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A STUDY ON REGIONAL WATER RESOURCE SHORTAGE IN THE BEIJING-TIANJIN-HEBEI REGION: DOMINANT ISSUES, EXISTING PROBLEMS AND SUGGESTED SOLUTIONS

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By

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Contents

Abstract

Traditionally, making use of water resources always involves requirements to face many limitations, which usually lead to water shortage, and those problems are more obviously prominent in developing countries than in the developed countries, for example, China. As a result, the research on regional water resources shortage problems becomes necessary.

This thesis is mainly focused on the case in the Beijing-Tianjin-Hebei Region to attempt to show the process about how to find the main issues, the problems, and the related and recommended solutions for water shortage, including the 1) analysis of the issues that lead to the current existing water shortage problems in the Beijing-Tianjin-Hebei Region by using a principal components analysis (PCA) model, 2)evaluation and analysis of the related problems led by those issues ,and 3) proposes the recommended solutions and the related possible responses for those issues.

Chapter 1 Introduction

1.1 Main Context of China's Water Shortage Status

Water is the most basic resource for humans' survival and production. People rely on water resources to motivate the continuous development of society and economy. Unfortunately, with the rapid development of social economy, the shortage of water resources and the pollution of water environments have become one of the most serious social problems among countries all over the world, and large numbers of countries are facing grave threats from the water shortage. China is one of these countries. According to the speech of Siyi Hu (2012)[1], the vice minister of the Ministry of Water Resources, China is facing five important issues that lead to the water shortage.

First of all, the ownership of water resources per capita is low. According to the data of the *Statistical Yearbook of China 2011*, the ownership of water resources per capita in China is around 2,100 m^3, which only accounts for the 28% of the world average level. That means the huge size of the population and the limited water resources in the nature conditions of China is one of the reason of the water shortage.

Second, the contradiction between the supply and the demand of water resources is significant. According to the data of the *Statistical Yearbook of China 2011*, the national average annual water deficit is more than 500 million m3, and 2/3 of all the cities in China have water shortage problems. On the other hand, there are almost 300 million people live in rural areas that do not have security even for drinking water. That means the water shortage problems widely exist in China.

Third, the method of water resource utilization is still extensive. The water utilization coefficient for farmland irrigation is just 0.50, and that is a significant gap compared to the world's advanced level, which is among 0.7~0.8. That means the utilization factor of water resources is another reason to lead to water shortage problems.

Fourth, a lot of local areas' water resources have been overdeveloped. For example, the degree of development and utilization of the Yellow River basin has reached to 76%, while the Huai River basin is 53%, and the Hai River basin is even over 100%, which is

[1] This speech was given by Siyi Hu during the press conference of the information office of the State Council of the People's Republic of China in February 16th, 2012.

already over its water carrying capacity, and that leads to a series of ecological and environmental problems. That means the overdevelopment of water resources not only can leading to the problems that are existing currently, but also can lead to problems in the future, which include water shortage problems and even a series of other problems.

At last, the water body pollution problem is significant. Currently, the water qualification rate in the local functional area in China is only 46%. According to the data of the year 2010 and the *Environmental Quality Standards for Surface Water (GB 3838-2002)*, 38.6% of the water in the river is worse than the Class III water[2], and 2/3 of all the local lakes in China had eutrophication problems. According to the *2013 National Economic and Social Development Statistics Bulletin* (National Bureau of Statistics of People's Republic of China, 2014), the 704 water quality monitoring sections of the 10 largest drainage basins showed that 71.7% of those water quality monitoring sections belong to Class I, II and III, and 8.9% of those water monitoring sections are even worse than the Class V water. Those 10 drainage basins had a water quality relative to mild pollution as a whole. The increasingly serious water pollution problem was not only decreasing the usability function of the water body, but also further aggravated the contradiction between water supply and demand, which made the water shortage problem worse. Because of the water shortage and water environmental pollution, industry in China loses more than 200 billion RMB (approximately 32 billion dollars, based on the assumed exchange rate of 6.25:1 between RMB and US dollar on April 15, 2013). The water pollution has been a main issue to lead to the water shortage problems.

