

Challenges of Developing a Sustainable Transport System in Chengdu, China

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ABSTRACT

This study describes transport conditions in Chengdu and examines opportunities to build a sustainable transport system in the city. The aim of the new transport system is to reduce environmental pollution. The study is divided into three main parts.

The first section introduces the importance of developing sustainable system in urban areas, and also provides good examples to explain how transportation policies supporting developed countries to develop a well-fit sustainable transport system. This section also shows readers the background of Chengdu in terms of population, construction and area function. In addition, the definitions of sustainable city and sustainable transport are also explained in this section to show a worldwide standard of developing a sustainable transport city.

The second section discusses the case study. The case study mainly focuses on Chengdu's experience of developing a sustainable transport system, and practical experience Chengdu government obtained to develop a sustainable transport development. By using some figures, challenges of developing a sustainable transport system in Chengdu has been explored.

The third section offers a solution to solve problems. This section contains the recommendations of the local urban environmental pollution reduction and the future research in developing sustainable transport system of Chengdu. When construction is undertaken, how to protect surrounding environment is given as a recommendation at the end. Moreover, alternative transportation, such as electric vehicle is an important part in developing a sustainable city, however, it's in an early age of development, a further research based on the development of alternative transportation is needed in the near future.

Key words: Sustainable transport, rapid transportation, Chengdu, city planning

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Abbreviations

UNFPA the United Nations Population Fund

CPMB Chengdu Planning and Management Bureau

MNE Multinational Enterprise

AQMS Air Quality Measurement Standard

BOD Biochemical needed Oxygen Demand

EPB Chengdu Environment Protection Bureau

1 INTRODUCTION

The theme of this thesis is to find out challenges of developing a sustainable transport system in Chengdu of China. Based on analyzing figures of local environmental indicators, such as air quality, reasons why Chengdu failed to establish a sustainable transport system in this city can be figured out. This paper will explain these reasons from three aspects: the first part mainly discusses the background of Chengdu in terms of population, urban structure and the area function; the second part explains Chengdu's experience of developing a sustainable transport system, and these practical experiences help Chengdu government to look for a feasible solution on local sustainable transport development. Figures of local environmental indicators to show both the challenges and the development planning on local environment. The third part mainly presents some solutions to solve these problems based on local situation.

This introduction includes five points. At first, it introduces the importance of developing sustainable transport system in urban areas. The second point focuses on how the transportation policies support developed countries to build up a well-fit sustainable transport system. The third point mainly describes the background of Chengdu city, and it introduces the geographical condition of Chengdu and the center government's urbanization development planning of Chengdu. The fourth point talks about the research questions, objectives and scopes in the sustainable transport system of Chengdu. The fifth point presents the structure of the research report, the paper is structured by five dimensions, the first gives an introduction of Chengdu's urban planning and introduces the scope and the objectives of this paper, the second introduces the lessons from developed countries, the third explains the process of this research, the fourth collects all the primary and secondary information to identify Chengdu's transport system, the fifth provides applicable recommendations to readers.

And the second section is a case study about Chengdu's experience on developing a sustainable transport system, this section is mainly divided into two parts. The first part is about the urban environmental change trend of Chengdu. The second part is about the current transport system of Chengdu, there are some challenges in this part, such as poor transit network connection, uncleared road use function, urban central area congestion, private cars fast increasing vs public transports developing slow down and the shortage of parking areas, and it gives some development planning focusing on these problems in this part.

The last section mainly discusses the opportunities to improve in the developing a sustainable transportation system in Chengdu of China. In this section, it contains two aspects: local urban environmental pollution reduction recommendations and the further research. At first, it presents the recommendations of reducing urban environmental pollution. And then, this part indicates the further research in the development of sustainable transportation system in Chengdu, the further research is that the recommended strategy of developing a sustainable transport system in Chengdu.

1.1 The importance of developing sustainable transport system in urban areas

The world population of 7.3 billion is predicted to increase by almost one billion people within the next twelve years, and it's estimated to reach 8.1 billion in 2025 and to reach 10.9 billion by 2100. The additional 3.7 billion populations will enlarge the population of developing countries. (UNFPA, 2014) In 2008, more than half of the world populations have been living in towns and cities, according to UNFPA's project research, this number will increase to almost 5 billion by 2030. Africa and Asia are the main areas, which contribute to the urban growth.

The key reason of people migrating cities are the social and environmental problems. The relatively comprehensive city functions can provide local residents with better education, improved health care system, more income and other effective services. Those advantages of scale and proximity of cities attract people from rural areas or small towns flooding to megacities. Outside workforces have filled the gap between cities development and the shortage of local suitable employees. They help expanding and developing cities. Thus, more and more megacities have been established those years. However, this rapid development can generate inevitable negative effect on cities that no city planners can ignore. First of all, the intensive use of nature resources such as land, water and energy can lead to all of them run out in a short time. This may significantly affect future generations. Secondly, the over-stretching of infrastructure increases the density of cities. Tokyo (Japan) is well known as the high density city in the world. Limited residential land encourages skyscrapers, and in certain areas, which are potentially threatened by earthquakes. People have to live within a very small space. Thirdly, social and economic inequalities occur in many countries, especially the developing ones. Thus, urban planning research nowadays more focus on solving city planning problems in developing countries.

In order to help creating a sustainable living environment for local residents, city planners make great efforts in developing sustainable cities. For many of them, the most core and important part to build up sustainable cities is to ensure sustainable transport systems in cities. Because a sustainable transport system can help all nature resources be used in an economic and effective way.

To identify how to develop a sustainable transport system in a city, some key terms need to be explained first.

First of all, what is called sustainable cities should be identified clear. There is no a specific definition for sustainable cities. But all the reseachers have a common sense on sustainability. The term sustainability first appeared in the 1970s, which resulted in the green movement's critique of a development model focused on economic growth. The definition of sustainability has been described in the Bruntland Commission Report of the World Commission on Environment and Development Our Common Future (1987):

Humanity has the ability to make development sustainable- to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs...Sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. (WCED, 1987:8)

In book "Sustainable cities: diversity, economic growth and social cohesion" (Pinelli, Reymen & Wallman 2009), sustainable cities are the cities integrate the relations of individual needs and social development, local particularity and global diversity, environmental protection and economic growth.

Secondly, sustainable transport system is another key term needed to be defined in this thesis. A sustainable transportation system as one in which fuel consumption; vehicle emissions, safety, congestion, social and economic access are of such levels that they can be sustained into the indefinite future without causing great or irreparable harm to future generations of people throughout the world. There are a wide range of factors influencing the conditions of sustainability, for example, market forces, low-price fuel, and vehicle-dependent land use patterns.

(Richardson 1999, 27-34) The urban lands can be used as roadways and bridges, pipelines and hazmat, railroads, pedestrians, waterways. All vehicles like automobiles, trucking and motorcoaches, aviation, public transit, railways, bicycles, maritime can be applied. A sustainable transportation system should take all of those vehicles into consideration.

