Research on Bicycle Network Planning of Nanjing in China

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OF NANJING IN CHINA

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Abstract

Although China has a huge cyclist population, the cycling condition in large cities is undesirable. The problem is mainly caused by the mixed-flow of cyclists and motorist on the road. Separation of cyclists and motorist is the key to solve the problem. Based on the research of the successful examples in Europe and a PEBOSCA inventory analysis of the cycling traffic in Nanjing, a set of suggestion is proposed on how to plan the bicycle network. A bicycle network separated from motor traffic and the planning on a cycling district division is introduced. The proposal also involves the suggestion on combination between cycling and public transport, and the experience route of historical culture and the natural beauty of the landscape.

Keywords: Bicycle network planning, specific bicycle lane, urban transportation, PEBOSCA, Nanjing, China.
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1 Introduction

1.1 Background: Transport problems of large cities in China

The cause of the transport problems in large cities appears to be the conflict between human, vehicles and roads. In fact, it is that the current transport service is not able to keep up to the growth of citizens’ transport needs (Ganzhi, 1997). Despite extensive investment on urban transport infrastructure, the transport problems in China become more widely-spread and escalating.

Congestion is the most common problem in big cities, and now, it is regarded as an important indicator of the urban transport service (Ganzhi, 1997). Along with the accelerated economic growth and motorization, an increasing number of people in China can afford and choose automobile, and as a result, increase the use of the road infrastructure and aggravate the congestion. Congestion leads to low efficiency transportation by wasting a lot of unnecessary time and fuel, and brings a lot of problems to people and goods delivery.

Figure 1. Congestion in large city in China
1.1.1 Sheer increase of motor vehicles

Despite the congestion, the growth of motor vehicles also causes potential safety problems (Tom E., Stewart S., 2008). In most cities of China, there is no exclusive bicycle path for cyclists to separate them from motorists. The cyclists and motorists share and are mixed on the road. Therefore, the motorists may scramble for their own space while they are travelling, which make cyclists feel less safe and increase the possibility of accidents. (Liu, X, 1993) The growth also resulted in fossil energy consumption increase and environmental deterioration.

1.1.2 Imbalanced transport structure

In China, the percentage of private car ownership in relative lower than developed countries. Nearly half of the trips in China are taken by cycling and about one third by walking, so the major components of private transport are cyclists and pedestrians. This imbalanced component structure of public and private transport make the transit between many difficulties and put a lot of pressures on urban transport, because the public transport is not sufficient at all for people daily commuting (Qing S. 1997).

Figure 2. Crowded busstop in China, which demonstrate the lake of public transport to meet the citizens’ travelling needs

1.1.3 Unbalanced road hierarchy

“The road hierarchy is a division of the road network into identifiable road
classifications or types which reflect the functionality of the roads making up the network”. Despite adequate length and width, a proper road hierarchy is necessary for a city desires for sufficient transport capacity, which demands for rational attribution and good connectivity between arterial roads, sub arterial roads, collector streets and local streets. Generally speaking, the numbers of roads of different hierarchy should increase from arterial roads to local streets, based on their functions and objectives (Gray W.S.2006). However, in china, most local governments have dominated preference to arterial roads, which leads to an irrational road system structure. It results in short support from the sub-road system, lack of connectivity and low efficiency of urban transport. The transport investments are mainly concentrated on the arterial roads, especially the ring roads outside the urban area. On the contrary, as the urban area continually developed rapidly, the most used sub arterial roads, Collector streets and local streets lack deserved investment for new corresponding transportation infrastructure (Eppell, V.A.T., McClurg, B. A. &Bunker J. M.,2001).

1.2 The confusion of developing bicycle transport

China, known as the “kingdom of bicycle”, owns nearly 500 million bicycles. On average every citizen has 0.85 bicycles, and bicycle is their first choice for daily trips (Liu, X, 1993). With the development of urban motorization, the conflict between the cyclists and motorists become one of the vital reasons of urban transport problems. This conflict evokes two hypotheses of how to develop bicycle transport in large cities. One hypothesis, named the vehicular cycling principle, says that bicycle is an irreplaceable transport mode in people’s daily life, and the rights of cyclists should be preserved, respected and equal with the motorists. The other hypothesis, cyclist inferiority superstition, argues that a smooth motor traffic is the key point of unimpeded urban transportation, but the motorists are remarkably slowed down by the cyclists. Therefore, the development of bicycle transport should be limited and restricted (John F., 1997).

However, no matter which hypothesis is accepted, today and even in the long future, bicycle will still be the indispensable mode of urban transportation for most of the cities in china, so how to plan, manage and control the cycling is the problem we have to face and solve.

1.3 Cycling and bicycle paths

1.3.1 The characteristics of cycling

Bicycle is inexpensive and flexible, providing a door-to-door transport solution but not needing much space or requiring for road condition and parking. People can use bicycle
almost anywhere. For the short trips, normally less than 8km, cycling is competent in terms of speed and travelling time, especially in the crowded urban area. Moreover, cycling is an exercise method, good for human health. It does not need any fuel, which make it no harm to environment and easy to maintain and repair.

On the negative side, cyclists are vulnerable on roads. Even the risk of accident is equal for cyclists and motorist, without covered protection, cyclist are much easier to be seriously injured. Thy bicycles are driven by human force, which determines it less comfortable, and even worse, if encounter the rainy, snowy or windy day, it suffers while cycling. Normally it is not suitable for long trips, more than 10km.

1.3.2 The effect of cyclists and bicycle paths on traffic

Under most circumstance, the impacts of cyclists have on the motor traffic are caused by overtaking. There are two different conditions while overtaking happens on road. One is next- lane overtaking, which happens between motorists as well, when the motorists occupy the next lane at the same time overtaking the cyclists. The other is lane-sharing overtaking that the motorists overtake the cyclists while they are within the same traffic lane. There is no positive evidence shows that the existence of cyclists will reduce the road capacity, but to some extent, it would influence the motor vehicles’ speed, and consequently increase their travelling time. When the next-lane overtaking occurs, the cycle traffic will reduce the overtaking motors’ speed, if the motor traffic on the next lane is too dense and cannot be cleared timely. Meanwhile, when the motorists try to overtake the cyclists as they are on the same lane, usually, they need to slow down for safety concern since they are too close to the cyclists. However, no evidence shows the direct relation between the increase of proportion of cyclists and the motorists’ travelling time. Generally, the delay happens only when the roads are too narrow to hold the huge amount of motorists, compared to the impacts caused by the enormously increased motors on road traffic condition, the ones caused by cyclists are far slighter.

On the other hand, there are good reasons to believe that the road capacity can be increased and the congestion and motorists’ travelling time decreased if considerable amount of motorists converted to cyclists (John F., 1997).
2 Aim

The aim of this thesis is, based on the analysis of current situation and problems of Nanjing transport system, to propose a set of suggestion on how to plan the bicycle network in Nanjing, which can not only improve the efficiency of urban transport system but provide citizen with a better way to experience the city and life.

3 Methodology

The Habitat Agenda is the main official document regarding to human settlement issues. It was a result of the UN Conference Habitat II in Istanbul in 1996. (Habitat Agenda 2010) The main conclusions can be drawn from the document is: “Sustainable habitation not only deals with physical aspects of sustainable development like energy, waste and water, but also includes biological, social, organizational, economic, cultural and aesthetic dimensions” (UN Habitat Declaration, cited in Berg, 2010) Framework PEBOSCA is a systems view to identify the relationships between all these different factors, which is a good way to analysis the individual factors and their interconnection as well. Transportation is an indispensable part of the society, and the framework PEBOSCA can provide an inventory analysis of how the different resource interacted within the traffic issue, and insight into what is the cause of the problem and opportunity.
4 Examples in Europe

4.1 Copenhagen, Denmark

Copenhagen one of the most bicycle-friendly cities all over the world, the first and the only “bike city” entitled by International Cycling Union (UCI). The bicycle network planning has a long history in Copenhagen. Back to 1960s, the bicycle network was firstly planned and established in some parts of Copenhagen, although they were fragments and not as much connected as it is today. Until now, the total length of the bicycle paths has extends to more than 300 kilometers, and 55% of residents in central Copenhagen use bicycle as their daily commuting tools.