[2] According to China's standard, the water quality has been divided into 5 Classes: I, II, III, IV, and V that are based on the contents of different kinds of organic and inorganic matters, pH, etc. under specified conditions. The Class I is the best, and the class V is the worst, and there still have water quality that is even worse than the class V. In short, Class I is mainly apply to the water in water source and in national nature reserves; Class II is mainly apply to the water in the primary reserves of the surface water source for centralized domestic drinking water, the habitats of rare aquatic organisms, the spawning grounds of fishes and shrimps, the feeding ground for larvae and young fishes; Class III is mainly apply to the water in the secondary reserves of the surface water source for centralized domestic drinking water, the overwintering grounds for fishes and shrimps, the swimming channels for fishes to swim across different water area, the aquaculture areas, and the areas for humans' swimming; Class IV is mainly apply to the water in water source for common industries and the water areas for entertainment without the immediate contact with human bodies; Class V is mainly apply to the water in the water sources for agriculture and water areas requested by landscape .For detailed indexes and other data of those standards, please visit and read the "Environmental Quality Standards for Surface Water" provided in the website: http://www.nxep.gov.cn/readnews.asp?newsid=543

Water resource shortage problems also have a strong possibility to impact the future development of China. According to the "2013 National Economic and Social Development Statistics Bulletin", the total water resource is 2,786 billion m^3, and the annual average rainfall is 665 millimeters. The total Water storage volume of all 613 large reservoirs at the end of year 2013 is 348.8 billion cubic meters, which was reduced by 5% over the previous year. The total water consumption in 2013 is 6,170 billion m^3 which increased by 0.6% over the previous year. Among those water consumptions, domestic water use was increased by 2.7%, industrial water use was increased by 2.7%, a 0.1% drop was in agricultural water use and ecological hydrating use growth was about 1.6%. This data shows that with the continuous industrialization and urbanization in China, the water demand will keep sustaining growth over a longer period, the contradiction between supply and demand of water resources will be more acute, and the problem of water resource shortage in China will be more serious. Water resource shortage has been and will always be an important factor of restricting most of China's vast areas in social economic development.

1.2 Main Objective of This Research

This research will focus on the process to solve the regional water shortage problem. It will not only analyze the dynamic relationship between water resources and the macro-social economic system and give the result of the relationship, but will also provide realistic supporting evidence and limitation size for the future economic development strategy and planning, so that people can control the human activities under the water resources situation to make it affordable. Based on analyzing the relationship between the supply and demand of water resources and setting up the shortage of water resources assessment system, this thesis will also apply them into the actual case according to the specific condition of Beijing-Tianjin-Hebei region, which contains one of the most important industrial zones(the Beijing and Tianjin Tang industrial zone) in China that not only have significant economic status, but also include the political and cultural center of China, Beijing, the capital of China, so it also could reflect how the social and political issues impact and induce the water shortage problems. Then the solutions under the restricted water resources status, as well as related possible results to make water resources and social economy to keep developing accordingly in this area will be discussed.

Therefore, analyzing the water resources supply and demand of regional relation with water shortages, finding the problem and then putting forward solutions of related researches, are not only practically significant for guiding the practice in the Beijing-Tianjin-Hebei Region and other areas that have similar problems of water shortage, but also important to the theoretical value. Going through this case study, it will provide a representative case about how to find the dominant issues, the existing problems, and the suggested solutions for regional water shortage problems in other regions.