Thirdly, because of heavy traffic congestion occurred worldwide, rapid transits become popular in modern world. Therefore, identifying rapid transits and how they work sticks many city planners. However, there are still good examples in the world. There are several successful cases world wide to evident rapid transit is a cost-effective transportation alternative for urban mobility. For instance, Curitiba of Brazil, rewarded a fame of sustainable city mainly by successfully developed a Bus Rapid Transit (BRT) line for local residents. Although BRT can not fully contribute to sustainability, the BRT line in Curitiba is quite effective and impressive to everyone. (WHO 2016)

Rapid transits not only benefit in cost-effective and time-saving for commute, but also result in developing real estate industry. According to a BRT research (Rodriguez, 2004) in Bogotá, Colombia, researchers found out “for every 5 minutes of additional walking time to a BRT station, the rental price of a property decreases by between 6.8 and 9.3%, after controlling for structural characteristics, neighborhood attributes and proximity to the BRT corridor.” This research illustrates that a property the nearer rapid transits, the higher the average price. The development of rapid transits brings people a convenient life and effectively encourage local economic growth. This explains why city planners priority the transport construction under the framework of city planning.

1.2 How transportation policies support developed countries to provide a well-fit sustainable transport system

Developed countries aim to build up sustainable cities in a long term. Development must meet the “triple bottom line” principal, which should concern about economic, social and environmental development all together. Prior to get into practise, many developed countries have published applicable policies to guide implementation. Three of them will be introduced in the following, United Kingdom, Finland and Germany. UK and Germany are two leading countries in European union, which always make their missions higher and stricter than European union required, especially in terms of reducing carbon emission. Finland nowadays is well known as a cleantech leading country in the world, and it successfully applies cleantech in everyday livings. All these countries give good examples on developing sustainable environment for residents.

UK central government concerns about building a sustainable transport system mainly due to “transport is vital to the economy” (Towards a Sustainable Transport System 2007) UK is a big capitalist country, which has its specific history and context to explain why transport is an essential part in British people’ life. During the post-war period, people were interested in personal mobility and had huge demand of various goods; this situation highly grew road traffic as well as air travel. Rapid development of industrialization caused the famous phenomenon of “British pollution”, from that on, UK government has to pay huge price for environmental pollution and turned to make effort to balance environment and economy. More recently, they have become much more concerned about” the adverse impacts of transport on climate, health and quality of life and about their own travel experience as congestion mounts” (Towards a Sustainable Transport System 2007). Especially 1997 Kyoto Protocol has been released as an additional item of United Nations Framework Convention on Climate Change, UNFCCC, which restricts the emission of

greenhouse gas. At the same time, UK announced many policies and regulations to reduce carbon emissions. In the “Towards a Sustainable Transport System”, UK department for transport set up goals to reduce transport emissions, and make plans to the next 10 years. In “A White Paper on Energy 2007”, department of Trade and Industry also announces a wide range of policies to energy saving. In terms of transport, they suggest measures to address transport’s carbon emissions, enable smarter, energy efficient use of transport, and bring changes in type of vehicles and fuels. But almost all of those policies, UK pay more attention on diversifying transport technology.

Finland aims to support the development of a sustainable transport system. “A smart transport solution” is in cooperation with stakeholders, such as local institutions, public sector, and private sector and bus operator. It aims to “create more efficient travel- and logistics chains and an overview of the status of the transport system in real-time.” (VTT 2014) “A smart transport solution” based on travelers’ feeling provides travelers with a convenient travel experience with several service options: private car, on foot, bicycle, bus, taxi, demand responsive transport, carpooling, car and transport joint use, tram, metro, train or aeroplane. It also can be seen as an intergrate transport system. Increasing the share of public transport helps reducing the ownership number of private cars. In order to ensure the sustainable transport developing in a long term, the Finnish Ministry of Transport and communications (MTC) has set out Finland's transport policy lines for 2012-2022, which different from UK, based on the “development of society” (MTC 2014), not mainly due to “transport is vital to the economy”.

Germany is always regarded as a leading country in terms of sustainable transport systems. The country uses trams, express trains, electric trams, shift buses, undergrounds, and the public transport share system,

separated cycling and walking passways. In the long run, the German sustainable transport system combined technological change and behavioural change. The technological change is based on the remaining transport, includes efficient drive technologies, lightweight construction and the new vehicle concepts. The behavioural change is the method to change values in society (the importance of environmental protection and quality of life) and to change framework conditions (the shortage of fossil energy source, etc) and political strategies (transport taxes, land use and city planning, etc) (ISI 2011).

However, even all of these developed countries make a great effort on making a sustainable planning, they also face difficulties to implement their plans. For example, due to the political reason, the UK central government is always sensitive to the employment rate, this causes the automation can not be entirely happening in UK, for example, the regular railway strike holds back government's plan on using automatic machine instead of workforce to sell tickets. This situation usually causes train delay or cancellation, which somehow increases the use of private cars. The UK has a problem with policy implementation, although they have a huge ambition to reduce greenhouse gas.

Finland is relatively large relate to its population (5 million), but the challenge is the same as well as in smaller cities such as Lahti, which has 100,000 inhabitants. So Finland's "Smart Transport" normally has been initialed in Helsinki region, when it comes out with an applicable result, this method will be promoted through the whole country.

Germany is a democratic country with several federal ministries, each federal ministry has rights to form their own policies. Therefore, Germany has different public ticket policies related to public transportations. This

somehow puzzles the public, especially visitors without knowledge of German language.

Different countries have different situations. Can developed countries' experiences be applicabled in developing countries, like China? How can China learn from developed countries? Can any Chinese city be a good example of sustainability for other developing cities?

1.3 Background

According to the statistics published by the state council of the people's republic of China, China has graded 400 cities into five different levels in 2016, based on an integrated index rather than only graded by GDP. All index includes workforce income, education resources, GDP, the number of global 500+ companies, airport capability, the number of embassy, the number of international airlines. By using a specific formation, every city received an average figure, which is the key to be graded. Therefore, from 2016, there are 19 cities in China have been graded as the first-level development cities. They are: Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Hangzhou, Nanjing, Wuhan, Tianjin, Xi'an, Chongqing, Qingdao, Shenyang, Changsha, Dalian, Xiamen, Wuxi, Fuzhou and Jinan. All these cities not only have abundant resources in terms of political and economic, but also are the very important bases for talents and global headquarters. They are potential for future development.

Since Ebeneser Howard introduced garden city movement in his publication "Garden Cities of To-morrow" in 1898, many countries aim to follow his solution to the related problems of rural depopulation, urban overcrowding and congestion. In the fifth International Association of City

Planning (IACP) in 2011, Chengdu (China) made a proposal of developing a garden city, which has been approved by the state council of the people's republic of China. Thus, as one of 19 cities in the first development level, Chengdu has been defined as a "garden city" and to be a good example for developing a sustainable transport system in China.

Chengdu is located in the South-west of China, which is the capital city of Sichuan province, and is also the political and economic capital for the west of China. In the municipal level, Chengdu has been planned as "Big Chengdu", which includes 14 sub-cities and small towns (or countrysides) with 5 main central districts. (Figure1)



Figure 1: Chengdu Transport System Map (city of China 2015)

This is due to the central government's urbanization development planning. In 2011, China's "the twelfth five-year plan" officially supposed to increase the urbanization rate from 47.5% to 51.5% in 2015.

(Chinanews 2011) The main functions of urbanization are to optimize the structure of urban areas, to strengthen small towns' industrial function, to release the pressure of over-population on big cities. Therefore, in Chengdu's "integrated city-towns planning", 21 specific industrial districts are formed in "big Chengdu".