4.1.1 Cycle tracks and cycle lanes

Copenhagen has clear definition between cycle tracks and cycle lanes. Traditional cycle tracks are exclusive paths for cyclists, with either vertical or horizontal separation from motor vehicles. They can be placed just aside the motor roads, but on a higher altitude, normally same as the pavement, or on the same altitude as roads with artificial or natural barriers. These were used to be the most common forms of cycle paths in Copenhagen, the height difference and the barriers completely prevent the motor vehicles stepping up to the cycle paths, providing security to cyclists. However, compared to bicycle lanes, the bicycle tracks demands much more investment and space. Bicycle lanes are parts of and on the roads, but identified with white lines marked and bicycle signs, and even with colored or unique material surface. The disadvantage of bicycle lanes is that there are no physical barriers between bicycle and motor flows and the marks are often treated more as an advice to motorists, which cannot efficiently separate cyclists from motorists on the road (The City of Copenhagen, 2002). Nowadays, a combination of bicycle track and bicycle lane, the reinforced cycle lane, is widely planned and used in Copenhagen. They are normally off-road, behind the curb or between the curb and street parking, thus separated from motorists, but meet the motor vehicles at the junctions (Cameron M, 2010).
The city of Copenhagen persists on the pursuit of high standard bicycle paths to satisfy the cyclists. To ensure the high standard, these bicycle paths is planned to be renewed at least every 15 year, which means 8 million Danish krones (1.6 million US Dollars) is needed (The City of Copenhagen, 2002).

4.1.2 Green cycle route plan and bicycle super highway

The green cycle route is a creation of Copenhagen. Bicycle has little advantage in long distance travelling, and with disturbance of other traffics on road, it has less appeals for those employees who need to go a long way to work every day, especially those who need to go across the city centre. In order to provide another option for the long distance daily commuter, a high-standard, wide-paths bicycle network with green surroundings is planned to supplement to the existing bicycle network. The green cycle route is isolated.
from other traffic to reduce the stops and blocks on route and increase the possibility, security and individual cycling speed. Moreover, the green surroundings has recreational function as well, it is favored by a lot of citizens who enjoy cycling excursions (The City of Copenhagen, 2002).

In order to provide a better cycling connection between the centre and the suburbs, a network of 13 bicycle super highway is planned. The routes offer smooth, wide and direct paths going to centre without detours to maintain the high speed, and service stations are equipped with air and tools along the roads. Moreover, cyclists are give priority at the crossing point, if cycle fast enough, they can enjoy green lights all the way without stops in some certain routes (Annalee N., 2009).
4.1.3 Parking space and combination of bicycle and public transport

An important and indispensable element in bicycle transport is bicycle parking. The increasing use of bicycle draws a huge pressure on parking space. In the cycle policy of Copenhagen, parking space should be available near connection with public transport, at homes and workplaces, at shopping area, and on street. The city gives permission for parking on the street and for residential area to install parking rack for bicycle parking. Moreover, the city sets standards for shopping area to establish enough bicycle parking places, and supervision needs to be improved to remove disused bicycles from parking area.
Sufficient parking facility at station, terminal and bus stops is a key element to combination of bicycle and public transport. The parking system at terminals is planned jointly by City of Copenhagen, Copenhagen Transport, and the Danish state railways. Besides the bicycle parking rack, 50% of the parking facility will be covered and lockable to prevent theft, although this new kind of paid parking facility is not commonly accepted by people. To extend the accessibility of the parking facility, double-decker racks are installed at central station (The City of Copenhagen, 2002).

In order to attract more cyclists use public transport with cycling as their pre- and post- transport, the restriction of carrying bicycle on trains is gradually removed. The bicycles can be on all commuter trains all day, despite rush hour, when the bicycles can only be allowed in the opposite direction to the rush traffic. However, the new metro and commuter trains have greater accessibility of bicycles, and eventually, the restriction applying on bicycle will be removed (The City of Copenhagen, 2002).

4.2 The Netherlands

It is said that everyone has more than one bicycle in the Netherlands. Nowadays, even cars are affordable for them, they do lot of cycling in their everyday life.
The Netherlands is a small but rather flat country with a dense population. Small, flat and dense can partly explain why cycling is so popular in the Netherlands. The flatness in topography can be seen as the precondition for the regional cycling-popularity, and the spatial limitation and dense population determines the average travelling distance in relatively short. Data shows that more than two thirds of all the journeys in Netherlands in within 7.5 km, which is a suitable or even desirable distance for cycling (Hugh M., 2002).

The development of bicycle policy in the Netherlands is interesting. Up to 1970s, there is little policy concerning the cycling development, the cyclists and the infrastructure. Most of the roads are planned for cars to encourage motor traffic, and after the Second World War, cars were regarded as the symbol of wealth, mobility and freedom. On the other hand, bicycles were marginalized and treated as the travelling tools for the poor and out of date. However, cycling was still recognized as an indispensable part of transport for daily life. The attitude of policy makers was tend to be pro-car, but not anti-bicycle, which is crucial for the continuation of cycling development for following decades. In the 1970s, the mass motorization start growing sharply, subsequently coming the traffic congestion, traffic casualties, environmental and health problems and etc. Until the shock of energy crisis in 1973, people rediscovered the advantages of bicycle transport and it might become a solution for the arised traffic problems. As the result, people pick back their bicycles and start cycling commuting again. The following decades, the bicycle transport in the Netherlands experienced a huge increase. Many cycling organizations were established and developed to struggle for the rights of cyclists. The bicycle-friendly attitude was gradually formed among policy makers in central government and all levels of traffic authorities. In 1990, the project, Bicycle Master Plan was launched by central government as an important part of new transport policy. The aim of the project is “promoting bicycle use while simultaneously increasing the safety of cyclists and increasing the appeal of cycling as a mode of transport” (Hugh M., 2002).
4.2.1 Sustainable Safety

In 1992, the vision of Sustainable Safety was first formed in the Netherlands and then in 2005, it was updated to Advanced Sustainable Safety. The aim is to achieve a sustainable safe traffic and transport system for everyone. In such a system, human mistakes are accepted as a system error, however, they believe most of the major errors can be prevented in advance and if not, can be reduced at least, by proper functioning design, planning, management, and infrastructure. Therefore, the traffic safety is not largely depends on individual traffic participant’s behaviors. There are five fundamental principles to the proactive approach of Advanced Sustainable Safety (Fred W., Letty A., 2006).

<table>
<thead>
<tr>
<th>Sustainable Safety principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality of roads</td>
<td>Monofunctionality of roads, as either through-roads, distributor roads, access roads, in a hierarchically structured road network</td>
</tr>
<tr>
<td>Homogeneity of masses and/or speed and direction</td>
<td>Equality in speed, direction and masses at medium and high speeds</td>
</tr>
<tr>
<td>Predictability of road course and road user behaviour by a recognizable road design</td>
<td>Road environment and road user behaviour that support road user expectations vis-à-vis consistency and continuity in road design</td>
</tr>
<tr>
<td>Forgivingness of the environment and of road users</td>
<td>Injury limitation through a forgiving road environment and anticipation of road user behaviour</td>
</tr>
<tr>
<td>Slate awareness by the road user</td>
<td>Ability to assess one’s own task capability</td>
</tr>
</tbody>
</table>

The cyclists and pedestrians are vulnerable on the road traffic, and most of the serious accidents are the crashes with motor vehicles. The major reason is the difference in mass,
speed and direction, therefore, separation is the best solution of this problem in the sustainable safety. In the Netherlands, the cyclists and motorists are separated as much as possible to avoid the direct encounters by any means of location, time or accessibility, and if not, the roads are converted to “safe speed zone” with limited speed of 30km/h for motor vehicles (Fred W., Letty A., 2006).

