DEVELOPING A USER-FRIENDLY BICYCLE NETWORK
IN FAST-GROWING CITIES IN CHINA:
TAKING ZHONGGUANCUN AVENUE IN BEIJING AS AN EXAMPLE

A CREATIVE PROJECT
SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FUFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE
MASTERS OF LANDSCAPE ARCHITECTURE

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ABSTRACT

This creative project redesigns Zhongguancun Avenue in Beijing as an example to explore strategies to develop user-friendly bicycle networks in China. Bicycles were once the primary mode of transport in urban areas in China. As cities have expanded and motor vehicles developed over time, this mode has been challenged by the diminished cycling space, deteriorated cycling environment, and outdated facilities. Cyclists risk safety when sharing and competing for space with motor vehicles. Setting the goal for designing a better urban cycling environment under this context, the project explores developing a safe and efficient transport environment for Zhongguancun Avenue in Beijing for bicycle commuting while providing a comfortable environment for recreational use for cyclists and pedestrians.

This project reviews existing literatures to identify solutions for establishing and improving bicycle networks, including bicycle path and bicycle lane design, conflict resolution, bicycle parking and storage design, and green bicycle network development. Then, the project presents basic information of the project site and analyzes problems and conflicts of the existing conditions, including conflicts along bike lanes, conflicts at intersections, and bicycle storage conditions. In the design section, this project offers possible design solutions by improving bicycle lanes, developing safer intersections, and adding efficient storage facilities. At the same time, potential green nodes were connected with landscape design strategies into a coherent whole cycling environment, which
increases comfort and aesthetics.

The redesign of Zhongguancun Avenue serves as a useful example to investigate design solutions for developing a bicycle network in Beijing. These solutions can be applied to other streets in the urban areas in Beijing. Some solutions provided by the project successfully meet the study objectives. However, some alternatives have constraints due to limited space or high construction cost.

The project also indicates that further studies for improving cycling environment are needed, especially the study for the conflict between motor vehicle parking and bicycles.
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CHAPTER 1. INTRODUCTION

1.1 Project Introduction

The bicycle is a significant means of transport that has a long history and is an established essential part of urban and rural life because of all its benefits. First is the energy efficiency and environmental advantage. Since bicycles do not use fuel as energy, cycling as an alternative to automobile use reduces the consumption of non-renewable resources, and eliminates pollutants and harmful airborne particulate matter caused by automobiles. Second is its contribution to traffic conditions. The rapidly increasing number of motor vehicles in Chinese cities causes serious traffic congestion, while bicycles need much less space and offer more flexible mobility to avoid most of the congestion. Third, are the physical and mental health benefits to the cyclists. Regular cycling reduces heart disease, body weight, and tension. Moreover, cost-effectiveness is also an important benefit of cycling.

Bicycles were once the primary mode of transport in Chinese cities. People used to commute riding their bikes, and bicycles were one of “The Three Must-haves” for families in Chinese cities during the 1970s. From the 1990s, as economic prosperity has rapidly increased and urban areas have expanded over time, motor vehicles are becoming increasingly popular in China. As personal automobiles gradually become the dominant way of commuting in large cities, bicycle usage decreases year by year (see figure 1.1).
Over time, rapidly increasing motor vehicle dependence has caused problems. One of the most significant problems is serious traffic congestion. The government has adopted a series of policies to limit the number of cars, such as traffic restrictions based on car license...
plate numbers. However, those methods have not really solved the problems, and have made people displeased with the regulations and even the government. In addition to limiting the number of private vehicles, the government also advocates using public transportation as an alternative mode of commuting. However, the existing public transportation system is poorly connected. Although there are developed subway and bus networks, the transfer from transit stations to final destinations is difficult. Bicycles also require much less space than cars, so they could be easily parked and stored near the subway or bus stations. Thus, bicycles would be an effective and efficient means to connect people with public transportation to achieve long-distance travel.

Setting the goal as promoting bike usage in urban environments in China, this study proposes a design project in Beijing to examine a better cycling environment. The creative project proposes to discuss the possibility of developing a bicycle network in Beijing, and integrating it with public transportation systems. The project studies the opportunity to develop the current bicycle networks by connecting existing green spaces and potential vacant areas. By using landscape architecture as an approach, the project attempts to achieve the goals of creating a safe and efficient transport environment for bicycle commuting while providing a comfortable human-scale environment for recreational use.

Objectives to achieve these goals include two aspects: improving existing road conditions and adding green corridor along the roads. Improving existing roads should
include developing bike lanes and paths, resolving potential conflicts, and establishing bicycle parking and storage facilities. The project will offer different design types of bike paths for different land uses, including the various needs of commercial areas, residential areas, offices, communities, plazas, and parks. The solution should integrate bicycles with public transportation by managing potential conflict spots with suitable adjusting or redesigning, plus locating bicycle parking and storage facilities near the subway and bus stations.

The second objective is using a landscape approach to establish a green corridor/belt along the roads, to provide a comfortable human-scale environment for both cyclists and pedestrians. Convenient connections and access to the transportation network will provide a barrier-free transfer system. The strategies include redesigning existing green spaces and reclaiming potential vacant spaces, setting pocket parks along the trail for cyclists to rest, and ensuring safety during transfers between transit modes.

1.2 Problem Statement

Major Problem

This creative project will explore how to develop a green bicycle network in Zhongguancun, Beijing, China.

Sub-problems

1. What Principles inform Bicycle Lane and Bicycle Path Design?
What are the best design strategies to design bike lanes (including lane width, barriers and separators, canopy, pavement and other aspects) following municipal policy and peak-hour traffic flow, while also providing cyclists an efficient transport means and comfortable atmosphere?

How should cyclist rest areas and stops be designed, and where should they be located?

2. *How To Resolve Potential Conflicts?*

   How can the design avoid interference with cars along on-road parking areas?

   How can the design avoid interference between buses and cyclists at bus stations?

   How can intersections be improved to maximize safety and efficiency?

   What are the best strategies for improving the environment that cyclists share with pedestrians?

3. *How To Establish and Improve Bicycle Parking and Storage Facilities?*

   What elements are needed in bicycle storage and parking design according to different land uses and locations?

   How can landscape design be used to enhance bicycle parking lots and facilities at subway stations?

4. *How To Develop The Green Networks?*

   What are the significant elements for establishing a bicycle network?

   How can landscape architecture elements be used to build comfortable human-scale
environments?

How might bike lanes connect existing and potential green spots?

What are the best means to build connections between bike paths along roads and in parks?

What are the best strategies for designing a clear way-finding system?

1.3 Assumptions

On this particular site, this creative project will propose a sample for designing modern green bicycle networks in Beijing to provide an alternative transport means for commuters in large Chinese cities, plus a recreational network of green spaces. The government will be supportive of the proposed modifications and changes, and accept possible adjustments to the existing planning codes. The project will have no funding or timing restrictions for design and construction. The project design will be based on existing land-uses and infrastructure conditions, but will also consider traffic flow and prospective users. If feasible, this theory could provide an exemplar for the whole area of Haidian District or even the entire Beijing City.

1.4 Delimitation

The creative project will be limited to urban settings that used to have quite advanced bicycle networks and have developed public transportation. Moreover, the site should have
existing or potential green spaces along or near the streets. And the design should be adjusted if applied to a site that has different climate or topology conditions.

1.5 Methodology

Methods used in this creative project will include on-site observation and mapping, review of documentation, relevant literature, case study, and individual interviews. A report will synthesize all the information and data collected. Design will also be used as a method for exploring potential solutions to problems within the site.

On-Site Observation and Mapping

On-Site Observation includes observations of the place and human activity on site. Information includes types of land-uses, buildings and structures; areas of green and vacant spaces; and number and location of subway stations and bus stations. Observation also includes specific inventory of existing conditions of bike lanes, bicycle storage, and conflicts among automobiles, bicycles and pedestrians. Some individual interviews with people on site will also be used as an auxiliary. On-site observations will address transport and parking experience, concerns and suggestions about on-site traffic problems, cycling experience in other areas in Beijing, and changes in transport experiences over time.
Review of Documentation and Relevant Literatures

Literature Review as a method of researching this creative project includes two parts. One is the review and study of literature addressing similar questions that my creative project intends to solve. This part has been stated more explicitly and comprehensively in Chapter 2 “Literature Review.” The other part of the literature review explores the site and larger area, which includes current site information, site history, and the government’s planning codes and policies affecting the site.

Case Study

The creative project will explore case studies at both system planning and site design levels, plus bicycle policies. At the system planning level, Boston’s Emerald Necklace is one case study that illustrates a larger version of park chain to study critical elements for establishing a green network. For the site design level, the cases will be collected and studied under the following three categories based on the sub-problems of the creative project: 1) bicycle lane and path design, 2) potential conflict solutions and, 3) parking and storage design. For this part, the creative project will research the New York City High Line, Indianapolis Cultural Trail, Madrid Rio, and Bikestation in Washington, D.C. as major cases. Some of these projects focus on one aspect, but more of the projects cover multiple problems of my research. Important lessons can be learned from these existing projects for
their success in achieving comfortable human-scale environments. Their shortcomings also provide lessons for this creative project.

1.6 Goals and Objectives

This creative project will explore how to improve bicycle networks in Zhongguancun, Beijing, China. The goals of the project are:

- To create a safe and efficient transport environment for bicycle commuting.
- To provide a comfortable human-scale environment for cyclists’ recreational use.

To achieve these goals, the objectives are:

- To improve current bicycle infrastructure conditions by a series of strategies, and to integrate it with public transportation systems.
- To connect the existing green spaces and potential vacant areas to establish a “green” network along the roads.