1.3 Research Method and Innovation

This thesis will take Beijing-Tianjin-Hebei region as a case study, including both theoretical and empirical studies of the possible issues that may lead to the water shortage problems, and use the historical data of the Beijing-Tianjin-Hebei area as a support basis of analysis for Beijing-Tianjin-Hebei region. Those issues will be listed based on the study of the background information of the region. Then a special economic model, the principal component analysis model(the PCA model), which is a kind of method that could reveal large sample and multivariate data or the internal relations between samples, will be used for analyzing those issues to find which of them have significant impact on the water shortage problems in the region(the details and features of the PCA model will be introduced and discussed later in chapter 4). After that, based on the issues, the specific problems that were led by those issues will be analyzed, and the corresponding possible solutions will be presented with analysis and evaluation of the possible responses. In addition, the best solution(s) will also be suggested with them.

The innovative nature of this research is embodied in the following aspects. First of all, the data used in this thesis were partly collected from the Ministry of Housing and Urban-Rural Development of the People's Republic of China, which are original and hard to be collected by other scholars. Second, in addition to the general analysis, this research will also use the PCA model for the case of Beijing-Tianjin-Hebei region, which could provide a reliable support for the analysis result of the issues that has led to the water shortage problems in that region. Finally, based on the specific issues observed in the analysis result of the PCA model, some creative solutions and related possible responses of those solutions will also be predicted and presented.

1.4 The structure of the thesis

This thesis will be divided into six parts. The second part covers the current background of water conditions for the Beijing-Tianjin-Hebei Region. The third part reviews the theories and the literatures that are related to this thesis. The fourth part will summarize the possible important issues that may lead to the water shortage in the region, and then introduce and use the PCA model to analyze the original data of the case study of Beijing-Tianjin-Hebei region to find the significant issues that impact the water shortage problem. The fifth part covers the related problems, the recommended solutions, and the analysis and evaluation of those solutions' possible future responses for the issues observed in the PCA model, and give the suggestions of those solutions. The last part will conclude the thesis.

Chapter 2 will present the background information, the water shortage situation and the historical data for water resources situation for Beijing-Tianjin-Hebei region, as well as the problems in the region, as a basis for finding the possible issues that led to the water shortage problems in the region.

Chapter 3 will review the theory and the background relevant to the study of water shortage and the PCA model.

Chapter 4 will present the nature, the meaning, and the theoretical basis of the PCA model which is used to analyze the issues that led to water shortage problems in Beijing-Tianjin-Hebei region. The possible issues will be picked according to the reviewed literatures and background information. The result of this model analysis will present the theoretically significant issues for the reason of the water shortage problems, and that is used as the basis for Chapter 5.

Chapter 5 will analyze the problems and then give the corresponding solutions that are based on the issues observed in the result of the PCA model in Chapter 4, including those currently existing solutions in China and in the Beijing-Tianjin-Hebei Region, and experience from other countries, etc., and then evaluate the possible responses and impact of those solutions assuming they will be used.

Finally, a conclusion will be drawn in Chapter 6 based on the previous results.

Chapter 2 Background

2.1 A Brief Introduction of the Beijing-Tianjin-Hebei Region

The political and culture center of China is located in the Beijing-Tianjin-Hebei Region. It is also the largest economic core area which has highest level of development in the north of China with the main industrial base for iron and steel, petrochemical chemical engineering, ocean chemical engineering, light spinning production, etc., and it is also the important hub and gateway for China to participate in the international economic exchanges and cooperation. On the other hand, according to the article "Sustainable development and utilization of China's water resources in the 21st century" (Chen, 2000), the Beijing-Tianjin-Hebei Region located into the Hai River Basin, which has the most heavily shortage for water resources in our country, with only 370 x 108 m^3 of water per year in average, and that is less than 1.3% of the total amount of water resources of China. In addition, it carries about 10% of the country's population, food and GDP (Chen, 2000). During the past 50 years, the Hai River Basin's population has been doubled, and the total area of irrigation has increased by 6 times, and its GDP have increased by 33 times, and the total water resource consumption of it has increased to $403\times108m^3$ from $91\times108m^3$. Meanwhile, the local water resources per capita amount is decreased to 293 m^3 from 353 m^3, which is the lowest in the national major basins, and that was only about 1/7 of the national average (Zhang and Jia, 2003) and 1/27 of the world's average, and far less than the minimum international standard of water resources per capita, which is 1000 m^3 (WWW.SOHU.COM, 2002). In addition, the population of the Beijing-Tianjin-Hebei Metropolitan Area has increased nearly 15,917,900 people, which mean about 1,325,800 people in average per year. With the increase of population, irrigation area, and GDP, water shortage has become a main factor to impact the economic and social sustainable development of the Beijing-Tianjin-Hebei Region in the 21st century (National Health and Family Planning Commission of the People's Republic of China, 2014).