Figure 15. Cycling mother with her three children in Netherlands

4.3 UK

4.3.1 The UK National Cycle Network

The history of UK National Cycle Network began in the late 1970s, with the construction of traffic-free paths built along the abandoned rail and a 27 km path between Bristol and Bath, when the charity- Sustrans (sustainable transport), the operator of the National Cycle Network, was established in Bristol. By August 2005, the National Cycle Network has reached 10,000 miles (16,000 km) cycle paths all over UK. It is made up of National and Regional routes. The former ones are aimed to link the main towns and cities; meanwhile, the later ones link up relatively smaller city centers, providing links to shop, Figure 16. Bicycle lane in London, UK.
school and working place in urban daily life. It serves walkers, wheelchair users and horse riders as well (Hugh M., 2002).

The planning of the network concerns a lot at the local scale and human scale. The network is planned accessible to as many people as possible, so the routes are placed within 2 miles of where 75% of UK population lives. Planners from Sustrans believe partnerships as a crucial part of planning, so they work with local people, authorities and other interest partners. Surveys are made to investigate what kind of bicycle paths is needed and expected by local people, and then every proposal of the planning is followed with a hearing and consultation process. They are open to local suggestions and proposals of the potential routes in order develop the useful and popular routes for local people and visitors. Sustrans reported that in 2009, the number of walking cycling trips reached one million on the Nation Cycle Network for the first time (Sustrans, 2010).

In order to developing cycling habit in the young, Sustrans launched a program called safe route to school. Dedicated traffic-free, cycle-friendly paths accessible to school are constructed to ensure the students cycle safely directly from home, provision for parking lots and lockers in school are equipped, and cycle training and activities is conducted in school (Sustrans, 2010). Above all, the created universal cycling culture involved local authorities, schools and residents, helps promote cycling in the young, benefited them with health, and benefited the community with less traffic and safe belonging (Hugh M., 2002).

To make the cycling journey less boring, addition to the planning and construction,
Sustrans work on the identity of each route (Hugh M., 2002). Natural attractions like landscaping are taken into consideration while choosing the potential routes and many artificial landmarks such as sculptures is decorated along with the routes to bring out its unique character of each route. The network also provides a great stage for outdoor art, which make every single path more unique and memorable (Sustrans, 2010).

Sustrans intend to change people travel behavior by practical provision for walking, cycling and public transport. They built National Cycle Network all over the UK, train the children on cycling skills, and provide cycling and local bus timetable for household. By doing so, they are trying to change people travel habit and even life style (Sustrans, 2010). For the trip within 5 miles, can be called short trip, cycling can be a great alternative, and within 1 mile, walking works. According to the car usage survey conducted in UK, more than 50% of the car users’ daily trip is less than 5 miles. Under the premise of convenient and useful cycle network and public transport system, people are more willing and easier to take the decision to adjust their life style to be localized, living close to work and school, cycling to shops, taking picnic in community garden (Hugh M., 2002). It would benefit the local community a lot, less traffic but better environment, more public space and facilities and more social interaction between residents. The benefit for individuals is remarkable as well, less stress but better health, more involvement into local life.
5 Nanjing

5.1 The city of Nanjing

Nanjing, also known as Nanking, is the capital of Jiangsu Province and one of the most important cities in China. It is situated in the southeast of China, the downstream drainage basin of Yangtze River.

Nanjing covers 6598 square kilometers, with a 7.7 million total population. The Yangtze River goes through the west of the city and the other three sides are surrounded by the Ningzheng Ridge.

Nanjing means “Southern Capital” in Chinese. With history of over 6,000 years, Nanjing is one of the Four Great Ancient Capitals of China, and it severs as capital of thirteen historical dynasties. Before the China Civil war in 1949, it is the capital of Republic of China. The history has gain lots of Chinese historical and cultural relics here.

Located in one of the largest economic zones of China, the Yangtze River Delta, Nanjing is an economic energetic city. It is the intersection of Yangtze River and Nanjing-Beijing railway, which gain it a convenient water and land transport. Besides, it is a city of colleges and universities that invigorate new vitality to its development (Nanjing Government, 2009).

5.2 The current situation of Nanjing transport system

5.2.1 Bicycle is citizens’ first choice

Statistics shows that there are more than 3.6 million bicycles in Nanjing, and almost four citizens in ten depend on bicycle for their daily travelling, which makes bicycle rank the first among all the transportation modes. Although there is a trend that less people use bicycle in recent years due to the safety concern or poor bicycle lane condition, high
percentage of bicycle travelling is still a significant character in Nanjing transport system (Nanjing Transport Bureau, 2011).

![Figure 20. The percentages of different transport modes in Nanjing](image)

The peak hours of cycling traffic in Nanjing are the periods 8:00 to 9:00 and 17:00 to 18:00. The volume of cycling traffic in peak hours is much larger than the ordinary ones, for example, the cycling traffic volume in the morning peak hours can take up 16% of the total volume of the day, but in an ordinary hour like 12:00-13:00, it is only 4% (Nanjing Transport Bureau, 2011).

5.2.2 The increasing use of electronic bicycles and private motor vehicles

Until the end of 2009, the total amount of motor vehicles has increased 14.2%, reached 1.076 million, among which 0.5 million are private cars, extended nearly one third. The rapid increase of vehicles plays a more important role and exerts more influence in the urban transportation. The fact that there are more drivers on the road has led the city to have increasingly busy streets less-inductive to pedestrians and bicyclists. It appears that the rising cost of fuel, a slowed economy and increasing ridership on the city trolley is already easing traffic congestion in the city (Nanjing Transport Bureau, 2011).

What’s more, the number of electronic bicycles also has a remarkable grow. Compared with the year of 2008, there are 37.44% more bicycles more, and the total is approaching 1 million now. Electronic bicycle is as convenient and flexible as bicycles, but much faster and less time-consuming. It doesn’t need human force if its battery is charged properly, thus, it is much more suitable for long distance travelling than bicycle (Nanjing Transport Bureau, 2011).
5.2.3 Public transport is improving

Recent years, in order to keep pace with the city growth and accommodate the transport needs of the citizens, Nanjing has improved the public transport provision a lot.

The first metro in Nanjing, Metro Line 1, was operated in 2004, which built a great connection between the southern and northern parts of the city. In the following years, the authorities put remarkable effort on the transferring between metro and buses to increase the traffic level of the metro and improve its capacity to serve the city. The average daily capacity of the Line 1 is 0.3 million, and the annual increasing rate is 9.68. Compared with the data from 2008 to 2009, which is 38%, 38.3%, 29.1% respectively, the increasing speed has a significant decline, implying it is approaching its maximum daily capacity. However, the newly built Line 2 has been into service, and the authorities are preparing to build Line 3 and more in 2011 to make a much stronger metro system and its service in Nanjing.

There are 135 routes of bus operated in Nanjing, with daily transit capacity of 0.7 million. In the year of 2009, new concept was introduced to give the bus priority and adjust the bus network according to the survey on the distribution of passenger volume. These solutions cut the average single bus travel time and improve the efficiency of bus service and increase the passengers’ satisfaction (Nanjing Transport Bureau, 2011).

Nanjing has a great ambition to develop the metro system. Nanjing already got 2 metro
lines, which provide a great connection not only within the urban area, but also between the urban and sub-urban center.