The first objective divided into 3 sub-topic for a total of four objectives of the creative project:

- Bicycle Path and Bicycle Lane Design
- Conflict Resolution
- Parking and Storage Design
- Green Network Development
CHAPTER 2. LITERATURE REVIEW

Introduction

Prior to design, alternative review is needed. According to the goals and objectives of this project, this chapter conducted a review of documentation and relevant literatures to identify current solutions for establishing and improving a bicycle network. The literature includes four sections: 1) Bicycle Path and Bicycle Lane Design, 2) Conflict Resolution, 3) Parking and Storage Design, and 4) Green Network Development.

2.1 Bicycle Path and Bicycle Lane Design

The bikeway design is one of the most basic and important considerations when establishing a bike network for this creative project. Aspects to consider include bikeway width, longitudinal design, surface and pavement, barriers and separators.

Most literature sources that are pertinent to study of bikeway design are design and construction guidelines and manuals. The most important sources this proposal refers to are “Bicycle Circulation” from Time Saver Standards for Landscape Architecture: Design and Construction, edited by Nicholas Dines (2nd ed., 1998) and Design Guidelines for Pedestrian and Non-Motorized Transport Systems in Beijing City (2010), published by the Beijing General Municipal Engineering Design and Research Institute. Both sources offer rules and guidelines for design factors based on the situation and policies of their relative regions.

The proposal also draws information from reports of city planning and design projects...
(Balshone, 1975; City of Portland Bureau of transportation, 2010; Department for Transport, 2008; Director of Environmental Services, 1998; Ponsorf, 1995.), which provide specific examples of bikeway design.

The “Bicycle Circulation” Section of Time Saver (Dines, 1998) notes four primary types of bikeways designed to meet cyclists’ functional and recreational needs: bicycle path, bicycle lane, wide outside lane, and shared roadway.

Among these four categories, bicycle path “refers to a facility separated from motor traffic by an open space or barrier either within the road right-of-way or an independent right-of-way, or for the primary use of bicycles” (Dines, 1998, p341-2). It should ideally be a dedicated right-of-way with separate furnishings and should be at least 2.4-3.6m(8-12ft.) wide (See Figure 2.1). Bicycle lane “refers to a portion of a roadway which has been designated by striping, signing, and pavement markings for preferential or exclusive use by bicyclists” (Dines, 1998, p341-3). It is part of the road but separated by markings or textured strip, and the lane should be 1.5-1.8m(5-6ft.) minimum in width (See Figure 2.2).
There are four factors to consider when determining widths for bikeways: 1) Spatial dimensions of bicyclist and bicycle, 2) Maneuvering space required for balancing, 3) Additional clearances required to avoid obstacles, and 4) Anticipated traffic volumes (Dines, 1998). *Design Guideline for Pedestrian and Non-Motorized Transport System in Beijing City* (2010) explains some of these factors more clearly and practically. For instance, designers should consider traffic circulation and adjacent land use types plus the peak flow of bicycle use and designed capacity of traffic volume of one single bike lane. Moreover, when deciding the width of bicycle paths or bicycle lanes along the road in urban settings, designers should also consider the status of road level and the comprehensive flow of bicycles. The bike path or lane must achieve a certain service standard.

Bicyclists require at least 1.0m (40 inches) of essential operating space based solely on their profile (American Association of State Highway And Transportation Officials, 1999). Based on this data, an operating space of 1.2m (4 feet) is assumed as the minimum width for cyclists, but a more comfortable operating space of at least 1.5m (5 feet) is desirable.

In addition, the width of pavement for non-motorized transport includes the width of the bicycle path plus 0.25m (10 inches) of marginal strip on each side. If there are large numbers of other non-motorized transport with bicycles traveling on a road, designers should provide a wider pavement area for non-motorized transport (Beijing General Municipal Engineering Design and Research Institute, 2010).
Longitudinal design is one important factor that must be considered when designing a bikeway. Based on *Design Guidelines for Pedestrian and Non-Motorized Transport Systems in Beijing City* (2010), it should be regulated by height restriction in the urban planning code, match the street building façade, and meet the surface drainage requirement of the adjacent area. The longitudinal slope should be less than 2.5%. When shared with motor vehicles, the slope design should be based on the climbing capacity of bicycles; when shared with pedestrians, the slope design should be based on the requirement of pedestrian slope.

The design of paving and surfacing is another significant factor of bikeway design. The pavement should integrate with the adjacent environment. The surface should be smooth, not be slippery, and have a certain level of abrasion resistance (Beijing General Municipal Engineering Design and Research Institute, 2010), and have a thickness capable of supporting normal-size maintenance vehicles (Dines, 1998), which in Beijing would be pick-up trucks. The material should be durable, economical, and easy to maintain, to achieve comfortable bicycle riding.

Bikeway surfaces should have a slight slope of at least 2% to provide drainage, depending on the texture and composition of the surfacing material. Curbs along the road should be interrupted to allow drainage. If the curbs are not interrupted, designers should provide surface drain inlets (Dines, 1998).
2.2 Conflict Resolution

Conflicts in this chapter indicate potential problems caused by confused intersections between bicycles, motor vehicles, and pedestrians. This chapter will review literature exploring four major problems that always occur in Beijing City: 1) Conflicts at crossings, 2) Conflicts at intersections, 3) Interference between buses and cyclists at bus stations, and 4) Interference between cars and cyclists along on-road parking areas.

Literature about this topic includes design and construction guidelines and manuals, which offer relative regulations and requirements, plus design principles and strategies. Academic journals also incorporated in this chapter discuss specific studies, such as the analysis of influence of left-turn bicycles on passage of straight-through vehicles (Xu, 2005). However, most of these journals are written by professionals who study traffic or transportation, and their major focuses are changes and improvements under the existing conditions and regulations. Few sources discuss landscape design strategies that offer innovative approaches to bicycle transit.

As for improving ease and safety at crossings, an elevated bicycle path could be one solution to resolve the conflict problem. A project in London has approved an elevated bicycle network above the primary streets (Wheels in the Sky, 2012), which will be built in 2015. An elevated system like this has benefits of separating bike path from the major traffic. It could also resolve conflicts at intersections and bus stations. Although an elevated structure for bicycles can be costly, it may cause many to rethink the city code.
Overpass is a more common solution in China, but causes cyclists to get off their bikes and push them up steep inclines. Designers could consider an overpass design which allows cyclists to ride up and down on their bikes (See Figure 2.3). Designing this type of overpass should follow the slope design guideline. While overpasses in United States are designed to cross the highways, in this study, an overpass is more like a footbridge in an urban setting, for pedestrians and cyclists.

A ground-level crosswalk is more common on roads that have less traffic flow. Strategies for improving safety and efficiency include painting (City of Copenhagen, Building and Construction Administration, 2002)(See Figure 2.4), changing elevation (City of Portland Bureau of transportation, 2010), and building a separator.

One way to avoid potential conflicts at intersections is extending entrances onto the road (See Figure 2.5). *Complete Streets: Best Policy and Implementation Practices* (2010)
mentioned this strategy. Adding curb extensions could reduce the crossing distance, and increase visibility of both motor vehicle drivers and the pedestrians. It could also slow right-turn vehicles by reducing the curb radius. This method is usually used for roads with on-road parking. When used without on-road parking, a lane should be dropped or added at the intersection (Ronkin, 2010).

Another strategy is reinforced cycle lane (City of Copenhagen, Building and Construction Administration, 2002), such as the dedicated bike lane in Copenhagen and the Cultural Trail in Indianapolis. The benefit of this strategy is to attract drivers’ attention to pedestrians and cyclists in order to improve safety. Another benefit it provides is an opportunity for celebrating aesthetic features and site significance.

Pedestrian overpasses for pedestrians and cyclists could also be used at intersections to reduce conflicts (See Figure 2.6). This strategy is generally used for intersections that have complex layout and heavy traffic flow. One drawback to this strategy is the high cost for construction.

Figure 2.5 Curb Extension (McCann, 2010)

Figure 2.6 Pedestrian Overpass at Intersection (Lakics, 2012)
As for interference between buses and cyclists at bus stations (in this situation, the road contains a bicycle lane instead of bicycle path), Du et al. (2011) analyze the impact of bicycles on buses at bus station by analyzing two different typical types of bus stations as examples. The authors propose two strategies for changing the bike lane. One pushes the sidewalk back and separates the bike lane into two lanes at the bus station, which makes the platform become an island. This allows cyclists to go around the back of the platform when a bus enters the bus station. Another strategy is to move the entire section of bike lane to the back of the platform at the bus station. Both strategies offer solutions for separating bicycle and bus flow. However, both also reduce the width of a section of pedestrian sidewalk, which may cause inconvenience in places with a large number of pedestrians.

No available peer-reviewed articles discuss interference between cars and cyclists along on-road parking areas. Some news on websites or in newspapers mentions this situation, but no one provides a way to solve it. However, this problem could be resolved by
referring to the previous strategy for resolving conflicts at bus stations. Establishing elevated bike paths or moving the bike lane beyond the curb could also resolve this problem.

2.3 Parking & Storage Design

Bicycle storage modes could be classified into three categories: storage building, shelter, and parking lot. The most common mode in Beijing today is a bicycle parking lot, which is mostly found at park entrances, department stores, business buildings, etc. Bicycle shelters are generally located in residential communities, on university campuses, in high schools, in some residential communities, office buildings, etc. Buildings for bicycle parking have not yet appeared in Beijing.

