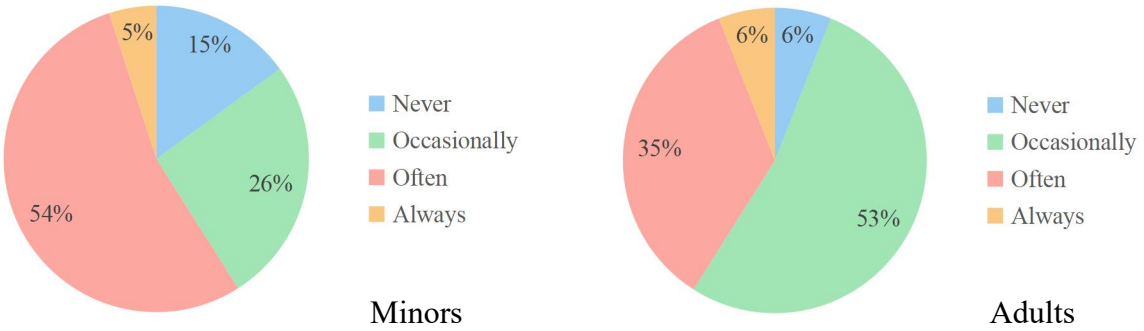


Figure 4-41: Frequency of active travel by minors and adults

Source: Self edited by the author

(2) Influence Factors to Active Travel

For the factors affecting residents' active travel, the questionnaire categorized them into eight themes, which are infrastructure, road maintenance, road safety, personal safety, time and distance, facilities, poor weather and personal factors (unable or unwilling). Respondents were only allowed to choose one factor that most affects their active travel. The purpose of this is to put ourselves in the perspective of the road users and get to the core problem of the residential roads in Clifford Estates, and to avoid the distraction caused by multiple choices. The percentage of each influencing factor below is taken from 1706 questionnaires, and is the result of combining the results of both minors and adults.

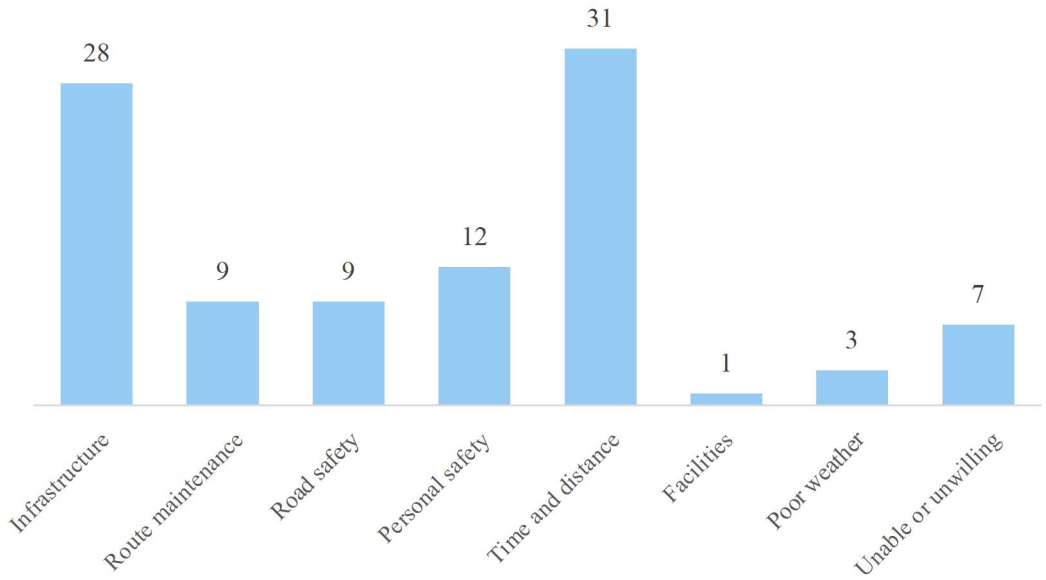


Figure 4-42: All respondents. Influence factors to walking

Source: Self edited by the author

From all the respondents' choices on the factors affecting walking, the influence of travel time and distance is in the first place, accounting for 31% of the overall proportion. From the conversations with some school students, it is also clear that although their homes are only about one kilometer from their schools, most of them go to bed late and wake up late due to heavy school workloads, and are afraid of being late, thus choosing to ride their bicycles to school. This is closely followed by the impact of infrastructure at 28%. This is mainly reflected in the fact that footpaths are sporadic and do not form a systematic network, but also

due to their width and surface material, which makes people give up walking on the footpaths. Adding up these two percentages to total 59%, it can be seen that they are the two most critical environmental factors determining whether residents in Clifford Estates choose to travel on foot.

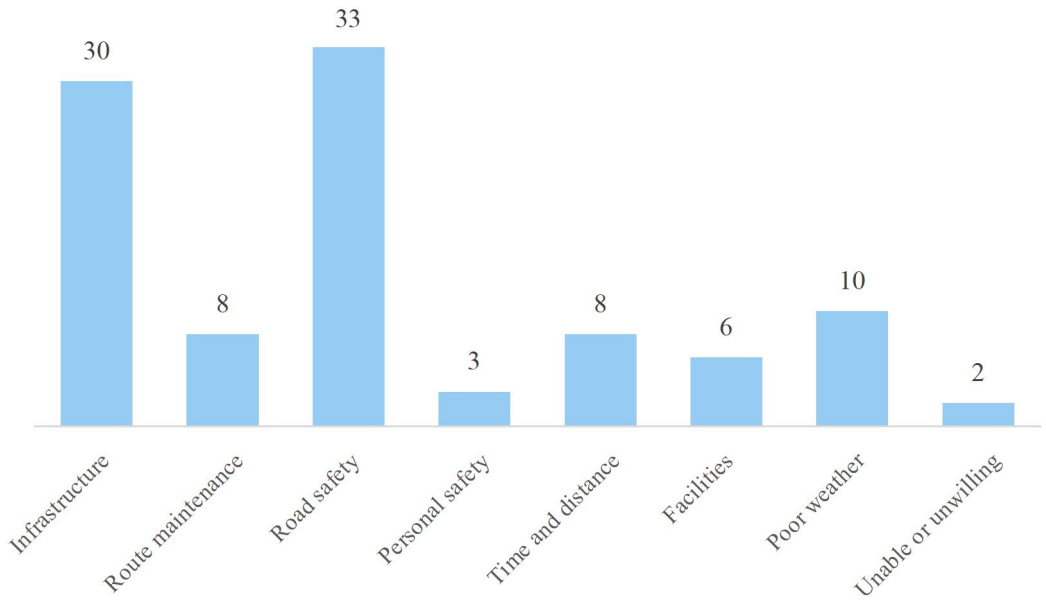


Figure 4-43: All respondents. Influence factors to cycling

Source: Self edited by the author

In terms of respondents' concerns about factors affecting cycling, road safety was the most important concern for residents, at 33%, reflected in concerns about high speed and volume of motorized traffic and the mixing of people and vehicles, as well as concerns about whether they might be in danger when crossing the roads. This is followed by dissatisfaction with the current state of the infrastructure at 30%. It is the lack of construction of cycling lanes that has led to a number of problems such as unsafe roads. The total of these two influencing factors is 63%, which are the two most important difficulties to cycling in Clifford Estates that can not be ignored.

(3) Desires for Residential Roads Space in Future

The final part of the questionnaire is to find out the desires of residents for the future residential roads space in Clifford Estates, which is the only multiple choice question set in

this questionnaire, with the aim of understanding the residents' aspirations for the road design from various perspectives, so as to provide guidance for the subsequent design part. Through the collation of data, it can be seen that more than half of the residents interviewed expected "footpaths suitable for walking, segregated cycling lanes, slower motorized traffic, and more efficient travel routes", which were 89%, 75%, 67% and 58% respectively. It can be seen that when facing the future residential roads in Clifford Estates, most respondents put the pursuit of travel safety and efficiency in the first place.

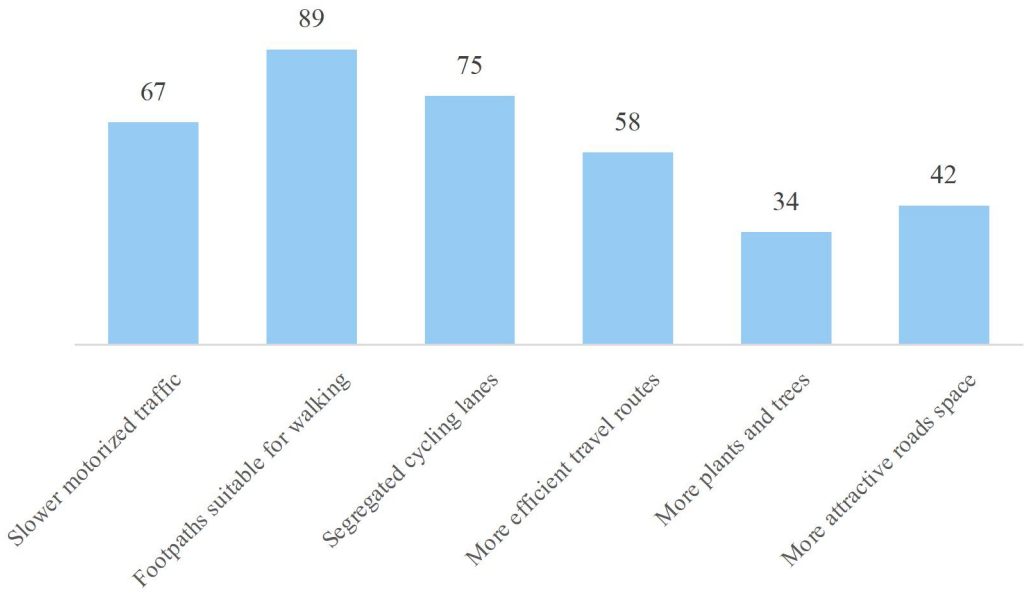


Figure 4-44: All respondents. Desires for residential roads space in future

Source: Self edited by the author

4.5 Chapter Summary

This Chapter firstly constructs a framework for evaluating residential roads space under the perspective of active travel on the basis of the previous two Chapters, and secondly analyzes the artery and sub-artery roads in Clifford Estates according to this framework, so as to draw out a series of problems faced by residents when they make active travel on the residential roads in Clifford Estates, and lists these problems in separate sections. Finally, the problems identified and supplemented the perception survey of residents, with a view to providing a more detailed basis for the development of the optimization methodology in the next Chapter.

Chapter 5. Methodology of Residential Roads Space Optimization in Clifford Estates

5.1 Principles of Residential Roads Optimization for Active Travel

(1) Coherent

As with motorized travel, it is the right of residents to freely choose active travel modes, such as walking and cycling, for their travel activities in residential areas. Good residential roads should be inclusive and provide space for all modes of travel, enabling residents to realize their active travel choices. Therefore, it is paramount that residents have access to coherent active travel paths within the constraints of their own physical abilities.

(2) Safe

Both pedestrians and cyclists are vulnerable in transportation travel compared to motorized vehicles. The safety of travel is a key factor influencing whether people choose active travel or not. Safe residential roads require the coordination of fast and slow traffic, namely a harmonious relationship should be established between active transportation modes and fast motorized traffic. Since active travelers are always at a disadvantage in fast and slow conflicts, residential roads suitable for active travel should give full consideration to human needs, prioritize human interests, minimize human-vehicle conflicts and ensure human safety.

(3) Convenient

Convenient residential roads require minimizing the extent to which active travel routes are blocked by barriers. Barriers in routes are elements of the residential area environment such as neighborhood fences, topographical differences, hillside and water flows, and also movable barriers such as such high volumes of motorized traffic. Convenient routes design should comply with the "minimum principle", which means that when people choose active travel, they tend to choose the routes with the lowest cost, the most time-saving and energy-saving.

(4) Comfortable

In addition to meeting the needs of safety and convenience, residential roads space suitable for active travel also need to improve the design of related road hardware to enhance the quality of residents' travel and the overall function of the residential area. Active travel, as a kind of physical activity, requires residential roads to be designed to provide residents with a certain amount of open space and encourage them to walk or ride. At the same time, the provision of suitable public facilities on residential roads, such as benches and bicycle parking spaces, can also provide residents with more opportunities to stay and socialize, creating residential roads that are more pleasant to live in, walk on and travel through.

(5) Enjoyable

The spatial environment of residential roads space belongs to the external public space of the residential area, which not only undertakes the function of transportation, but is also an important place for people's leisure and communication activities, so the quality of the active travel spatial environment in addition to meet the basic transportation function, there should be more humane considerations for the people's leisure, interaction, recreation and other diversified travel activities to provide place support for the people in the process of active travel. So that people could feel the residential roads environment of humane flavor during the trips of active travel, to achieve the purpose of physical and mental pleasure.

The five design principles and the five design strategies below are broadly in a one-to-one correspondence. However, it is worth noting that the relationship between the principles and strategies can not be viewed in a static and compartmentalized manner because they are often compounded. For example, creation of protected active travel spaces is motivated as much by safety concerns as it is by the desire to improve the comfort and enjoyment of residents during active travel.

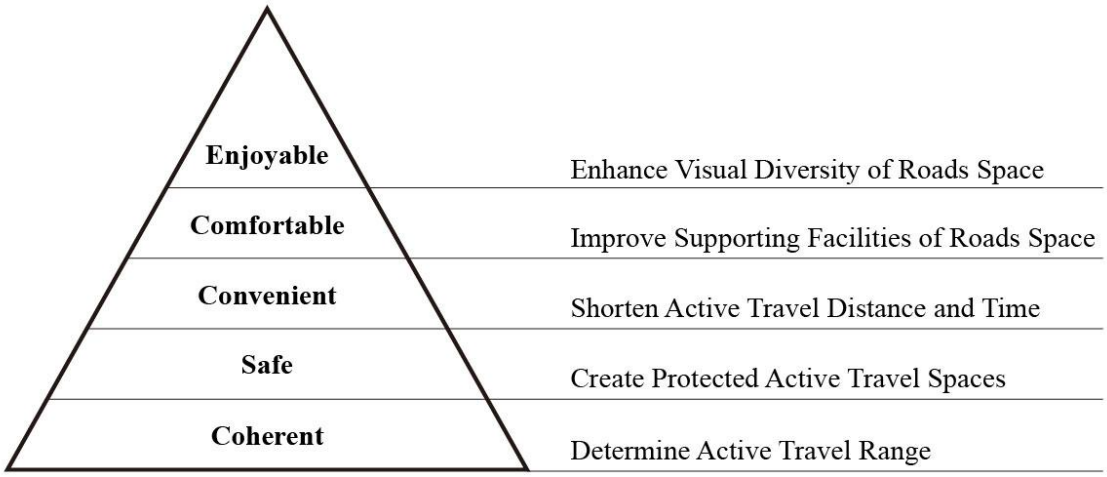


Figure 5-1: Correspondence between principles and strategies

Source: Self drawn by the author

5.2 Strategies of Residential Roads Optimization for Active Travel

5.2.1 Determine Active Travel Range

The range of active travel by human is susceptible to a variety of objective conditions, not the least of which is the limitation of their own physical capacity. Active travel is to people's own physical exertion as the driving force of the mode of travel, subject to the constraints of physiological and psychological factors, often can only withstand a certain time and distance range. According to the results of existing research on the threshold of suitable walking distance for residents, the threshold of limit walking distance obtained from acceptable walking time is 1,500 meters; the threshold of limit walking distance obtained from walking distance is 950 meters[64]. Besides, Jan Gehl earlier also talked about 400 to 500 meters for ordinary people is generally accepted walking distance, 500 to 1,000 meters is the limit of comfortable walking distance, more than 1,000 meters when people will rarely choose to walk. For bicycle travel, from the spatial distance of travel, the distance of bicycle travel in the range of 4 kilometers, the proportion of the overall bicycle travel accounted for 85.56%, with the highest concentration in the 0 to 2 km range, accounting for 60%[65]. Relevant studies have shown that[66], walking dominates within 1 kilometer, with only 1% of trips by bicycle; the proportion of trips within 1 to 5 km by bicycle increases to 18%; trips within 5 to 10 km are

dominated by motorized trips, with the proportion of cycling dropping to 10.4%; and the proportion of trips by bicycle accounts for very little of trips over 10 km. In summary, this section will use 1 kilometer as the distance threshold for walking and 4 kilometers as the distance threshold for cycling trips.

Traditional methods of defining the range of travel mostly use the point of residence as the origin of travel, and the distance threshold as the radius outward to make a buffer zone. Such research methods, although simple and clear, but used to define the range of active travel error is larger, because the travel distance is seldom a straight line distance between the two points, it is difficult for people to avoid the detour on the way to walk or ride. Therefore, this section uses the actual distance traveled between trip origins and destinations as the travel distance, which is more appropriate for active travel. The residential quarters within the residential area are the travel origin points, and the schools, commercial, medical and other public service groups within the residential area are the attraction points for the trip. At the same time, active travel routes should be planned based on the shortest walking path between the origin and attraction points, because when people are clear about the orientation of the destination or know the direction of movement, it is people's natural reaction to go straight to the target. Through this method could give a relatively more accurate range of active travel by residents, and residential roads within this range should have coherent paths for active travel.

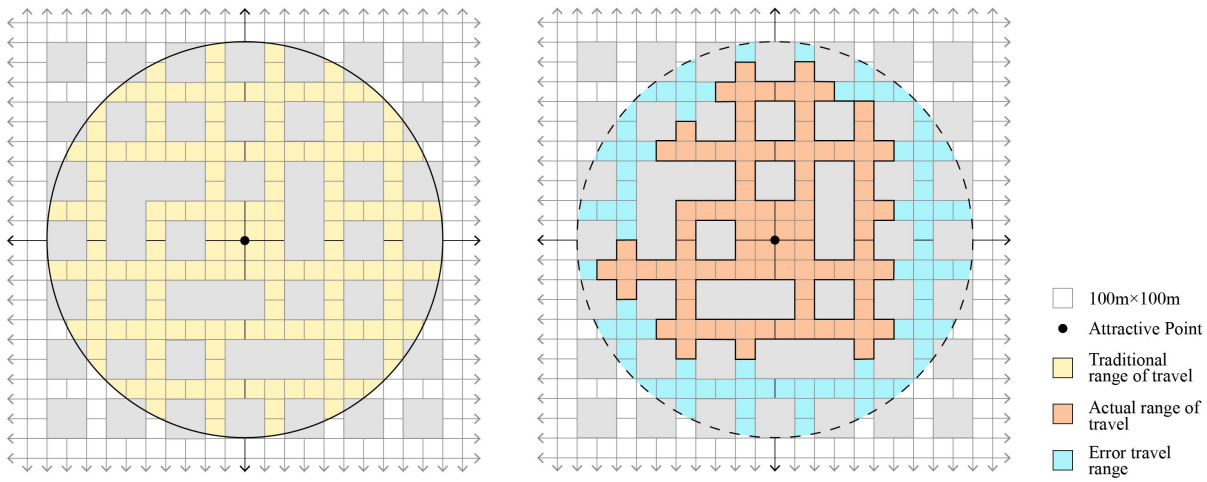


Figure 5-2: Traditional and actual range of travel

Source: Self drawn by the author

5.2.2 Create Protected Active Travel Spaces

Creation of protected active travel spaces is intended to create pleasant travel environments for active travelers that meet the basic safety needs of residents for active travel. When optimizing the active travel network, it should be based on the existing road plan of the residential area, and should be reasonably adapted according to the conditions of the road itself (such as the hierarchy and width of the road itself, the availability of footpaths and bicycle lanes) and the relationship between the roads and buildings. Clarify the relationship between active travel routes and the layout of residential roads planning, ensure that active travel space is built on the basis of current road space, emphasize important intersections and road-crossing nodes, reduce unnecessary interference of motor vehicles with active travelers, and build a travel network that is harmonious between people and vehicles.