Chengdu is also one of the historical cities in China, with more than 3000 years long history. It's famous by beautiful landscape and the easy lifestyle. Therefore, during last 10 years, Chengdu has been rewarded as "National Garden City", "Best Travel Destination in June", "International Urban Agriculture Pilot City", "China Habitat Environment Award (outstanding example of urban water environment governance)", "Best Commercial City in Western of China", "The Happiest City in China", "National science and technology advanced city", "the MNE's first destination in Secondary cities" and so on. Chengdu has a long-term urban planning goal, which is to develop a world-known "garden city". In order to meet the goal, Chengdu's city planning, based on local situations, is divided into four planning sections, which are "city and town planning", "integrated transportation planning", "rural planning", "Sichuan Tianfu new district planning". Those planning sections all together are distributed to make Chengdu as a "world gardening city" in the near future.

In addition, plenty of policies and regulations related to urban planning have implemented by local government. For example, "Chengdu rural-urban planning act", "Chengdu communities planning and regulations", "Chengdu urban ecological reservation park management regulation", "Chengdu urban gardening act", "Chengdu reserved trees and plants management act" and so on. Those acts and regulations effectively restrict the real estate industry to produce air pollutions, and educate people to protect local environment. Meanwhile, "penalty regulation" has released to stop actions on harming environment.

1.4 Research questions, objectives and scope

Prior to conduct this thesis, one main research question is addressed to lead the theme, which is that what are the main challenges to develop a sustainable transport system in Chengdu. Besides, finding out the relative stakeholders and potential problems in current transport system can be seen as sub-questions.

The main objective of the thesis is to describe how Chengdu has started to develop a sustainable transport system. Due to the climate change and rapid growing population, cities in the world, not only the developed ones but also developing cities, are looking for a sustainable method for long-term development. Traffic problem nowadays becomes a severe issue, which effects people's daily life.

Due to Chengdu's city planning has been divided into four specific plans, this paper is going to follow up city planners' idea and to recommend solutions based on the scope of "Mega Chengdu". This paper will more focus on "land transportation", for example, metro, motors, railways, and relative infrastructure. Aviation is excluded because local resident more care about their daily life, while aviation is not the transport people may use everyday.

1.5 Structure of the research report

This paper is structured by three sections. Those sections all together to support building an overall view of Chengdu's urban planning, and to provide city planning with recommendations of developing a sustainable transportation system in Chengdu.

Section one gives an introduction of Chengdu's urban planning, mainly including the importance of developing sustainable transport system in urban areas, how transportation policies support developed countries to develop a well-fit sustainable transport system, the background of Chengdu city, the research questions, objectives and scopes about this topic and the structure of the research report. From this section, it can provide a overall basic information about this topic to readers.

Section two introduces the case study of the development of sustainable transport system in Chengdu. This section mainly presents the trend of Chengdu urban environmental change and the Chengdu's current transport system. From this section, the readers can see the challenges and the development planning in the Chengdu's current transport system.

Section three provides readers an applicable recommendation about the development of sustainable transportation. It contains the local urban environmental pollution reduction recommendations and the future research of this topic. From this section, it can present the limitations of this research, and the directions and possibilities for future research are also addressed.

2 CASE STUDY: CHENGDU'S EXPERIENCE ON DEVELOPING A SUSTAINABLE TRANSPORT SYSTEM

With the rapid growth of economy and traffic demand, the central urban area of Chengdu road traffic load is high, and the traffic congestion becomes a bottleneck restricting the development of the city. Chengdu municipal party committee priorities working out a solution for traffic problems. Because traffic problems, such as gas emission, have already heavily effected people's health. Moreover, local urban environment has been changed year by year.

Chengdu's urban environment has a dramatic change year by year. This is mainly due to the rapid urban economic development, which causes the increasing demand of private cars and attracts immigrates from lower development areas. Traffic is regarded as one of the major problems causing on environmental problems globally. Migration to urban areas for a higher quality of lives is the result of the unbalanced area development in terms of education, living conditions and transportation. Therefore, Chengdu's current urban planning is trying to solve these problems. Developing a sustainable transportation system is one method to reduce private cars. This section will use figures and facts to indicate the importance of developing current local transportation system.

Air, water and noise are the three important indicators to measure wether the environment are good. According to China's "Air Quality Measurement Standard" (AQMS, GB3095-2012), in 2013, Chengdu's SO₂, NO₂ and PM₁₀ lever are all beyond the national standard. As shown in Figure 1, although compared to 2012, SO₂ has been reduced 6.1%, NO₂ and PM₁₀ have increased 23.5% and 26.1% respectively. Chengdu's urban air

quality hasn't reach II level in China's standard. (Chengdu Environmental Statement 2013)

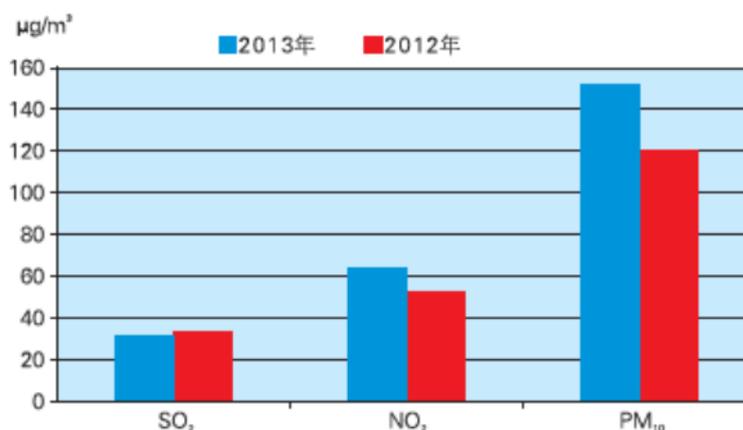


Figure 2: Chengdu Air Quality 2012-2013 (Chengdu Environmental Statement 2013)

Figure 2 shows the density of three main pollutants, SO₂, NO₂ and PM₁₀ in three different circles in Chengdu. The central circle is the urban central area, the second circle is the suburban district, and the third circle is the countryside. The central circle and second circle have the similar density of PM₁₀, while the third circle has much less of that. The central circle also has the highest density of NO₂, which is less in the second circle and the lowest density is in the third circle. The highest density of SO₂ is in North of the central circle, a major part of the third circle has lowest density. This is because the North of central part is the old industrial district of Chengdu, which has many old, long-historical factories, for example, the Seamless Steel Tube Plant.