These two lines form a cross within the urban area, one branch headed south to north, and the other from east to west, connecting the main residential area, business zone and the city center. It also make the urban area accessible for the sub-urban center in Xianning (Qixia County), Dondshan (Jiangning County), and Olympic village.

With the Line 3 under construction, more lines are under discussion. One is said to be 8 metro lines are planned, another is said to be 17 lines by the year of 2030. No matter how many lines will be on the blueprint of Nanjing metro, they will form a dense metro network underground, which will improve the public transport service a lot, and can relief the pressure of bus system.

5.2.4 Congestion
The peak hours of automobile in weekdays are the periods 8:00 to 9:00 and 17:00 to 18:00 and it is 14:00 to 16:00 in weekend. According to the data of 2009, the average speed of the automobile on express roads in urban area is 37.38 KPH in rush hours, which slowed down about 9 KPH, compared to 2008. What’s more, in the peak time seldom roads’ access speed can reach 20 KPH, and even worse, in Beijing West Road, the access speeds in only 15.03 KPH, which is almost the same speed as walking (Nanjing Transport Bureau, 2011).

In recent years, the sheer volume of commuters between urban and suburb has put a great pressure on the existing road network, and part of the roads has reached their maximum access. The commuting corridors between urban and suburb are approving the choke points. However, with the city expansion and development of the suburb, the communication will keep rising. Therefore, it is urgent to enlarge the road network and magnify its access (Nanjing Transport Bureau, 2011).

5.3 Inventory analysis

5.3.1 Physical resources

Land use—not enough land for cyclists

When travelling, the average space every cyclist required on road is 9 m², while the motorist needs 40 m² individually, nearly 4.5 times as cyclist does. As to parking space, bicycle only need 1.6 m², while a small provide motor car need at least 22 m², 14 times as bicycle (Fan W., Cheng L., 2007). In Nanjing, the transport system takes up 12.21%
of the total land use. In a cycling and walking dominated city, the percentage should be less than 10%, and in a motorized city, the percentage would be 30%, plus extra 20% parking space (Yang Y., Wei Z., 2006).

Lanes over-taking

However, even the limited space bicycled required cannot be promised in Nanjing. The bicycle lanes in Nanjing are insufficient for the huge number of cyclists, which are generally narrow and crowded and many roads do not have bicycle lanes. It is common to see that the bicycle lanes are overtaken. In Hongwu North Road, the bicycle lane is taken by motors, and the cyclists have to share the pavement with pedestrians, which only 2 meter wide. In such a dense area, it obviously cannot meet the needs of the cyclists and pedestrians. Moreover, some bicycle lanes are removed from the arterial roads when the authorities plan to extend the motor lanes for the rapidly increased motors. In local street, like Wenchang Alley, which is narrow but busy, the authorities marked out the lane aside the pavement as the street parking area, which forces the cyclists to share the narrow and crowded alley with motorists.

5.3.2 Economic resources

Problem of increasing cars

With the growth of income, the number of private cars experiences a huge increase, which becomes a challenge to accessibility of the road system. The sheer volume of automobile has been far beyond the capacity of urban transport system. The existing roads become over-crowded, and impede the development of bicycle transport.

In order to release this pressure, the authorities decide to widen the existing roads for automobile, and then, some of the bicycle lanes and pavements are taken over by motorways. As a result, the space of cyclists is shrinking, and accessibility of bicycle lanes is cut down. Moreover, some existing physical barrier between motorways and bicycle lanes are been replace by virtual lines, with the increase of automobile, the safety of the cyclists is on the slide (Tom E., Stewart S., 2008).

Cost of congestion

Time loss and delay, wasted fuel, and the greenhouse gas emission are the three key components that can be converted to economic cost of traffic congestion. Research showed that in some big cities in china, the monthly cost of congestion per person is more than 250 Yuan, and in Beijing, it reaches 335.6 Yuan. If assumed it is 200 Yuan in Nanjing, the economic cost of congestion would be 18.5 billion per year (Xinhuanet, 2009). Compared to the GDP of Nanjing in 2010, which is 508.6 billion, the economical loss caused by congestion equals to the 3.6% of the GDP.
5.3.3 Private travelling cost

It is obvious that walking and cycling are low-budget transport modes. Walking barely require no investment, while cycling require a bicycle. A bicycle in china, is not as expensive as in Europe, and normally, it costs 200 to 800 Chinese Yuan (equals to Swedish Kr.) to get one in good condition. The speed of cycling in Nanjing is around 15 KPH, and 8km is an acceptable distance of daily commuter. We can compare the private cost of commuting per month by cycling, public transport, and private car. Assumed that a commuter needs to commute twice per day and 24 days per months, there are totally 48 trips a month. Usually, bicycle parking in residential area and working place is free. Even if it is charged, it cost 0.2 Chinese Yuan per parking. Repair fee is normally less than 10 Yuan, and we suppose the bicycle need a repair every three month, then the total fee of cycling is less than 10 Yuan per month. Within 8 stops, the metro ticket is 2 Yuan, and bus ticket is 2 Yuan per time. More than 8 metro stops is too long distance to compare it with cycling. If the commuter does not need to change the bus to finish the daily trip, the travelling fee is 96 Yuan, and if needed, it doubles. With a Nanjing Public Utility IC Card, it can receive a 5% off on metro and 20% off on bus tickets. If the commuter use a car to travel every day, the parking fee is 300-500 Yuan per month, and the petrol fee depends on the distance, the petrol price and so on, which is at least 200 Yuan per month.

5.3.4 Biology resources

The city green corridor

Great road trees are commonly seen not only on the arterial roads, and many local streets as well. The typical road tree are Known as French Wutong tree (London plane, *Platanus acerifolia*) to citizens, which has a history of more than 70 years (Grace K. L., 2011). When the Mausoleum of Dr.Sun Yat Sen was built in Zhong Mountain, in order to show respect to him, 1034 planes were transplant to Nanjing. Because it was said the seeds of these planes were from France, it is called French Wutong in Nanjing. The green corridors first formed from Zhongshan Gate to the Mausoleum, and then extended to Zhongshan wharf, which is exactly the route of transferring Dr.Sun Yat Sen’s body to the Mausoleum. After the civil war, the road greening became popular in Nanjing, when the planes were planted in every arterial road, and the total numbers reached 80 thousands and gradually grew to be each beautiful green corridors in Nanjing.
The roadside greening is a huge biology resource in Nanjing city, but with the expansion of motor lanes, it can be seen to put the widest road within the limited green belt. If we rearrange the bicycle lanes, the sidewalk and the green area to be the non-motor road, the structure and function of it is similar to the green area in the park, and then the bicycle network will become a green network. Cyclists and pedestrians, which take up more than 60 percent of the total population, can use and enjoy it every day, without the requirement of any location or time. This kind of green belt is alterable according to the environment, and can be connect with the other parts, for example, parks of the city green structure. Thus the bicycle network will not destroy but enhance the value of the green structure in the city.

5.3.5 Organization resources

The planning problems of road system

The increasing population and motorists are biggest challenges of the traffic system, which make the city more crowded and more congestion. Therefore, thousands of proposals are made to solve this problem, which are mainly the extension and expanding of the existing roads and the construction of new roads, but the function of those roads are becoming murmured and the importance of road hierarchy is ignored. Without specific function defined, motorists, cyclists and even the pedestrians can be mixed on road, and the heavy vehicle flow from the arterial roads cannot be distributed evenly by the sub- arterial or collector roads. The phenomenon that the automobiles and the bicycles are mixed on the road has huge negative influence on both of them. When there
is no barrier to separate them on the roads, the automobile directly threaten the safety of cyclists, and the bicycles limit the speed of automobile as well. Additionally, the unbalanced road hierarchy escalates the congestion problem.