(1) Road Space Reallocation

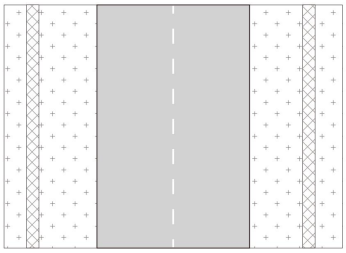
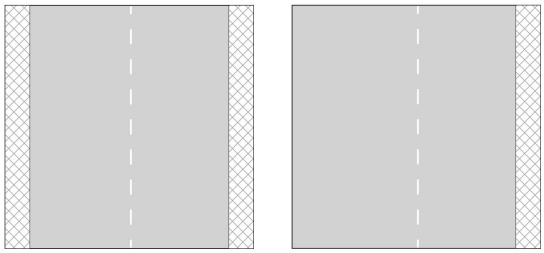
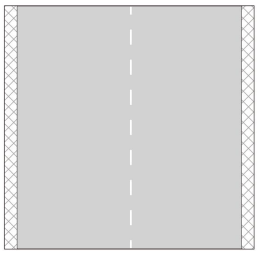
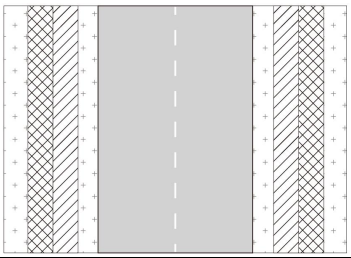
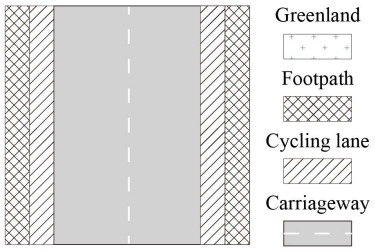
Artery and sub-artery roads in residential areas are the types of roads with the highest traffic volumes and speeds, and without space for active travel, pedestrians and cyclists are forced to share the road with cars, which poses a greater danger to people. Therefore, these types of roads could be improved by road space reallocation. For example, Calle 107, a 19-meter-wide urban road in Medellín, Colombian second largest city, has been reallocated to create a better and safer road environment that supports active travel.

Figure 5-3: Road space reallocation in Calle 107, Medellín, Colombia

Source: Reference[67]

The road space reallocation is not mechanical allocation of all residential roads for sure. As mentioned above, the range of active travel consists of two parts: the walking range and the cycling range, and the cycling range is obviously larger than the walking range, so the artery and sub-artery roads within the walking range will be equipped with segregated footpaths and cycling lanes on both sides of the road; the artery and sub-artery roads that are only in the cycling range but not in the walking range simply need to be reallocated to have cycling lanes in the road space. However, it is also important to note a special case where the roads are not wide enough to incorporate both footpaths and cycling lanes, then priority should be given to ensuring the access to footpaths.

Table 5-1: Road space reallocation for footpath and cycling lane

Road with sufficient greenland space	Road with usable footpaths (both sides/one side)	Road with unusable footpaths
Existing	Existing	Existing
		
Redesign	Redesign	
		

Source: Self drawn by the author

Different modifications can be made for different existing road conditions (see Table 5-1). For the artery and sub-artery roads with enough green space on both sides of the roads, footpaths and cycling lanes can be placed in the green space, which not only provides a greener travel environment, but also isolates some noise and hazardous gases from motorized vehicles with the plants next to the paths. For the artery and sub-artery roads that already have comfortable

footpaths on both sides, only cycling lanes should be added; if only one footpath is available, another footpath should be added. Although some roads have footpaths on both sides that are not wide enough for residents to walk, they can be widened if possible, or if there are no conditions for widening, such as when road trees are located on the footpaths, the space in the carriageways can be used to allocate space for active travel.

If there is space left after the first reallocation, the road space can be reallocated twice to further reduce the space of the carriageways and parking lanes. The space gained can be used as new green space, which can be modified later in conjunction with supporting facilities and landscaping, such as adding seating, landscaping sketches and public space with activities.

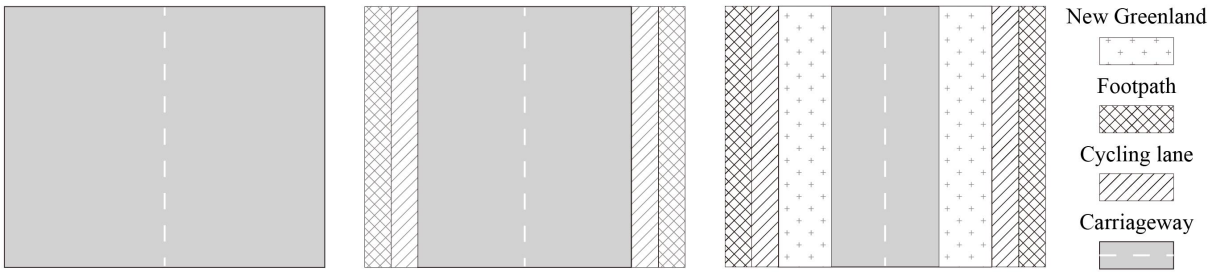


Figure 5-4: Second reallocation for new green space

Source: Self drawn by the author

While reallocating road space, the widths of the new footpaths and cycling lanes themselves should also meet the basic needs of people. If the footpaths and cycling lanes are too narrow to meet the needs of people commuting, the active travelers will be forced to walk up to the carriageways to share the space with cars, resulting in a potential safety hazard. Therefore, the minimum width of footpath should not be less than 1.5 meters, which means that it can meet the needs of two people passing side by side, and the desired width not less than 2 meters. The limit width of a cycling lane should not be less than 2 meters, and the desired width not less than 2.5 meters. At the same time, as cycling lanes are mostly used as non-motorized paths in China, where there are not only bicycles but also electric bicycles with relatively high speeds,

it is desirable to provide physical separation between the footpaths and cycling lanes in some cases, such as busy commuter routes, e.g., with green belts, curbs, elevation differences, or materials. For vehicular space, the width of the carriageway is 3.5 meters with buses running, or 3 meters if no buses are running; the width of the perpendicular parking lane is 5 meters, and the width of the side way parking lane is 2.5 meters.

Table 5-2: Road space reallocation width standards

Footpath width		Cycling lane width		Carriageway width	
Minimal	Desired	Minimal	Desired	Bus running	No buses
1.5m	⩾2.0m	2.0m	⩾2.5m	3.5m	3.0m

Segregation measures are also provided between cycling lanes and carriageways, either in the form of green belts if there is enough space, or in the form of bollards if there is not enough space, with bollards spaced 1.5 meters apart, as overly dense bollards can form barriers to crossing the road and reduce the directness of active travel.

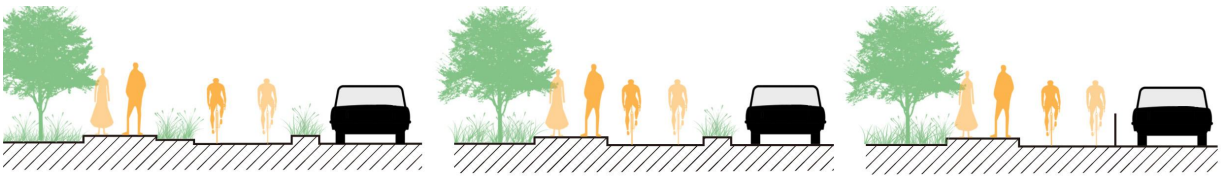


Figure 5-5: Cross section of active travel paths

Source: Self drawn by the author

Road junctions are intersections of two or more arterial roads where human and vehicular activities are more intensive. Current junctions designs focus much of their attention on motorized traffic and relatively little on active transportation. This makes it easy for slow active transportation to conflict with fast motorized traffic, and it is also a place where the probability of traffic accidents for active travelers is higher. The design of junctions should fully consider the interests of various road users, and should fully balance the needs of walking, cycling and motorized traffic to ensure the safety and convenience of active travelers. For example, in Bogota, the capital of Colombia, the staff of the local transportation bureau

used colorful paintings to increase the travel space for pedestrians and cyclists, prompting vehicles to travel at safer speeds; a Dutch-style roundabout was introduced in Cambridge, where the space for human and vehicles is differentiated by paving materials and greenery, with pedestrians, bicycles and cars going their own way to avoid people-vehicle conflicts.

Figure 5-6: Roundabout in Bogotá

Source: https://twitter.com/JSadikKhan/status/1179506047909801984/photo/1

Figure 5-7: Dutch style roundabout in Cambridge, UK

Source: Reference[39]

(2) Utilize Non-motorized Traffic Routes

Non-motorized traffic routes away from the main roads can form an important part of the active travel space, such as health trails and cycling lanes in parks and greenways along the lakes or rivers. They are attractive to those who prefer to avoid motorized traffic, not only for a safe travel environment, but also the landscape along the lakes can also provide a good visual experience for walking and cycling journeys.

Figure 5-8: Signage in the entrance of non-motorized traffic routes

Source: Reference[56]

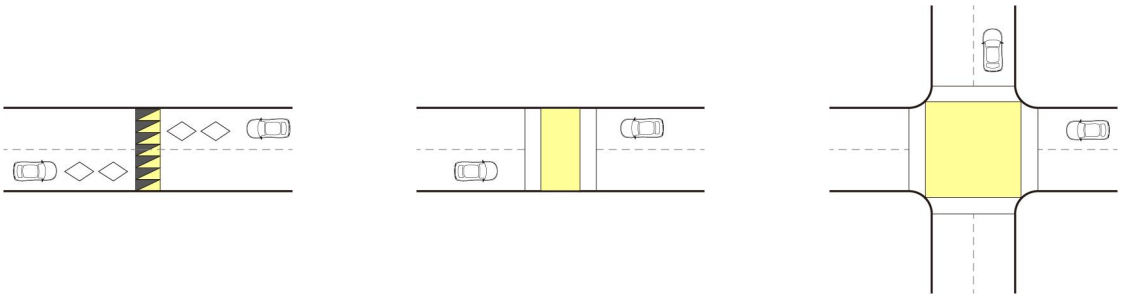
In order to realize the full potential of non-motorized traffic routes, they also need to be optimized and maintained at a high quality, particularly in terms of accessibility, pavement width and materials, and lighting. For accessibility, they should be integrated with the wider travel network, with clear signage in the immediate area and appropriate connections between non-motorized traffic routes and adjacent roads (see Figure 5-8). The quality of the surfaces affects the comfort of active travel, and smooth, level solid surfaces such as asphalt and permeable brick provide the best conditions for active travel. Similarly, footpaths and cycling lanes in non-motorized traffic routes should meet the minimum width standards noted above.

(3) Introduce Traffic Calming Measures

In addition to the two approaches mentioned above, traffic calming measures can be introduced on a localized basis, and the calming measures of roads is mainly aimed at urban and residential roads with motorized traffic, where certain measures are taken to protect the safety of pedestrians and cyclists. Traffic calming measures are divided into two aspects: flow control and speed control. Flow control is mainly used to protect the road environment by cutting down and diverting traffic flow, such as road closure. However, special attention should be paid to the fact that the flow control will not appear in Chapter 6 next, the traffic calming measures taken on the residential roads are still speed control as the first priority, as far as possible to ensure that the roads through but not smooth. Speed control is mainly through the geometric alignment of the road to limit the speed of vehicles, specific measures include vertical raising, horizontal bending and horizontal shrinking.

Vertical raising speed control measures involve raising a section of the carriageway to achieve speed reduction. Typical measures include speed humps, speed tables, and raised intersections. A speed hump is an arched raised area across a carriageway that is relatively easy for bicycles to pass through and can effectively reduce speed. A speed table is a longitudinally elongated, flat-topped speed hump. Constructed of brick or textured material, its flat top is wide enough to accommodate the stopping of a passenger vehicle. It is suitable for locations where speed control is required and comfort for large vehicles is a concern. Raised intersections are

intersections where the entire intersection is raised with bricks or other materials to make it easier for drivers to recognize the crosswalk and slow down in advance by changing the height of the intersection, and are suitable for intersections where major roads converge.



Speed humps Speed tables Raised intersections

Figure 5-9: Vertical raising speed control measures

Source: Self drawn by the author

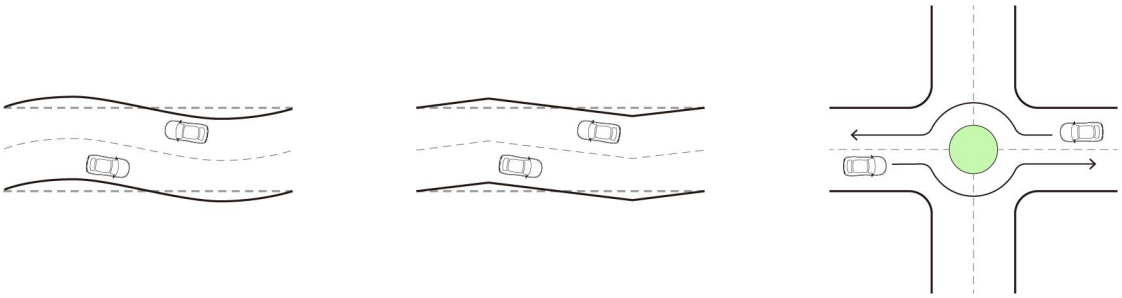
From some overseas practices, vertical raising measures can be designed in conjunction with crossings. As shown in Figure 5-10 below, vertically raised crossings have been introduced in Australian local roads and are referred to as active travel priority crossings.

Figure 5-10: Active travel priority crossings

Source: Reference[38]

Horizontal bending speed control measures involve the use of alterations to traditional straight-line travel to reduce speeds. Typical measures include curve bending, zigzag bending, and mini roundabouts. Curve and zigzag carriageway refers to the purpose of slowing down traffic by intentionally transforming the roadway into curved and bending shapes, forcing vehicles to constantly change from side to side. Mini roundabouts are circular traffic islands

set in the center of an intersection along which vehicles travel in a counterclockwise circle. They are generally used within the urban residential area, especially in locations where traffic volumes are low and the focus is on speed reduction and traffic safety.



Curve bending Zigzag bending Mini roundabouts

Figure 5-11: Horizontal bending speed control measures

Source: Self drawn by the author

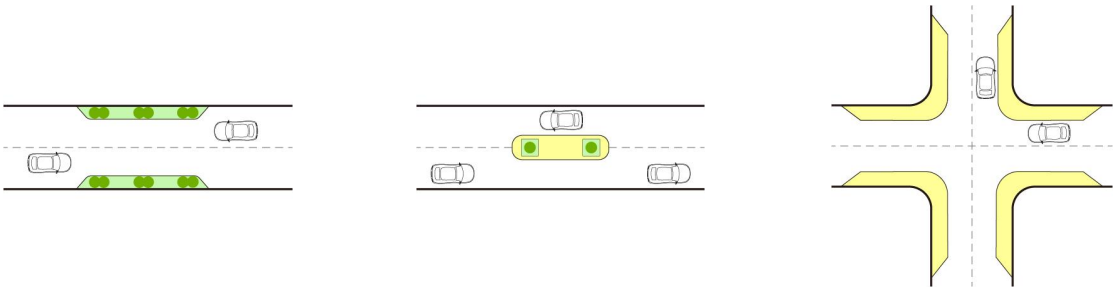
Horizontal shrinking speed control measures refer to the use of shorter road cross-section widths to reduce vehicle speeds. Typical measures include pinch points, center islands and curb extensions.

Pinch point is in the pedestrian crossing, through the widening of footpaths or green belts to extend the curb, in order to narrow the carriageway cross-section, usually divided into single-way narrowing and two-way narrowing, with crosswalk markings, namely the "safety crosswalk". It is used in locations where speed limits are required and there is no shortage of on-road parking.

Center island is set up in the road median raised center traffic island, in order to narrow the two sides of the carriageway, generally used in two-way roads, the center island for green to improve visual aesthetics. It is applicable at entrances of residential area and locations where roads are wider and pedestrian crossings take longer.

Curb extensions refer to the extension of the curb on both sides of the carriageway at an intersection to the center, thereby reducing the inlet width of the intersection. By reducing the distance pedestrians have to cross the intersection and the raised traffic island makes it easier

for motor vehicles to pay attention to pedestrians, it is a kind of "pedestrianized" intersection. It is suitable for locations where pedestrian activity is high and where the use of vertical speed control measures is not appropriate to generate noise.



Pinch points Center islands Curb extensions

Figure 5-12: Horizontal shrinking speed control measures

Source: Self drawn by the author

Different calming measures have their own advantages and disadvantages, and a combination of several calming measures is usually required to achieve the purpose of reducing vehicle speed. The combination of application methods include: the same section of the road can be used vertically raising, horizontal bending and horizontal shrinking simultaneously, can also be set up in conjunction with road facilities and landscaping. In addition, it is also necessary to set up separately according to the location of the calming measures in the residential area, in which the intersection connecting with the outside of the zone should be set up with a weaker deceleration effect, to avoid the safety problems caused by the instantaneous deceleration of the vehicles from outside the zone when they turn into the zone. When in the center of the residential area, stronger measures can be installed, such as speed humps, speed tables and mini roundabouts.

(4) Use Textured Pavement Materials

Group and house roads with low traffic volumes and low speeds do not require dedicated footpaths and cycling lanes and can be paved with textured materials such as block paving. The textured paving provides a visual reminder that this section of the carriageway is a low speed environment and can be effective in helping to further reduce motor vehicle speeds. For

example, in a residential block in Bristol, UK, the surface of the carriageway between houses is paved with block paving and red asphalt to remind drivers that they are entering a residential area and need to slow down for pedestrians and cyclists. Similarly, in German home zones, in addition to the use of block paving, traffic calming measures such as speed tables have been introduced to further limit the speed of motorized vehicles and create a safer residential environment for active travelers.

Textured surface in British local roads

Traffic calming in German home zone

Figure 5-13: Examples of residential roads with textured pavement

Source: Reference[56]

5.2.3 Shorten Active Travel Distance and Time

(1) Overcome Natural Barriers

Natural barriers in active travel routes reduce the connectivity of travel routes and make them inefficient and difficult to use. Common natural barriers in residential areas are categorized as mountain barriers and water barriers.

Mountain barriers are mainly reflected in the distribution of height differences in road space. Some residential quarters in the residential areas are distributed on mountains with large changes in topography, forming residential roads that climb uphill and create barriers to active travel; another pattern that produces mountain barriers is the formation of cul-de-sac, which is impossible to pass through on foot or by bicycle. These types of barriers can be resolved through tunnels, steps or ramps after assessing the environmental condition of the terrain.

Water barriers refer to the blockage of active travel by natural or man-made bodies of water, and are more common in residential roads adjacent to rivers and lakes. In the absence of river crossing infrastructure such as bridges, active travel is inevitably blocked; temporary water body blockages are also formed, such as those created by heavy rainfall or flooding.