According to Dines (1998), bicycle racks and parking facilities “should be located as close to destinations as possible without interfering with pedestrians traffic” (341-14). If the storage facilities are more than 15m (50ft.) away, most cyclists will prefer to attach their bikes to the nearest structures, such as light poles, instead of the storage facilities. He also suggests designers should establish storage facilities with visual supervision, lighting, and shelter from inclement weather. The size of a bicycle parking area should be based on usage of the building it services, average peak day traffic flow, average parking time, and turnover times of the area, etc. (Beijing General Municipal Engineering Design and Research Institute, 2010).
In Beijing, people cannot bring their bikes into the subway station. Therefore, bicycle storage at subway stations becomes an essential problem for commuters who want to cycle to a subway station. Bicycle storage at subway stations could combine with site design projects using landscape architecture as an approach. One possible storage method at subway stations is bicycle cages or bicycle shelters. One of the case study projects is the Bikestation in Washington, D.C., near the Union Station, the city’s central transit hub (Stocker, 2009)(See Figure 2.9). The freestanding 1,600 sq. ft. ultra-modern glass and steel structure houses over 100 bicycles. The benefit of this type of locked shelter is that it is durable and theftproof. It could be applied to locations near subway stations in large cities. The drawback to this structure is its limited volume, and it is unmovable. Moreover, the construction costs are much higher when compared with bicycle parking lots.

Figure 2.9 Bikestation in Washington D.C. (Bikestation, 2013)

Bicycle parking lots (See Figure 2.10) could be another storage method at subway stations. They should be installed with bike racks for neat arrangement and theft prevention. The major benefit of bicycle racks is cost-efficiency. This storage method is
flexible and could be used for other purposes when there are few bicycles. However, the biggest drawback of bike racks is they do not effectively prevent theft. Thus, designers should place them in locations with lower theft rate or offer locks attached to the racks, such as those used in the Hangzhou bicycle sharing system (Yang, 2011)(See Figure 2.11). As a landscape element, a bike rack’s design could communicate interests, contain elements of bicycles, or indicate the significance of the site.

![Bicycle Parking Lot](image1)

![Anti-theft Lock](image2)

**Figure 2.10 Bicycle Parking Lot**
*Smart, 2011*

**Figure 2.11 Anti-theft Lock of Hangzhou Bike Sharing System**
*Pin, 2010*

The storage method at bus stations could be bike racks combined with benches (Nifty, 2011). Protection against theft is another essential issue at a crowded bus station, so attached locks could be considered. Economic bicycle lockers could also be adopted (NYC Dept City Planning Transportation Division, 2009), but they cost more and require more maintenance, and also not as space-efficient as bike racks or bike parking lots.

Bicycle storage buildings could be used for storage at the entrance to commercial
centers. A project located in Amsterdam, Netherlands is a three-story structure with a capacity of 2,500 bicycles (VMX, 2004) (See Figure 2.12). The benefits of a multi-level bicycle storage building are it contains more bicycles with occupying less space and is easy to be supervised and protected with an access control system. While the drawbacks of this method include its inflexibility, required construction approval from planning and architecture departments, and greater costs in money and time than shelters or racks.

Figure 2.12 VMX Architects Bicycle Storage (VMX, 2004)

University campuses have among the highest bicycle usage (Xue, 2010), but also the highest bicycle theft in Chinese cities. The most common bicycle storage method on campus is gated bicycle shelters with guards, generally located near staff dwellings and student dormitories. Students and staff could store their bikes in the shelters for a certain period (usually semiannually or annually) by paying a small fee. There are also some bicycle shelters or racks located at each department building, but most universities do not manage them well. The bicycles are disordered, and the parking areas are over-loaded. This impacts
the appearance of the campus and disturbs traffic. Besides, bicycles not attached to the racks are easily stolen. A bicycle storage building may be a better solution for university campuses. However, every piece of land in Chinese cities is highly prized; thus, large space requirements cause the most resistance.

During the early 2000s, there were generally gated bicycle shelters in residential areas in Beijing. Before that, bicycle racks in front of each residential block were more common. However, automobile ownership has increased dramatically, and now vehicle parking occupies almost every single piece of available space in traditional residential communities, leaving no space to park bicycles. For this situation, a concept project of hanging bicycles on the wall could be referred (Kelly, 2011)(See Figure 2.13). The Bike Hanger is an essential facility for the city of Seoul designed by Manifesto Architecture. Each hanger can store between 20-36 bicycles is installed attached to the sides of buildings to take advantage of many of the underutilized spaces that exist around the city. It might be used

Figure 2.13 Bike Hanger by MANIFESTO (Kelly, 2011)
for residential communities or other types of places experience an extreme lack of space. Drawbacks include finding suitable structures to attach the structures to and management of bicycles.

Few people park their bicycles at office buildings, and theft risk is also limited, so bicycle racks could meet the need of these areas.

High schools students typically have the most advanced and expensive bicycles. Most of the high schools in Beijing have gated bicycle shelters and bicycle racks in school areas. Because most high schools do not allow others to enter, the theft percentage is not high. Tiered rack systems (See Figure 2.14) and Vertical systems (See Figure 2.15) could be considered if there is a lack of space (NYC Department of City Planning, 2009).

2.4 Green Bicycle Network Development

The literature informs a green bicycle network design at three levels: green nodes,
green paths, and green network. At each green node, a comfortable human-scale environment can be built by using landscape architecture as an approach. Then green bicycle paths connect existing and potential green nodes. Finally, by building connections between bicycle lanes on roads and bicycle paths along roadsides, and adding a clear way-finding system, a design can complete convenient bicycle circulation and achieve a comfortable user-friendly green network.

To decide what types of green space each node needs, and what elements each type requires, the author reviewed the book *People Places* (Marcus, 1997) and picked three typologies of places that could apply to this study’s chosen site based on their definitions. The three typologies shall be defined as: urban plaza, neighborhood parks, and miniparks and vest-pocket parks.

Ye (2010) classifies four levels of bicycle path in the article “Bicycle path network planning in big cities based on bicycle/motor vehicle separation system” and recommends path density, distance, and width for each level (See Figure 3.16). The green line in this project fits the third class, and sections of bike path at the roadside fit the fourth class.

Chapter 7 of the book *Complete Streets: Best Policy and Implementation Practices* (2010) includes a catalog of specific design treatments for developing a complete street. The editor mentions, “Landscaping softens any streetscape to create a more inviting and visually interesting pedestrian experience” (98). The method used to connect the green spots should also be green. A user-friendly green belt could be applied to the site to connect the
existing and potential green nodes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Class</th>
<th>Design Goals/Objectives</th>
<th>Bicycle Right-of-way</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Municipal level bikeway</td>
<td>Should have two lanes for quick and slow flows;</td>
<td>Prioritize the transport of biking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connected among districts</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>District-level bikeway</td>
<td>Well-connected within the district;</td>
<td>Guarantee the flow of bike traffic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connect major roads</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Within district-level bikeway</td>
<td>Connect district roads within the district</td>
<td>Fulfill the minimum accessibility requirement of bike traffic</td>
</tr>
<tr>
<td>4</td>
<td>Green bicycle path for leisure</td>
<td>Has entertainment function; Close to water and green</td>
<td>Motor vehicle should be separated from the bike lane</td>
</tr>
</tbody>
</table>

Figure 3.16 Orientation of Four Classes of Bicycle Paths and Rights-of-way

Establishing an effective traffic-oriented green network requires five basic traffic control strategies: 1) Fulfill a need, 2) Command attention, 3) Convey a clear, simple meaning, 4) Command respect of road users, and 5) Provide adequate time for response (Dines, 1998).
CHAPTER 3 SITE INVENTORY AND ANALYSIS

3.1 Current Urban Conditions in Beijing

Social Conditions of Beijing

Beijing, the capital of China, is the nation's political, cultural, educational, and transportation center. It covers an area of 16,410.54 km² (6,336.14 sq. mi) in which 1,368.32 km² (528.31 sq. mi) is urban area. As of 2013, Beijing has a population of 20,693,000, and the average density is 1260/km² (3,300/sq.mi), with 86.2% urban population ("Beijing," 2013).

Beijing has been the capital of China since ancient times (1267), and also the capital of the People’s Republic of China since its founding in 1949. It boasts both rich cultural heritage and contemporary lifestyle. These old and new integrate and influence each other, making Beijing a unique cosmopolitan city.

Geography Conditions of Beijing

Beijing is located at 39°56'E, 116°20'N. It has a monsoon-influenced continental
climate, characterized by hot, humid summers due to the East Asian monsoon and generally cold, windy, dry winters which reflect the influence of the vast Siberian anticyclone. Spring and fall are moderate but short.

Beijing has a typical monsoon climate, with 60% of the precipitation in July and August, and relative dryness in other seasons. The monthly daily average temperature is -3.7°C (25.3°F) in January, and 12.3°C (79.2°F) in July. Record extremes range from -27.4°C (-17°F) to 42.6°C (109°F) (“Beijing”, 2013).

Beijing is situated in the North China Plain between the Taihang and Yanshan Mountains. It is surrounded by mountains on the north and east, but flat in the center. The average elevation is 43.5 m (142.7 ft.). The center of the city is on a plain at an elevation about 20 to 60m (66-199 ft.), and the mountain area ranges from 1000 to 1500 m (3281-4921 ft.) (“Beijing”, 2013).
The watershed system in Beijing is broadly divided into two parts: natural and artificial water bodies. Rainwater flows from east and north mountains to the plain, and gathers into five main rivers, which integrate the entire natural watershed system in Beijing. As the key zone of water conservancy construction since ancient time, Beijing has numerous artificial water bodies. After alterations during various dynasties, remaining artificial water bodies include the most northern section of Beijing-Hangzhou Grand Canal, the reserved sections of the moat system surrounding the fortifications, and some lakes in and near the imperial city. All of the artificial water bodies are connected to each other and finally connected with natural rivers to integrate an entire watershed system in Beijing.

**Air Pollution in Beijing**

Air pollution is a major environmental problem in Beijing today. Although the Beijing Municipal Environmental Protection Bureau has claimed that annual average PM2.5 (“particulate matter that has a diameter of 2.5 micrometers or less”) Index has been declining over the past decade, “Beyond index” situations (when the instant Index exceeded 500 micrograms) have happened during late fall and winter when the air flow is steady (“Particulates”, 2013). For instance, during September 2013, the PM2.5 of Center Beijing was recorded beyond index for 14 days. That is why People jokingly call Beijing “the City of Haze.”