2.2 The Endowment and the Status of the Development and Utilization of Water Resources in the Beijing-Tianjin-Hebei Region

Before finding the possible issues that lead to the water shortage problems in the Beijing-Tianjin-Hebei Region, it is important to learn about the nature of water resources in this region, which include the . Let's start with the "local water resources" of this region—the ground water resources.

2.2.1 Ground Water Resources

More than 90% of the area of the Beijing-Tianjin-Hebei Region belongs to the Hai River basin, which mainly includes two major river systems, the Hai River water system and the Luan River water system. The Hai River water system consists of the Jiyun River, the North Canal, the Yongding River, the Qing River, the Ziya River, and the Zhangweinan Canal; the Luan River water system includes the Luan River and rivers near the sea of the coast of Jixi. In addition, there are 16,100 km^2 of land belonging to the continental river and the Liao River basin, accounting for 9% of the total area of the district, which includes 11700 km^2 of land belonging to the inland river basin, 4,400 km^2 of land in the northern part of Chengde belonging to the Liao River basin, and the southern part of Cangzhou belonging to the Tuhaimajia River system (Figure 2-1).

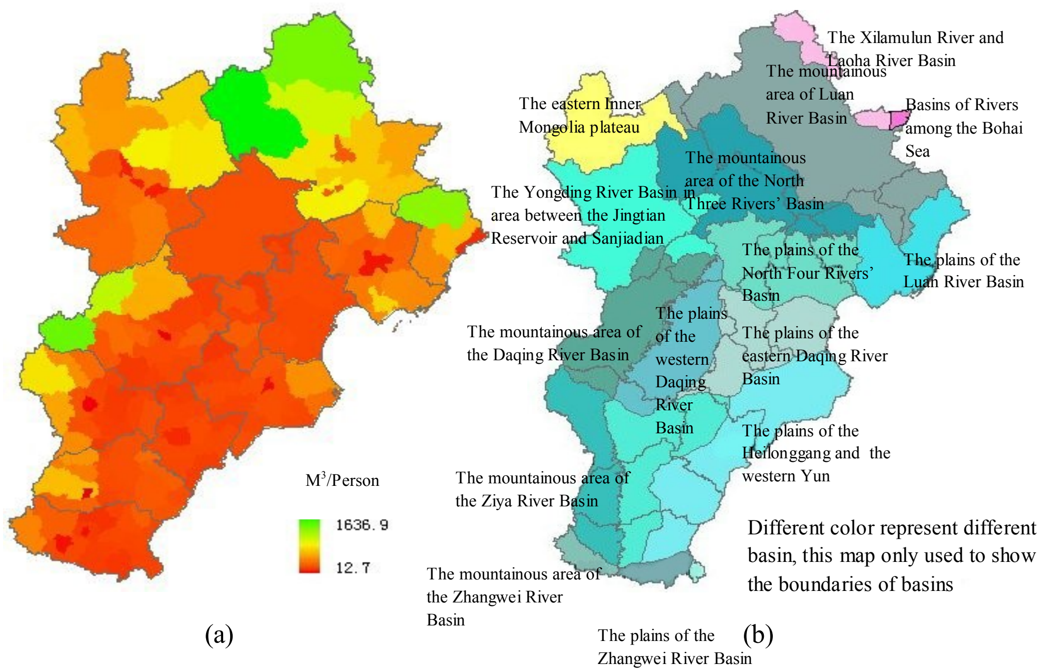

Figure 2-1 (a) Beijing-Tianjin-Hebei Spatial Distribution of Water Resources Per Capita (Modified from the original version)