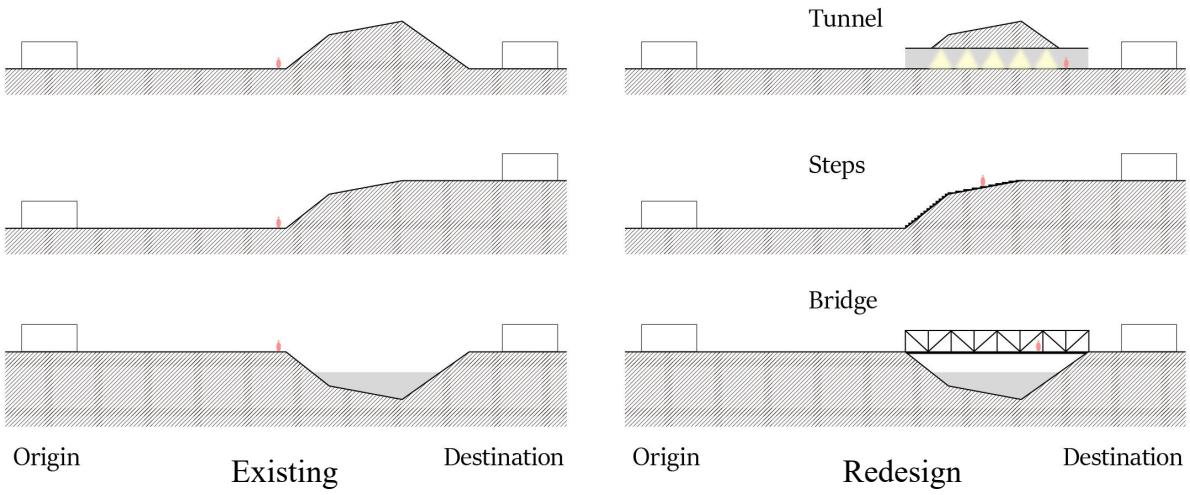


Figure 5-14: Overcome natural barriers

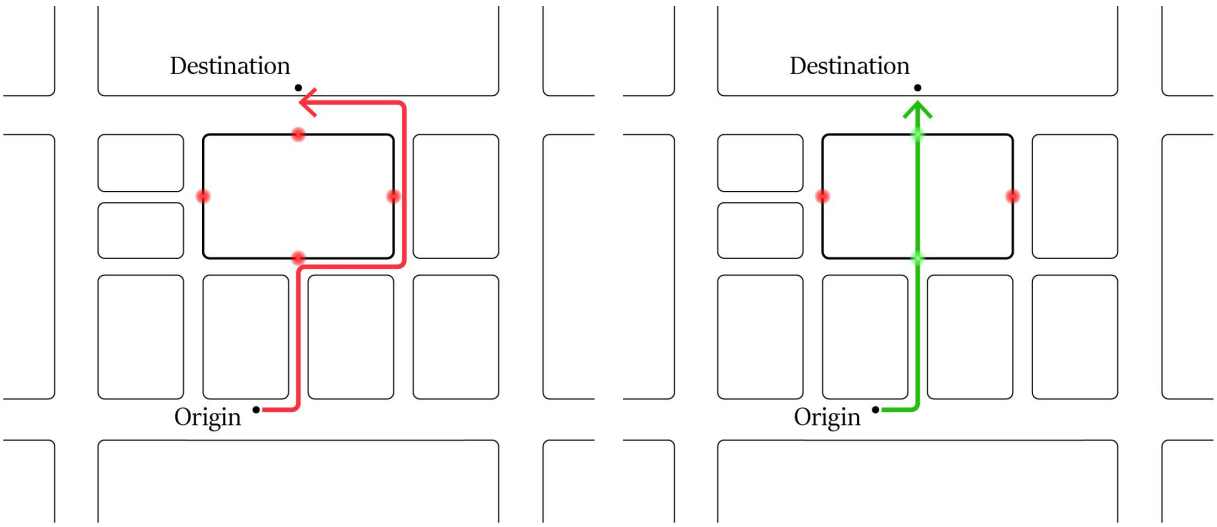
Source: Self drawn by the author

(2) Opening of Closed Residential Quarters

In addition to natural barriers, over-scaled closed residential quarters are themselves artificial barriers to active travel. The road system in each closed quarter is independent and separate, and is only used by the residents of this quarter, resulting in a waste of road space. If such quarters are in the way of other residents' active travel routes, it will be difficult to avoid increasing the travel distance. In February 2016, the Central Committee of CPC and the State Council issued “Several Opinions on Further Strengthening the Management of Urban Planning and Construction”, which clearly states that completed residential quarters should be gradually opened up to realize the publicization of internal roads, solve the problem of the layout of the traffic road network, and promote the economical use of land[68].

The opening of residential quarters does not target all closed residential quarters in Clifford Estates or all entrances in closed quarters for sure. The open entrances are limited to those that

can greatly reduce the distance of active travel for residents, as shown in Figure 5-15, and the opening is only for all residents living in Clifford Estates and does not involve outsiders.



Existing (strict access control or closed gates) Redesign (Moderate opening)

Figure 5-15: Opening of closed residential quarters

Source: Self drawn by the author

(3) Add Crossings and Shorten Crossing Distance

The artery and sub-artery roads with high traffic volumes are also one of the artificial barriers to active travelers in residential roads. On road sections with high human and vehicular traffic, the density of crossing should be increased where appropriate. Although footpaths and cycling lanes are provided on both sides of the roads, the actual travel routes are parallel to the traffic flow when used by pedestrians and cyclists on both sides.

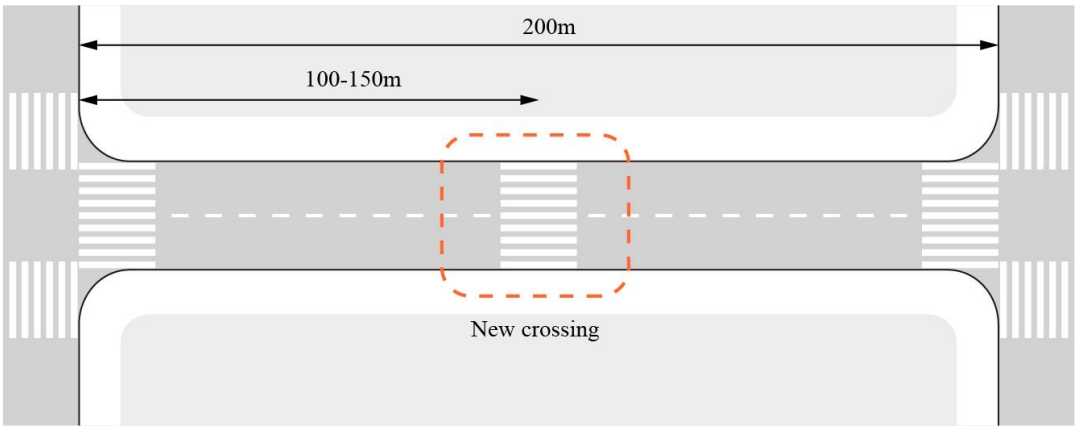
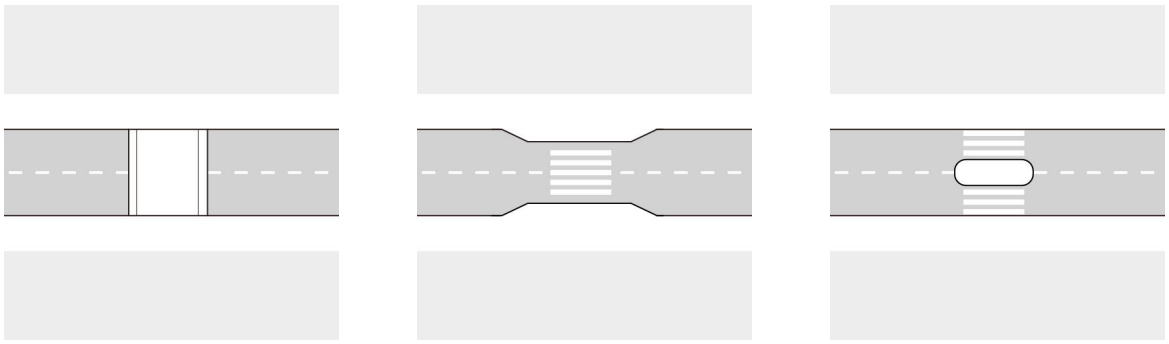


Figure 5-16: Add new crossing

Source: Self drawn by the author

For such cases, additional crossings should be provided to connect parallel walking and cycling routes. Road crossings can be combined with entrances to closed residential quarters and travel destinations, and on-road crossings should also be provided in roads with high human traffic. The spacing of general road crossing should be controlled within 100 meters, with a maximum of 150 meters.

Furthermore, added crossings can be designed with the traffic calming measures mentioned above. For example, raised speed tables can be used as pedestrian crossings, where vehicles are forced to reduce their speed to avoid pedestrians and cyclists as they approach the tables, which in turn shortens the time it takes for active travelers to cross the road. This is also true for pinch points and center islands, both of which force motorized vehicles to slow down by shrinking the carriageways. Meanwhile the shrunk carriageways create additional space for footpaths, which also further shortens the distance people have to across the road and reduces the amount of time residents have to spend. New added crossings can also be painted ground markings to alert drivers to avoid pedestrians and cyclists.



New crossing combined with speed tables | New crossing combined with pinch points | New crossing combined with center islands

Figure 5-17: New crossing combined with traffic calming measures

Source: Self drawn by the author

(4) Introduce Floating Bus Stops

Floating bus stops are a design concept for public transportation infrastructure that involves the complete separation of bus lanes from cycling lanes and carriageways. In contrast to the

traditional method of loading and unloading buses directly on the curb, floating bus stops are located on raised platforms or islands between the bus lanes and the adjacent cycling lanes or carriageways, and are therefore also known as "bus harbors". The so-called bus harbor is a lane behind the bus stop for bicycle to ride, so that cyclist can go around to the back of the bus stop when the bus enters the station, which reduces the need for emergency braking and restarting, and avoids mixing with motor vehicles in the same direction, which improves the safety and convenience of cycling. At the same time, when passengers get on and off the bus, they can also temporarily move away from the approaching bicycle traffic, reducing the interference between each other, thus reducing the risk of accidents and improving the overall safety of the road. However, it is inevitable that the optimization of bus stops needs to take up a certain amount of green space, so it should be considered with road space reallocation simultaneously.

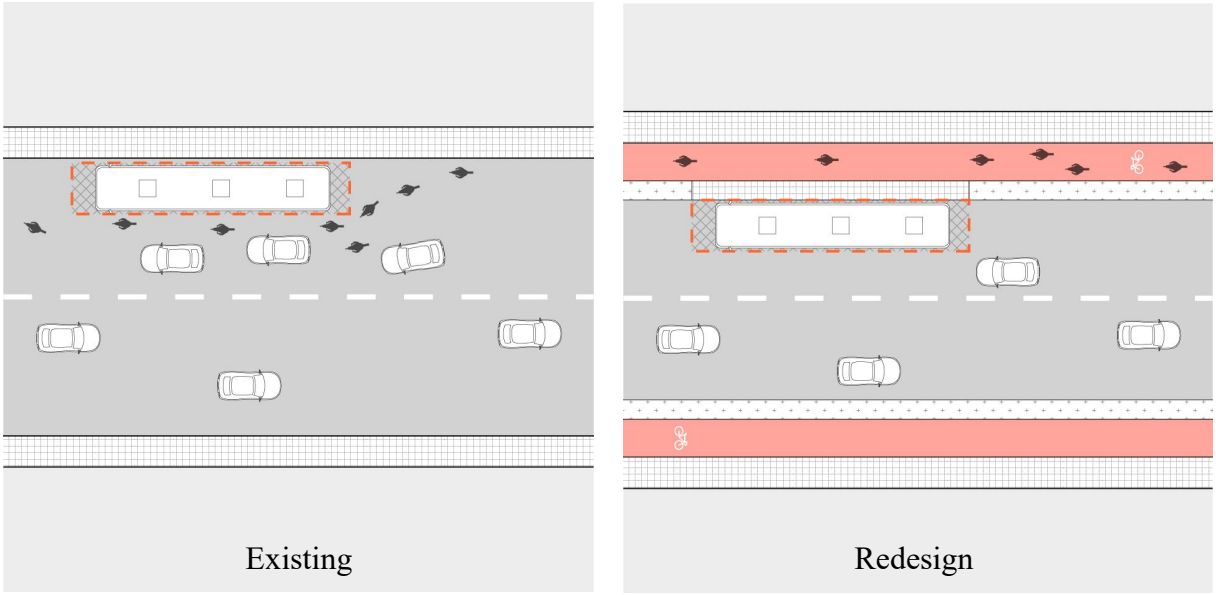


Figure 5-18: The change to bus stops

Source: Self drawn by the author

This design concept has been corroborated by relevant practices. According to a report by Beijing Youth Daily in July 2016, given that there are few floating bus stops on the Third Ring Auxiliary Road in Beijing, and in order to effectively address the interplay between non-motorized vehicles and buses entering the bus stops, Beijing transportation department

has indicated that it plans to convert seven bus stops into floating bus stops, in in an effort to reduce the conflicts between different road users[69]. Therefore, it should also be appropriate to introduce floating bus stops on residential roads with high traffic volumes and speeds and potential for upgrading.

5.2.4 Improve Supporting Facilities of Roads Space

The supporting facilities of the roads such as seats, road lights, road signs are not large in scale, but they are directly linked to the active travel experience, and they directly affect the residents' satisfaction with the active travel environment in terms of function, and reinforce the impression of the road space in details. Therefore, the supporting facilities of roads are important parts of residential roads optimization for active travel.

As the physical elements in the road spaces, the supporting facilities have a wide range of contents and refer to various facilities other than buildings, structures, and roads, such as those used for traffic, rest, directions, and lighting. This section according to the function of the supporting facilities will be divided into the following categories, as shown in Table 5-3. It should be noted that the functions of these facilities are not always independent, and some of the functions of the facilities overlap, for example, traffic facilities can also have rest function.

Table 5-3: Classification and characteristics of road supporting facilities

Categories	Names	Function
Traffic facilities	Shared bikes parking	Promote cycling travel
	Semi-closed bus shelter	Provision of sheltered space
Rest facilities	Seats	Meeting the need for rest
Signage facilities	Roadside maps	Provide way finding aids
	Road text marks & Traffic signs	Warnings for vehicles
Lighting facilities	Road lamps	Ensure safety at night

Source: Self edited by the author

(1) Traffic facilities

Improvements to the traffic facilities include the placement of shared bike parking space and modifications to bus stops, the former of which has the transportation function of further enhancing residents' ability to travel by bicycle, and the latter of which can provide sheltered space for active travelers at moments of need.

Cycling, as an important part of active travel, is a prerequisite and necessary condition for encouraging residents to use this mode of transportation to get around by first increasing the number of bicycles in residential areas. Bicycle sharing operates on a time-sharing model that is convenient and affordable. In the past few years, while the "dockless" concept of parking has brought great convenience to residents, it has also led to a greater prevalence of shared bicycles occupying footpaths and cycling lanes, making the maintenance of residential roads more difficult. Therefore, the placement of shared bicycles in residential roads should be "staked" parking spots (as shown in Figure 5-19) next to the bicycle lanes on the roads to avoid the above situation.

As Guangzhou City is located in Lingnan Area, the summer heat and rain, and active travel is mostly walking and cycling, by the impact of inclement weather than by vehicular travel. Therefore, where conditions permit, the existing bus stops can be improved and optimized to a semi-closed form. Semi-enclosed refers to the addition of a top interface and three side interfaces to open-air bus stops, such as the semi-enclosed bus shelter on Bedford Avenue in Brooklyn, New York, shown in Figure 5-20 below. The roof interface is designed to not only insulate waiting passengers from heavy rain and sunlight, but also to provide a temporary shelter for active travelers during heavy rainfall. The side interfaces provide partial protection from the slanting wind and rain. The new bus shelters are also equipped with seats for the elderly, children and other vulnerable groups to rest while walking. Besides, modifications to the form of the bus waiting facilities could be made in conjunction with the floating bus stops.

Figure 5-19: Shared bikes parking

Source: https://www.freepik.com/free-photo/rent-bike-city_1004301.htm#&position=0&from_view=search&track=ais&uuid=09360cc5-de85-4077-b785-b066f527d254

Figure 5-20: Semi-closed bus shelter

Source: https://www.nycstreetdesign.info/furniture/bus-stop-shelter

(2) Rest facilities

If the length of the road is long, then should be set rest space for a short break according to the actual situation, research results show that the length of human walking fatigue between 400 and 500 meters, so every four or five hundred meters in the case of not affecting the pedestrian traffic to place some rest facilities. The creation of rest space is relatively simple, through the installation of additional seats, or in the case of sufficient space into the public space nodes, supplemented by landscaping and greening, the formation of a miniature comfortable and cozy independent rest space. In terms of the seat form, it can be shaped with recognizable and interesting seat shape, such as combining the seat with floor lamps and flower pools to form a novel and creative feature landscape. Adding rain shelter and sunshade for the seats could meet the diverse needs of people.

Seat with greenery

Landscape seating

Seat with sunshade

Figure 5-21: Seats with landscaping features

https://logic-bespoke.com/logic-products/plano-integrated-seating/

https://www.pinterest.com/pin/161918549095972778/

https://www.pinterest.com/pin/225186855613750/

(3) Signage facilities

Signage facilities include ground marking patterns, traffic signs and way finding aids. As a medium of public information, signage facilities provide guidance to people in traveling and reflect their indispensable and important value. The information to be conveyed by the signage is generally expressed through text, illustration, marking and other ways, the text expresses the meaning most accurately, the effect of marking is the most intuitive, strong visual impact, the illustration is more suitable for the expression of the current location. In the design of these ways can be utilized comprehensively, to play their respective advantages, can make active travelers easier to understand the information of the sign, to avoid getting lost on the way to avoid travel, resulting in a waste of physical energy.

Road text marks

Traffic signs

Roadside maps

Figure 5-22: Road signage facilities

https://annastarkey.medium.com/what-does-slow-mean-to-you-d83e0e8de9d2

https://www.freepik.com/free-vector/traffic-signs_800037.=4f30cb79-bd34-482b-a970-018a2

https://www.gov.wales/sites/default/files/publications/2022-01/active-travel-act-guidance.pdf

(4) Lighting facilities

Lighting facilities primarily refer to a variety of yard and road lamps, are important road furniture in travel spaces. Good lighting space is essential for the personal safety of residents, creating lively, attractive spaces at night and preventing crime. Therefore, dedicated lighting for pedestrians and cyclists should be provided on all roads in residential roads, ensuring appropriate levels of brightness and spacing and avoiding dark spots between light sources. And light poles and lamps should never form barriers to travel routes.

In terms of height, the standard light poles height for footpaths and cycling lanes is 4.5 to 6 meters. The lamp posts on the roadbed vary depending on the type of road and land use. In most cases, the standard height of narrow roads in residential, commercial, and historical environments is between 8 and 10 meters. A high pole between 10 and 12 meters is usually suitable for wider roads in commercial or industrial areas.

In terms of spacing, the distance between two light poles should be approximately 2.5 to 3 times the height of the light poles. Shorter light poles should be installed at closer intervals to avoid dark areas. In addition, the type of light source for lighting facilities will also determine the ideal height and spacing, and the diameter of the light cone should be roughly the same as the height of the facility from the ground[67].

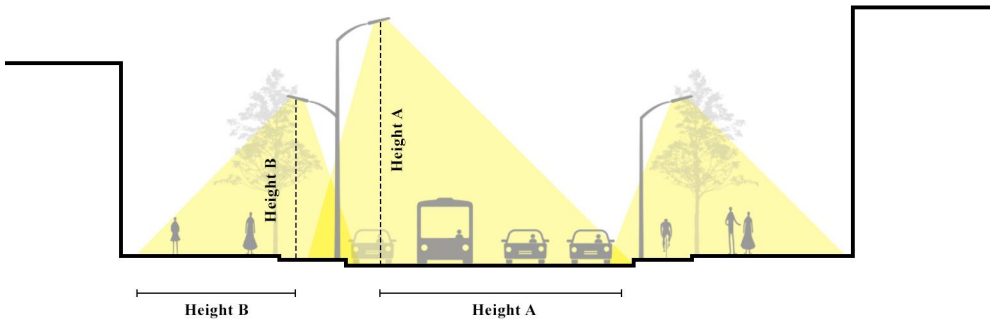


Figure 5-23: Lighting for pedestrians and cyclists

Source: Self drawn by the author

5.2.5 Enhance Visual Diversity of Roads Space

Compared with vehicular travel, active travel is relatively slower, and people can easily pay attention to the fine features of their surroundings, thus obtaining more environmental information and rich experiences. People will be subjected to a variety of sensory stimuli, including visual, auditory, olfactory and tactile senses while walking or riding. Since most of the effects of the environment on people are realized through vision, visual perception is the most important of the above sensory stimuli. Improving the visual diversity of the roads will bring a better sensory experience to the active travelers, thus further strengthening the healthy habit in their daily life.