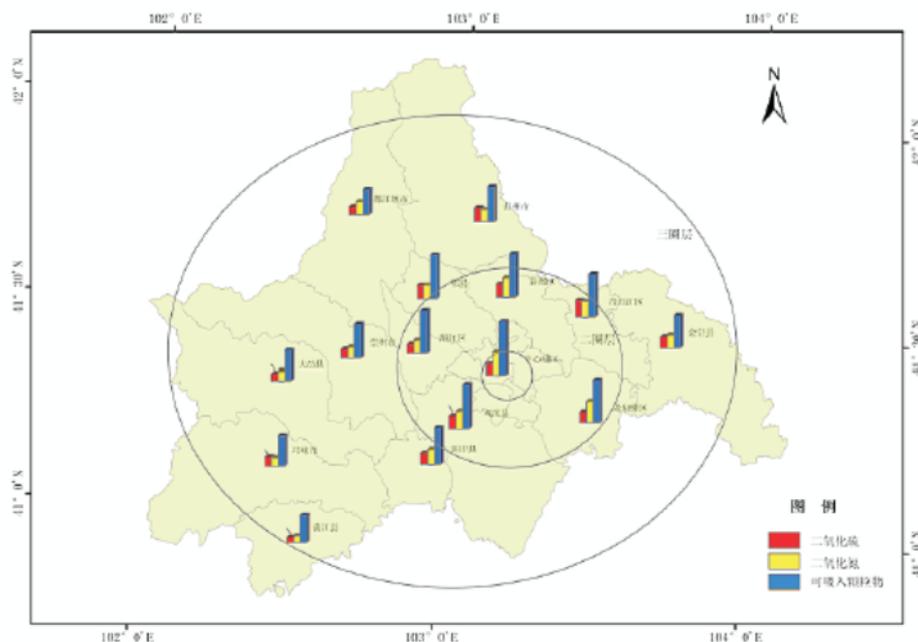


Figure 3: The Density of the Three Main Pollutants in Chengdu in 2013 (Chengdu Environmental Statement 2013)

Based on the analysis of Chengdu Environment Protection Bureau, there are three main reasons to explain why the pollutants are on a higher level compared with the condition in 2012. Firstly, Chengdu blanketed in toxic haze during the period of January, February and March 2013, which makes a great distribution to higher PM10. Until 2013, Chengdu has been one of top three cities in China with more vehicles than other cities. Transport gas and dust emissions have become the vital source of air pollution. Traffic digestion increases commute time that leaves more chance to gas emissions. Thus, in 2013, Chengdu's NO₂ emission has increased by 23.5% to that in 2012. Thirdly, Ozone emission turns to be the NO.1 pollutant in summer, which intensifies local air pollution.

The other important element of environment is water condition. In 2013, Chengdu's surface water is assessed as "Light Polluted". The polluted level has been divided into six levels (from good to worst): level I, level II, level III, level IV, level V and worse level V. According to the monitoring

results of 80 places of surface water in Chengdu, the percentage of six levels is: 27.5%, 45.0%, 6.3%, 5.0% and 16.3% respectively. The main pollutants are Ammonia gas, Total phosphorus and BOD. The main polluted river is Min River, which can be seen in Figure 3.

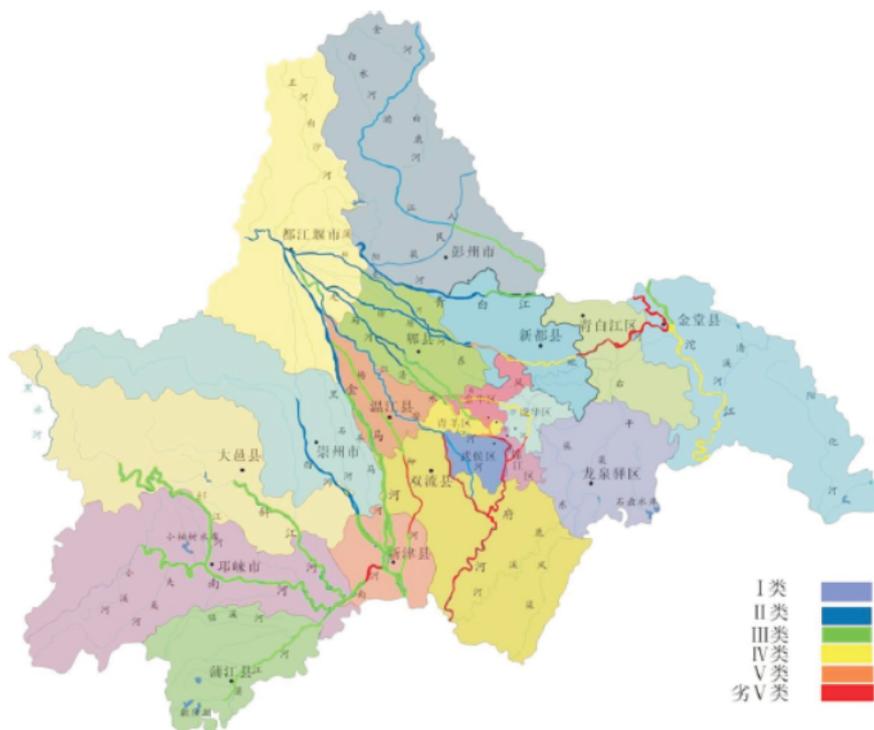


Figure 4: Water Quality of Min River and Tuo River in 2013 (Chengdu Environmental Statement 2013)

Figure 4 and Figure 5 show the water quality of Chengdu's two main water resources, Min River and Tuo River. Min River is the most important water source to supply daily drink water to local residents. Tuo River is assessed by EPB as "Medium Polluted".

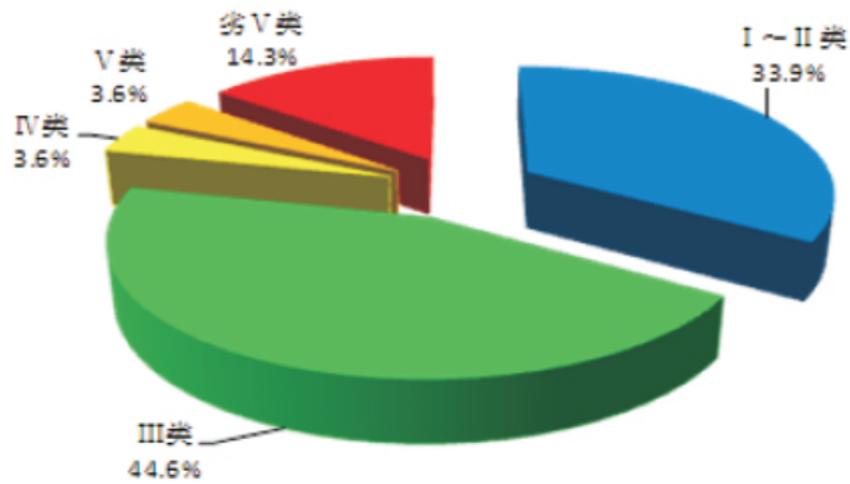


Figure 5: Min River Water Quality in 2013 (Chengdu Environmental Statement 2013)

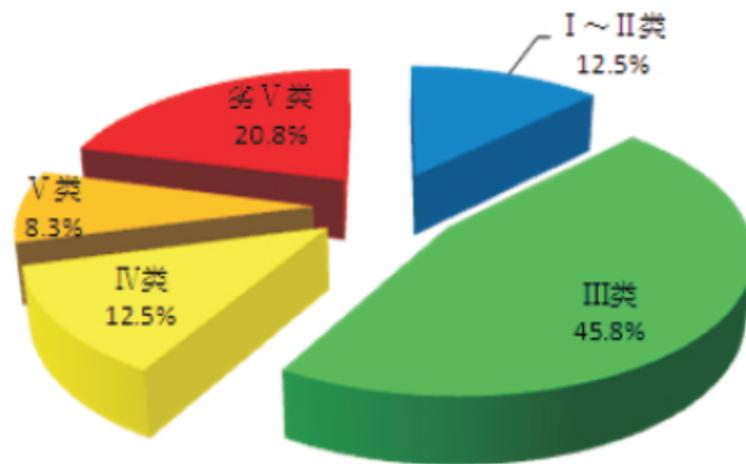


Figure 6: Tuo River Water Quality in 2013 (Chengdu Environmental Statement 2013)

Another environmental pollution element is noise pollution. According to EPB's monitoring, Chengdu's urban noise during 24 hours, the lowest time

is 2-4 am, the peak time is 6am, after 11pm, the noise level decreases significantly. During the daytime, traffic noise in central area in average is 69.2 dB(decibel), which is relatively good. However, In Finland 55 dB is the maximum noise level in residential buildings in daytime and 45 dB in night time, so compared with that these noise levels are really high. During night, traffic noise in central area is 62.0, which is recorded as “Average” in Chengdu.