(b) Beijing-Tianjin-Hebei Watershed Distribution; (Modified from the original version)

Source: 2005 China Water Resources Bulletin, The Ministry of Water Resources of the People's Republic of China

2.2.2 Rainfall Water Resources

As a supplement for ground water resources, the rainfall water resource also plays an important role in the water status of this region. For the rainfall in this area, according to the time distribution and the total annual precipitation, the rainfall during the flood season (June to September) accounted for about 80% of the total annual rainfall, and the rainfall during the flood season was mainly concentrated in 1-2 rainfall processes in July and August, which made it easy to form floods. The rainfall in spring (March to May) only accounted for about 10% of the annual rainfall, which frequently led to a spring drought. In addition to the uneven distribution of rainfall during the year, the interannual rainfall also changed a lot. The annual rainfall of low flow years could only reach 50% of the rainfall of high flow years. Dry years often appear continuously, for example, the period of 1980-1984 and 1999-2004 both had consecutive 5-year low flow years. Significant differences also exist in the spatial distribution of rainfall areas. Tangshan and Qinhuangdao have relatively rich rainfall, which is more than 600 mm, while upstream of Yongding River, which located in the Zhangjiakou area, the average annual precipitation stays stable around 420 mm for many years. In the plains areas, Shijiazhuang area, and Hengshui area, the rainfall is also relatively poor, which is less than 450 mm.

Other water source, include the basin long distance water transfer project and other sources, will not be discussed here since they are not "natural source of water".

2.2.3 Time and Space Distribution

After the discussion about the source of water, as partly mentioned in the paragraphs above, the time and space distribution of the water resources in this region could lead to specific and changeable problems and features of water resources that people need to keep them and their lives in tune.

The average surface water resource volume among the past years in the Beijing-Tianjin-Hebei Region is 14.865 billion m^3. Surface water resource volume in time and space distribution characteristics and precipitation are almost the same, and it is relatively abundant in the Chengde-Tangshan city-Qinhuangdao area. The annual change of surface water resource volume is even more than the rainfall, which during the high flow year is more or less six times that of the low flow year. The average underground water resource volume on salinity (with the degree of mineralization being less than 2 g/L) in the past years in the Beijing-Tianjin-Hebei Region is 12.65 billion m^3. Additionally, there are 950 million m^3 of brackish water (with the degree of mineralization being 2-3 g/L) in the south of Tianjin, Tangshan, Baoding, Langfang, Cangzhou. The average total water resource volume in the past years in the Beijing-Tianjin-Hebei Region is 25.774 billion m^3, with 3.732 billion m^3 in Beijing, 1.57 billion m^3 in Tianjin, and 20.47 billion m^3 in the Hebei province (Figure 2-1). The Beijing-Tianjin-Hebei Region belongs to the serious resource shortage region with only 300 m^3 of water resources per capita, which is only about 1/7 of the national average; it also only has 305 m^3 occupancy of water resources per acre, which almost equal to 1/5 of the whole country average. From the regional analysis, Chengde, Qinhuangdao water resources volume per capita could reach more than 600 m^3, which have relatively abundant water resources, and Chengde city's water resources volume per capita is 1039.78 m^3. But Tianjin, Langfang, Cangzhou, Hengshui's water resources volume per capita is less than 200 m^3, which have a high demand on extraneous water. Other cities are between 200 m^3 and 500 m^3 (China academy of urban planning and design, Department of planning of the Ministry of Housing and Urban-Rural Construction of the People's Republic of China, 2014).