The formation of haze in Beijing is caused by topography, climate conditions, and
explosive transformation of sulfur dioxide to sulfate caused by coal-firing for power production and heating in surrounding provinces. Continuous pollution is caused by emission of organics from local motor vehicles and coal use. Yuesi Wang, scholar working at the Institute of Atmospheric Physics, Chinese Academy of Sciences, analyzed the data and discovered that motor vehicle emissions are a major source of PM2.5 in Beijing, accounting for 25% of its formation (Zhao, 2013).

**Urban Expanding of Beijing Area**

Figure 3.4 Beijing Urban Area Expanded Map
Beijing is the world’s 12th largest urban area and is larger than any urban area in the United States except New York. Beijing Urban Master Plan (1957) drew up the major urban area’s spatial development pattern: one center with a network of radial and ring roads. The economic development in Beijing has resulted in unprecedented population growth and urban expansion. As shown in Figure 3.4, in 1990, the urban area was 571.00 sq. km (220 sq. mi), and the population was 7,362,000. By 2004, urban area expanded to 1,423.38 sq. km (550 sq. mi) with a population of 10,718,000. In 2010, the urban area had spread to 3,421.51 sq. km (1321 sq. mi) and the population became 11,741,000. The urban area has expanded up to 6 times within just 10 years (1990-2010), and this trend is still continuing.

The radial and ring urban pattern has many negative effects, such as overcrowding, traffic congestion, heat island effect, air pollution, and escalating real estate values. People
have realized this would be a problem. In the 1983 version of *Beijing Urban Master Plan*, the city planned to restrict the further expansion of the urban area by developing satellite cities beyond the suburbs, which did not result well. The 2004 version of *Beijing Urban Master Plan* proposed a pattern of “Two axes, two belts, and multiple centers,” and planned a greenbelt around the urban center to limit expansion (See figure 3.5 and 3.6), which resembles to the Urban Green Belts in many US cities. But the trend of Beijing’s urban expanding never slows down its pace.

**Transportation Conditions of Beijing Area**

Beijing’s expanding has resulted in expanding ring roads. As of 2013, the city had 6 enclosure ring roads surrounding the center (See Figure 3.7). While the business hubs are still in the center areas, residential regions have been pushed further away. This results in longer commute distances and more people purchasing private vehicles. Moreover, it causes traffic congestion from surrounding areas to the urban center during morning rush, and the opposite direction during afternoon rush hours. The 7th Ring Road is under construction and will open to traffic in 2015. This road is just a conceptual “ring” and does not have the actual effect of national expressways as other ring roads. It will extend to adjacent provinces, and its main task is to divert all the freight traffic from the 6th Ring Road.
Public transportation is further emphasized to relieve the problems. The rate of traveling by public transportation usage reached 42% in 2011, which marked a degree of success (Beijing Transportation Research Center, 2011).

The Beijing subway network is one example that shows the efforts of the city’s infrastructure departments. The subway system once had two lines in Beijing but has been rapidly developing since 2002. In 2013, Beijing subway has 17 completed lines and 270 stations (See Figure 3.8). The total length of track in operation is 456 km (283 mi), making
it the third longest subway system in the world. The subway system also ranks third globally in annual ridership, with an average weekday ridership of over 10 million. Beijing subway network is still under extensive expansion today. The plans call for 708 km (440 mi) of track in operation by the end of 2015 and longer than 1,000 km (650 mi) by 2020.

Figure 3.8 Beijing Current Subway Network Map (Beijing Mass Transit Railway, 2010)

Beijing subway has a low fare of RMB2.00 (about USD0.32) per ride with free transfers on all lines except for the Airport Express. It is the lowest cost rapid transit system in China. Keeping a low fare is another policy to increase the usage of public transit systems.

The construction of the subway network brought great convenience to people.
especially commuters. However, the existing network still cannot meet all of the city’s mass transit needs caused by urban expansion and population growth. Every subway line becomes overcrowded during rush hours as soon as it opens to traffic.

**Variation in the Number and Usage of Bicycles in Beijing**

Bicycles were once the primary mode of transport in Beijing. “There were three peaks of bicycle ownership variation in Beijing: 1.5 million in 1981, 2.8 million in 1985, and over 4 million in 1989,” former deputy director of Beijing Traffic Management Bureau Prof. Liren Duan stated in an interview (Beijing Government Claim, 2010). Bicycle ownership in Beijing exceeded 6 million in 1993, but after 2000, the growth rate slowed down slightly.

Figure 3.9 is developed based on data from multiple sources. The graph clearly shows that bicycle ownership in Beijing has linear growth after 1981, while the automobile ownership grows exponentially. Even so, compared with decreasing bicycle ownership across the country (See Figure 1.1), bicycle ownership is still growing in Beijing. It could be a support basis of the demand of building a bicycle-friendly city.

However, the ownership does not mean usage. Bicycle usage in Beijing has decreased year by year. Prof. Liren Duan said the proportion of travelling by bicycle in Beijing dropped from 57% in 1990, to 40% in 2000 (Beijing Government Claim, 2010). Another source from the municipal traffic department indicates the number decreased by more than a half in the following decade (Friends of Nature, 2011), which means the proportion
of travelling by bicycle in 2009 was less than 20%. The September 23, 2013 morning news from Beijing Television (BTV) indicated this rate has decreased to 15% in 2013.

**Pedestrian and Bicycle Policy Changes**

The history of Beijing has witnessed the up and down of policy makers’ attention on biking as an important component of the holistic transportation system. The city started to develop its urban master plan in 1953, but the use of bicycles as transport was not planned in these documents until 1991. Even then, the “Urban Transportation” portion just said in brackets: “The passenger capacity of all types of transportation (including bicycle) in urban areas will increase from 6.8 million in 1991 to 8.26 million in 2000, and to 9.44 million in
2010. The percentage of population travelling by public transportation in 2000 and 2010 will reach 47.4% and 58.4%" (Beijing Municipal Commission of Urban Planning, 1992, Author's translation).

The subsequent 2004 version of _Beijing Urban Master Plan_ added a separate subsection for Pedestrian and Bicycle Transport under Chapter 13 “Integrated Transport System”: It states, “Pedestrian and bicycle transport is still one of the major modes of transportation. The city will promote walking and bicycling, prioritize pedestrian, and create a safe, convenient, and comfortable environment for pedestrians and cyclists, including disabled groups.” The same subsection calls to “provide convenience for pedestrian street crossings and bicycle transport when planning, constructing, and enacting policies and regulations. Plans should ensure effective width of sidewalks. Crossing facilities in the urban center should be mainly in plane form, supplemented by three-dimensional modes. Future development should improve transfer environment between bicycle and public transportation. It should also achieve physical isolation between auto vehicle and bicycle on the second level of roads and above to ensure a safe and unobstructed cycling environment. Planners should draw up urban pedestrian planning, bicycle transport planning, and incorporate these into the city's comprehensive transportation planning” (Beijing Municipal Commission of Urban Planning, 2005, Author's translation).

For the benefit of energy conservation, Beijing government is paying greater attention to bicycle traffic. _Beijing “Twelfth Five Years” Energy Conservation National Action Plan_
(2011) clearly encouraged bicycle travel and proposed special bicycle paths on key avenues, historical preservation areas, business centers and other regions. This plan also proposed constructing “Beijing On-bike Sightseeing Routes” and improving bicycle sharing networks. This action plan also asked the Beijing Municipal Commission of Transport to lead the action and work collaboratively with other related departments.


Social groups in Beijing have started to organize ridership-promoting activities. Friends of Nature was the first non-government organization in China to deal with environmental issues. The group seeks to raise awareness about environmental protection through workshops, field trips, and teacher training. It has published several reports on the current situation of bicycle use in China and encourages people to bicycle whenever they can.

While the society is paying greater attention to bicycle transportation, the attention can hardly offset the effect from the growing number of private cars.

3.2 Site Location and Context

Site Location

This creative project selects a site in Zhongguancun area, Haidian District, Beijing,
China, between the Northwest 3rd and 4th Ring Roads (See Figure 3.10), which represents a typical combination of all the urban elements in a large, fast-growing city. The length of the site is about 2.1 km (1.3 mi), and the site area is about 23 ha (57 acre) (See Figure 3.12).
The site is located in Zhongguancun Haidian Park. It is the center and the original site of the “Zhongguancun Science & Technology Zone” (Shown in gray in Figure 3.11), which is often referred to as "China’s Silicon Valley." Located in adjacent areas are China’s two most prestigious universities--Peking University and Tsinghua University--plus the Chinese Academy of Sciences. Five prominent IT and electronic markets are located in this area, and some successful local technology companies, including Lenovo, which originated and developed here.

**Transportation Context**

The major part of the site is a section of Zhongguancun Avenue, a north-south second-level road conducting major transportation to Zhongguancun Science & Technology
Zone. This section is an important transportation connection between the 3rd and 4th Ring Roads. As shown in the road section (See Figure 3.14), moving out from the middle, each side of the road has four vehicle lanes, a 1.5m (4.9 ft.) separator with bus stations, a 6.5-meter-wide (21.3 ft.) bicycle lane, and a pedestrian lane along the curb.