(1) Create Public Spaces with Activities

Although the active travel discussed in this thesis is only functional travel and does not involve residents' recreational travel, the public space with activity in residential roads can effectively promote human interaction, enhance the place characteristics of road spaces. As can be seen from the previous analysis, there are still large areas of green space on both sides of the roads that have not yet been utilized in Clifford Estates; therefore, one of the design measures to improve the visual diversity of during the trips of active travel is to optimize the design of the unused green space on both sides of the roads and to increase the types and scales of the activity spaces in residential roads. Such design measures have been discussed in Chapter 3, unused green area was transformed into outdoor cinema and children's playground in Lea Bridge Road, Waltham Forest.

The inclusion of new public spaces will follow the principle of multi-level, creating public spaces with rich spatial levels according to the different locations of the public spaces at house level, group level and settlement level, which can maximize the satisfaction of residents' requirements for leisure, recreation, communication and other activities. Besides, after an on-site investigation to Clifford Estates, the outdoor activity spaces in the entire residential area are mostly used by the elderly and adults, and there is a lack of children's playgrounds. Therefore, the functional complexity of the activity space should also be improved to provide the possibility for people of all ages to use the activity space; in addition, taking into account the need for adults to take care of children, the activity space for adults can be placed in close proximity to the playground for children.

For example, the design team Saturday&Sunday transformed the unused green space with 440m^2 into a parent-child playground in Lane 491, Xiangyin Road, Shanghai. According to the characteristics of children of different age groups, the space is divided into six areas: entrance area, play area under six, play area above six, vegetable garden, parent rest area, and garbage classification area[70].

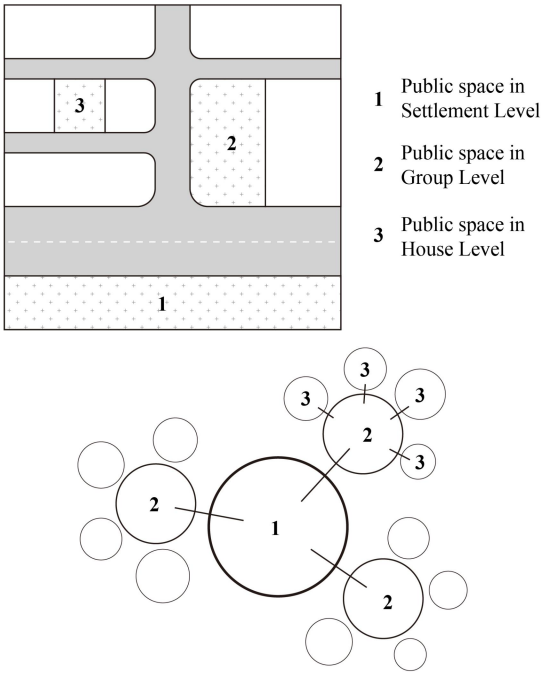


Figure 5-24: Multi-level public spaces

Source: Self drawn by the author

Figure 5-25: Elephant Utopia, Shanghai

Source: Reference[70]

(2) Upgrade Pavement Materials

Road pavement design is an indispensable part of in residential roads design for active travel, and the different attributes of the paving materials and the form of the paving have a certain influence on the expression of the effect of the active travel environment. In the design of pavement of residential roads, the permeable bricks should be applied to the footpaths. Brick is a kind of paving material that can be formed through artificial transformation with various forms. Using in the walking space not only can form patterns through color pattern, but also the permeability can reduce the accumulation of water in the footpaths, and avoid pedestrians from slipping in the rainy days.

In addition, natural wood with good permeability give people a sense of nature, because the unique natural texture can soothe the nerves. It can be combined with the existing important landscape nodes in the residential area for paving design. Parking space should be paved with permeable grassblocks to weaken the coldness of motorized space and increase green space. Permeable concrete should be used in the choice of paving materials for cycling lanes,

because it has a variety of color matching scheme, can achieve different environments and personalities required by the decorative style.

Permeable bricks Woods Permeable grassblocks Permeable concretes

Figure 5-26: Diverse pavement materials

Source: https://s.shengyibang.com/shop/48067/home.html, http://www.bjtylh8.com/tingyuanlvhua/tingyuanlvhua229.html https://www.smartstone.co.za/paving-applications/driveway-paving-ideas/permeable-grassblocks/, http://xinpingjz.com/product/2.html

Due to the physical characteristics of permeable concrete, different color contrasts can be achieved, so cycling lanes can be highlighted with bright colors. Colored cycling lanes are not mandatory, but colored pavement can help cyclists to follow the correct route and to keep themselves in the proper position in the cycling lane. In the mean time, it also helps to alert pedestrians and drivers to watch out for cyclists and avoid conflicts with them. Normally, colored cycling lanes are available in red, blue and green, which can be mixed and matched or the same color can be used throughout the whole residential area for overall harmony.

Figure 5-27: Colored cycling lanes

Source: https://climbfinder.com/en/climbs/amersfoortse-berg-doctor-abraham-kuyperlaan https://assets.publishing.service.gov.uk/media/5ffa1f96d3bf7f65d9e35825/cycle-infrastructure-design-ltn-1-20.pdf

In addition to using the colors of the materials themselves to enhance visual diversity, it is also possible to add vibrancy to the roads by painting them. In August 2018, for example, the

city of Fortaleza, Brazil, launched a new 'People's City' project in Dragão do Mar. Municipal contractors and local volunteers painted 5,000 square meters in three days with bright colors and bold patterns, and used 1,000 liters of paint to improve the geometry of the roads. The projects were simple and inexpensive, and the redesigned roads are safer and have brought new life and vitality to the neighborhood.

Ciudad 2000, one of the major renovation projects, was once a piece of land centered around motorized vehicles, and specific measures were taken to transform it from a vehicle-only transit station into a small plaza for the enjoyment of the community and a playground for children. As the city's most important road, which is also the busiest and most vibrant commercial road, the removal of on-road parking, planting, adding color and arranging urban furniture were undertaken.

Figure 5-28: Road surface painting in Ciudad 2000

Source: https://www.eltiempo.com/bogota/fortaleza-brasil-ejemplo-de-urbanismo-tactico-en-america-latina-519546

https://nacto.org/program/global-focus-cities/

(3) Increase Landscaping Plants

The optimization of landscaping mainly focuses on the space visible to the eye in the road spaces, with plants on both sides of the road and next to building boundaries. In residential areas where people and vehicles coexist, the green belts on the artery and sub-artery roads formed by plants on both sides of the carriageway can reduce the interference of motorized traffic on the active travel space, effectively block dust, noise and harmful gases, and maintain the quietness and cleanliness of the active travel space. For artery and sub-artery roads

without green belts, plants next to building boundaries can also provide good shade for active travelers, while also improving the aesthetic quality of the road. In general, through the optimization of landscape planting can achieve good visual effect of the road environment.

The landscaping configuration on the artery and sub-artery roads is based on the planting structure of "trees- bush- grass". By reasonably matching different sizes of landscaping plants, the different levels of vegetation landscape to create spatial wholeness, forming a hierarchical composite ecological communities. If space permits, active travel space with a strong sense of enclosure can be created through the arrangement of plants. Vertical rows of trees can form a strong visual focus, with dense foliage plants stacked in a way that both sides of the road to form a visual barrier, guiding people's eyes to converge on the end of the road, forming a unique vista landscape. It can also be adjusted through the plant species to improve the diversity of plants in terms of color, to avoid the monotony of active travel roads space.

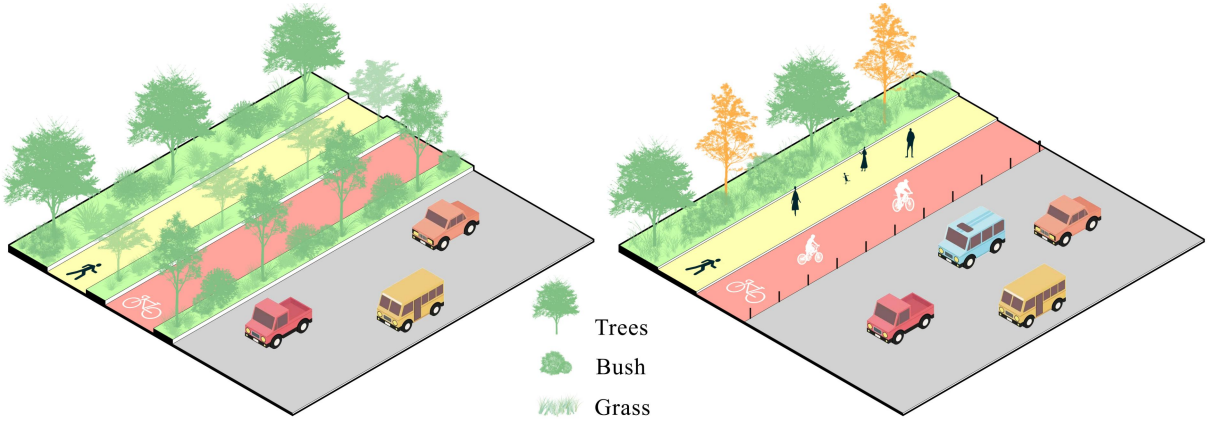


Figure 5-29: Planting structure in artery and sub-artery roads

Source: Self drawn by the author

As described above, traffic calming measures could be introduced on residential roads, some of which create additional road space while limiting motorized vehicles speed. Landscaping can therefore be designed in conjunction with some of these calming measures. For example, by planting grass and bush around speed humps, and trees on the curb extensions. These landscaping designs not only optimize the environmental quality of the road and improve the visual experience of the trips of active travel, but also serve as a visual warning to drivers,

reminding them to slow down here and giving priority to active travelers.

Figure 5-30: Landscaping plants combined with traffic calming measures

Source: Reference[67]

(4) Placement of Landscaping Sketches

Landscaping sketches play a crucial role in shaping the characteristics of the environment. The sketches that are coordinated with the color scheme of the surrounding environment can give road users a comfortable and pleasant feeling in order to achieve overall psychological balance and comfort. As the embellishment of the road environment, set up along the road landscape art works, can improve the artistic quality of the road environment, enhance the overall artistic atmosphere of the road environment. Based on the coordination between landscaping sketches and the overall artistic style of the road, artistic sculptures and lighting landscape facilities can be placed along the residential roads to enhance the detailing of the road environment space. At the same time, landscaping sketches can also be combined with the above mentioned rest facilities and activity space designed together to increase the demand for residents' activities in the public space of the road, to avoid the road due to the travel distance is too long and make people feel bored.

Sketch with rest and play Sketch with activity Sketch with light

Figure 5-31: Landscape sketches combined with supporting facilities

Source: https://www.gooood.cn/rounds-by-sports.htm?lang=en_US, https://www.pinterest.com/pin/247416573272874393/ https://www.pinterest.jp/pin/533535887117824895/

5.3 Chapter Summary

This Chapter focuses on the series of problems identified in the active travel environment in the residential roads of Clifford Estates, and combines the on-site research of Clifford Estates with the analysis of perception surveys to establish five optimization principles for residential roads that suitable for active travel, namely, available, safe, convenient, comfortable and enjoyable. Based on the five optimization principles, five optimization strategies are proposed, namely, determine active travel range, create protected active travel space, shorten active travel distance and time, improve the supporting facilities of roads and enhance the visual diversity of roads. The relationship between the principles and the strategies is generally one-to-one, but at the same time, the strategies are complex in nature and the purpose of their implementation can not be viewed uniquely. Specific implementation programs will be discussed in Chapter 6 below.

Chapter 6. Residential Roads Space Optimization Design in Clifford Estates

6.1 Determination of Design Research Scope

Before determining the design research scope of residential roads in the residential area, the range of active travel by residents needs to be clarified at first. Given that active travel is essentially a kind of physical activity, subject to the limitations of human physical ability, one kilometer has been taken as the distance threshold for walking and four kilometers as the distance threshold for cycling in subsection 5.2.1. Then the next step is to use the attraction point (travel destination) as the spatial origin, and expand the buffer zone for travel outward with a distance threshold to determine the range of active travel by residents. The design research scope studied in this section is the superposition of the active travel range of each attraction point. In addition, it should be noted that the establishment of a buffer zone does not radiate outward with a radius of distance threshold, but based on the actual walking distance of people to establish.

Based on the distribution of commercial functional groups both inside and outside of Clifford Estates, a line segment with a length of no more than one kilometer diverging outward from the entrance of each commercial group as the travel endpoint. This method broadly indicates the residential quarters that can be reached by walking from the commercial groups, and establishes walking buffer zones with the commercial groups as the core. Due to the relatively uniform distribution of commercial groups within and outside the Clifford Estates, it can be seen from the below Figure 6-1 that using commercial groups as walking attraction can cover the entire Clifford Estates. In other words, residents living in any residential quarter in Clifford Estates can reach a certain commercial functional group by walking no more than one kilometer.

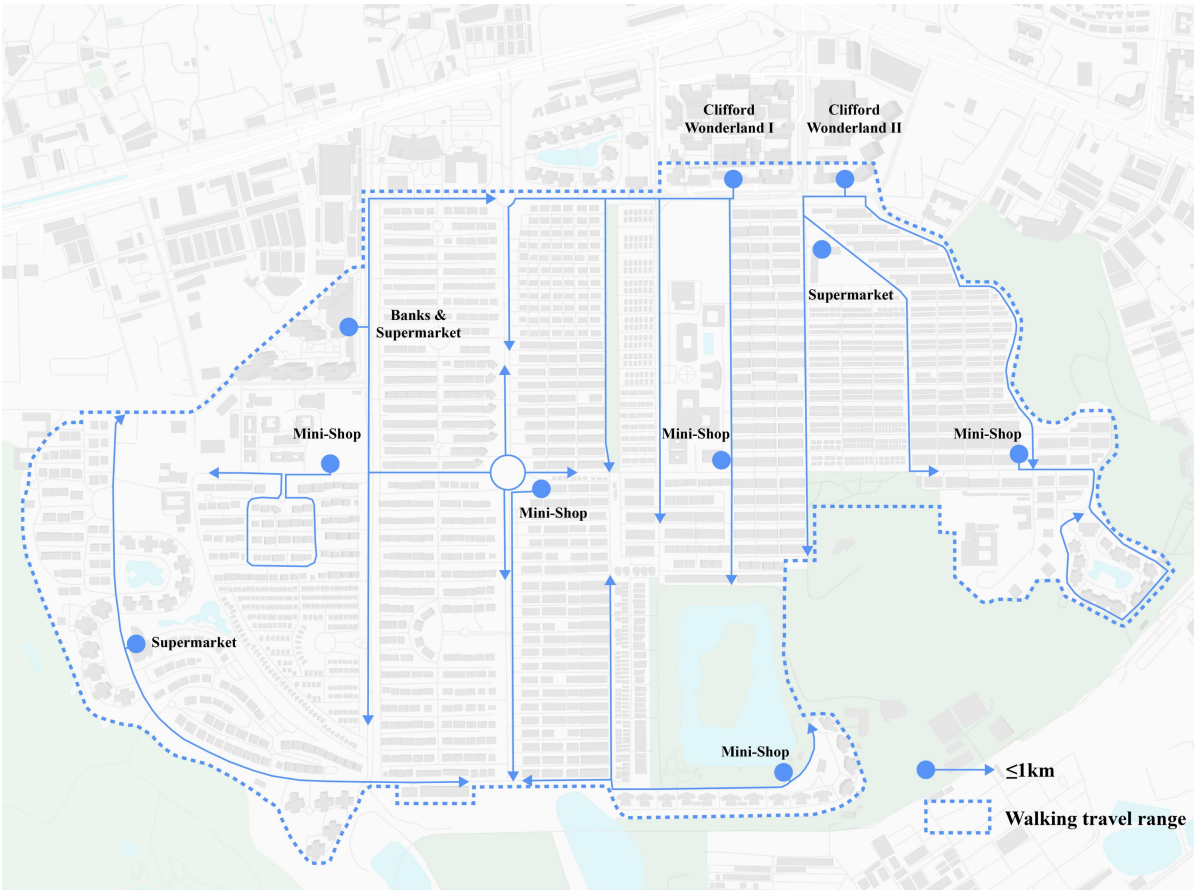


Figure 6-1: Walking travel range determined by commercial groups

Source: Self drawn by the author

In Clifford Estates, the second most accessible public servicing groups after the commercial groups are the education groups, which area more centrally located in the western, central and eastern parts of the residential area. Apart from the bus stops within the residential area, public transportation services connecting to the city center are located in the northeast corner of the residential area, and the walking range to it is relatively small, which is roughly confined to Zones A, B, and C. Similarly, the community library and Clifford Hospital are located in the southernmost and northernmost parts of residential area respectively. Therefore, the below Figure 6-2 analyzes education, healthcare, urban transportation and other functional groups in a unified manner, and it can be seen that with the above functions, residents living in Clifford Estates can access a certain type of public service within a walking distance of less than one kilometer. Residents' activities extend to the north-eastern part of the residential area, which is beyond the original property management boundary of Clifford Estates.

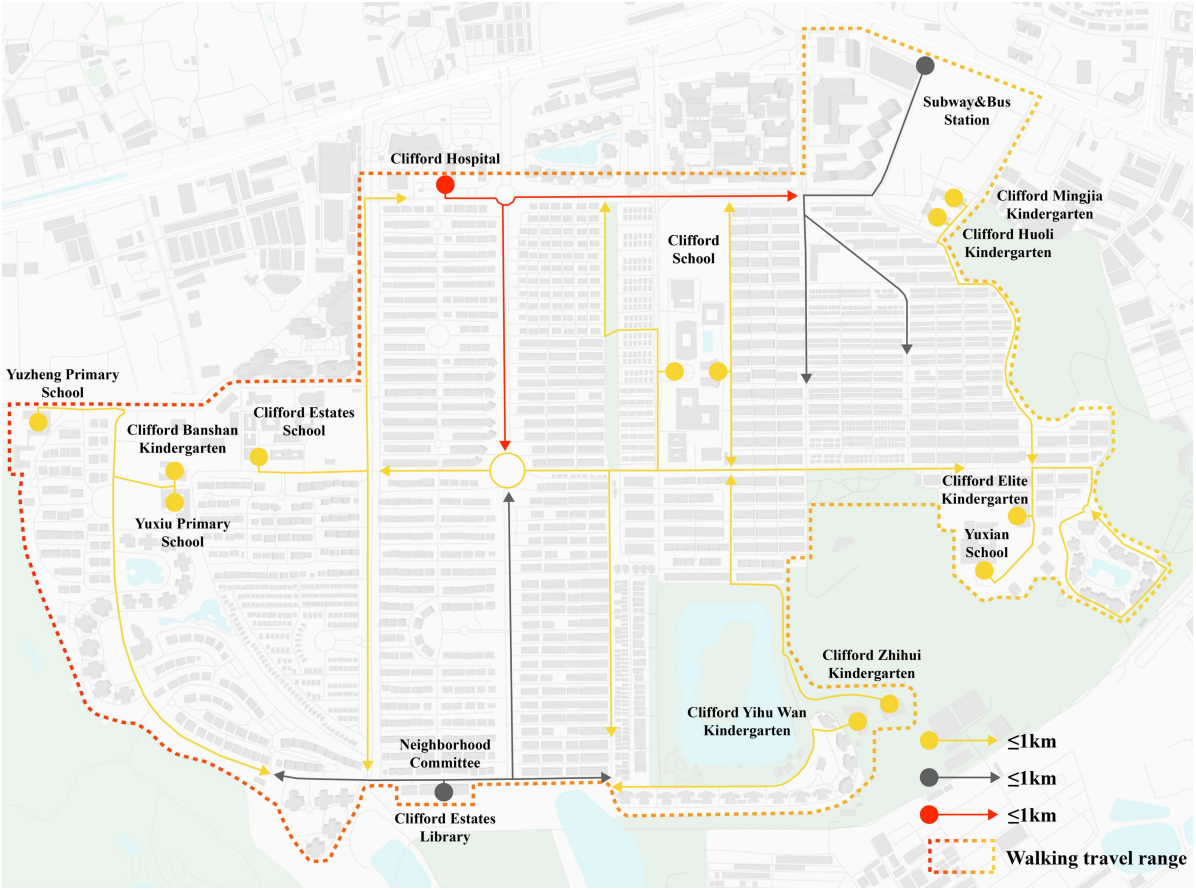


Figure 6-2: Walking travel range determined by educational medical and other functions

Source: Self drawn by the author

As the distance threshold for cycling travels is larger than that for walking, it is not difficult to deduce that the range of active travel determined by the walking distance threshold must be within the range of cycling travels. Moreover, as shown in Figure 6-1 and 6-2, the range of walking travel by residents has fully covered various public serving groups in Clifford Estates. Therefore, by taking the union of the walking travel range, the optimization design research scope of residential roads in the Clifford Estates can be derived, as shown in Figure 6-3.