Figure 7: Daily Air Quality in Major Cities of China in 2001

RANK	CITY	AIR COMPOSITE INDEX	RANK	CITY	AIR COMPOSITE INDEX
1	Ma er kang	2.40	12	Yi bing	4.46
2	Kang ding	2.56	13	Nan chong	4.47
3	Ba zhong	3.05	14	Da zhou	4.57
4	Xichang	3.34	15	Le shan	4.62
5	Ya an	3.55	16	Nei jiang	4.92
6	Guang yuan	3.72	17	Lu zhou	4.99
7	De yang	3.86	18	Mei shan	5.04
8	Pan zhi hua	3.99	19	Zi gong	5.42
9	Mian yang	4.01	20	Zi yang	5.79
10	Suining	4.02	21	Chengdu	5.85
11	Guang an	4.25	/		

Figure 8: Air Quality Composite Index Chart of Sichuan Province in 2015

Above these two figures, it indicates the comparison between air quality of Chengdu in ten years ago and which is like to be now. The figure 7 is about the daily air quality in major cities of China in 2001 including Chengdu city, and the figure 8 is the air quality composite index chart of Sichuang province in 2015 including Chengdu city.

From the figure 7, it shows that the daily air quality of Chengdu is 52 in 2001, and according to the standard of the daily air quality in the figure, presenting the daily air quality in 51-100 belongs to the good condition of the air quality, so in the 2001, the air quality of Chengdu is very good among the other major cities in China. However, after 10 years, the air quality of Chengdu has gone from bad to worse. From the figure 8, it indicates that the air composite index of Chengdu is 5.85 in 2015, and figure 8 is about the comprehensive index of air quality in all cities of Sichuang province, Chengdu was ranked the last one in the air composite index. That is to say, from 2001 to 2015, the environmental quality of Chengdu becomes worse gradually.

Why does the environmental quality continue to deteriorate in Chengdu? According to the research and the analysis in this paper, there are some reasons about this issue as following:

First, the development of industries together with the social change has changed the livelihoods in the city. Therefore, more and more factories are built in the Chengdu, so the pollutants emitted by factories have a serious impact on the air. Secondly, many people move to the city from the countryside in order to pursuit a better life, so many pollutants of the people's daily life, like vehicles gas emission, can be damage to the air quality.

Thirdly, the development of the transportation. Nowadays, the traffic becomes more and more convenient, and the development of modern traffic makes people can choose a variety of transport. The transportation, such as cars, planes, trucks and so on produce a large amount of waste gas to pollute the air.

Therefore, if the Chengdu's city planning aim to establish a sustainable transportation system in the city, it is very important to concern environmental problem. the more sustainable the transport system is, the better the condition of the environment is.

This provides some effective solutions to solve the environmental issues in Chengdu. At first, the government of Chengdu area can make sure that related laws are put into practice. when harmful gas emissions get into the air directly without disposal it would be punished. Secondly, people are educated about what they could do to stop the air pollution, like everyone using more public transportation and less private vehicles will reduce emissions dramatically. Thirdly, letting the forests play an important and positive role, and more trees can be planted to purify the air instead of cutting them down.

2.1 Chengdu's current transport system

Chengdu's current transportation system includes national railway, rapid railway, metro, bus and taxi services. National railway is the connection of Chengdu and other Chinese cities with Poland, Europe. In 2013, the first railway connection between West of China and Europe has been established in Chengdu, which encourages East-West trade, significantly reduces logistic time and increases the amount of import-export. Rapid

railway closely connects central urban area and suburban districts. This is an independent line, by operating on its own railway, which can significantly improve the commuting in the area. From city planning's point of view, the rapid railway helps to reduce the number of immigrants entering into central urban area, which shortens the commute distance and time-saving, people can buy less-expensive property in sub-urban areas. Recently, Chengdu has two metro lines under operation, and until 2020, there will be total 9 lines operated in this megacity. Bus is the most important transport close to residents' daily lives, so Chengdu government makes a great effort to create a new public bus system, a rapid transit. It's separated with regular bus lines, established above the middle of main road like a bridge in the sky. This massively shortens the commute time. Until 2013, Chengdu has 17,684 taxis, and the increase rate keeps up by 9.3% (Travel China 2013).



Figure 9: The Transportation of Chengdu in the 1990s (Travel China 2013).



Figure 10: The Transportation of Chengdu in 2015.

1. Sha xi west road: remove 80m length of central green belt, build up one more left-turn traffic lane.
2. Nan deng xiang road: remove green belt, build up a left-turn traffic lane.
3. Huang men hou jie road: remove 30m length green belt, build up a 3m wide left-turn traffic lane.
4. Chuang ye road: remove 21m length green belt from both sides, build up a left-turn traffic lane, a u-turn traffic lane and a direct traffic lane.
5. Zong shu road: remove the green belt from west entrance, build up a new traffic lane.

6.Chang shou road: remove 30m length green belt from both sides, build up a right-turn traffic lane.

7.Liu li road: remove 80m length central green belt and 160m length green belt from west entrance, build up two left-turn traffic lane on both sides.

8.Mo zi qiao road: remove 100m length green belts from East and West entrance to increase the room for left-turn, move bus stop 100m to West.

9.You lou jie road: remove 120m length of green belt to ensure the traffic from West to East can directly move into You lou jie road from left-turn traffic lane.

10.Bei da jin jie road: remove 75m length of central green belt and remove 60m length of isolation zone on both sides to increase the length for left-turn. Meanwhile, build up a new left-turn traffic lane.

Figure 9 is a picture that is about the transportation of Chengdu in the 1990s, from this picture, it shows the condition of Chengdu's transportation 20 years ago. In the 1990s, there are just bicycles and buses on the street, and the means of transport in Chengdu is very simple, which rarely caused as much pollution as we do today.

Figure 10 is about the transportation of Chengdu in 2015, this figure mainly presents the completion of the ten major block rectification in Chengdu. According to this figure, it indicates that the transportation system of Chengdu is changed from the simple model to the complex model. That is to say, following the development of the technology and the science, the transportation system of Chengdu becomes more and more complex and convenient.

Although the development of transportation system in Chengdu indicates that this city is on the progress, there still exist some problems on the development of transportation system.

The first problem is that the transit network connections are poor. There are only two metro lines under operation so far in Chengdu, so many of local residents still have to commute by bus or by private cars. More and more private cars can result in air pollution. In Chengdu, gasoline is still popular for car use.

The second problem is that The management of the roads is not in a sufficient level: road areas are lacking clear signs which might cause traffic accidents.

According to the report, until 2020, the number of private cars will be around 3.5 million while the amount of city center residents is going to increase up to 7.5 million. (Report 2010) It shows that the majority people will choose private car for travelling.