Figure 3.14 Section of Zhongguancun Avenue

Figure 3.15 Sections of the 4th Ring Road

Figure 3.16 Sections of South Haidian Road

Figure 3.17 Sections of the 3rd Ring Road
Figure 3.18 Zhongguancun Avenue (Yan, 2008)

Figure 3.19 S. Haidian Road (Gargar, 2007)

Figure 3.20 Zhongguancun West Area (Yu, 2012)

Figure 3.21 Zhongguancun Avenue Overpass Crossing 4th Ring Road (Phoenix New Media, 2011)

Figure 3.22 Zhongguancun Avenue Underpass Crossing 3rd Ring Road (Wu, 2008)
A 2nd-level road crossing Zhongguancun Avenue in the middle of the study area, South Haidian Road is narrower and has much less traffic. Beijing’s 4th and 3rd Ring Roads are expressways with no at-grade intersections. The 4th Ring Road main expressway passes underneath Zhongguancun Avenue, and its auxiliary or feeder remains at the ground level. A massive pedestrian overpass over this intersection separates pedestrians and cyclists from ground-level traffic flow (See Figure 3.21). Main vehicle lanes of the 3rd Ring Road pass over Zhongguancun Avenue (See Figure 3.22).

Subway line 10 goes along Zhongguancun Avenue underneath the site, and another crosses it. Three subway stations, each with 4 or 5 pedestrian-only entrances, are located on the site.

Figure 3.23 Sections of Adjacent Lower-Level Roads
Landscape Context

As the map in Figure 3.24 shows, green circles indicate parks and green spaces with or near water bodies. The map indicates that green spots concentrate in two areas. The first area is centered around the Imperial City includes Beihai Park, adjacent to the Forbidden City. Built in the 10th century, Beihai Park is the oldest existing imperial garden in the world. Its scenic beauty and gorgeous structures reflect the design and construction techniques of Chinese traditional landscape and architecture. It is a must-see destination for tourists.
Another cluster of green spaces is at the northwest of the city. The Summer Palace and the Old Summer Palace near the north end of the project site were both imperial gardens during Qing dynasty. The Summer Palace was recognized as a UNESCO World Heritage site in December 1998. It was declared "a masterpiece of Chinese landscape garden design. The natural landscape of hills and open water is combined with artificial features such as pavilions, halls, palaces, temples and bridges to form a harmonious ensemble of outstanding aesthetic value" (UNESCO, 1998). The Summer Palace is a popular tourist destination and also serves as one of Beijing's most popular recreational parks. It attracts people of all ages for its proximity to the urban center and a beautifully designed environment that mimics the naturalistic beauty.

Extending along the rivers, Beijing's furthest northwest green spots reach the mountains. Located beyond urban Beijing, Xiangshan Mountain Park presents a pristine beauty. It is the best place to watch fall foliage and to hike with family and friends, especially senior citizens. The bus routes from the city to Xiangshan Mountain are extremely full every morning, and the crowds must often wait through several buses to return home when the park closes.

Figure 3.24 shows barely any green space between the 3rd and 4th Ring Road. Busy traffic and over-construction have cut off potential connections among green areas. This project proposes that all the green spots can be connected into a more integrated green network by adding green corridors between the 3rd and 4th Ring Roads.
3.3 Land-use

Areas along the major road cover multiple land use types, including residential, commercial, office building, administration and public service, university campus, high school and primary school, hospital, and public green spaces.

The northernmost part on the west side of Zhongguancun Avenue is located with
business buildings for Administration and Public Service. The first floor of buildings near the avenue house retail specializing in information technology and electronic markets. People travel here by bus and subway to purchase PC-compatible hardware, peripherals and software. Away from the avenue are business offices. Employees usually live far away and commute to work mostly by subway, taxi, or private cars.

The commercial area to the adjacent south is a popular place for shopping and dining. Together, this area and the one above belong to Zhongguancun West Area. A short section of pedestrian-only street in the area hosts cultural or information technology-related activities a few times every year. A large shopping mall with a supermarket is underneath Zhongguancun West Area. Numerous people from nearby residential communities, universities, and business buildings come here for daily shopping and dining. People come to Zhongguancun West Area mostly by private vehicles, taxi, subway, or bus. Few people ride bicycles to this area, as there are few places to store bikes. Cyclists have to park their bike in front of the huge buildings without attaching to any rack, and worry about it being towed by the building’s security.

In Figure 3.25, the large pink area on the southwest is Renmin University of China, one of the nation’s prominent universities. Bicycles are the most popular transit mode on the campus, like other Chinese universities. Wireless telephone companies even distribute free bicycles to students who refill their account with a certain amount of money. Renmin University provides marked areas with racks for bicycle parking and storage in front of dorms and major teaching buildings (See Figure 3.26), and areas in front of every building also allow bicycle parking. Most students take the bus or subway for longer distance travelling. Zhongguancun West Area is a popular place for students of shop, enjoy
entertainment and learn English (a main teaching division of the most famous English learning agency, known as New Oriental, is located adjacent to this study's project site).

Most residential communities on site are located on the east side of the avenue. Most of them were built around 1980, others during the 1990s. Most of the communities on the site belong to the China Academy of Science for faculty residence. But nearly 30% of the homes are currently rented, mostly to nearby primary and high school students’ families. A typical residential community is shown in Figure 3.27. These communities used to be dominated by bicycles, but cars have gradually become the major transit. However, the original plan did not consider the increasing ownership of cars, so currently every possible space in these residential communities has been adapted for car parking (See Figure 3.28).

Figure 3.26 Campus of Renmin University of China (SosoMap, 2012)
Figure 3.27 Huangzhuang Community, a Typical Residential Community on the Site (Zhan, 2012)

Figure 3.28 Car Parking in Residential Communities on the Site (SosoMap, 2012)
Areas shown in light blue are high schools and primary schools. Located on the west side of Zhongguancun Avenue, the largest is one of the most recognized high schools in Beijing: the High School Affiliated to Renmin University. Most students are from Haidian District, which means the distances between their homes and the school are not too long. Ten years ago, when the author studied there, most students rode their bikes to school. Most residential areas in Haidian were within 20 minutes riding distance from these site, which is an acceptable time to a teenage rider. However, more families have owned cars during the past decade, and parents of the current generation spoil more their only children. Plus, some families have moved to new communities further north, so creating an increased number of parents drive their children to school. This causes serious traffic jams in front of the school gate, taking over the bicycle lane and sometimes even the main road (See Figure 3.29). This situation is worse in the afternoon when the parents are waiting for their children in their cars. Bicycle right-of-way should be indicated when redesigning this type of car-dominant area.

Figure 3.29 Cars Waiting for Students in Front of the High School Affiliated to Renmin University (SosoMap, 2012)
3.4 Building Footprints and Heights

Old residential buildings on site have long rectangular footprints and 3 to 6 stories. Newer residential towers are 15 to 18 stories. Most business buildings have huge massing are higher than 10 stories. Four buildings on site exceed 20 stories, including one located on Zhongguancun Plaza (the front Plaza of Zhongguancun West Area located in its
southwest). Further, there are plenty of permanent or temporary one-story buildings and structures on site. Some of them need to be blocked when redesigning to create a clearer view, and some could be involved as part of the human-scale landscape.

The building facades along Zhongguancun Avenue are generally continuous enclosed and adjacent to the avenue. Besides two open spaces at the southeast and northwest ends, Zhongguancun plaza is the only open corridor on the site towards the center of Zhongcuancun West Area. The landmark of Zhongguancun West Area, a 22-story building (Marked in Figure 3.31) and arched structure on an elevated platform, create a view to attract people from the avenue. Moreover, the elevated terraces from the plaza to the arch enhance this feeling (See Figure 3.32).

![Figure 3.32 View to Zhongguancun Plaza from the Site](Wei, 2012)  
![Figure 3.33 HuiCong Acadamy](A Guide, 2013)

A small courtyard located at the entrance of the pedestrian-only street was originally a temple, dating to Ming or Qing dynasty. After reconstruction, it is now an office location for a family business. The building retain the structural and decorative features of a Beijing traditional courtyard. It offers an opportunity to change this courtyard into a public
teahouse or a small museum introducing the history and development of the site. Therefore, the designed bicycle path could lead to this courtyard.

![Figure 3.34 Existing Building Model](image)

### 3.5 Subway and Bus Stations

Three subway stations are located on site, each with 4 or 5 pedestrian entrances. All three stations serve subway Line 4, and Huangzhuang Station also serves as a transfer station of Line 10. Entrances of all the stations connect both sides of the avenue, or all four quarters of intersections for the convenience of passengers. Huangzhuang Station has an additional entrance at the front of New Zhongguan Shopping Center, extending more than 250m (820 ft.) away from other entrances for the convenience of shoppers.

There are four bus stations on site, all with platforms on both sides of the avenue. Among them, South Huangzhuang Station is smaller which serves 10 bus routes. The other
three bus stations serve more than 20 routes. Buses have their dedicated lane on each side of Zhongguancun Avenue during rush hours (from 7am to 9am and from 4pm to 7pm). Other vehicles cannot use the dedicated bus lane during these times.

The circles shown in the map (See Figure 3.35) indicate 5 minutes walking distance
from subway station entrances or bus stations. According to *Design Guidelines For Pedestrian and Non-Motorized Transport System in Beijing City*, walking speed can be counted in the range from 0.8 m/s to 1.2 m/s (2.6-3.9 ft./s), and the average number 1.0 m/s (3.3 ft./s) is used by this study. Thus, a circle with a 300-meter (984 ft.) radius indicates the area that pedestrians could reach within 5 minutes. As the map shows, walking between two adjacent bus stations is acceptable, but longer distance can cause fatigue for pedestrians. Since all three subway stations serve the same line, and most of the bus routes go along the four stations on site, the proposed design will focus on activities within the proposed boundary.

![Figure 3.36 A Typical Bus Station on the Site (SosoMap, 2012)](image)

**3.6 Pedestrian Overpass**

No pedestrian crossing on site crosses the entire width of the avenue except at the intersection in the middle of the site. While the entrances of subway stations are connected underneath the avenue, pedestrian overpasses serves pedestrians (mostly from or to the
bus stations) and cyclists over the road. As shown in Figure 3.37, except the No.1 overpass above 4th Ring Road (excluded from this project) and the No.3, the other four overpasses are located near bus stations and have the same distances between each other. The No.3 overpass connected to Zhongguancun West Area indicates the strong need for pedestrian flow to and from that area.