6.2 Overall Optimization Design of Residential Roads Space

6.2.1 Optimization Design Objectives

The optimization design of the residential roads in Clifford Estates will follow the principles and strategies in Chapter 5 to achieve the networking of active travel paths, traffic calming of

residential roads, as well as the enhancement of road space landscaping and the implantation of new service spaces.

(1) Construction of Active Travel Network

The primary objective of optimization design of residential roads is to build a coherent, safe and convenient active travel network. The reasons for this are as follows: first, the footpaths width of residential roads as a whole is mostly difficult to support walking activities, while dedicated cycling lanes are lacking; second, the phenomenon of pedestrian-vehicle mixing is serious in residential roads, which is not able to guarantee the personal safety of all road users; third, residents on their trips of active travel will be obstructed by various aspects such as roads with high traffic flow, access control management, and topography, which will increase the travel time and detouring distance.

(2) Residential Roads Traffic Calming

Traffic flow with high speed, on the one hand, creates potential safety hazards for active travelers, making people fearful of walking or cycling and thus further deepening their dependence on motorized vehicles; on the other hand, residents are forced to stop in the face of fast vehicles when crossing the roads, which also increases the travel time. Therefore, the second objective of optimization design of residential roads is to achieve traffic calming or slower speed in residential roads, which in turn will bring about an overall harmony between people and vehicles in residential areas.

(3) Enhancement of Road Space Landscape

In view of the problems of spatial dilapidation and insufficient aesthetics in residential roads, the third objective of optimization design is to enhance the landscape of the road space. This not only helps to increase greening, purify the air, improve the environmental quality around the roads, and enhance the living comfort and quality of life of the residents; at the same time, through the integration of culture and art, it gives the road space more aesthetic attributes and a humanistic atmosphere.

(4) Implantation of New Service Spaces

When building the active travel network, the optimization design will involve the road space reallocation, thus creating new spaces. These newly created public spaces, along with existing unused spaces, can be upgraded and transformed into spaces with public services, such as children's playgrounds or outdoor cinemas, new parking spaces, and so on.

Table 6-1 below shows the design principles that each design objective satisfies, and the corresponding design strategies to achieve that objective.

Table 6-1: Relationship between objectives with principles and strategies

Objectives	Satisfied Principles	Corresponding Strategies
Construction of Active Travel Network	Coherence Safety Convenience	● Road space reallocation ● Utilization of non-motorized traffic route ● Active travel priority crossings (vertical raising in disguise) ● Overcome natural barriers (tunnel, steps, ramp, elevator, bridge) ● Opening of access control management and gates of closed residential quarters ● Pave textured pavement materials ● Introduce floating bus stops
Residential Roads Traffic Calming	Safety Convenience	● Vertical raising (speed hump, speed table, raised intersection) ● Horizontal bending (curve bending, zigzag bending, mini roundabout) ● Horizontal shrinking (pinch point, center island, curb extension) ● Add new crossings combined with traffic calming measures

(continued Table 6-1)

Enhancement of Road Space Landscape	Safety Comfort Enjoyment	● Improve lighting facility ● Add traffic facility (shared bikes parking, semi-closed bus stops) ● Add rest facility ● Improve signage facility (road text marks, traffic signs, roadside maps) ● Increase landscaping plants ● Placement of landscaping sketches ● Upgrade pavement materials (Permeable bricks, permeable grassblocks, colored permeable concrete)
Implantation of New Service Spaces	Comfort Enjoyment	● Public space with activities ● New parking space with permeable grassblocks

Source: Self edited by the author

6.2.2 Optimization Strategic Master Plan

After defining the scope of design research based on the range of active travel by residents, this subsection classifies the residential roads in the scope of design research that need to be upgraded according to the hierarchy of the roads themselves, the actual conditions, the existing problems and the potentials for upgrading as follows.

Roads of the same optimization type have similar spatial characteristics and problems, so the optimization strategies adopted will be similar, but different optimization strategies will be adopted for the upgrading of different optimization types of roads. The overall optimization objectives will be achieved by completing the upgrading of all optimization types.

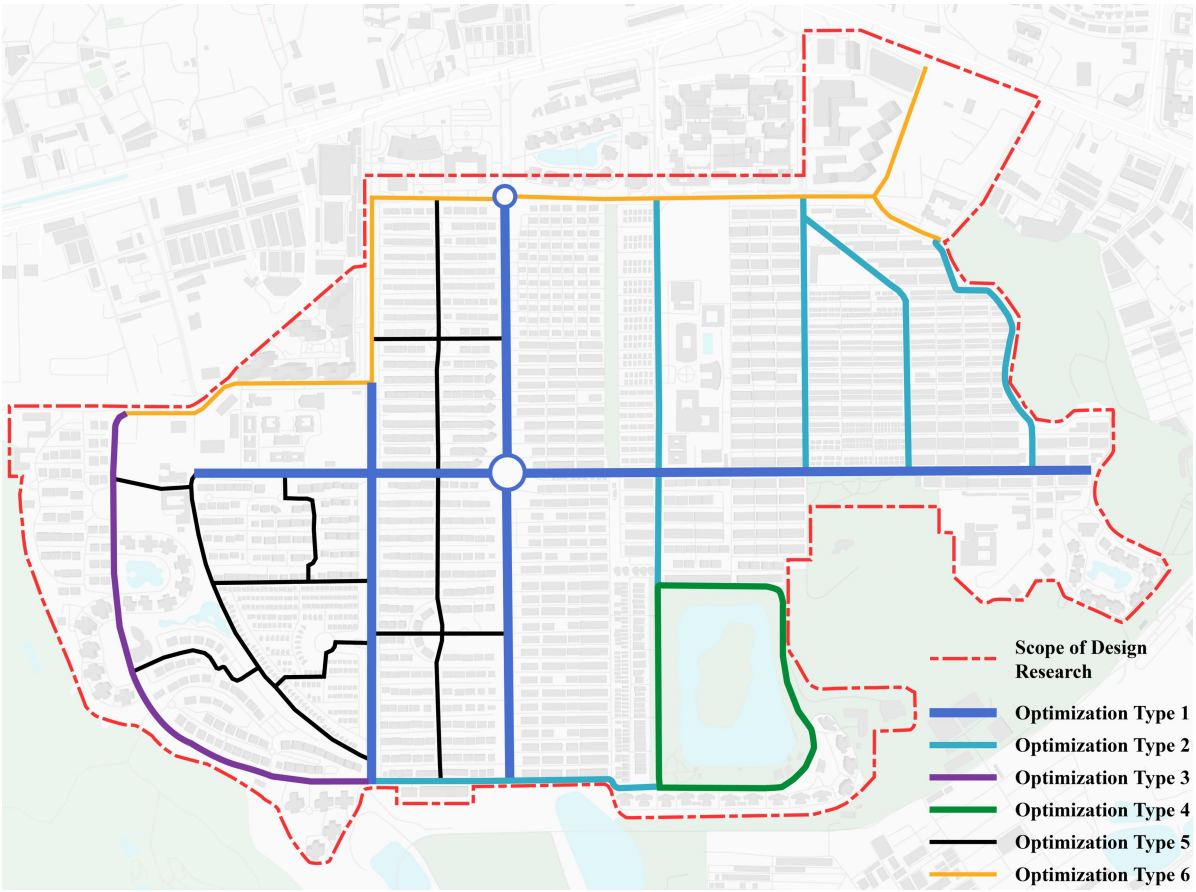


Figure 6-3: Residential roads optimization strategic master plan

Source: Self drawn by the author

(1) Optimization Type 1

Optimization Type 1 includes Clifford Avenue, Fuyi Road, Lvyi South Road and 19th Street. Among them, Clifford Avenue and Fuyi Road are connected to the main entrance of the residential area, and there are green belts for isolation in the center of the roads, which are the two artery roads with the highest level in the residential areas; Lvyi South Road and 19th Street form the most important sub-artery roads in the residential area, which run through the east and west sides of the residential areas. These four roads have the greatest potential for optimization due to their greater widths and ample green space on both sides, and are therefore classified in the same type.

Clifford Avenue (half)

Fuyi Road (half)

Lvyi South Road/19th Street

Figure 6-4: Optimization Type 1 on-site photos

Source: Photographs by the author

In response to the current problems in the roads space of Type 1, the optimization objectives for this type are to place new footpaths and cycling lanes, introduce traffic calming measures, enhance the roads space landscaping and implant new activity spaces and parking spaces, and the specific optimization strategies are shown in Table 6-2 below:

Table 6-2: Strategies for Optimization Type 1

Current problems	Corresponding Strategies
● Inadequate footpaths width and no cycling lanes	● Road space reallocation for footpaths and cycling lanes
● Inadequate protection for people at crossings	● Add new crossings combined with traffic calming measures
● Conflicts between bicycles and buses	● Introduce floating bus stops
● High traffic speed	● Vertical raising (speed hump, speed table, raised intersection) ● Active travel priority crossing (vertical raising in disguise) ● Horizontal bending (curve bending, zigzag bending, mini roundabout) ● Horizontal shrinking (pinch point, center island, curb extension)
● Poor lighting in nighttime	● Improve lighting facility
● No seats for rest	● Add rest facility
● Lack of information guidance	● Improve signage facility (road text marks, traffic signs, roadside maps)
● Monotonous road spaces	● Increase landscaping plants ● Placement of landscaping sketches
● Poor pavement materials	● Upgrade pavement materials

(continued Table 6-2)

● Adequate green space but not utilized and designed well	● Add traffic facility (shared bikes parking, semi-closed bus stops) ● Public space with activities ● New parking space with permeable grassblocks

Source: Self edited by the author

(2) Optimization Type 2

Optimization Type 2 includes Xueyuan Road, Fuhua Road, Fulin Road, Fuxiang Road and Hujing 1st Street. The first four roads are connected to the main entrance of Clifford Estates and are the artery roads in Clifford Estates; Hujing 1st Street is located in the southernmost part of the residential area and is a sub-artery road. The commonality of the five roads is that their road widths are smaller compared to Type 1. They are often unable to carry more public service space after ensuring sufficient width for dedicated footpaths or cycling lanes, and are therefore grouped together.

Xueyuan Road

Fuhua Road

Hujing 1st Street

Figure 6-5: Optimization Type 2 on-site photos

Source: Photographs by the author

The first optimization strategy for this type of roads is to prioritize availability of footpaths through the road space reallocation, followed by dedicated cycling lanes. The next step is to reduce motorized traffic speeds, which will not only allow pedestrians and cyclists to travel safely in the new paths, but will also help them to better cross through carriageways. Other optimization strategies such as road facilities and landscaping are shown in Table 6-3 below.

Table 6-3: Strategies for Optimization Type 2

Current problems	Corresponding Strategies
● Inadequate footpaths width and no cycling lanes	● Road space reallocation for footpaths and cycling lanes (footpaths are prioritized over cycling lanes)
● Inadequate protection for people at crossings	● Add new crossings combined with traffic calming measures
● High traffic speed	● Vertical raising (speed hump, speed table, raised intersection) ● Active travel priority crossing (vertical raising in disguise)
● Poor lighting in nighttime	● Improve lighting facility
● No seats for rest	● Add rest facility
● Lack of information guidance	● Improve signage facility (road text marks, traffic signs, roadside maps)
● Monotonous road spaces	● Increase landscaping plants ● Placement of landscaping sketches
● Poor pavement materials	● Upgrade pavement materials

Source: Self edited by the author

(3) Optimization Type 3

In the entire residential roads of Clifford Estates, Optimization Type 3 only has one artery road, Peak Road. Because both sides of Peak Road are equipped with two-meter wide and smooth footpaths for pedestrians to walk on, but lack of dedicated cycling lanes, result in non-motorized vehicles are often seen riding on the footpaths, so the subsequent optimization design only need to add new cycling lanes. Another reason is that there is still a large area of unused green space along one side of Peak Road, which has great potential for improvement.

Figure 6-6: Footpath and unused green area next to Peak Road

Source: Self drawn by the author and photographs by the author

Both of these realities are reasons why Peak Road is one single type of optimization, and Table 6-4 below demonstrates other existing problems and corresponding optimization strategies for Peak Road.

Table 6-4: Strategies for Optimization Type 3

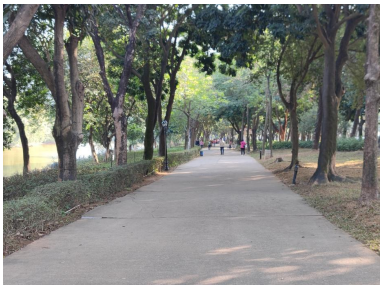
Current problems	Corresponding Strategies
● No cycling lanes	● Road space reallocation for cycling lanes
● Lack of dedicated pedestrian crossings	● Add new crossings combined with traffic calming measures
● Conflicts between bicycles and buses	● Introduce floating bus stops
● High traffic speed	● Vertical raising (speed hump, speed table, raised intersection) ● Active travel priority crossing (vertical raising in disguise)
● Poor lighting in nighttime	● Improve lighting facility
● No seats for rest	● Add rest facility
● Lack of information guidance	● Improve signage facility (road text marks, traffic signs, roadside maps)
● Monotonous road spaces	● Increase landscaping plants ● Placement of landscaping sketches ● Add traffic facility (shared bikes parking)
● No outdoor leisure spaces	● Add public space with activities

Source: Self edited by the author

(4) Optimization Type 4

Like Optimization Type 3, Type 4 has only one sub-artery road, the Huanhu Road. The special feature of this road is that although it is not equipped with footpaths and cycling lanes, it is highly overlapped by the existing greenway that surrounds the Clifford Lake and consists of a four-meter-wide health trail and a two-meter-wide one-way cycling lane separated from the carriageways by green space, making it the most important non-motorized traffic route in the residential area.


Huanhu Road


Healthy trail

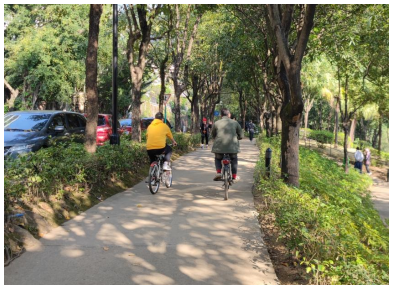

One-way cycling lane

Figure 6-7: Huanhu Road and existing greenway

Source: Photographs by the author

Therefore, one of the optimization strategies for Huanhu Road is utilization of this existing non-motorized traffic route, but the pavement material and width of the greenway need to be optimized, and adequate road signs should be installed along the greenway to remind active travelers to use this route. In addition, there should be adequate seating in the greenway for pedestrians and cyclists to rest, and good nighttime lighting should be ensured. Considering that the Clifford Lake is an important space for recreational activities in residential area and there are many residents who come here to relax and play, a vertically raised crossing should be provided in the roads to ensure the road safety. At the same time in the roadside can also be added to the shared bicycle rental points, to encourage nearby residents to ride.

Table 6-5: Strategies for Optimization Type 4

Current problems	Corresponding Strategies
● No footpath and cycling lane ● Potential conflicts between bicycles and buses	● Utilization of non-motorized traffic routes (The non-motorized traffic route itself should meet the pavement material and width requirements)
● High traffic speed	● Active travel priority crossings (vertical raising in disguise)
● Poor lighting in nighttime	● Improve lighting facility
● No seats for rest	● Add rest facility
● Lack of information guidance	● Improve signage facility (road text marks, traffic sign, roadside map)
	● Add Traffic facility (shared bikes parking)

Source: Self edited by the author

(5) Optimization Type 5

Optimization Type 5 refers to potential walking or cycling routes in residential area. The purpose of creating new routes is to improve the overall connectivity of the active travel network, thereby significantly reducing the active travel distance, reducing physical exertion during the trips, and thus encouraging residents to active travel. Today, however, they are either excluded by the strict access control management of closed residential quarters or blocked by the differences in elevation between the terrain.

Figure 6-8: Barriers from access control and terrain

Source: Photographs by the author

Therefore, the strategies for this type of roads is firstly to reduce the height difference of the terrain by adding infrastructures such as steps, ramps or elevators; and secondly, it is recommended that the access control of closed residential quarters, which can effectively shorten the active travel distance, should be opened to all residents in Clifford Estates, so as to realize the communalization of the internal roads. At the same time, there is also a need to further improve the road lighting facilities to ensure personal safety when traveling at night. There is also a need for sufficiently visible signage at intersections to allow residents to recognize the existence of new routes.

Table 6-6: Strategies for Optimization Type 5

Current problems	Corresponding Strategies
● Barriers of the terrain	● Overcome natural barriers (tunnel, steps, elevator, bridge)
● Strict access control management and closed gates	● Opening of access control management and gates of closed residential quarters ● Utilization of non-motorized traffic routes
● Lack of information guidance	● Improve signage facility (road text marks, traffic signs, roadside map)

Source: Self edited by the author

(6) Optimization Type 6

Optimization Type 6 are roads located outside the property management boundary of Clifford Estates. Although located outside the management boundary, the residents' travel activities are not only limited within the residential area, but also go to the commercial complexes outside the residential area to buy necessities or take urban metro stations which are still in the scope of this research. It has been observed that most of the residents use these roads mainly for crossing, and the commercial complexes outside the residential roads are designed with wide pedestrian streets due to their late construction.

Figure 6-9: Roads outside the property management boundary

Source: Photographs by the author

Therefore, the optimization strategies for this type of roads will focus on updating crossing facilities by replacing existing crossings without any protection measures with crossings with traffic calming measures, forcing motorized vehicles to reduce their speeds when approaching pedestrian crossings; in addition, visual warnings to drivers need to be further strengthened

through information-based signage, so as to give priority to active travelers. At the same time, in order to better encourage residents to use cycling to get around, bike-sharing rental points will be introduced at the entrances to residential area, commercial groups, entrances to metro stations and other places with high pedestrian traffic.

Table 6-7: Strategies for Optimization Type 6

Current problems	Corresponding Strategies
● Inadequate protection for people at crossings	● Active travel priority crossings ● Vertical raising (speed hump, speed table, raised intersection) ● Add traffic facility (shared bikes parking) ● Improve signage facility (road text marks, traffic signs, roadside maps)

Source: Self edited by the author

(7) Other Roads

As can be seen in Figure 6-3 above, there are a number of remaining roads in the residential area other than the six highlighted Optimization Types above, which are mostly group roads and house roads within the residential quarters. Due to the lack of public nature of this type of roads, they are more for the use of the households within the residential quarters and can be left unoptimized in fact.

Figure 6-10: Internal roads in residential quarters

Source: Photographs by the author

In principle, however, the "people-centred" spatial optimization of residential roads advocated in this thesis is essentially a form of inclusive design, and therefore only constructive but

non-mandatory recommendations are made for this type of road.