**The management problems of the traffic system**

Due to the lack of concern from planning stage, bicycle parking lots, for the huge amount of cyclists, are insufficient in Nanjing. The parking problem cannot be properly solved, not only near the residential area and office building, even some shopping mall and other public places do not provide parking lots for bicycles. In consequence, the cyclists have no choice but to park their bicycles on pavement, greenbelt or even on the road, which cause a lot of problem to the daily life, traffic, public security and environment.

Facing so many problems, there is not enough on-duty personnel to supervise the cyclists’ misbehavior, such as failing to obey the traffic rules, putting their bicycle in wrong place, which may form the potential danger to the automobile transport and pedestrian. The development of infrastructure, management, and governance cannot keep up to growing transport demand and the mix flow consisted by conflict between automobile, bicycle and pedestrian make the city transport less and less efficient and safe.

5.3.6 **Social resources**

**Safety and health issue**

Safety issue is the main concern of the people who are still use bicycle as their commute vehicle. In fact, in Nanjing many people are considering giving up cycling just because they feel unsafe on road (Wachtel A., Lewiston D., 1994). With increasing cars and decreasing space for cycling, the society totally transfers its focus from bicycles to cars and the cyclists feel like being pushed away from the mainstream of the society. Safety cannot be promised on road, thus many parents are too worried to let their children cycle to school.

76% of Chinese white-collars suffer from the sub-health. Despite the high pressure from tons of work and intense competition, people are physically inactive nowadays. Increasing people are at risk of overweight, depression cardiovascular disease, and other chronic diseases (CMDA, CHA, 2011). Regular aerobic exercises help increase the individual fitness. It can strengthen the heart and reduce the rate of cardiovascular illnesses. The best aerobic exercise that can make a change in our health status is the one we can do it almost every day. Cycling has a great advantage that it can be part of people daily life, but can yield the same healthy benefit as the specific aerobic training.
People do not need to spend extra time and money to do exercises in the gym, if they can cycle to work, to school and to shopping every day (Nick C., Adrian D., 2007). Furthermore, despite the physical health benefit, cycling can improve the mental health as well. Cycling is a much more open transport mode compared to car, exposed in the air, which give people more opportunities to communicate. The bicycle is a slow and short distance vehicle, which makes people tend to discover and enjoy more local life and spend more time with the neighborhood (CRC, 2005).

5.3.7 Culture resources

Bicycle culture is dying

The bicycle industry started in 1930s, at that time, the factories could only do the assembly for foreign-made bicycles. The development of china-made bicycles began in 1940s, and after the People’s Republic of China was established in 1949, the authorities decided to promote the production of china-made bicycle. Bicycle was the dominated transport mode, and cycling was given great priority. Many of the well-planned bicycle paths that are still in use today were built at that time. By the 1970s, the whole country was moved on bicycles, and China got the name of “Kingdom of Bicycles”. People cycled to school, to work, to shops and to everywhere they can be, and people were talking, laughing, sharing and communicating while they were travelling. It is said that 70 percents of the travelers and their life were carried and connected on bicycles (Terhi M., 2009).

In the past two decades, the bicycle has gradually lost its position is people’s daily life. People strive to buy their own cars, even they don’t need one. Bicycle is now considered to be poor, old-fashion and only for the people with low income cannot afford a car. Meanwhile the cars are considered as the symbol of wealth, higher social class. People may even be judged according the kind or the price of car they drive. Nowadays, the city is full of cars, and there are more and more traffic jams every day. In fact, with the jams, cars are not making the travelling speed inside city any faster. However, people would rather be trapped in the jam within their own cars, than cycle in the smooth flow on the street (Ines B., 2009). The increasing cars are taking over the space that used to belong to bicycles. They are given great priority from on-road travelling to city planning. Maybe there is no another country in the world had a bicycle culture as it used to, but it is dying when it is needed most now.

The capital of thirteen Dynasties

The history of the Nanjing city began at more than 2500 years ago. Dragon and tiger is the symbol of king and kingdom in China. Based on Fengshui, the Geomantic Configuration, the Castle Stone in the west is a crouching tiger, and the Zhong Mountain
in the east is a coiling dragon. Therefore, Nanjing is regarded as a perfect place for kingdom, and be established as capital for as many as 13 dynasties (Cotterell, A., 2007). Due to the war and lack of protections, the historical look of Nanjing is fade away, only a little of them survive until today, telling the stories of glorious past of this capital city. They are the ancient city axis, Ming Dynasty Palace district and city wall.

Former republican-era Culture

Nanjing is former Republican-era capital, many heritages is preserved well from that time (Musgrove, Charles D., 2000). The universities, the government buildings, and the residential area can still be seen on streets, and the Mausoleum of Sun Yatsen is untouched in Zhong Mountain.

5.3.8 Aesthetic resources

Landscape- waters and mountains

Waters and hills are the two indispensable elements of landscape in Nanjing. The Yangtze River goes along the west of the city, and the other sides are surrounded by the Ningzheng Ridge, which is gentle but beautiful. All the hills in Nanjing is rather small
and low, expect the Purple mountain, which is 448 meters high, and others are generally less than 100 meters and some even only 30 meters high. However, these small hills make Nanjing a city full of changes. The northern branch of the ridge is developed towards the west along the southern bank of Yangtze River, thus, it provide many great view points of the Yangtze River. Parts of ridge are cliffs, which form natural barriers to protect the city and used as the positions for defense buildings in the past. Many of the defense buildings are persevered till today, as tourist attractions, such as the Castle Stone, to tell people the stories of the ancient wars (Till, Barry, 1982). The middle branch is much connected to city life. City walls, temples, gardens are build along the ridge. Many city parks and street parks are construction along those hills. The old town was developed in the basin formed by the Qinhuai River and the west end of the middle branch. The southern branch surrounds the city in the south and southeast. It belongs to the newly developed suburban, and becomes popular casual place for citizens. Many people go to there for BBQ and hot spring.

Yangtze River is the largest and longest river of China, heading to the East Sea, as a natural moat to protect the city from invader in the ancient time. The view of the Yangtze River is open and peaceful, and standing along the river bank, you will feel relaxed but shocked by its power. A lot of the parks are build along the water front, and the Yangtze Bridge is a very popular spot for tourists nowadays (Danielson, Eric N., 2004). Due to spectacular view of Yangtze River, the Emperor Hongwu decided to build a view tower on the Lion Hill near it, called Yuejiang Tower in 1374. Although the construction was finally delayed to 1999, now it is the best point to get the panorama view of Yangtze River.
There are two waters characterized Nanjing. One is the Qinhuai River and the other is Xuanwu Lake. Qinhuai River is the major watercourse around Nanjing City and regarded as the birthplace of Nanjing Culture. The civilization of Nanjing started here, and it used to be the one of the most flourishing places. Its beauty is a combination of natural scenery, historical sites, royal gardens, ancient buildings, colorful barges, folk culture and streets, and the Qinhuai River serves as a bond to connect all these spots together.
The Xuanwu Lake is situated in the central of Nanjing, just at the foot of Zhong Mountain. Several isles are decorated in the lakes. In spring, the cherry blossoms make it a pink wonderland; in summer, the willow branches are dancing with the rhythm of the breeze; In autumn, the fallen leaves give Xuanwu a gorgeous golden look, and in winter, the pines and cypresses make a perfect undertone of the snow.

City green corridors

The road trees are regards as an iconic part of Nanjing, which are rare to see in large
cities in China. Every resident in Nanjing is proud of those trees, and every visitor to Nanjing is impressed by the special feeling those trees draw to Nanjing. Due to the hot summer, Nanjing is known as one of the four famous furnaces in China. However, those road trees form nature corridors inside the urban area, and provide shade from the heat. They are like an air conditioner and travelling into the shades of those trees, you will feel cooled down immediately, and the breeze kiss your cheek. The temperature difference between green corridors and naked road can reach 3°C, in some great green boulevards such as Zhongshan East Road and Zhongshan North Road.