![Figure 3.37 Pedestrian Overpass Map](image)
A typical overpass has four ramps providing access from north and south on each side of the avenue. The four ramps of an overpass have different gradients, two approximately 13% and two 30% (See Figure 3.38). A ramp of a typical overpass on site has steps in the middle and two narrow ramps on the sides for cyclists pushing their bikes (See Figure 3.39). Bicycles sometimes are parked underneath the ramps, which is vulnerable to theft.


3.7 Green Space and Vegetation

Figure 3.40 illustrates the limited green spaces on site. The largest piece of green is the Zhongguancun Plaza, which leads to further northwest green spaces. In 1997, street trees were planted along some sections of the avenue, but most are not yet large enough for shade. The original large trees were removed during the avenue widening construction in
1997. Also, some sections on the north part of the avenue do not have any street trees. In contrast, South Haidian Road maintains its street tree canopy. Residential areas and campuses have the highest density of trees and ground vegetation; however, Zhongguancun West Area holds almost no trees at all. One reason is that this area has an underground parking corridor and an underground shopping mall, which means certain areas could not support large trees. Another reason is this area has huge clusters of buildings close to each other and streets here are narrower, so they have little place for trees.

### 3.8 Lighting

Streetlights cover the entire length of Zhongguancun Avenue and the cross streets (See Figure 3.42). Commercial and business areas have sufficient lighting with a large amount of fixtures providing high-intensity illumination. Landscape lighting on Zhongguancun Plaza offers an appealing and safe environment for people to enjoy evening life (See Figure 3.43). A pedestrian overpass could be built at this spot to involve and enrich the brilliant night scene. The university campus has installed lighting facilities along every road, with longer intervals between lights. Even fewer lights exist in residential areas. In newer communities, lighting is concentrated around community gardens. However, lights between buildings in both older and newer residential communities are limited and tend to be dimmer. More landscape lights could be added for safety and utility.
3.9 Existing Bike Lane Conditions

Zhongguancun Avenue is a street originally constructed during the Qing dynasty. It was rebuilt as four-lane, two-way in 1982. Due to the increased traffic flow, it was widened to eight-lane, two-way during the reconstruction in 1997. Because of the space between
existing buildings and structures, the two sides are fixed, so the lanes of Zhongguancun Avenue, which is approximately 2.8m (9.2 ft.), are narrower than those of other similar level streets. The dedicated bus lane is about 3m (9.8 ft.) wide, while the running buses have a maximum width of 2.55m (8.4 ft.). The narrower bus lane causes difficult turning at intersections and docking at bus stations.

As shown in the road sections in Figure 3.44, moving out from the middle, each side of the road has four vehicle lanes, a separator with bus stations at certain spots, a 6.5-meter-wide bicycle lane, and a pedestrian lane with variable width along the curb. The original bike lane is partitioned into two parts: one for bicycles and the other for on-road parking or right-turning vehicle lane.
Figure 3.45 Existing Bike Lane Condition Map
In Figure 3.45, the dark reddish purple areas show where bicycle lanes are located with on-road vehicle parking. On-road parking is located along the right side of bicycle lanes. Conflicts occur when cars pull in and out of the parking spots (See Figure 3.46). When cars occupy the narrowed bicycle lane, cyclists have to make way for cars and ride through the gaps between them. Bicycle flow can be blocked, and safety issues would occur.

The magenta areas in Figure 3.45 show sections of the avenue, which have added a vehicle lane on the left side of the bicycle lane, which is common for right-turning vehicles only. The original bicycle lane was wide enough (6.5m/21.3ft.) before the vehicle lane was been added, so right now bicycles and cars could travel together in peace, with conflicts only happening at intersections (Show in purple in Figure 3.45) with cars turning right but

Figure 3.46 Conflicts of Bicycle Lane with On-road Parking

Figure 3.47 Conflicts of Bicycle Lane with Right-turning Vehicle Lane

bikes going straight (See Figure 3.47). Two sections on site (shown in light pink in Figure 3.45) have no fence between bicycle lane and cars, but do maintain the same width. Adding
fences along this type of bicycle lane could make them the same as the second type.

Dedicated bus lanes are located inward along the separators. Except the bus station adjacent to Overpass No.2 on the north, which has connected stairways (See Figure 3.48), at other bus stations, pedestrians moving to and from platforms cannot reach the sidewalks unless they cross the bicycle lanes (See Figure 3.49). Conflicts happen between pedestrians and bicycles and even the right-turning cars, or drivers looking for parking spots (See Figure 3.50). Due to the limited avenue width, separators on site are very narrow. Plus, bus stations on site have large carrying capacity, so people waiting for the bus often block the
road, which generates unsafe conditions.

![Figure 3.50 Additional Conflicts between Bicycle Lane and Bus Station](image)

3.10 Existing Bicycle Storage

As shown in Figure 3.51, storage on site could be classified into four types. The best-designed type is a dedicated area with a permanent structure surrounding vegetation (See Figure 3.51, photo 1). These occupy large areas near subway stations and business buildings, and these facilities charge 0.4-1 RMB (less than twenty US cents) per bike per day. Figure 3.52 shows the storage areas of this type on the north have high usage rates during the day, while the other ones in the middle of the site and on the south have extremely low usage. This can be attributed to northern storage areas being used by commuters working in nearby office buildings. On the other hand, the storage areas in the middle and on the south of the site were built recently for serving subway stations. However, people rarely park their bicycles at subway stations during the day because
Figure 3.51 Existing Bike Storage Type Map (Photos from SosoMap, 2012)
Figure 3.52 Existing Bike Storage Occupancy Rate Condition Map
subway stations are always the starting points to the final destinations, which are their places of employment. Moreover, the new established storage areas at subway stations charge more. Thus, people who commute by bike every day would rather park their bicycles on adjacent sidewalks for free (Storage Type 3. See the middle part of Figure 3.52). Among all the users of the paid storage, cyclists who operate electric bicycles have higher rate of use as their vehicles’ security is seen as a good value for the money.

The second type of bicycle storage is a small area defined within movable fences (See Figure 3.51, photo 2). They are seen near a post office and restaurant, at an entrance of the supermarket, in front of a theater, and at the university gate. Few people go to the first three places by bike, and those cycling to the university always ride though the gate into campus but do not park outside. These storage areas are located at notable places, and cyclists need them for storage, but their random temporary storage facilities could be aesthetically unpleasant. These storage areas typically do not charge, and no one guards the bikes, although fences do deter theft in principle. In Figure 3.52, one can see that the usage rate for this bicycle storage type is more than 50%.

Storage type 3 is bicycle parking along sidewalks. Most sections of sidewalks along Zhongguancun Avenue are wide enough for bicycle parking along one side. Cyclists could park their bikes between street trees, or along the fence (See Figure 3.51, photo 3). This type of parking happens spontaneously, showing the existing parking areas are where bicycle storage facilities actually need to be established. Parking along sidewalks is free but not guarded, so bicycles at these areas are vulnerable to theft. From Figure 3.52, the usage rate of this type runs a large range. That is because almost all the sidewalks on site have a potential for being bicycle parking lots. When demand is high, bikes could be overloaded at
one parking spot.

The fourth type is bicycle parking underneath pedestrian overpasses. These used to be largely used as fenced paid bike storage areas before the 2010s, which was also a proper use for the gray spaces. This former way could be a reason why some people keep parking their bicycles underneath overpasses, although these spots are no longer designated bicycle storage areas. A problem caused by this parking type is overpasses always go together with bus stations, so many people riding from home park their bikes here to transfer to the bus. But due to lack of management, bicycles are observed to be overloaded some spots (See Figure 3.51, photo 4) and obstruct pedestrian flow. Cyclists prefer to park their bikes with other bikes, so the density of this parking type is even, but the size of each parking spot is different.

3.11 Opportunities

Based on the inventory and analysis above, author argues that the site can be improved to provide a better traffic environment for cyclists, pedestrians, and vehicles, while achieving a safer and convenient way to ride and store bicycles. Opportunities for potential development engage the following design objectives:

- Reestablish original bike lanes by type, to resolve conflicts between bicycles and on-road parking or right-turning vehicles.
- Redesign road intersections to avoid conflicts between vehicles and bicycles.
- Redesign bus stations by adding connections to adjacent pedestrian overpasses and separating the boarding platforms from bicycle lanes to avoid traffic interruption.
- Redesign selected pedestrian overpasses by reducing the gradient of the ramps to
make it accessible to the riding cyclists and enlarging pedestrian overpasses with higher bicycle and pedestrian flow.

- Design for indicating bicycle right-of-way at some car-dominant spots, such as in front of the high school.
- Improve connections between subway stations and adjacent bicycle storage areas to increase usage and establish storage facilities at the existing informed parking spots along sidewalks and underneath pedestrian overpasses.
- Supplement transport-focused bicycle infrastructures with paths and landscape features in potential areas along the avenue to create entertainment environment.
- Strengthen the connection between Zhongguancun Avenue and Zhongguancun Plaza by creating both physical and visual access.
- Arrange the food and rest areas, add landscape planting to site, and use existing lighting.
CHAPTER 4. DESIGN APPLICATION

4.1 Bike Lanes

Chapter 3 Section 9 reveals the most urgent problem that must to be solved is the conflict between bicycle and on-road vehicle parking. The conflict between cyclists and pedestrians is another problem included in this section. Conflicts between bicycles and right-turning vehicles will not happen before reaching intersections, so this situation will be discussed in the next section.