Table 6-8: Recommendations for Other Roads

Recommendations	Functions
● Textured pavement materials	● Alert drivers that they are driving in residential quarters currently
● Vertical raising (speed hump, speed table)	● Slower motorized traffic speed
● Lighting facility	● Good lighting environment
● Traffic facility (shared bikes parking)	● Encourage cycling travel
● Rest facility	● Provide resting space
● Signage facility (traffic sign, roadside map)	● Provide information guidance
● Increase landscaping plants	● Enhance travel space landscaping
● Placement of landscaping sketches	● Enhance travel space landscaping
● Public space with activities	● Enhance travel space landscaping
● New parking area with permeable grassblocks	● Improve road surface water permeability

Source: Self edited by the author

6.3 Renewal Examples of Each Optimization Types and Other Roads

After identifying the strategies for each Optimization Types of roads and recommendations for other roads, this section describes specific spatial design initiatives for each type of residential roads through seven renewal examples.

6.3.1 Example 1: Clifford Avenue

Located in the center of Clifford Estates, Clifford Avenue is the most important artery road in the residential area. The original allocation of road space is poorly designed for active travel, with pedestrians on both sides of the road given only a one-meter walking width, and a large amount of road space occupied by motorized traffic and road greenery. In addition, the walking path is constantly interrupted by house roads and group road entrances, resulting in discontinuous paths. Due to the large road width of Clifford Avenue and the high traffic volume and speed at peak travel times, residents take a longer time to cross the road, and the risk of collision with motorized vehicles increases significantly in the process. At the same time, residents face other problems such as a lack of dedicated lighting and route guidance during the trips of active travel.

In order to solve the above problems, the first strategy for Clifford Avenue is to add new footpaths and cycling lanes through road space reallocation, and at the same time introduce active travel priority crossings to ensure the coherence of the new paths. Next is to adjust the layout of the road plan, the original straight-line plane updated to a curved type, reducing the acceleration of motorized vehicles traveling along the straight line, to achieve the road "through but not smooth".

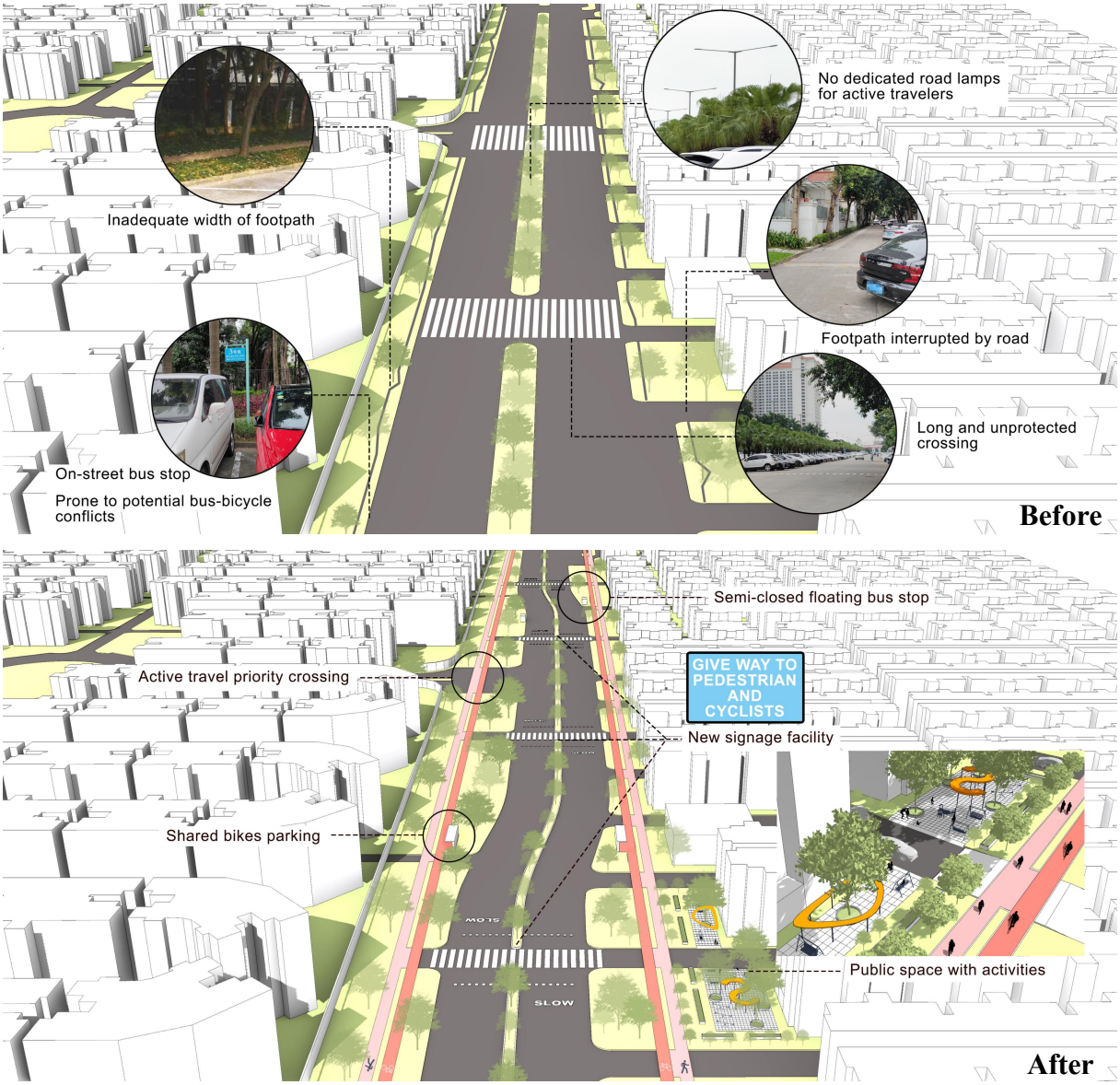


Figure 6-11: Clifford Avenue Optimization Scheme

Source: Self drawn by the author

Following the road space reallocation, public activity areas and new landscaping greenery will be incorporated into the new green space to enhance the visual diversity of residents on their active travel routes, and shared bicycle rental service will be introduced to encourage cycling traffic. The existing on-street bus stops on Clifford Avenue will be transformed into floating bus stops as the new road layout is equipped with separate cycling lanes and there will no longer be any direct conflict between bicycles and buses.

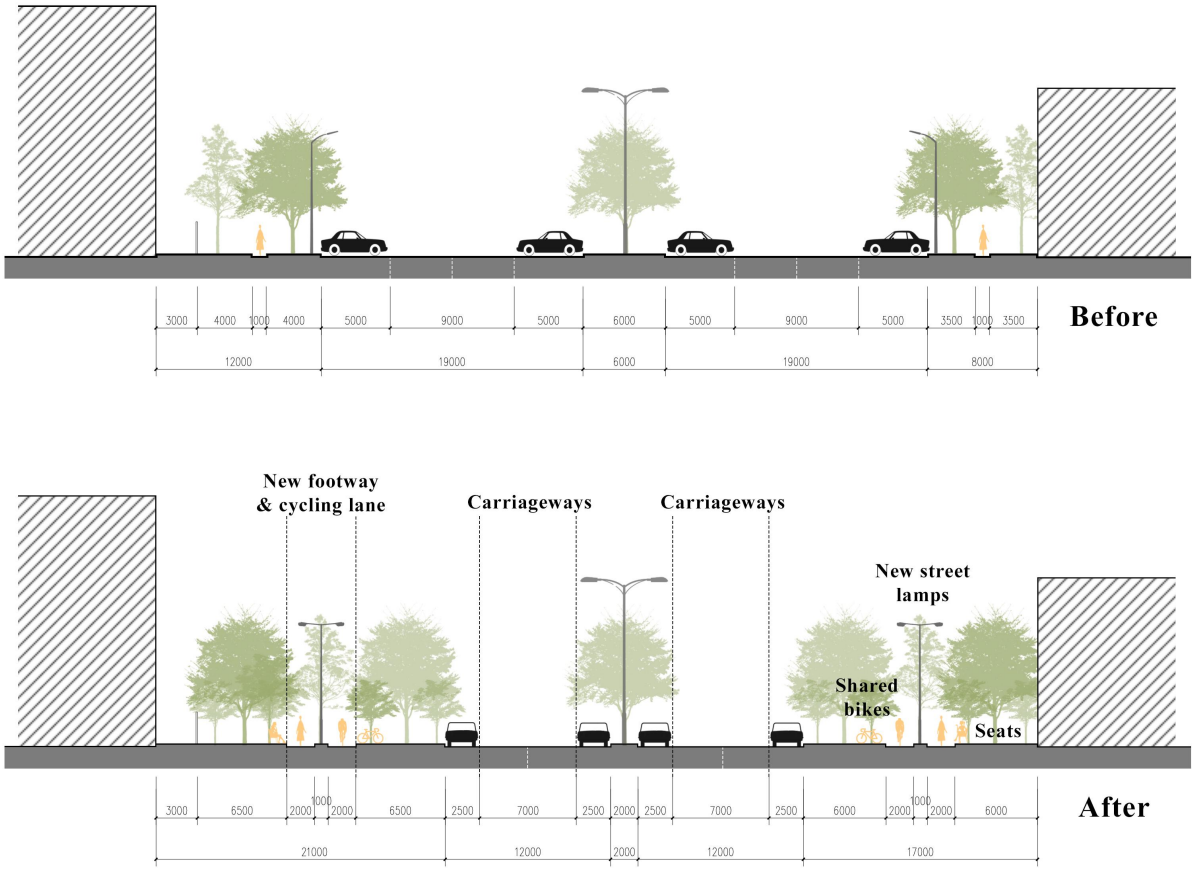


Figure 6-12: Road space reallocation of Clifford Avenue

Source: Self drawn by the author

The new road cross-section will be designed to better accommodate residents' active travel needs by incorporating new footpaths and cycling lanes on both sides of Clifford Avenue, each 2 meters wide. The green barrier in the center of the road and the carriageways will be contracted, with widths adjusted to 2 meters and 3.5 meters, respectively. The narrower carriageways will be conducive to traffic safety, as drivers driving motorized vehicles in the

contracted carriageways will have to be more careful to avoid collisions with other vehicles, and will therefore be forced to slow down, reduce lane changing and overtaking, and drive with caution. At the same time, the previous perpendicular parking layout will also be adjusted to parallel, further freeing up road space.

As the road width of Clifford Avenue is the widest in the entire residential area, many new green spaces will be created after adjusting the layout of the road space. These new green spaces can be transformed into public space with activities for recreation, and at the same time can be reused as new parking area with permeable grassblocks. In order to provide a better sensory experience for residents on their active travel, parking lots must be completely separated from footpaths and cycling lanes, and the separation zone may use trees or planters.

As mentioned earlier, to avoid the interruption of footpaths and cycling lanes by vehicular traffic, active travel priority crossings will be introduced on Clifford Avenue. By raising the carriageway surfaces at crossings to the level of footpaths, motorized vehicles will be forced to slow down as they enter or exit the crossings, creating a safer crossing environment for pedestrians and cyclists passing through the crossings.

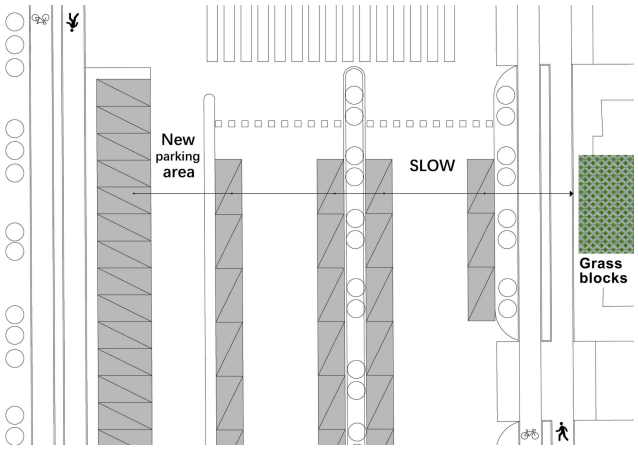


Figure 6-13: New parking area

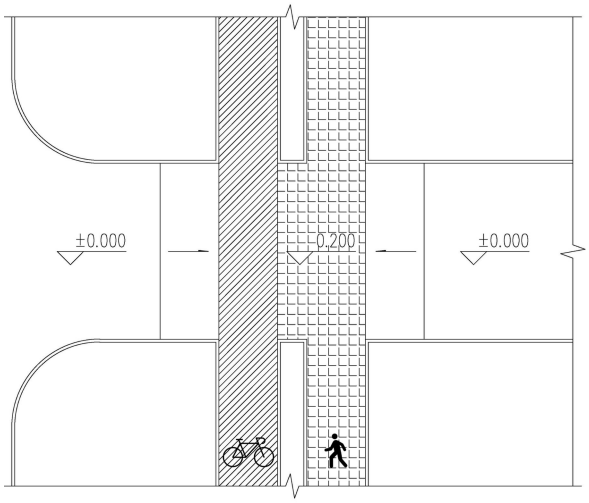


Figure 6-14: Active travel priority crossing

Source: Self drawn by the author

Below is an example of an active travel priority crossing. As seen from Figure 6-15, vehicles have to walk up the ramp when passing through the crossing, which gives drivers a cue to slow down and observe the road conditions, giving priority to active travelers. In addition to ramps, there needs to be sufficiently visible signage around the perimeter of the crossing to provide a visual reminder to drivers that they need to slow down.

Figure 6-15: Example of an active travel priority crossing

Source: Self drawn by the author

Compared to motorized travel, active travel is a slower type of travel that involves human exertion. As people walk and cycle, they visually scrutinize the road space more closely and inevitably become fatigued. Therefore, after adding new footpaths and cycling lanes, it is also necessary to improve the corresponding road space support facilities.

First of all, set up a guide map of Clifford Estates next to the footpaths, so that pedestrians can more intuitively obtain the current location information and clarify their own travel routes, thus reducing the possibility of getting lost on foot and making their travels more efficient. Secondly, the number of wooden seats on both sides of the roads will be increased to provide

pedestrians with sufficient resting and socializing space, adding a humanistic and living atmosphere to residential roads space. Thirdly, new lighting facilities will be double-armed road lamps with a good range of lights to cover the footpaths and cycling lanes, providing safety for residents walking and cycling at night. Lastly, given that owning a bicycle is a prerequisite for cycling behavior to occur, shared bicycle rental service will be introduced alongside the cycling lanes, with a view to increasing bicycle ownership in Clifford Estates and providing residents with more choices for travel.

Figure 6-16: New supporting facilities in Clifford Avenue

Source: Self drawn by the author

Since there is no dedicated cycling lane in the original road space, bicycles are forced to mix with buses traveling in the same direction. In the face of the bus's temporary stop, the rear of the bicycle has to slow down and adjust the direction of travel, in addition, the bicycle and the side of the motorized vehicle in the process is also easy to collision, reducing the safety and convenience of cycling.

The floating bus stops can completely separate the cycling lanes from the bus lanes to ensure the safety and efficiency of active travel. At the same time, the original open-air bus stops will be replaced with semi-closed shelters, an additional roof interface and three side interfaces. In addition to improving the waiting experience for residents, the new bus stops will also be able to provide short breaks and shelter for pedestrians and cyclists at necessary moments, improving the comfort of the active travel routes and giving residents a sense of the human dimension of the road space.

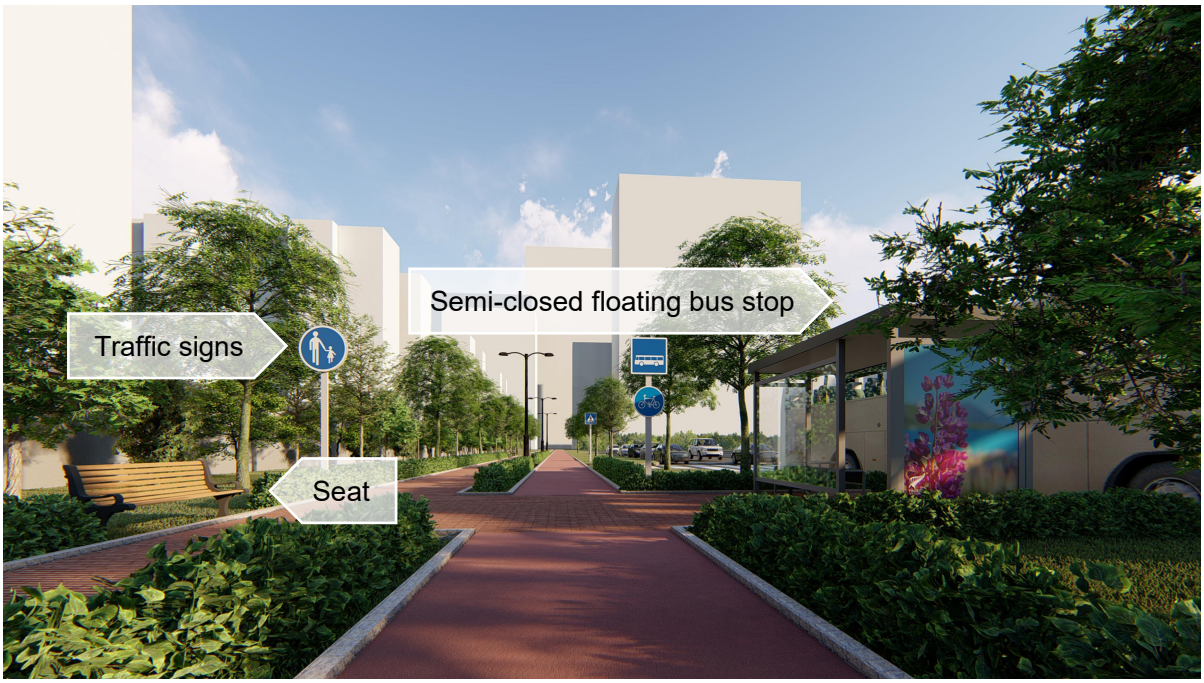


Figure 6-17: Semi-closed floating bus stops in Clifford Avenue

Source: Self drawn by the author

6.3.2 Example 2: Fuhua Road

Fuhua Road is an important artery road in Clifford Estates connecting internal and external transportation, but compared to Clifford Avenue, the width of Fuhua Road is much smaller. Although both sides of the road are equipped with footpaths, their width is only one meter, and the trees growing in the footpaths, road lamps and signboards erected in the footpaths continue to compress the space for walking. It was observed that most of the residents gave up walking on the footpaths and switched to walking with cars on the carriageways.

Figure 6-18: Footpaths current condition of Fuhua Road

Source: Photographs by the author

Given the small width of Fuhua Road, it is not possible to construct adequate footpaths and cycling lanes at the same time, and pedestrians' right of way must be prioritized in this case. Therefore, the primary improvement measures for Fuhua Road were to reduce the width of the carriageways by reallocating the road space to reduce the speed of vehicles, to construct footpaths of sufficient width for pedestrians, and to remove all permanent obstacles on the footpaths surface, including vegetation, lamps, and signage, as shown in Figure 6-19 below.

In addition to adding new footpaths, new road lamps will be upgraded from the previous single-arm type to double-arm type to ensure nighttime illumination of both pedestrian and vehicular spaces; and sufficient seats will be incorporated to provide facilities for pedestrians' short resting needs. Active travel priority crossings will also be introduced on Fuhua Road to further reduce the speed of motor vehicles, providing safety for pedestrians crossing the road and ensuring a more harmonious travel environment for cyclists.

Sufficient signage facilities will be incorporated into the new road space on Fuhua Road to remind passing vehicles to reduce speed and yield to pedestrians and cyclists. Roadside maps will also be included to provide way-finding information to pedestrians so that they can get their coordinates and find their desired destinations as quickly as possible.