Focusing on the problems of the Chengdu's transportation system, it is very important to develop a sustainable transportation system in Chengdu. There are some recommendations about establishing a sustainable transportation as following: the government of Chengdu should improve the quality of the roads. people should be encouraged to travel by bus or bike instead of using private cars, which will reduce the air pollution as well. Also, people can go to work or go outside by subway in the rush hours.

2.1.1 Challenges

In the process of stimulating local economic development, Chengdu government is facing a series of problems to retard its plan. Among those, environment issue is the key one. Because the main cause of environment issue is the transportation problem, prior to developing a sustainable transportation system, finding out reasons of transport problem is the important step.

Poor Transit network connection is one of the most important reason to cause transport problem. Reasonable transit network connection can

greatly reduce commute time. However, recently Chengdu hasn't build up a good transit network connection. The number of bus stops is not enough; walking from home to nearest bus stops takes a lot of time (practical measured: 10 minutes is the maximum for people to stand). There are only two metro lines under operation so far, so majority of local residents still have to commute by bus or by private cars. The increasing number of private cars will put more and more pressure on environment.

Uncleared Road use function is another bad impression for drivers. Mismanagement can be reduced or get rid of by useful methods applied by city planning.

In the past, "regularly road amending" is the phenomenon of local government's corruption. But now, Chinese central government has carried out a series of actions to anti corruption, "regularly road amending" is not going to happen any more, only the constructing transportation project causes inconvenient for road use.

Near 10 million people commute to Chengdu central area every day, this requires a scientific transportation system to support. However, because of old narrow road and construction projects, urban central area congestion becomes daily normal phenomenon. Plus, poor transit network connection raises private cars use in central area.

Private cars fast increasing compared with public transports developing slow down significantly causes a huge environmental problem. Until 2020, the number of private cars will be around 3.5 million; town center residents are going to be 7.5 million. Estimated total travelers are near 10 million/day, public transports should take 50% of the total travelers (rapid transits can take 5 million people/day, regular buses will take 5.4 million people/day). (Report 2010)

Shortage of parking areas is also the urban problem. Because land is extremely expensive in town centre. Commercial buildings surrounded. It's very hard to find parking areas in centre. Although there are some new

ground parking areas and parking buildings have been built, increasing private cars are blocking on the street. Shortage of parking areas is a severe problem in nowadays.

2.1.2 Development planning

So many serious problems require city planning provide the public with a clear, applicable and feasible development planning immediately.

Chengdu is planned to be an “ecological city” by the central government, therefore, developing a sustainable transportation system should be based on this theory.

Figures below explain the big images that Chengdu city planning has to build up a better place for residents in terms of developing an integrated transportation planning, establishing a logistics centre, designing rapid transits network and enhancing infrastructure.



Figure 11: Mega Chengdu Integrated Transportation Planning (Chengdu City Planning Bureau 2016)

Chengdu's transport planning based on "one circle and twelve lines" principle. One circle is in the urban central area, in which there are twelve transport connection points. Based on those points, transport channel can efficiently connect urban central area and East, West of Mega- Chengdu.



Figure 12: Chengdu Long Quan Logistics Centre(Source from: Chengdu City Planning Bureau 2016).

By establishing a large logistics centre in suburban area, large transportations, e.g logistic trucks and freight train can be restricted entering into city centre. It also can attract logistic companies and make goods vehicled in an efficient way.



Figure 13: Ground Metro Design Planning (Chengdu City Planning Bureau).

Ground metro designed on a separated rail, which is built above the ground but connected with an overpassed bridge, so that people can cross over the road without stopping travelling transportations.



Figure 14: an example of chengdu rapid railway(chengdu-dujiangyan) (Chengdu city planning bureau).

Rapid railway is a way connecting urban central area and affiliated districts. For example, DuJiangYan is an affiliated city of Chengdu, which is one-hour-by-car area to urban central area. Rapid railway is trying to

reduce the commute time into 15 minutes from cities, like DuJiangYan, to Chengdu.



Figure 15: The Second Highway Around City (Chengdu City Planning Bureau).

Highway is the most important way connecting Chengdu with other cities. It's responsible for hundreds of thousands of vehicles travelling everyday. Expanding and building new highways help improving suburban areas' function.

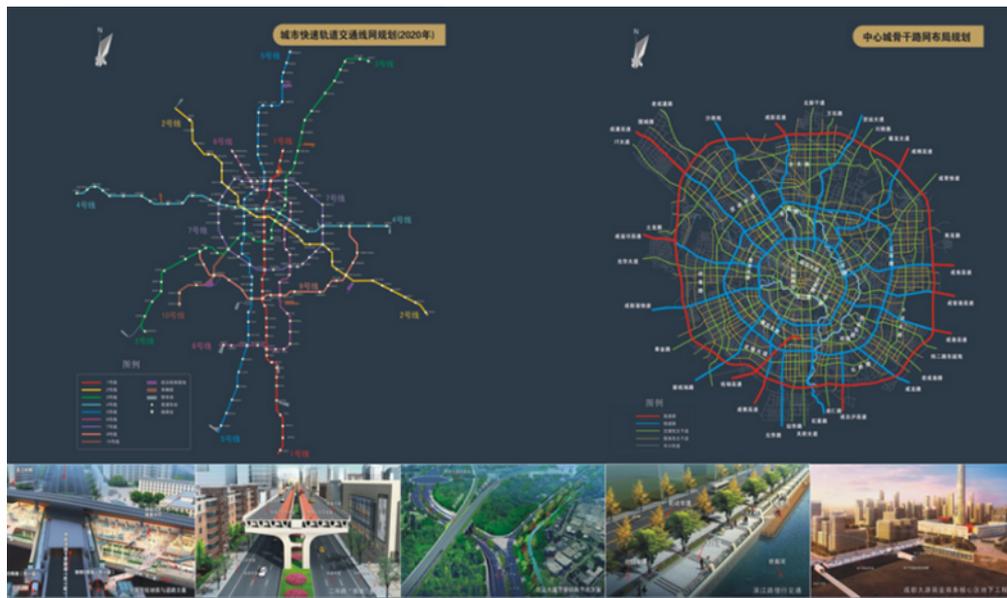


Figure 16: Chengdu Metro Planning until 2020(left) and Urban Central Area Transit Network Planning (Chengdu City Planning Bureau).

9 metro lines and “one circle and twelve lines” plan will provide residents with more travel options. This integrated transportation planning aims to realize traffic diversion and to reduce vehicle emissions.

3 ROOM TO IMPROVE

Chengdu government has announced its “ecological city” planning principles, which aims to develop this central city of South-West in a sustainable way with building up underground transportation and over-ground transportations, like high-bridge pathway. It will make a positive effect in a long term. However, due to the aim based on encouraging local economy, this planning along with current construction put a significant negative effect on local environment. Therefore, some recommendations are provided in this paper to help reduce environmental pollution while the planning is in implementation.