4.1.1 Bicycles vs. On-road Vehicle Parking

This project provides four methods to solve the problem and to create a safer and more comfortable environment for cyclists. Because the existing road is too narrow to support changes and to provide safety, all methods discussed here presume that reducing existing vehicle lanes is the only way to improve cycling environment. The extra traffic flow will be absorbed by the nearby roads, which are also connected to the 3rd and 4th Ring Roads.

Solution 1: Traffic Lane Separation

The first solution suggests reducing one vehicle lane and moving inward the separator, the existing bicycle lane (also used by vehicles looking for parking spots), and the vehicle on-road parking lane. It also adds a separator or fence and a real bicycle lane between on-road parking and the sidewalk (See Figure 4.1). The advantage of this method is it achieves the entire separation of motor vehicles, bicycles, and pedestrians. But the limitation is a reduced vehicle lane is less than 3 meters (9.8 ft.) wide. If the width of the
A bicycle lane (3.5 meter/11.5 ft.) is maintained, there will not be enough space for a new separator with trees or even shrubs. The best result will be a fence between on-road parking and the new bicycle lane. There are four drawbacks of this method. Drivers who park their cars need to cross the bicycle lane to reach the sidewalk. Pedestrians from bus stations to the pedestrian lane need to cross both the parking and the bicycle lane. The on-road parking occupies two lanes on the road, so the space is not fully utilized. The separator needs to be dismantled and rebuilt, which is costly.

Solution 2: Diagonal Parking

The second solution suggests reducing one vehicle lane, combined with the existing separator, to reconstruct diagonal parking along the street, which restricts vehicles pulling in and out from the traffic lane close to the bicycle lane (See Figure 4.2). The bicycle lane is separated from vehicle parking areas by curbs or fences. Bus stations can be set on the void of parking spots in the new separator. The separator with diagonal parking provides larger...
space for bus stations, eliminating the potential dangers of crowds. Parking space can be greened with vegetation along one side and permeable brick. The drawbacks of this solution include conflicts between vehicles backing out and driving on the outer lane.

Solution 3: Eliminating On-road Parking

The third solution removes the existing on-road vehicle parking and uses this area as the new bike lane. The separator is broadened outward with more vegetation (See Figure 4.3). This will make the bicycle lane an isolated comfortable environment with overhead canopy, which will be very favorable in Beijing’s hot summers. The drawback of this method is the existing on-road parking is lost, so underground vehicle storage would need to be constructed nearby. Moving the on-road parking to the side of the main road can be another solution. However, this will reduce the traffic speed and cause congestion, which is not good for roads with this large carrying capacity.
**Solution 4: Bicycle in the Middle**

The fourth solution suggests reducing one vehicle lane, puts the bicycle lanes in the middle of the avenue, and adds planted separators along both sides, to provide a comfortable and safe environment for cyclists (See Figure 4.4). This solution also suggests relocating bus stations onto the new separators and moving the bus lane inward to the
innermost vehicle lane. Subsequently, passengers board and exit a bus from the left side, and reach the sidewalk by ramps extending to pedestrian overpasses. The drawback of this method is it needs new buses with left side entrances like most existing trains and subways.

4.1.2 Bicycle Vs. Pedestrian Conflicts at Bus Stations

Because of the distance requirement for on-road parking area, bus stations on the site are always located on the road sections with right-turning vehicle lanes instead of on-road parking areas.

Solution 1: Adding Ramps Connecting Separator Areas to Pedestrian Overpasses

Safety is The major advantage of adding ramps connecting separator to pedestrian overpasses. Ramps lead the entire pedestrian flow from (or to) the bus station through the overpass and separate pedestrians from conflicting motor vehicles (See Figure 4.5). The drawback of this method is the added ramps will be too long and take too much space from the separator, which will diminish the existing limited green area. Further, this method requires high financial investment.

Solution 2: Crossing on Ground

Because both pedestrians and bicycles are slow, as are the right-turning vehicles, conflicts at pedestrian crossings are not critically dangerous. So this solution suggests improving the on-ground crossing. Pedestrians, as the most vulnerable group, should be given the right-of-way over other transit modes. Motor vehicles and bicycles need to be
warned to reduce speed by different color painting, perpendicularly grooved pavement, or speed bumps. Plus, reflectors can be added along the pedestrian crossing for night visibility (See Figure 4.6).

![Figure 4.5 Adding Ramps to Pedestrian Overpasses](image1)

![Figure 4.6 Crossing on Ground](image2)

### 4.2 Intersections

A typical at-grade intersection is located in the middle of the project site and will be used as a sample to discuss the possible redesign for intersections. Efficient solutions are designed to address the conflicts at the ground level due to the achievability. Each direction of the existing traffic signal at the intersection has separate lights for motor vehicles going straight and turning left, but just one light for bicycles going straight. Cyclists who want to turn left at the intersection are supposed to drive straight though the first crossing then turn and wait for the other direction's green light. Any transit mode can turn right unrelated to the traffic signals.
Solution 1: Curb Extension

This design solution suggests connecting the existing bicycle lanes (shown in blue in Figure 4.7) and adding extended bump outs (shown in green in Figure 4.7) at the four corners of the intersection to define space and provide extra for bicycles. The connected bicycle lanes will be painted in color and highlighted with markings at the crossings for more attention. One advantage of this method is cyclists can wait at the corner in front of the cars, so right-turning motorists have a very clear view of the cyclists and will yield to them at the intersection (See Figure 4.8). Extending curbs also expands the turning radius.
for right-turning cars, which will slow their speed and provide more safety. Another meaningful advantage is the left-turning bicycles can wait in the extended bumps for the second green light before the turn. The drawback of this method is the right-turning cars go in front of left-turning bicycles waiting at the corner (See Figure 4.8). Because the right turns are beyond the control of the traffic signals, the left-turning bicycles could face up to four conflicts with right-turning vehicles from three directions. The adjustment of traffic lights that complement this solution is mentioned in a later section.

**Solution 2: Bike Box**

This method has been used by many existing projects. A bike box is a designated area placed ahead of stopped vehicles at an intersection for bicycles waiting during the red signal phase. It puts cyclists in the full view of cars and provides the right-of-way to the bicycles. When the light turns green, cyclists can move ahead of the cars and go whichever
direction they wish (See Figure 4.10). However, when used for this particular major intersection with very busy traffic, bicycles will disturb too much of the traffic flow, and cause safety issues for the cyclists. Moreover, because the existing traffic signals have separate lights for straight and left-turning cars, the bicycles stopping in front of all vehicle
lanes could block the traffic. To make this method more applicable to the existing condition, the bike box can be divided by the directions the cyclists are heading (See Figure 4.11). Also, the traffic signal rules need to be changed: adding a left-turn light for bicycles so they can turn left with the motor vehicles going the same direction. Proposed traffic flows with straight and left-turn green lights are shown in Figures 4.12 and 4.13, and the modified design solution is shown in 4.14.

Figure 4.14 Intersection Solution 2: Bike Box
For meeting the existing traffic signal condition, the bike box method can be adjusted by adding a marked off area within the middle of the intersection (See Figure 4.15), defining the bicycle right-of-way in the intersection, and providing left-turning waiting zones for the left-turning bicycles waiting for the second green light (shown in green in Figure 4.15). The advantage of this adjusted method compared with Solution 1 is the right-turning motor vehicles go beyond the waiting bicycles, which avoids half of the conflict opportunities between them (See Figure 4.16).
Supplemental Solution Coordinated Adjustment: Traffic Signal Reorganization

Figure 4.16 Conflicts between Left-turning Bicycles and Right-turning Motor Vehicles

Figure 4.17 Existing Traffic Signal Rule
Using the first solution as an example, Figure 4.17 shows the existing signal rule and the conflicts it causes between bicycles going straight and right-turning motor vehicles. Adding signals for right-turning vehicles can easily avoid this conflict. As Figure 4.18 shows, the added right-turn light for each direction remains red for half of the cycle, while bicycles can cross the avenue without any interruption during this phase. This adjustment eliminates all existing conflicts between bicycles and right-turning motor vehicles.

Figure 4.18 Traffic Signal Reorganization
Solution 4: Elevated Bike Paths

Elevating bike paths is another alternative for this intersection. But it will be achieved with more restrictions, such as zoning and vehicle clear height requirements. Entire bike
lanes can be raised to achieve dual-level transportation, or they can be elevated just at the intersection as a large overpass. The major drawback of this method is the gentle gradient of the ramp must be designed for comfortably riding up and down. Therefore, the ramp will be long and occupy much sidewalk space, which may bring inconvenience to the ground-level pedestrian flow.

4.3 Bicycle Storage

Bicycle storage locations will be rearranged or modified based on the analysis presented in Section 3.10, according to their existing usage rates, objectives and locations. (All existing condition figures in Section 4.3 are from SosoMap, 2012).

4.3.1 Storage Underneath Overpasses and Along Sidewalks

Presented in Section 3.10, the parking areas underneath pedestrian overpasses and along sidewalks are spontaneous bike parking places, which may inform where bicycle storage facilities actually should be established.

1. Underneath Overpasses

This design solution establishes bike racks underneath all the pedestrian overpasses and adds tiered storage facilities for currently overloaded spots. Planting beds and trellis-style green walls under the edge of the overpasses provide isolation and security. The design allocates void space between sections of racks to create passageways for cyclists and pedestrians.
2. *Along Sidewalks*

This design solution organizes the existing spontaneous bicycle parking along sidewalks by designating permitted bicycle parking areas. These areas do not provide special antitheft measures because most are for short-term daytime parking. Bike racks are added facilities for bicycle storage at these spots. The racks should be visually pleasing and simply designed, with a style working along with the entire bicycle network.
4.3.2 Storage in Front of Notable Places with Temporary Facilities

The second storage type mentioned in Section 3.10 (in front of notable places with temporary facilities) does not serve a large amount of bicycles. Cyclists always park there during daytime for short periods. Most of this temporary storage has plenty of space in adjacent areas, which can be integrated for providing rest spots with inviting landscape features. Lighting and vegetation can be added to these spaces.