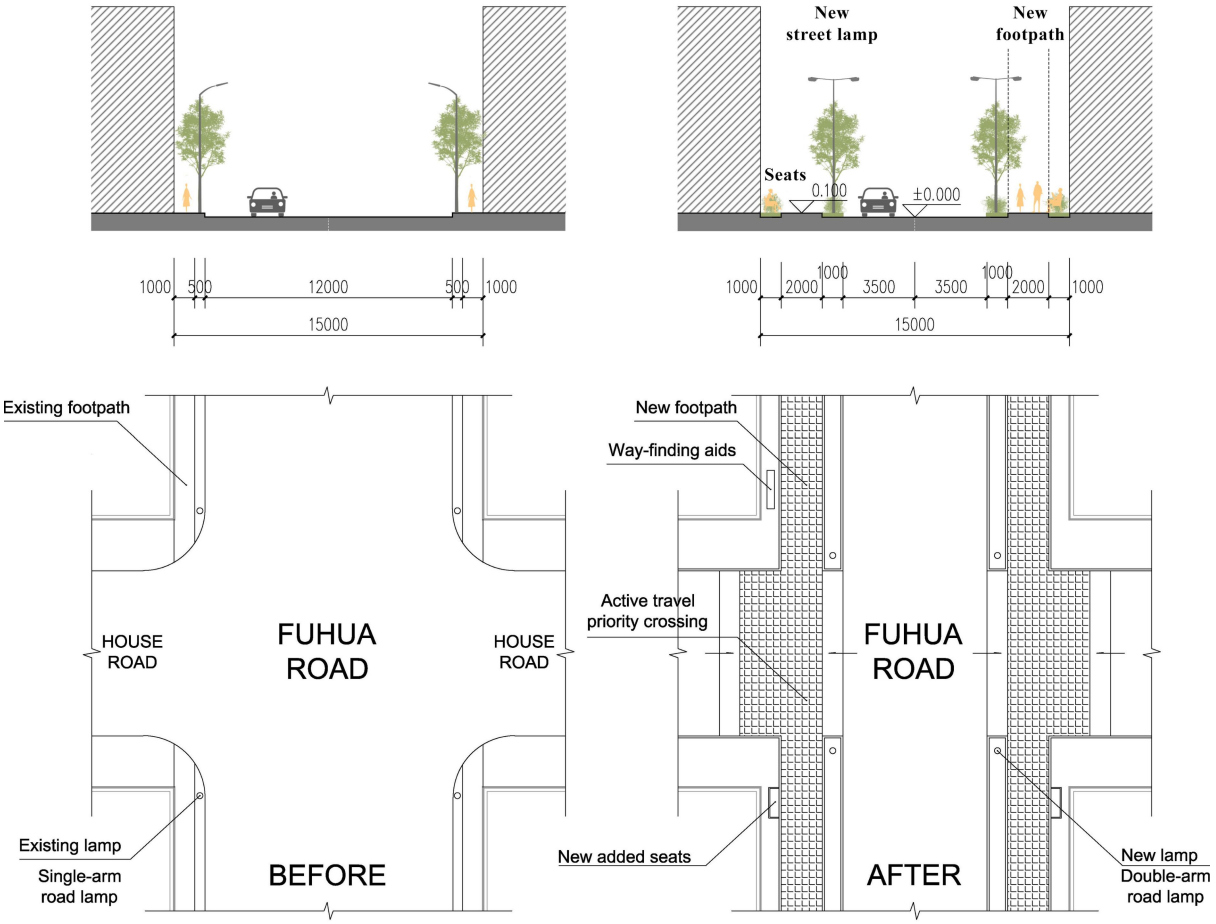


Figure 6-19: Fuhua Road Optimization Scheme

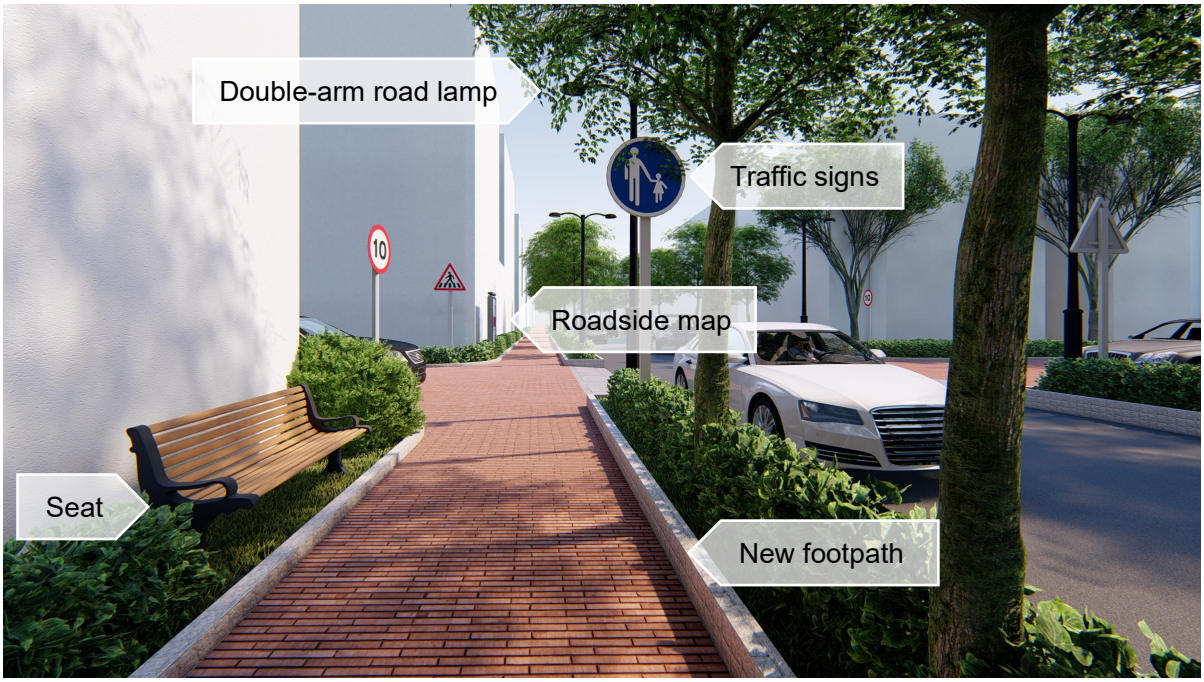


Figure 6-20: New road space of Fuhua Road

Source: Self drawn by the author

6.3.3 Example 3: Peak Road

Peak Road is the only artery road in the entire Clifford Estates with footpaths on both sides, and the footpaths are walkable in terms of width and material. Therefore, in reallocating road space on Peak Road, only additional cycling lanes are required. Since cycling travel at speeds intermediate between those of pedestrians and motor vehicles, a reasonable spatial layout for a cycling lane should be the same, namely, the cycling lane should be located between the footpath and carriageway. According to the reality of Peak Road, there is no longer enough space between the footpaths and carriageways or parking lanes to accommodate new cycling lanes, so the specific approach is to keep the original footpath, continue to use it as a new cycling lane after renewing the original permeable bricks to permeable concrete, and create a new footpath in the green space on its outer side. Potential conflicts between bicycles and buses will be greatly reduced with the inclusion of dedicated cycling lanes, so all existing bus stops on Peak Road will be updated with floating bus stops. At the same time, new supporting facilities such as double-arm road lamps and wooden seats are added to the road space on Peak Road. The specific optimization scheme is shown in Figure 6-21 below.

As mentioned above, the southwest side of Peak Road has a large area of unused green space, and there are fewer children's playing spaces in Clifford Estates. Therefore, after reallocating road space on Peak Road, the remaining green space can be transformed and revitalized into a children's playground, which on the one hand can enrich the spatial composition of the roads space and enhance the visual changes; on the other hand, it also can allow children to stop on their way from school to do appropriate physical activities and enhance their physical fitness.

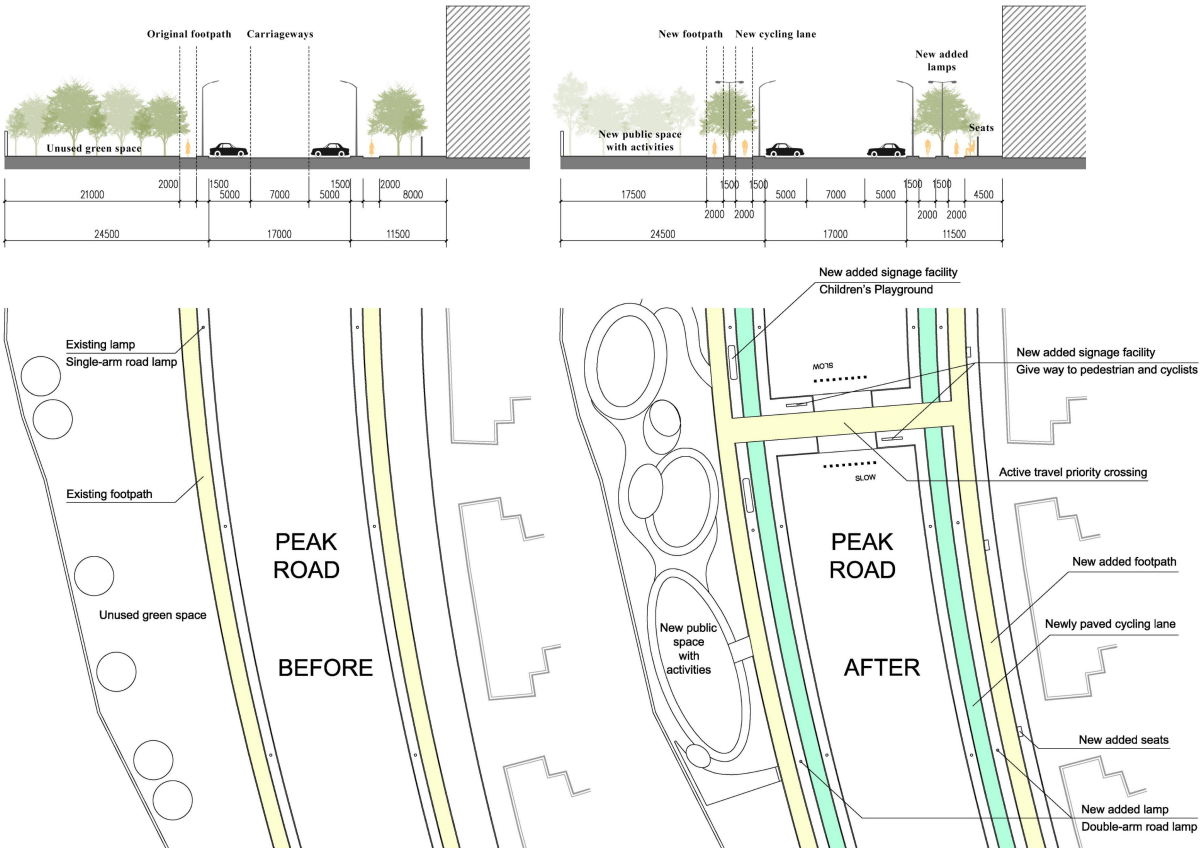


Figure 6-21: Peak Road Optimization Scheme

Source: Self drawn by the author

Figure 6-22: Children's playground

Source: Self drawn by the author

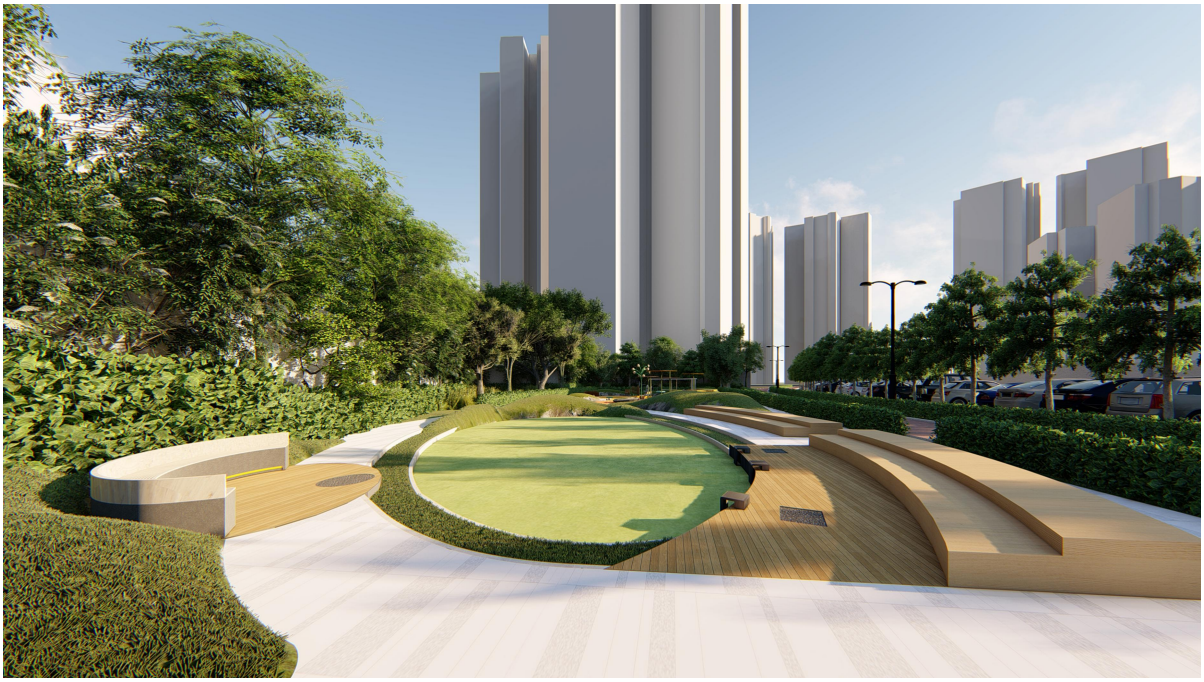


Figure 6-23: Rest area for parents and children

Source: Self drawn by the author

The specific design scheme is divided into two parts: children's playground together with parents and children's resting area. The children's playground is paved with orange plastic flooring, which enhances the colorfulness of the playground and also protects the safety of the children when they are chasing and playing. Compared with the elevation of the road surface at Peak Road, the ground level of the playground is lower, which aims to isolate as much as possible the visual and auditory disturbances caused by motorized traffic and to create a more comfortable and harmonious play environment for children. Adjacent to the playground is a rest area for parents and children, which, in addition to its resting function, but also provides space for public events in the residential area, facilitates neighborhood interaction and enhances the vitality of the active travel space.

6.3.4 Example 4: Huanhu Road

Huanhu road is named because it circles around the Clifford Lake, and between the Huanhu road and the Clifford Lake has been built a circle of greenway around the Clifford Lake. This greenway system is also the most important non-motorized traffic route in Clifford Estates. It

consists of a circle of 4-meter wide healthy trail and a circle of 2-meter wide one-way cycling lane, which mainly take on the function of residents' daily leisure activities, but can also be used as a traffic functional route.

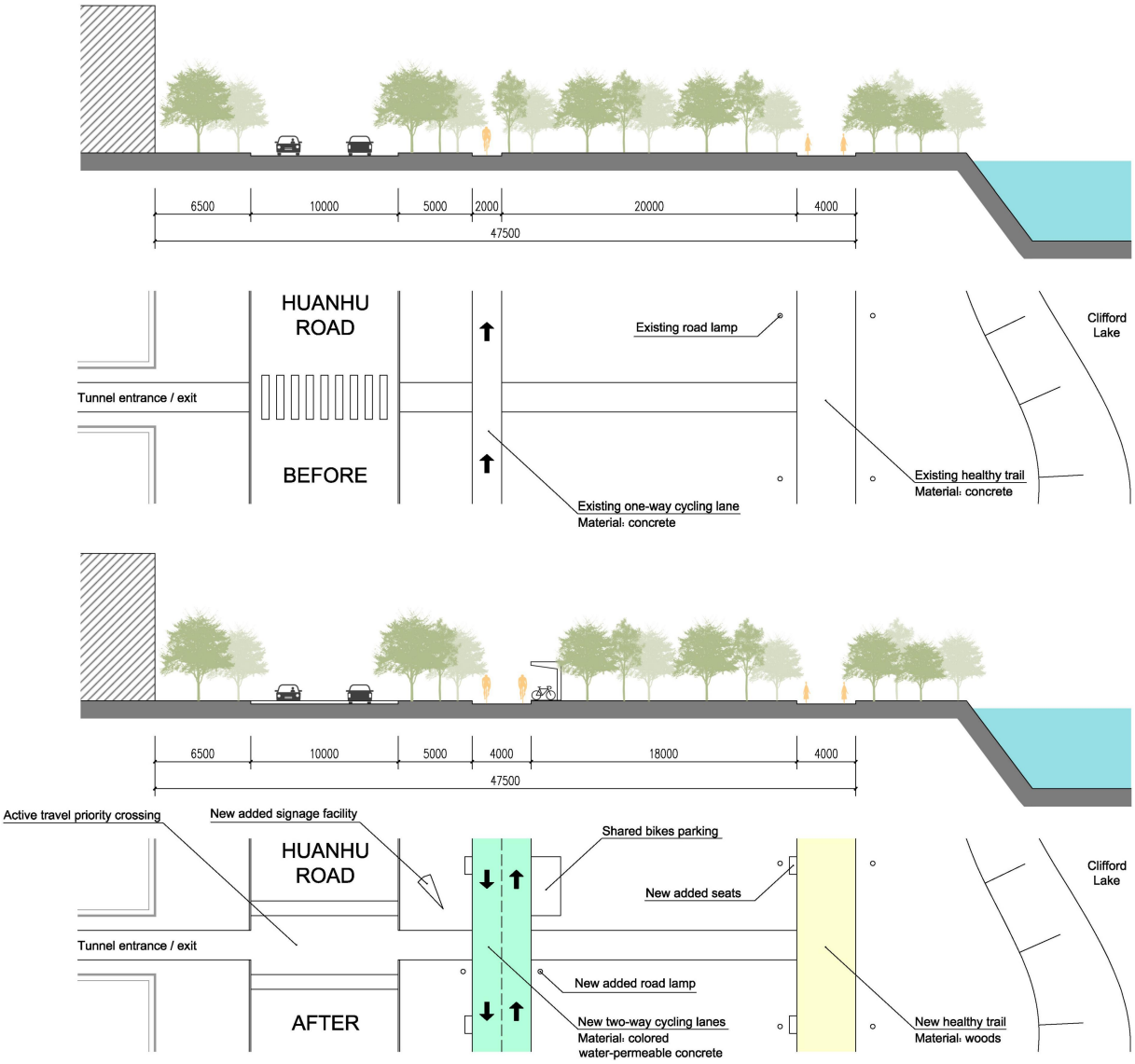


Figure 6-24: Huanhu Road and greenway Optimization Scheme

Source: Self drawn by the author

Given the high degree of overlap between the Huanhu Road and the existing greenway, it is possible to avoid reallocating the road space on the Huanhu Road, and simply build on the existing health trails and cycling lane to make them better able to take on the traffic function of active travel for residents. The optimization strategy adopted for the Huanhu road itself is

mainly to update the existing crossing to an active travel priority crossing to ensure that pedestrians and cyclists can enjoy a higher right-of-way when crossing the road, and to improve the safety and convenience of crossing.

The optimization strategy for both healthy trail and cycling lane was to update the pavement material. Both of the original surface material is concrete, surface smoothness is good, but the aesthetic is poor, and with the beautiful surrounding lake scenery looks out of place. The new health trail surface will use natural wood as the paving material, can better match the natural attributes of the Clifford Lake, to give residents a sense of return to nature; at the same time, the wood also has a good permeability, can effectively channel the road surface water, to prevent accidental falls. On both sides of the trail will also be added to the new seats, so that residents can get a temporary rest when walking.