3.1 Local urban environmental pollution reduction recommendations

Air

At the beginning of 20th century, more attention has been paid to the relationship between air pollution and motor vehicles due to the vehicle market requires updated international standards to obey and market creation, plus, environment issue is always concerned by people. Asif Faiz, Christopher S. Weaver and Michael P. Walsh had done a research in 1996 on standards and technologies for controlling emissions. They found out that technical measures and good market management can dramatically reduce air pollution, noise and other adverse environmental impacts of road transportation. It is not a new idea for now, but still working on today. Improved technology for controlling and reducing emission from vehicles in terms of changes in engine technology can reduce pollutant emissions significantly. In addition, improved technology such as the development of electric cars, turn to be the outstanding-long-term solution for reducing emissions. As mentioned before, until 2020, the number of private cars in

Chengdu will be around 3.5 million. In order to improve urban air quality, city planners can promote to the use of cleaner vehicles, fuel technologies and non-fuel cars. Encouraging the use of public transports, such as metro and buses, by adding market incentives is also another method to reduce emissions.

Water

Water can be polluted by several processes. The construction and the maintenance of local infrastructure can easily turn a pollutant from airborne state to solute state. Air pollution, such as dust and fallouts, formed under construction is dissolved in water can also easily cause water pollution. Chemical particulars and heavy metal are those pollutants very harmful for people and very easy adding to water. Especially when a city is planning establishing an underground transport system, ground water should be comprehensively protected, because ground water is the main source of drink water. Chengdu has a long-term metro planning, some recommendation for water protection is shown as below:

Use water efficiently through high efficiency fixtures, elimination of leaks, etc. Construction in off-peak time can help reduce pollution. Using energy-saving equipments and high-tech to save water use. And build up water storage for water re-use (especially for running water), separate construction-used water and drink water.

Noise

Traffic noise is caused by various types of transports, which has significant features that of occasionally happened and volume can be changeable. The noise can not be eliminated entirely, but the suitable solution to control or reduce traffic noise is possible and applicable.

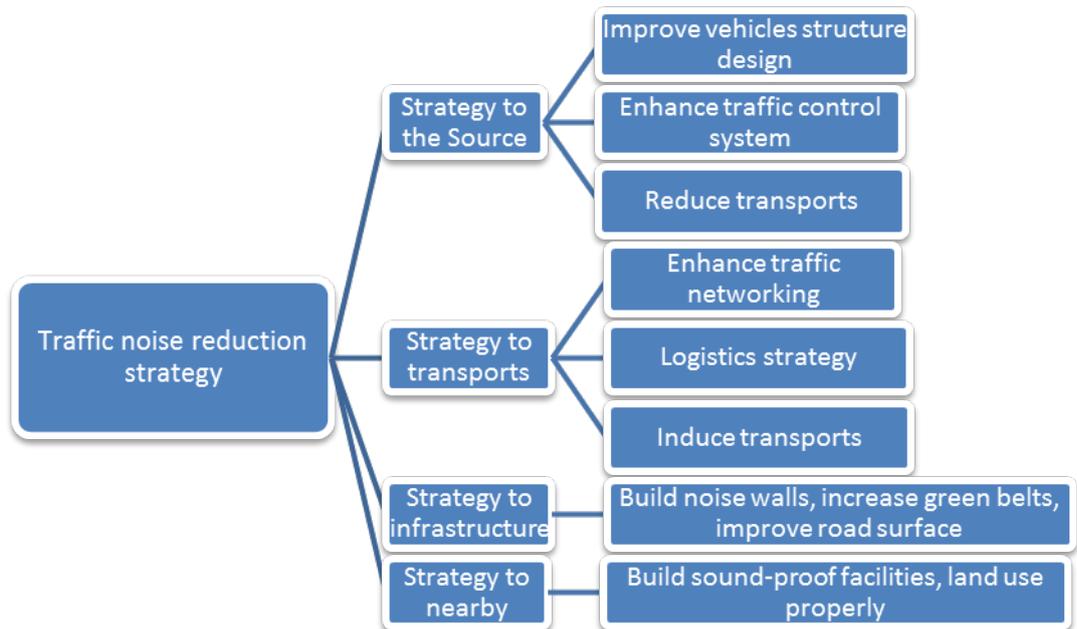


Figure 17: Traffic Noise Reduction Strategy for Chengdu

Figure 17 shows the applicable method to reduce traffic noise in Chengdu. The first is the improving vehicles structure design: emphasis the different pollution level of large and small size vehicles encourage car owners maintaining vehicles regularly, encourage the development of electric cars. The second is the enhancing traffic control system: applying traffic control system and signal system to ensure a healthy traffic line, limiting driving speed and separating driving lanes. The third one is the way to reduce transports: improving public transports, encourage shared vehicles. The fourth is to enhance traffic networking: building voeux road to separate transports. There is also a logistics strategy which means setting up logistics centre to limite large vehicles entering into city centre. Reducing transports by using traffic signs or traffic signals is recommended to help reduce urban traffic noise in Chengdu.

Surroundings of the road area

The construction and the maintenance of infrastructure always bring problem to local residents, for example, which affects the routine to commute and changes local landscape. City planning should pay more attention for protecting the landscape during the construction period. According to Mr Zhang 2015, a previous city planner of Chengdu, saying “Public construction is based on the budget from local government. The majority of the whole budget is reserved for materials purchase and for workforce. Equipment for landscape maintenance is only for temporary use, it’s a waste of money to buy or rent a lot.” however, because transport construction is a long-term project, plus, there were some accidents happened due to the lack of protecting-net, city planners should pay more attentions on protecting landscape. Here are some recommendations for them to protect local landscape:

Build fencings to separate traffic and construction, ensure traffic security. Landscape bollards also can be used to stop vehicles moving into the construction area.

Install night- lights in construction area to guide traffic and to reduce construction pollution

Select native or regional plants to make the local landscape unique and sustainable. Because native or regional plants are used to local climate conditions, which also have a strong relationship with local wildlife. To make a city transport sustainably, first make inhabits locally.

Protect existing nature environment. Try not to change the stream corridors and meadows.

Reduce the use of powerful equipment on trees and plants. Beautifying cities by putting lights on trees or plants is a waste of energy and also is the very bad way to grow plants.

Reduce use of pesticides. Try to use natural alternatives to avoid pest. Using plants for cooling or heating purpose. In summer time, appropriate trees can reduce the temperature in certain distance. In winter time, some trees allow Sun' rays to make building warmer.

3.2 Further research

A sustainable transport system is strongly connecting with local residents, environment, and natural wildlife, various transportations (manufactures and gas, oil suppliers), government development mission. Satisfying all of these stakeholders is not easy. First of all, government's planning on developing a sustainable transport system is the key. The planning is not only an image that shows a beautiful picture to all may concern, but also an applicable blueprint to explain how it can be achieved. Therefore, a strategy is required to address steps of developing a sustainable transport system. Chengdu government do have a strategy to expand their ambition, but it more focus on the influence on economy, pays less attention on environmental protection. The recommended strategy of developing a sustainable transport system in Chengdu concerns the balance between local residents and the local environment.