Figure 4.21 Existing and Proposed Bicycle Storage Along Sidewalk
4.3.3 Storage Areas Adjacent to Subway Station Entrances

Subway stations are frequent transfer points to work places, so a large amount of office workers store their bicycles nearby for a whole day and probably over night. However, as shown in Section 3.10, the existing storage areas adjacent to subway stations are rarely used. The main reason is although the facilities of these parking areas are the most advanced of the site, their theft prevention systems do not work as people expect.
Improvements for these storage areas include building storage cages (mentioned in Section 2.3) to meet the security requirements for overnight bicycle storage. Way-finding strategies could be used to strengthen connections and directivity between the storage cages and the subway entrances.

Figure 4.23 Existing and Proposed Bicycle Storage at an Entrance of Huangzhuang Subway Station Within the Project Site
4.4 Green Network Concept Design

Integrated with design solutions along roads, at the intersections, and around storage areas, potential green spots throughout the site can be connected by constructing bicycle paths along the site avenue. By arranging recreational and leisure spots at suitable places within site and using a clear way-finding system, all the design elements can be integrated into a green network. Figure 4.23 shows the Green Network Concept Map of the project site.

A good way-finding system connects various design elements to make them a complete system. It can make the environment more enjoyable and recognizable, and lay the foundation for expanding and extending the green network. The way-finding system for the project site includes: color painting along bicycle lanes and at crossings and intersections, traffic signs, directional signs and maps, and lighting at night. Bicycle cages and racks, structures, and site furnishing should also be designed in unified style. A successful example is the Indianapolis Cultural Trail, which uses these elements to guide residents and visitors throughout the area of downtown Indianapolis.
Figure 4.24 Green Network Concept Map
4.5 Typical Node Design

4.5.1 Node 1

Figure 4.25 Node 1 Location and Analysis Diagram

Node 1 is located on the south end of the project site. The five entrances of Renmin University subway station are distributed at the four corners of the intersection the 3rd Ring Road and Zhongguancun Avenue. Two of them are in a vacant lot at the northeast corner of the crossing with sparse vegetation. An existing bicycle storage place with poor
facilities (following the bicycle storage with permanent facilities typology) is adjacent to one of them. To their north, is a 40m-diamiter (131 ft.) nearly round simple paved open area. An aesthetically unpleasant cluster of one-story buildings is on the east side. On the north, a pedestrian overpass connects two sides of the site avenue to the university gate at the west side. Students use this overpass to reach the bus station at the east side of the avenue to travel to Zhongguancun West Area and further north. However, the overpass has the typical steep ramps which could not allow cyclists riding up and down.

To create enclosed spaces and offer convenient transit for cyclists and pedestrians, this project builds a partly elevated bicycle path, which connects the bicycle storage place, the subway entrance, the open space (transformed into a plaza), the pedestrian overpass and the university gate. The path is bicycle-only one-way from the south until it reaches the overpass. Selected sections of the path have fences with vegetation along one or both sides as vertical screens to block undesirable views to the one-story-building cluster, and to define a clear view to the plaza and farther up Zhongguancun Avenue.

The original pedestrian overpass is reconstructed with existing columns and integrated as part of the path. The overpass ends in front of the university gate and connects a painted bicycle lane though the gate for a safer and more convenient transfer for student cyclists. All ramps of the overpass slope less than 12% to ensure comfortable riding.

The plaza is redeveloped as a gathering place. It is recessed and half enclosed by the elevated bicycle path. It has steps and sloped lawns for sitting and resting, stairs for
pedestrian and a curved ramp for cyclists going up and down. A few bike racks are set at the south offer temporary bicycle storage. Along the northeast edge underneath the elevated bicycle path, is a gallery with art pieces and informative video screen promoting bicycle use.

Replacing the bicycle storage area adjacent to the south subway station entrance, a

Figure 4.26 Node 1 Bird’s-eye View
bicycle storage cage is built around the entrance to achieve safety and visual integrity. It contains 2-tiered parking facilities, and the storage capacity is 320 bicycles.

These landscape design strategies improve bicycle infrastructure, enhance the aesthetically quality of the site, and promote social activities. While the bicycle lanes along the avenue provide a better way for commuting, the bicycle path defines a place for cyclists' recreational use.

Figure 4.27 Node 1 Location and Plan
Figure 4.28 Node 1 Plaza: View from South

Figure 4.29 Node 1 Plaza: View from North

Figure 4.30 Node 1 Plaza: Night View
Figure 4.31 Node 1 Bicycle Path

Figure 4.32 Node 1 Bicycle Storage Cage

Figure 4.33 Node 1 Bicycle Storage Cage Interior
4.5.2 Node 2

Node 2 located on the north of the intersection of South Haidian Road and the site avenue. Zhongguancun Plaza is on the west side of the avenue with the super mall underneath and two mall buildings adjacent at ground level. The traditional courtyard discussed in Section 3.4 is on the roadside and the pedestrian-only street extends to the northeast. There is no at-grade crossing for pedestrians and cyclists at this location. Two existing overpasses are on this node; the northern one is mainly for connecting the supermarket entrance and the southern one is mainly for connecting the bus stations.
However, neither of them is good for people going to the pedestrian-only street, the courtyard and the plaza main entrance (at southeast). People have to walk far after crossing the overpasses. Moreover, the aesthetic lighting on the Zhongguancun Plaza is not fully appreciated because there are no good overhead views along the axis of the plaza.

The project builds a bicycle-friendly pedestrian overpass to connect every direction leading to the plaza. It connects west and east sides of the avenue, leads to Zhongguancun Plaza along its axis with two ramps connecting to both sides of the main
entrance corridor, joins the courtyard with spiraled path, and attaches the mall building at southwest. The overpass makes a tight connection between separated parts and extends the flourishing atmosphere form Zhongguancun West Area to the site avenue. Most important, it provides a better transit connection for pedestrians and cyclists. All the ramps of the overpass slope less than 12% for easy cycling, and construction columns are locate in existing separators. It is painted and lighted underneath to provide safety and interests to the traffic flows on the ground level. Vegetation on the overpass helps provide a more comfortable human-scale environment.

Figure 4.36 Node 2 Location and Plan
Figure 4.37 Node 2 View to Zhongguancun Plaza from the Overpass

Figure 4.38 Node 2 View to Zhongguancun Plaza from Underneath the Overpass
Figure 4.39 Node 2 Site Furniture on the Overpass

Figure 4.40 Node 2 View to North Underneath the Overpass

Figure 4.41 Node 2 Spiral Ramp from the Overpass to the Courtyard
CHAPTER 5 CONCLUSION

As the previous chapters have shown, Zhongguancun Avenue is a typical example of compressed bicycle traffic space along roads in fast-growing Chinese cities, such as Beijing, where rapid urban expansion and motor vehicle development have pushed bicycles aside. This street has a rich past of bicycle transportation, so it retains a sufficient framework for reestablishing bicycle infrastructure. Plus, it contains a developed public transportation system, which can be integrated to the proposed bike network. Therefore, Zhongguancun Avenue has a suitable potential to be established as a section of Beijing’s bicycle network, to restore a more comfortable riding environment to cyclists.

The goals of this creative project are to create a safe and efficient transport environment for bicycle commuting and to provide a comfortable human-scale environment for cyclists’ recreational use. This project analyzes the problems and conflicts of the existing bicycle lanes, intersections and bicycle storage conditions on the site. It also reviews the literature and design guidelines to identify current solutions for establishing and improving a bicycle network. Using these information, the author designs solutions for the project site that provide a comfortable and safe travel environment for cyclists. Advantages and drawbacks of each solution are listed. This project also tries to connect the potential green segments along the site with the redesigned traffic pattern to integrate the site into a coherent whole. Landscape design strategies create a comfortable and aesthetically enjoyable space for people.
In the mission of this design project, the three solutions with added traffic signal adjustments would substantially improve the intersection. It provides thoughtful and definite alternatives for this single intersection based on its characteristics: size, shape, traffic flow, and traffic rules. Reorganization of bicycle storage based on the existing and expecting parking conditions is another successful approach. On the other hand, although the study provides several solutions for avoiding the conflicts between bicycles and on-road parking vehicles, all of them have similar constraints due to heavy construction costs.

Implementation of these solutions provided in this project requires support from relevant governmental departments. Final design decisions would be based on the construction scale and budget control, and complements to the existing planning and construction codes.

To make the project manageable throughout the limited time frame, it was proposed with a limited scope. If taken further, several other aspects should be addressed:

- Arrange rest spots on site for cyclists. Provide designs with landscape features for more comfortable environment. Combine with breakfast and afternoon tea spots, which provide ride-through and ride-in service for cyclists.

- Provide a suggested native plant list for this project. Propose a greening plan, especially including adding overhead tree canopy along the separators adjacent to the bicycle lanes. And offer planting design for specific areas such as public plazas along the bike
path.

- Provide design solutions for every bicycle storage spot based on their storage type, location, and capacity, including the size and footprint of structures, the calculation of bicycle racks, and allocation of vegetation and signs.

The redesign of Zhongguancun Avenue may serve as a useful example to investigate the possible solutions for developing a bicycle network in Beijing. These solutions can be generally applied to other streets in Beijing urban area, and to be integrated into a complete bicycle network for the entire city. While no two design problems are exactly alike, other streets should also consider their particular characteristics and existing conditions when improving bicycle infrastructure. Ultimately, the project aims to provide an example to all the fast-growing cities that have the needs and wishes to develop their bicycle networks. To achieve this, they may consider solutions offered by this project that meet their own needs, and create more suitable solutions based on their own circumstances, for building their distinctive green bicycle networks.
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