5.3.9 Conclusion

The situation in China is different from Europe. In Europe, one of the main purposes to built convenient and good bicycle network is to encourage more people to use bicycle instead of cars by providing fine infrastructure. However, in China, there is already a large cyclist population, but their space is being taken over by increasing cars, their safety cannot be promised, and they are even be excluded in city planning. Therefore, the purpose of built a proper bicycle network in Nanjing is to ensure and protect the rights of the huge cyclist population to get a safe and convenient travelling condition on roads. The function of the road system in Nanjing is not clear, and the motorists and cyclists are mixed on the road is the most important problem. Based on the analysis, the problem of mixed flows on roads are main caused by the planning, however, with a proper planning the influence of mixed flow can be largely reduced.

The rail transit system in Nanjing is taken into the planning process, but still needs a long time to be developed into a network to cover the city. The bus system is improving but does not have much potential to expand in the urban area. Therefore, cycling will play the role as the most important private travelling mode in Nanjing. However, Nanjing has a great ambition to develop the rail transit system. If the bicycle network planning can take the combination with rail transit system development into account, it will become much more convenient, efficiency and attractive to the residents.

The natural beauty and history culture is precious treasure of Nanjing, and the bicycle network has the potential to enhance these values at the same time solving the traffic problems. With the planned experiencing routes, residents and tourist will get more chance to enjoy the landscape and discover the history and culture of the city.
6 Proposal

6.1 A bicycle network separated from the motor traffic

The separation of cyclists and motorists is the key to solve their conflicts on roads, and it is also the aim to develop bicycle lanes, no matter which kind. In fact, it is a huge challenge for a big and overcrowded city like Nanjing to build a completely separated bicycle network from motor traffic.

6.1.1 The types of bicycle paths in Nanjing

There are three kinds of bicycle paths in Nanjing. One is separated by physical barriers, one is marked by painted lines, and another is sharing lane.

The bicycle tracks with physical barriers are used many arterial and sub arterial roads in Nanjing. Generally, the cyclists and motorists are completely separated on road, but meet at the crossing points. The green belt is the most organized and best barrier, because it not only helps reduce the noise and air pollution, but it cannot be moved easily. In some roads of Nanjing, the artificial barriers are partly or completely disappeared, and the lanes are overtaken by motor parking or street business.

![Figure 34. The bicycle track separated from motor lanes with green belt in Nanjing](image)

![Figure 35. The physical barriers is missing in Nanjing](image)

The bicycle lanes marked by painted lines is also very common in Nanjing, and they usually can be found in collector road, where the traffic volume is not very large. This is an economical way to construct a bicycle lane, but it doesn’t function well in Nanjing. Because the motorists and cyclists are not physically separated, they are mixed on the road, which is a huge potential safety hazard. Motorists tend to overtake the bicycle lanes in some rush hours, and sometimes the surface condition of bicycle lanes are not as
well maintained as the motor ones, cyclists even like to take use of the motor lanes. Moreover, because the painted line on the ground is not clear as the physical barriers, people overlook or ignore it take the bicycle lanes for other uses, such as street parking.

Sharing lane is commonly existed in the local street of residential area, where the traffic volume is rather small. On this kind of lanes, the motorists and cyclists are self-organized and self-adjusted during different rush hours, and make full use of the lanes. However, the motorists and cyclists interrupt each other, which would reduce the speed, and they need to be very cautious, because the safety cannot be promised.

6.1.2 Specialized bicycle lanes

The rapid increase of cars on the road has become the first issue of the local authorities concerning on traffic. More cars call for more space, and more cars lead to more congestion. Due to the pressure, some proposal even has been made to remove the bicycle lanes in some arterial roads in Nanjing. It is inappropriate, but it is a new angle to solve the problem, which is completely separate the cyclists from motorists, and even in the crossing point, avoid them encounter as much as possible, especially on the arterial road (Taylor D, Davis W., 1999). The specialized bicycle lanes are exclusive, which prevent the conflict between motorists and cyclists completely but keep the direction of the routes same as the main flow of motors. The specialized bicycle lanes should form a network and can access to the any shopping more, main residential area, business district, city center and green area.

In reality, the specialized bicycle lanes do not have to be absolutely exclusive. For example, the lanes can be exclusive to cycling only in peak hours, because one third of cycling traffic volume is happened during the periods 8:00-9:00 and 17:00-18:00, and in the rest time of the day, it can be accessible for all kinds of traffic. Some road which
used to have bus routes are planned as specialized bicycle lanes, if the width and the condition permit, the bus routes can be kept to maintain the coverage of the public transport.

There are a lot of alleys available close to the main roads, and they share the similar route and same direction. They have the great opportunity to be developed as specialized bicycle lanes and can relief the pressure on main road greatly. Take Zhongshan North Road for example, it is the one of the most important and busy arterial road in Nanjing. Just next to the Zhongshan North Road, one can find an alley, which exactly follow the same direction and have good connection with it and other sub-arterial roads nearby. The road is wide enough to hold a double-bicycle lane, which can be planned as a specialized bicycle lane, and if necessary, a bus lane can be added in.

Figure 38. The example of alley can be used as the as specialized bicycle lane, the red line is an arterial road and the yellow line is an alley of the similar route and same direction
6.1.4 Plan the network on district basis

Nanjing has 13 county-level divisions, of which 11 are called districts and 2 are counties. The counties in urban area, which are Xuanwu, Baixia, Qinhuai, Gulou, Jianye and Xiaguan, are relative small and dense, but they don’t expand too much. The newly developed areas, mainly in the sub-urban and rural area, like Qixia, Yuhua, Pukou, Liuhe and Jiangning, form their own center and functional community with residential area, shopping malls, good schools and hospitals. Therefore, Nanjing is on its way of developing to a metropolis with multi-center, or can be described as a set of sub-cities. This kind of development mode has great advantage to develop bicycle transport. There are mainly two kinds of trips in these residents’ daily life, one is dense and short-medium trip within the county, near the center, and the other is the medium-long trip between each centers. For the former, proper bicycle network should be constructed to provide cyclist with convenient connect between home, work, school and shopping mall. For the latter, bicycle-public transport combination should be recommended and encouraged with smooth transit system. With a proper plan, all the needs for trips of different distance can be covered, and it would be desirable if the network could attract some motorists transited to cyclists.

The key point of the network is the separating cyclists from motorists and great connectivity, but it is impossible to build a bicycle network that can cover the whole city. The most proper network mode for Nanjing is district plan. Because the suitable travelling distance for cyclists is 3-8 km and normally 3-5 km in dense urban area in Nanjing, the district should cover at least 28 km² in urban area (assumed the cycling radium as 3km). The division of the district should be based on the volume, the frequency, the average distance and the complexity of the cycling traffic within the district. The balance between adjacent districts, the administrative issue and the natural barriers should also be taken into consideration. As a result, the cycling traffic should mainly happen with the district or adjacent districts, and the cycling across several districts can be accomplished with help of public transport.

The large residential areas are the origins of each cycling trip, and they can be located as the center of the districts, and set as the control points of the bicycle network. The arterial roads have the great opportunity to be set as the border of the district. With some adjustment, the district division for bicycle network can be made.

Within the district, the route and the direction of the bicycle lane should keep the same as the mainstream of the traffic in order to meet the residents’ daily traveling needs. The cycling traffic should harmonize with the other traffics, in order to make the traffic flow balanced and cycling functioned well within the district. Addition to the specialized
bicycle lanes, the network can make a full use of the collector road within the district, the local street in the residential area, and the alleys nearby.