Figure 6-25: New wooden surface of healthy trail

Source: Self drawn by the author

Figure 6-26: Widened cycling lanes and new pavement materials

Source: Self drawn by the author

New cycling lane will be surfaced with green permeable concrete, which will both improve water permeability and characterize the cycling space, attracting cyclists to use it. In addition, the original cycling lane was only 2 meters wide and could only be used as a one-way lane; the new cycling lane will be widened to 4 meters in order to meet the needs of two-way traffic. At the same time, new lighting, resting and signage facilities will be added on both sides of the cycling lane, on the one hand to meet the various needs of cyclists, and on the other hand to improve the diversity of elements in the active travel space and enrich the visual effect. Rental service for shared bicycles will be set up at the entrance to the greenway and at other locations, with the aim of increasing the number of bicycles in the entire residential area and encouraging cycling activities.

6.3.5 Example 5: New Active Travel Route

The establishment of new active travel routes can effectively improve the connectivity of the overall walking and cycling network. The optimization of active travel network connectivity is mainly divided into two aspects: firstly, it is recommended that the access control

management and closed gates of a number of specific closed residential quarters should be opened to all Clifford Estates residents, while the premise of opening is that it does not involve visitors outside of Clifford Estates, and therefore this opening is only moderate; secondly, after the on-site investigation to Clifford Estates, it is recommended that two new connections (C1 & C2) should be established at the two breakpoints shown in Figure 6-27 below to dissolve the mountain barrier brought about by the topographic elevation difference, thus effectively shortening the time and distance for residents to walk or ride and promoting the occurrence of active travel. Detailed analyses of the above two aspects is presented in Chapter 4, subsection 3.3.

At the same time, the establishment of new routes needs to be accompanied by sufficiently visible signage facilities around the perimeter of the new routes so that residents can be made aware of their existence and encouraged to use these shortcuts.

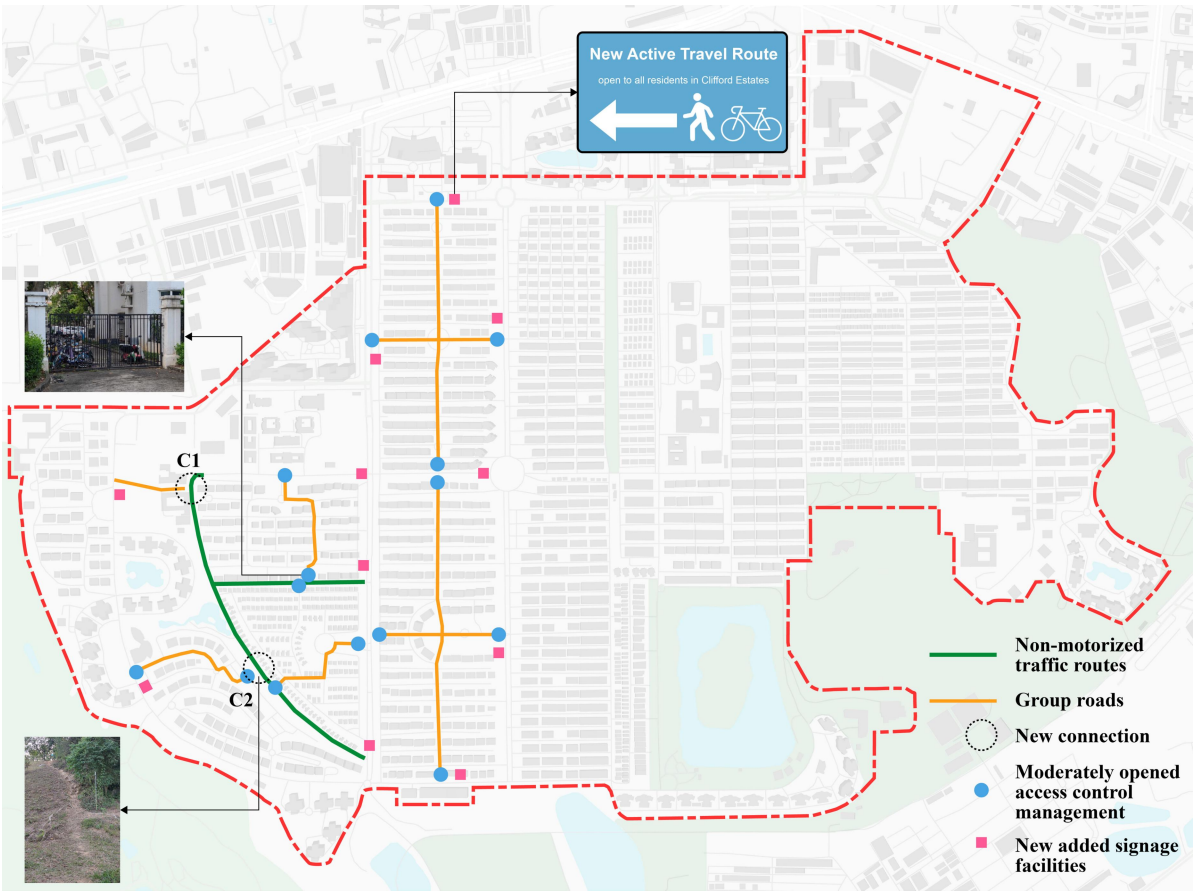


Figure 6-27: Optimization of active travel network connectivity

Source: Self drawn by the author

The following is an example of the new connection C1 to describe the specific optimization measures. As mentioned above, the straight-line distance from a residential unit of Haiqing Ju to Yuxiu Primary School and Clifford Banshan Kindergarten is just less than 100 meters, but due to the limitation of nearly ten meters height difference on the direct route, people are forced to take a detour of 2,500 meters in order to reach the destinations. Under such a huge psychological gap, it is inevitable that some students simply choose to be driven to and from school by their parents, giving up any active transportation modes to participate in travel activities.

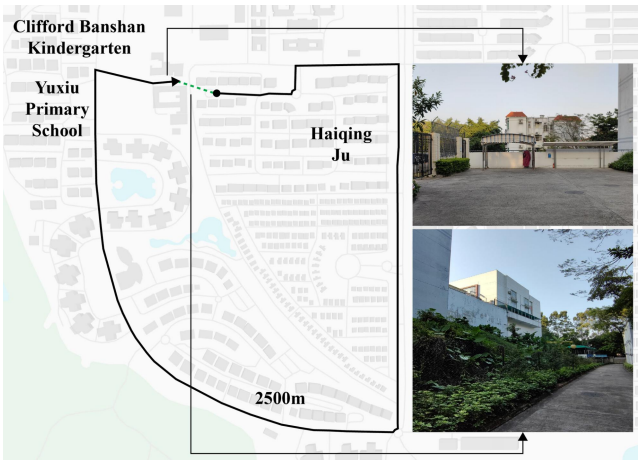


Figure 6-28: Detour due to mountain barrier

Source: Self drawn by the author Source: Baidu Map screenshot

Following on-site investigation and survey, new steps and a elevator will be introduced to eliminate the nearly ten-meter height difference between the two sites and activate this potential active travel route. The new route will significantly reduce the time and physical costs for students to get to school, as well as promote interaction between residents living in different residential quarters nearby.

Figure 6-29: New Connection 1

Source: Self drawn by the author

6.3.6 Example 6: Roads Outside Property Management Boundary

Due to the fact that the medical and commercial functional groups on the periphery of Clifford Estates were built a little later, that there is already wide walking space, and that the travel activities of the residents on the roads outside of the property management boundary are mainly through-traffic, the first optimization strategy to be implemented on this type of roads within the design research scope is to provide adequate protection for the crossing activities of the active travelers. With the exception of the two signalized intersections, active travel priority crossings will be introduced together with visible signage facilities (give way to pedestrians and cyclists) will be provided at the crossings to remind drivers to give priority to pedestrians and cyclists crossing the carriageways. There is also a need to incorporate shared bike rental points at the main entrances of commercial and medical functional groups as well as plazas so that residents have access to bikes to participate in active travel practices.

Figure 6-30: Roads Outside Boundary Optimization Scheme

Source: Self drawn by the author

6.3.7 Example 7: Other Roads

Most of the other roads in Clifford Estates are group roads and house roads, which have much lower pedestrian and vehicular volumes and average speeds compared to the six optimization types mentioned above, and the road spaces within the residential quarters serve more of the residents of their own neighborhoods; therefore, this thesis only makes recommendations for improvements to this type of roads as part of the overall optimization initiative for Clifford Estates. These recommended measures are further elaborated in the following section through several spatial imagery.

An important aspect of the recommended measures is the replacement of the existing concrete pavement material with textured pavement surfacing, which visually reminds drivers that they are entering residential quarters and need to slow down and be mindful of pedestrians and cyclists, as well as providing a good road environment for residents' active travel. The new pavement will work in conjunction with traffic calming measures to raise the road surface moderately at appropriate locations on the roads, forcing drivers to reduce their speeds. At the same time, the new parking spaces will be paved with permeable grassblocks to replace the original concrete pavement, the purpose of which is, first, to improve the permeability of the road surface and reduce the amount of water in rainy; second, to limit the parking area so that motor vehicles do not arbitrarily take over the roadway and encroach on the travel space.In

terms of road supporting facilities, new lamps will be incorporated on both sides of the road to improve the light environment in nighttime and enhance safety for residents during the trips of active travel at night, and to enhance the goodwill of residents towards the roads space.

Figure 6-31: Improvement schematic of group road in Diewu Xuan

Figure 6-32: Improvement schematic of house road in Lvyi Ju

Source: Self drawn by the author

The above is the optimized imagery for ordinary group roads and house roads, but more consideration is needed for the special road sections in this type. For example, there is a special road space in a residential quarter named Yihu Wan, which is a road section leading to a kindergarten. The original road surface material of this section is concrete, with a cold and gray tone, which is less attractive to children. The green space around the road is unused, and there are no resting facilities for parents to use. It was found that during the afternoon school hours, parents mostly gathered on the road waiting for their children to come out from the campus, which overlapped with the motorized traffic flow, resulting in a chaotic situation for people and vehicles.

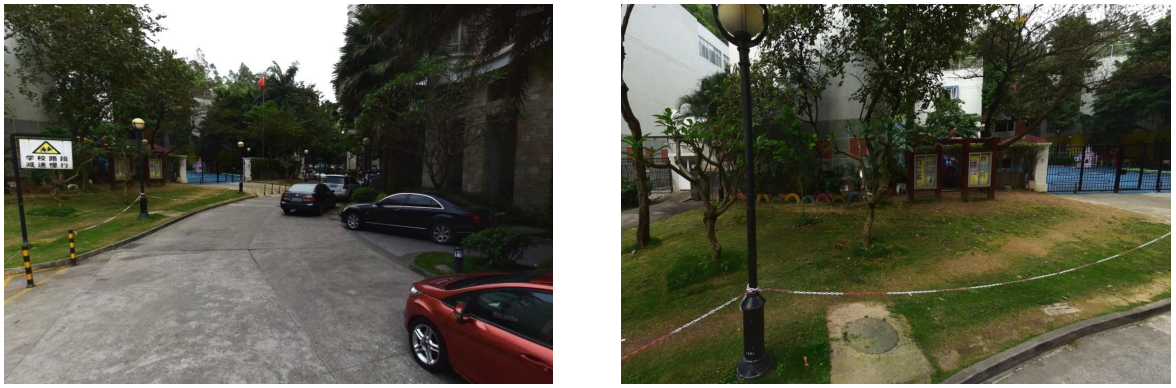


Figure 6-33: Current road space condition ahead of the kindergarten entrance

Source: Photographs by the author

Therefore, the optimization proposal for this road section space is to liven up the road space by adding bright colors to it. Bright colors are usually more attractive to young children, attracting their attention and stimulating their curiosity, and bright colors are often associated with positive emotions and pleasure, which is good for children's mental health. At the same time, colorful road surfaces can also remind passing motor vehicles that they are entering the school section and need to slow down to avoid young children and parents.

The proposed optimization scheme will use more colorful pavement to create a more positive active travel environment for children. At the same time, the green space alongside the road will incorporate landscaping sketches with resting features, seating in the form of blocks, and

flowers in the center of the blocks to create a comfortable and enjoyable resting environment for parents waiting for their children to be released from school.

Figure 6-34: Colorful road space ahead of the kindergarten entrance

Source: Self drawn by the author

6.4 Chapter Summary

The main content of this Chapter is to implement the design strategies of Chapter 5 into the specific roads of Clifford Estates for figurative expression. Firstly, centering on the travel destinations of residents, walking buffer zones are established according to the actual distance traveled by people, thus defining the scope of design research in this Chapter. Secondly, the overall design objectives of residential roads optimization are proposed, and residential roads are classified according to their existing problems and regeneration potentials, followed by targeted response strategies for each optimization types, and optimization strategic master plan for residential roads space in Clifford Estates is obtained. Finally, seven examples are used to illustrate the specific implementation schemes and spatial imagery.

Conclusion and Prospection

1. Research Conclusion

In this thesis, in view of China's national health, the background of the negative impact of motorized travel to residents, as well as existing problems of physical space dilapidation and public space decay in residential roads of Clifford Estates, combined with the theoretical research related to active travel and practical experiences reviewed, putting forward the optimization methodology of residential roads space for active travel in Clifford Estates. The optimization of residential roads space in Clifford Estates seeks to improve the spatial quality and restore the vitality of the roads space, while at the same time promoting residents to choose active transportation in their daily lives, in order to achieve the purpose of improving people's health. The main conclusions of the thesis can be summarized as follows:

(1) Active travel is both a type of travel behavior, commonly walking and cycling, and a kind of physical activity that involves human physical power. Therefore, active travel is affected by socioeconomic characteristics on the one hand, such as family income will determine whether individuals own private cars or bicycles; on the other hand, it is also affected by personal factors such as conceptual attitudes and physical capabilities; and then it is also affected by the physical environment, which is reflected in the residential roads space as the coherence, safety, connectivity, comfort and aesthetics of roads space.

(2) The results of the perception survey showed that the residents of Clifford Estates have a great demand for active travel in general, however there are a series of problems with the residential roads space carrying travel activities. First, the lack of human consideration in the road space allocation in residential roads has led to deficiencies in the coherence of active travel routes. Secondly, the safety of active travel routes is negatively affected by high traffic volume and speed, unprotected crossings, potential conflicts between road users, and poor nighttime lighting. Third, residents face barriers from topography and access control when walking or riding, weakening the connectivity of active travel routes. Fourth, inadequate rest

seats and informational signs and poor pavement quality reduce the comfort of active travel routes. Fifth, monotonous road spaces tend to repel people, and active travel routes lack aesthetics.

(3) The principles and strategies for the optimization design of residential roads space in Clifford Estates that are suitable for residents' active travel are proposed. First, the range of residents' active travel in residential areas should be determined according to the distribution of travel destinations, and residential roads within this range should realize the construction of coherent active travel network. Second, safer active travel spaces should be created by reallocating road space, introducing traffic calming measures, and utilizing non-motorized traffic routes. Third, closed residential quarters should open up internal roads for use and build potential travel routes within areas to achieve connectivity of active travel routes. Fourth, more comfortable active travel environments can be achieved through the rational placement of road facilities. Fifth, create enjoyable active travel space by revitalizing unused roadside green space, increasing landscaping plants, and placing landscaping sketches.

2. Research Prospection

This thesis discussed the spatial optimization design of residential roads in Clifford Estates from the perspective of active travel, which needs to be further improved in terms of the compilation of ideas and the depth of argumentation, and still has some deficiencies:

(1) As discussed in Chapter 1, active travel is not limited to walking and cycling, but also includes other modes of travel that involve human physical power, such as jogging, scooter riding, and manual wheelchairs. This thesis only discusses walking and cycling, the two most common modes of active transportation, and does not consider other modes. The scope of the research will be expanded in subsequent research to investigate in-depth other active travel modes in residential areas, and also to increase the focus on vulnerable groups such as the elderly, children, and people with disabilities to improve the inclusiveness of the design.

(2) As mentioned in Chapter 2, active travel is a type of human behavior, so it is not only influenced by the physical environment of residential areas, but also by the actors' own habits, attitudes and perceptions. As an urban design of residential roads space, this thesis has not properly given consideration to the guidance of human values, and in the subsequent research, relevant supporting measures can be introduced with reference to foreign practices, such as cultivating children's habit of riding in campuses, setting up cycling clubs in urban residential areas, and training residents in safe driving, so as to enhance people's awareness of and behavioral conscientiousness towards active travel.

(3) This thesis proposed the optimization design methodology for residential roads space in Clifford Estates, which is targeted but at the same time has certain limitations, and may not be applicable to all residential roads. The whole discussion in this thesis is both an attempt and a hope that this is an opportunity to arouse the attention of more colleagues to promote the depth of the research in the field of residential roads space and active travel.

Appendix

Appendix 1: Active Travel Perception Survey Questionnaire

Dear residents in Clifford Estates,

I am a mater postgraduate at the School of Architecture, South China University of Technology, and completing my thesis on "Optimization Exploration of Residential Roads Space in Clifford Estates from the Perspective of Active Travel". Now I am conducting a perception survey on your daily active travel in order to provide the scientific basis for the formulation of the relevant optimization strategies for residential roads space in the future.

This perception survey is conducted in a completely anonymous way, and all data collected will only be used for academic research, and your personal information will not be disclosed in any form or way.

Thanks for your help and support, and I would like to express my sincere gratitude to your participation.

(1) Are you a minor or an adult: (Single choice)

A. Minor

B. Adult

(2) In and around Clifford Estates, do you choose active transportation (e.g. walking/cycling) to go to school, MTR station, grocery shopping, picking up and dropping off children, buying medicine and asking for medical consultation, etc.: (Single choice)

Note: Riding an electric bike is not an active mode of transportation, and traveling on an electric bike is not active travel.

A. Never

B. Occasionally

C. Often

D. Always

(3) In Clifford Estates, what is the factor that most affects your choice of traveling on foot: (Single choice)

Theme	Description
A. Infrastructure	• Footpaths are sometimes present and sometimes absent • Insufficient footpath width • Poor footpath materials
B. Road maintenance	• Footpath surface is badly damaged • Rain on the footpath surface makes me easy to slip and fall
C. Road safety	• High speed and volume of traffic • Mixed pedestrian and vehicular traffic • Afraid to cross the roads • Conflicts with other road users
D. Personal safety	• Stranger danger • Fear for own safety • Dangerous drivers and poor attitude towards pedestrians
E. Time and distance	• Not enough time to walk to destination • Distance to destination to far
F. Facilities	• Poor lighting at night • Lack of seats for resting • Lack of way finding aids
G. Poor Weather	• Heat • Heavy rain • Typhoon
H. Unable or unwilling	• Disability or health conditions • Laziness • Personal choice to take the car • Family not allow me travel on foot alone • Unable to send children to school and continue work normally

(4) In Clifford Estates, what is the factor that most affects your choice of traveling by bike: (Single choice)

Theme	Description
A. Infrastructure	• No fully segregated cycling lanes
B. Road maintenance	• Road surface is badly damaged • Rain on the road surface makes me easy to slip and fall

C. Road safety	• High speed and volume of traffic • Mixed cycling and vehicular traffic • Afraid to cross the roads • Conflicts with other road users
D. Personal safety	• Stranger danger • Fear for own safety • Dangerous drivers and poor attitude towards cyclists
E. Time and distance	• Not enough time to cycle to destination • Distance to destination to far
F. Facilities	• No shared bikes rental services • Poor lighting at night • Lack of seats for resting • Lack of way finding aids
G. Poor Weather	• Heat • Heavy rain • Typhoon
H. Unable or unwilling	• Disability or health conditions • Laziness • Personal choice to take the car • Family not allow me travel by bike alone • Unable to ride or have no bike • Unable to carry work or personal items on a bike • Unable to send children to school and continue work normally

(5) If you are a pedestrian or cyclist, what would you prefer to see in Clifford Estates in the future: (Multiple choices)

A. Slower motorized traffic

B. Footpaths suitable for walking

C. Segregated cycling lanes

D. More efficient travel routes

E. More plants and trees

F. More attractive roads space

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