As mentioned before, Chengdu's transport planning based on "one circle and twelve lines" principle. One circle is in the urban central area, in which there are twelve transport connection points. It provides local residents with a convenient gateway to get to other parts of mega Chengdu. The development of metro and rapid transit have tremendously changed people's life. Travelling is faster than ever. According to the investigation, local residents are all welcome the planning, especially the elderly people, those people used to have an economic lifestyle, they spend money within budget, like to share, happy with consume products on sale. On the contrary, young people prefer expensive products, and care about having a high-quality life. So, a private car for them is necessary. With more than

10 million permanent inhabitants. Chengdu government is under great pressure to create a sustainable transport planning. Moreover, until 2020, there are going to be 3.5million private cars in Chengdu (estimated by current raise rate). When public transports occupy the majority of space, where can private cars park will continue to be another big issue in future. Plus, more cars mean more pollution. To end this bad situation, developing a sustainable transport system should include the development of small electric mobiles as an alternative. Electric mobility is in its early age, still under development. It needs a strong aid from local government. Electricity grid and charging station needs to be planned as part of sustainable transport system. Electric mobile and the whole installation package can be done as further research.

In addition, the further research is needed to focus on the habit of the local resident in transportation. The habits of the local resident play an important role in the development of sustainable transportation systems, because the choice of traffic tools is an essential part of the traffic construction. Following the improvement of the life standard and quality, the purchasing power of the people is greatly enhanced, so that many people have owned their private car. Therefore, more and more people go outside choosing to take private car, the increase of the private car will result two big problems. On the one hand, the vehicle exhaust will make air pollution; on the other hand, although there are some new ground parking areas and parking buildings have been built in Chengdu, increasing private cars are blocking on the street. At the same time, the government of Chengdu should promote the education of the public transportation, making people to get education about what they could do to stop the air pollution, and everyone using more public transportation and less private vehicle will reduce emission dramatically. That is to say, developing a sustainable transportation system in Chengdu successfully, it not only relies on the govern department, but also the local resident should make their own efforts.

SOURCES

AICGS.2013. Transportation and Land-Use Planning in Germany and the U.S.: Lessons from the Stuttgart and Washington, Dc Regions. American Institute for Contemporary German Studies. [accessed 1 December 2016].

Available at:

<http://www.aicgs.org/publication/transportation-and-land-use-planning-in-germany-and-the-u-s-lessons-from-the-stuttgart-and-washington-dc-regions/>

Barbara, C. R, 1999.Toward a policy on a sustainable transportation system. Journal article of Transportation research board of the national academies. Volume 1670/ 1999 Transportaion and Environment.pp.27-34.

Chengdu Environmental Statement 2013. Edited by Chengdu Environment Protection Bureau.

Chengdu intergrated transportation planning. 2013. CPMB .[accessed 1 December 2016]. Available at:

<http://www.cdgh.gov.cn/wsggg/zjzt/100.htm#p=1>

Chengdu has 17,684 taxis, and the increase rate keeps up by 9.3%. 2013.Travel China. [accessed 1 December 2016]. Available at:

http://www.china.com.cn/travel/txt/2013-03/14/content_28239902.htm

Danel, A. R, 2004.Value of accessibility to Bogotá's bus rapid transit system. Transport Reviews: A TransnationTransdisciplinary Journal. Volume 24, Issue 5, 2004.

The environmental assessment report of Chengdu urban rapid transits construction planning (2010-2012). 2010. Editor: China Metro Engineering Consulting Co., Ltd. [accessed 1 December 2016]. Available at:

<http://wenku.baidu.com/view/2c9148fef705cc1755270944.html>

Faiz, A., Weaver, C. S. and Walsh, M. P. 1996. Air Pollution from Motor Vehicles: standards and technologies for controlling emissions.[accessed 1 December 2016].Available at:

https://books.google.co.uk/books?hl=en&lr=&id=Hqsyv_KD0lgC&oi=fnd&pg=PR13&dq=air+pollution+and+vehicle+emission&ots=De3ypuJI5k&sig=7rpR14kndnP3drQCLqkPUtjtjGQ#v=onepage&q=air%20pollution%20and%20vehicle%20emission&f=false

Finland to become a model country for sustainable transport by 2020.

2014. VTT. [accessed 1 December 2016]. Available at:

<http://www.vtt.fi/haku/Pages/results.aspx?k=Finland%20to%20become%20a%20model%20country%20for%20sustainable%20transport%20by%202020>

Health and sustainable development. 2016. WHO. [accessed 1 December 2016] Available at: <http://www.who.int/sustainable-development/cities/case-studies/en>

Janssens, M., Pinelli, D, Reymen, D.C., Wallman, S. 2009. Sustainable cities: diversity, economic growth and social cohesion. Edward Elgar Publishing Limited, UK.

Jenks, M.M., Burgess, R. 2000. Compact cities: Sustainable Urban Forms for Developing Countries. Spon Press, London. [accessed 1 December 2016], available at:

https://books.google.fi/books?hl=fi&lr=&id=ORmIB-I_nZ0C&oi=fnd&pg=PR8&dq=sustainable+city+&ots=wsxCvhNNQt&sig=N715sKTAkBdWwwS6ocMv8WV7S8A&redir_esc=y#v=onepage&q=sustainable%20city&f=false

Meeting the Energy Challenge, A White Paper on Energy May 2007. pp. 235-252. [accessed 1 December 2016]. Available at:

<https://www.gov.uk/search?q=Meeting+the+Energy+Challenge+A+White+Paper+on+Energy+May+2007>.

MTC. 2014. [accessed 1 December 2016]. Available at:

https://www.lvm.fi/en/publications_series

Our Common Future. 1987. WCED. Oxford: Oxford University Press.

Smart Sustainable Mobility - A user-friendly transport system is a combination of intelligence, low carbon energy, and adaptable services. 2014. Authors: Raine Hautala, Veikko Karvonen, Jukka Laitinen, Juhani Laurikko, Nils-Olof Nylund, Mikko Pihlatie, Karri Rantasila, Anu Tuominen. VTT. Vision 5. [accessed 1 December 2016]. Available at:

<http://www.vtt.fi/haku/Pages/results.aspx?k=Finland%20to%20become%20a%20model%20country%20for%20sustainable%20transport%20by%202020#k=Authors%3A%20Raine%20Hautala%2C%20Veikko%20Karvonen%2C%20Jukka%20Laitinen%2C%20Juhani%20Laurikko%2C%20Nils-Olof%20Nylund%2CMikko%20Pihlatie%2C%20Karri%20Rantasila%2C%20Anu%20Tuominen>

Towards a Sustainable Transport System-Supporting Economic Growth in a Low Carbon World. 2007. [accessed 1 December 2016]. Available at:

[https://www.gov.uk/search?q=Towards+a+Sustainable+Transport+System-Supporting+Economic+Growth+in+a+Low+Carbon+World"%2C+2007](https://www.gov.uk/search?q=Towards+a+Sustainable+Transport+System-Supporting+Economic+Growth+in+a+Low+Carbon+World)

The twelfth five-plan: China's urbanization rate goes up to 51.5% until 2015. 2011. Chinanews. [accessed 1 December 2016]. Available at:

<http://www.chinanews.com/gn/2011/03-05/2886127.shtml>

UNFPA. 2014, .[accessed 1 December 2016], available at:

<http://www.unfpa.org/world-population-trends>

VIVER-A sustainable transport vision for Germany. 2011. Authors: Wolfgang Schade, Anja Peters, Claus Doll, Stefan Klug, Jonathan Köhler, Michael Krail. ISI. Working Paper Sustainability and Innovation. No. S 3/2011. [accessed 1 December 2016]. Available at:

http://www.isi.fraunhofer.de/isi-wAssets/docs/e-x/working-papers-sustainability-and-innovation/WP3-2011_VIVER-english-Version.pdf