<table>
<thead>
<tr>
<th>County</th>
<th>Area (km²)</th>
<th>Population</th>
<th>Population Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulou</td>
<td>24.77</td>
<td>867100</td>
<td>35006.06</td>
</tr>
<tr>
<td>Baixia</td>
<td>26.46</td>
<td>628800</td>
<td>23764.17</td>
</tr>
<tr>
<td>Qinhua</td>
<td>22.69</td>
<td>391600</td>
<td>17258.70</td>
</tr>
<tr>
<td>Xiaguan</td>
<td>28.30</td>
<td>457800</td>
<td>16176.68</td>
</tr>
<tr>
<td>Xuanwu</td>
<td>75.17</td>
<td>515300</td>
<td>6855.13</td>
</tr>
<tr>
<td>Xianye</td>
<td>82.66</td>
<td>460600</td>
<td>5572.22</td>
</tr>
<tr>
<td>Yuhuatai</td>
<td>134.6</td>
<td>361400</td>
<td>2684.99</td>
</tr>
<tr>
<td>Qixia</td>
<td>376.09</td>
<td>525400</td>
<td>1397.01</td>
</tr>
<tr>
<td>Pukou</td>
<td>912.33</td>
<td>609400</td>
<td>667.96</td>
</tr>
<tr>
<td>Jiangning</td>
<td>1572.87</td>
<td>996600</td>
<td>633.62</td>
</tr>
<tr>
<td>Liuhe</td>
<td>1467.12</td>
<td>923200</td>
<td>629.26</td>
</tr>
<tr>
<td>Gaochun</td>
<td>791.98</td>
<td>430700</td>
<td>543.83</td>
</tr>
<tr>
<td>Lishui</td>
<td>1067.26</td>
<td>417200</td>
<td>390.91</td>
</tr>
</tbody>
</table>

Table1 The population density of each county in Nanjing.

The densest-populated areas in Nanjing are Gulou, Baixia, Qinhua, Xiaguan and part of Xuanwu and Jianye County. It is also where the cycling mainly happened. If we mark this area as the target area, the area would cover about 200 km². Because the population is not distributed evenly between each county, the cycling-based districts will focus on the large residential area and cycling traffic volume, and use the arterial road as border of the districts and the passage connect them as well. The District A is the business and government district, and the southern part is part of Baixia residential area. In the north of District A is the District B, which consists of part of Gulou and Xiaguan County, and the cycling here are mainly daily commuting between work and home. The District C is Jianye County, which is relatively low-dense, but has a large traffic volume within the district. The District D is newly popular area in the urban area, where are mainly residential and leisure area. The daily commuting rely largely on the metro, however, the newly built business zone bring much more cycling traffic here. Moreover, the Olympic Gymnasium and Virescence Expo Garden here are the popular spot in weekend.
Figure 39. The cycling district division in urban Nanjing.
Figure 40. The example of bicycle network planning in District B

Take the District B for example to explain the principal how to plan and manage the cycling traffic each traffic zone. District B is the area that connects the center of Nanjing (District B) and the north bank of Yangtze river (Pukou County), and the Zhongshan North Road is the main passage connecting them. During the morning and evening peak hour, the congestion sometimes can last nearly one hour. Furthermore, the Gulou County is the densest residential area in Nanjing, which determines the large volume of cycling traffic in peak hours as well. Therefore, it is better make full use of the alleys nearby to build a specialized bicycle lane to remove the existing bicycle lane on Zhongshan North Road to give out more space for the motorists. The cross section of the bicycle lanes or the arterial road should be marked as the control point. Moreover, cycling and its combination with public transport should be encouraged to relieve the pressure from over-load traffic. The combination of bicycle and public transport can improve the situation that the traffic between centre and north bank rely on the bus system. As the metro system developed, rental bicycle provided at the metro station would be a good solution.
6.2 Combining cycling and public transport

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>2km</th>
<th>4km</th>
<th>6km</th>
<th>8km</th>
<th>10km</th>
</tr>
</thead>
<tbody>
<tr>
<td>bicycle</td>
<td>11min</td>
<td>21min</td>
<td>31min</td>
<td>41min</td>
<td>51min</td>
</tr>
<tr>
<td>bus (without transfer, walking to station)</td>
<td>16.5min</td>
<td>24min</td>
<td>34min</td>
<td>40min</td>
<td>48min</td>
</tr>
<tr>
<td>bus (without transfer, cycling to station)</td>
<td>N/A</td>
<td>21min</td>
<td>32.5min</td>
<td>34min</td>
<td>40min</td>
</tr>
<tr>
<td>bus (with one transfer, walking to station)</td>
<td>20min</td>
<td>27.5min</td>
<td>36min</td>
<td>43.5min</td>
<td>51.5min</td>
</tr>
<tr>
<td>bus (with one transfer, cycling to station)</td>
<td>18min</td>
<td>24min</td>
<td>32min</td>
<td>37min</td>
<td>44min</td>
</tr>
</tbody>
</table>

Table 2. The travelling time of different transport modes

It is very clear that cycling to station save much time than walking, and when the travelling distance reaches 8-10 km, the combination of cycling and bus is the best time saving transport mode. When the distance to station is more than 400m, people would rather choose cycling instead of walking. Therefore, it is one task of transportation planning to combine the cycling and public transport in order to get the best traffic efficiency. The trend of sustainable transport in large cities is large capacity, high efficiency and low pollution. Public transport cannot provide a door-to-door travelling solution like cycling, and the service area of public transport station is limited. Thus the combination cycling and public transport will make the most their individual advantage.

The combination of cycling and public transport is an efficient way to encourage more people to choose the low environmental impact transport mode. Normally, people can accept a 10 minute distance to public transport station, while in the same time, cycling can travel 5 to 10 times more than walking can do. As a result, the combination will increase the service area of public transport 25 to 100 times. The key problem of the combination is transfer.

The cycling and public transport should complement each other to achieve a coordinated development. The planning of bicycle network should taken the transfer system with public transport into account, and provide suitable parking system in the transfer point such as bus and metro station (Hugh M., 2002). The travelling process can be like this: based on the bicycle network, people cycling to station instead of walking, put the bicycle in the parking area, and then take the public transport to the nearest station of the destination. If the destination still needs a long way to go, rental bicycle can be a good choice to cover the last part. One goal of the bicycle planning is to offer a travelling solution to anywhere in the city for majority of the residents, which is “less than 10 minutes cycling-public transport- less than 10 minutes cycling”. That calls for an integrated planning of the bicycle lanes, the public transport station and the transfer.
Bicycle parking is an indispensable element of bicycle network, which serves as the node of the network and the transfer point between cycling and public transport as well. The planning of the parking lots should according to the demand and the space available. Making full use of available space can save the cost of the parking facility, which can be the green belt near the road, dividing strip between motor road and bicycle lane (Hugh M., 2002). In the place with high demand but limited space, double-decker racks or even triple ones can be considered to increase its capacity and save the space at the same time. If the road is wide enough and it won’t disturb the traffic, street parking can be allowed. Furthermore, the parking is better to be attributed widely over the city, and the shopping mall and the business district should have specific parking space in order to provide the stable and safe parking for the large number of bicycles. In the transfer point, the distance between the parking lots and public transport station should be taken in to account while planning. It is better to limited it within 100m, if not possible, make sure it won’t exceed 150m. The entrance or exit of the parking lots should avoid the crossing point of motor road or place near the arterial road.

Rental bicycle would be a promoter of the combination of cycling and public transport, which can provide a fast and time-saving transfer solution between the gap of public transport or the last stop and destination. Nanjing has taken the rental bicycles into consideration while plan the new metro line (Peter M., 2011). Mini bicycles are once allowed on metro, however it is forbidden because many citizens complain the on-metro bicycles make the carriage even more crowded. It is
challenging to carry bicycle on bus or metro, but many city are working on it. If it works in Nanjing, more people will choose combining cycling with public transport as their long distance travelling solution.

Figure 42. The rental bicycles in Hangzhou, China.

6.3 The experiencing routes

6.3.1 The historical route

The city axis

The section from Zhonghua Road to Jinxianhe Road is the city axis of Six Dynasties. The residents lived in the southern part of the city used to boat on the Jinxian River to the Jiming Temple to offer incense to Buddha, and that is why the river got the name of Jinxian (Till, Barry, 1982). However, it is hard to find things related to Six Dynasties along the axis nowadays. At the northern end of this axis is the Jiming Temple and Beiji Pavilion, which is the only thing maintained from the lost history. The cycling condition here is very good, with metasequoia shadowing the road.
The section from Yudao Street via Minggugong Road to Bei’anmen Street is the city axis of Ming Dynasty. Minggugong means the Palace of Ming Dynasty in Chinese (Till, Barry, 1982). This route starts from the most to the Fugui (means wealthy in Chinese) Mountain, which can give people the context of history and culture back to that time. This section still preserves the symmetrical building structure of ancient capital, and the Wuchao Gate serves as the mid-point of the structure, which maintains the atmosphere of the ancient capital. With some designs like dragons embossed with on the bridge and fretwork on the street, the style of ancient royal boulevard is restored.

**The city wall**

The city wall from Ming Dynasty is the longest among all the preserved ancient city walls in China, and 24 km now out of 34 km in history more than 600 years ago can be found (Hobart, Alice T., 1927). The spectacular wall was built facing the open moat, which created a great view from the top and of itself as well. The authorities are taking good care of the wall, and after the full-scale reparation and restoration, they are planning a
green belt along it.

Using the city wall as background, green space are created consisting of water front park and ring road of the wall or water.

Bicycle lanes are constructed inside the green belt, separated from the motor ways, which provide a nice condition for the cyclists to explore the history of the city wall and enjoy the green space.

6.3.2 Former republican-era route

The features of former republican-era are easy to find in the city, such as the buildings. They are mainly located in Changjiang Road, Yihe Road and the Zhongshan road.

Changjiang Road is where the former government located, and those buildings are
preserved well. The road is shaded by the great Wutong trees, and the facilities here are specially design blending the style of former republican-era. Moreover, a cultural corridor with sculptures and Embossed walls are constructed here, telling the stories of the former republican-era.

The Yihe Road is where the former official residence cluster located. This area is almost untouched and keeps the same style as it was in the former republic-era, including the buildings and the way of arranging them (Musgrove, Charles D., 2000). The building density is rather low while the green rate is pretty high. Most of the buildings are with gardens, which are western style and of unique design and good quality. The greening of Yihe Road is blended perfectly with those flora gardens. The roadside trees are mainly planes and sweetgum, which form a nice green corridor as well. However, the Yihe road is rather narrow and has no bicycle lane, which the only flaw one can find within this picture.

![Figure47. The proposals of former republican-era route, the spots are related interests](image)

### 6.3.3 The landscape route

**Xuanwu Lake**

The Xuanwu Lake ring road owns the best view of the city, which connect water, mountain, royal parks and temple together. The eastern side of the road is where Xuanwu Lake and Zhongshan Mountain meet, the southern side is decorated by the historical interests and royal gardens, the western side is the ancient city wall and the green belt, and the northern side is the Couple Park and the Nanjing Railway Station.
However, even the lake ring road provide such a good view, there is no path designed for the cycling here. With only one entrance and the city wall surrounded, the accessibility for motorists is rather low. Therefore, the ring road of beauty has a great potential to be developed as part of the best view of Nanjing experiencing route.

**Zhong Mountain**

There is a tourist ring road planned surrounding the Zhong Mountain, which is a beautiful green road, and you can enjoy the forest while you travelling here. It is favored by the cycling fans, but unfortunately, just like the lake ring road, bicycle line is not installed here, which is a big safety threat to those cyclists. The road is not wide enough to hold a bicycle lane here, and the traffic volume here is not very large, therefore, a proper solution would be restrict the motor cars to enter in. it may open to the motorist in the rush hour, but in the weekend and non-rush hours, this green lanes should be preserved to the cyclists.

**The green corridor route**

The section from Zhongshan East Road via Zhongshan Road to Zhongshan North Road is the best green corridor in Nanjing. The trees were planted in honor to Dr.Sun Yat Sen and have gain a history of more than 70 years. The Zhongshan road was the main part of
the route when his body was transferred to his mausoleum across the city. Nowadays, it is regarded as the first avenue of Nanjing, and travelling inside this green corridor, one can experience many historical building such a DrumTower, Zhongshan Gate, Ming Dynasty Palace and its museum.

Figure 49 The proposal of the green corridor route
7 Conclusion

Congestion is the problem that bothers all the big cities in China nowadays. Large volume of cycling traffic, and it is mixed on road with the motor traffic is the one of the most important reasons of the congestion.

Compared to the cities in other counties all around world, the cycling traffic problem in China seems to be unique. Simply copying their solution and experience is not working well on the traffic problems in China. The large number of cyclists is the characteristic why Chinese traffic problem different from other country, but travelling condition of the large cyclist population is poor. It is clear the existing bicycle paths cannot satisfy the cyclists’ travelling needs, and because of they have to share the lanes with motorists without barrier, their safety is facing threat. The fact of large cyclist population on road will not be changed for a long time. As the increasing of the cyclists, it is the problem we have to deal with. Nowadays, the policy gives a great priority to the motorists, and the research is focus on the motor traffic as well. However, what attitude should be taken towards cycling traffic, how to plan the bicycle paths and manage the cycling traffic are the problems we must deal with. In this essay, base on the research on the cycling theory and the analysis on the problems of the urban transportation, a proposal of planning suggestion is made to deal with the cycling traffic problem in large city like Nanjing in China.

The main results of this essay are as following:

1. The inventory analysis of the cycling traffic in Nanjing. The analysis is made based the framework PEBOSCA, which provide an insight into the cause of the problem and the opportunity to improve the cycling traffic and the cycling culture as well.

2. The proposal of planning the cycling network on a district basis. The area of the district is determined by the normal cycling distance in urban Nanjing, and the division the cycling district is based on the travelling volume, focusing on the residential area, and using the arterial road as the border and connection of each district. In this way, the cycling condition of short-distance trip can be great promised.

3. The suggestion of combining cycling with public transport. The combination of cycling and public transport can be the substitution to private car for the long-distance travelling inside the city. Key point of the combination plan is concluded, which are the bicycle parking facilities at transfer point and the rental bike.
4. The proposal of the experiencing routes in Nanjing. Four kinds of experiencing routes are proposed, which are the historical, the former republican-era route, the landscape and the green corridor route. The experiencing route is helpful to attract more people to try cycling and restore the cycling culture in Nanjing.

There are still a lot needed to be improved. This essay only gives out a preliminary and basic understanding of the bicycle network planning. While, in reality, the planning process involved a lot of theory and technical issues. Things like the traffic light system adjustments to give more priority to cyclists, detail design of the bicycle lanes are not included are this essay, but they can improve the cycling condition a lot.

There are a lot definitions of sustainable urban transportation. For the crowded and large city like Nanjing, the aim should at least consist of co-ordination between transport supply and travelling demands, the safety travelling condition to every traveler, and low-environmental impact. People do not have to buy a private car to meet their travelling demands, and cycling as an main transport mode in cities should be encouraged, at least promised. China used to have a great cycling culture, and it worked well. With proper plan and infrastructure construction, the cycling culture and be restored one day, and the city will benefit from it.
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