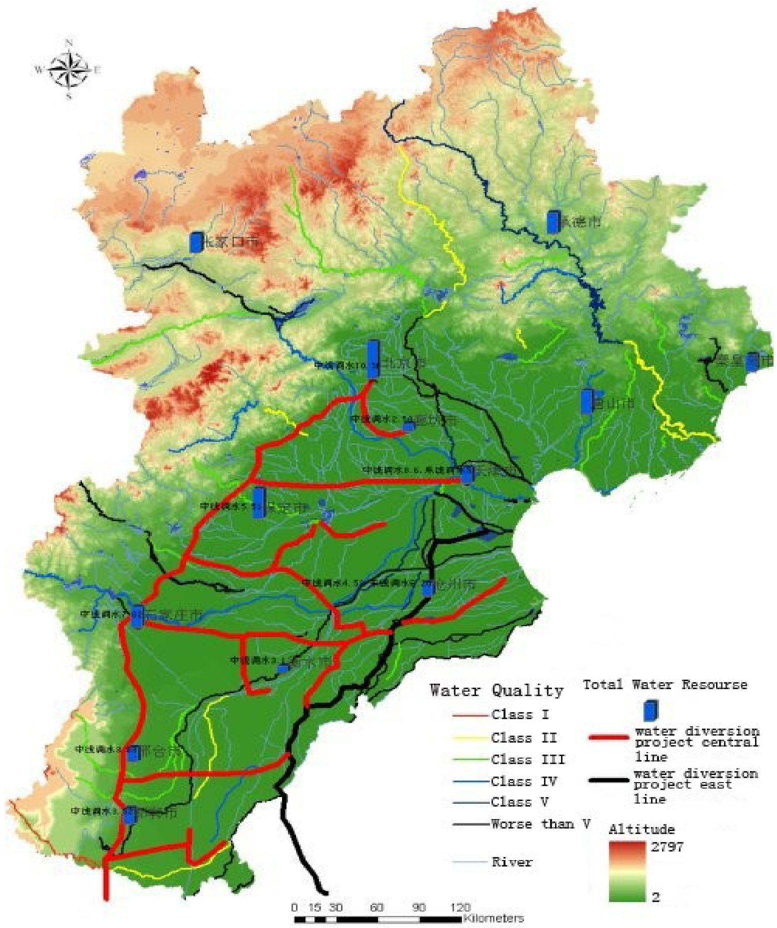

Figure 2-2 Water Resources Situation of the Beijing-Tianjin-Hebei Region (Modified from the original version)

Source: 2005 China Water Resources Bulletin, The Ministry of Water Resources of the People's Republic of China

2.2.4 Supply and Demand of Water Resources

After the discussion about the water resources' sources and distribution, it is time to talk about the relationship of the supply and demand for water resources. The total water supply in the Beijing-Tianjin-Hebei Region in 2005 was 25.803 billion m^3. Among them, the local surface water volume is 7.135 billion m^3, which accounted for 28%. Underground water volume (including shallow water and deep confined water) was 18.063 billion m^3, which accounted for 74%. Other water supplies (including the Yellow River's water for emergency water supply for Tianjin and Cangzhou, the brackish water, the recycle and reuse of waste water and sewage, a tiny amount of rain water utilization, and desalination, etc.) have 338 million m^3, which accounted for 1.69%.

The total water consumption of each industry for the Beijing-Tianjin-Hebei Region in 2005 is 25.803 billion m^3. The production water (including industrial water and agricultural water, while agricultural water includes water that was used for irrigation, forestry, animal husbandry and fishery) had 21.955 billion m^3, which accounted for 85.1% of the total water consumption in 2005. Life water consumption (including the domestic water for urban residents and rural residents) had 3.598 billion m^3, which accounted for 13.9%. Ecological water consumption had 249 million m^3, which accounted for about 1.0% , as showed in Figure 2-2.

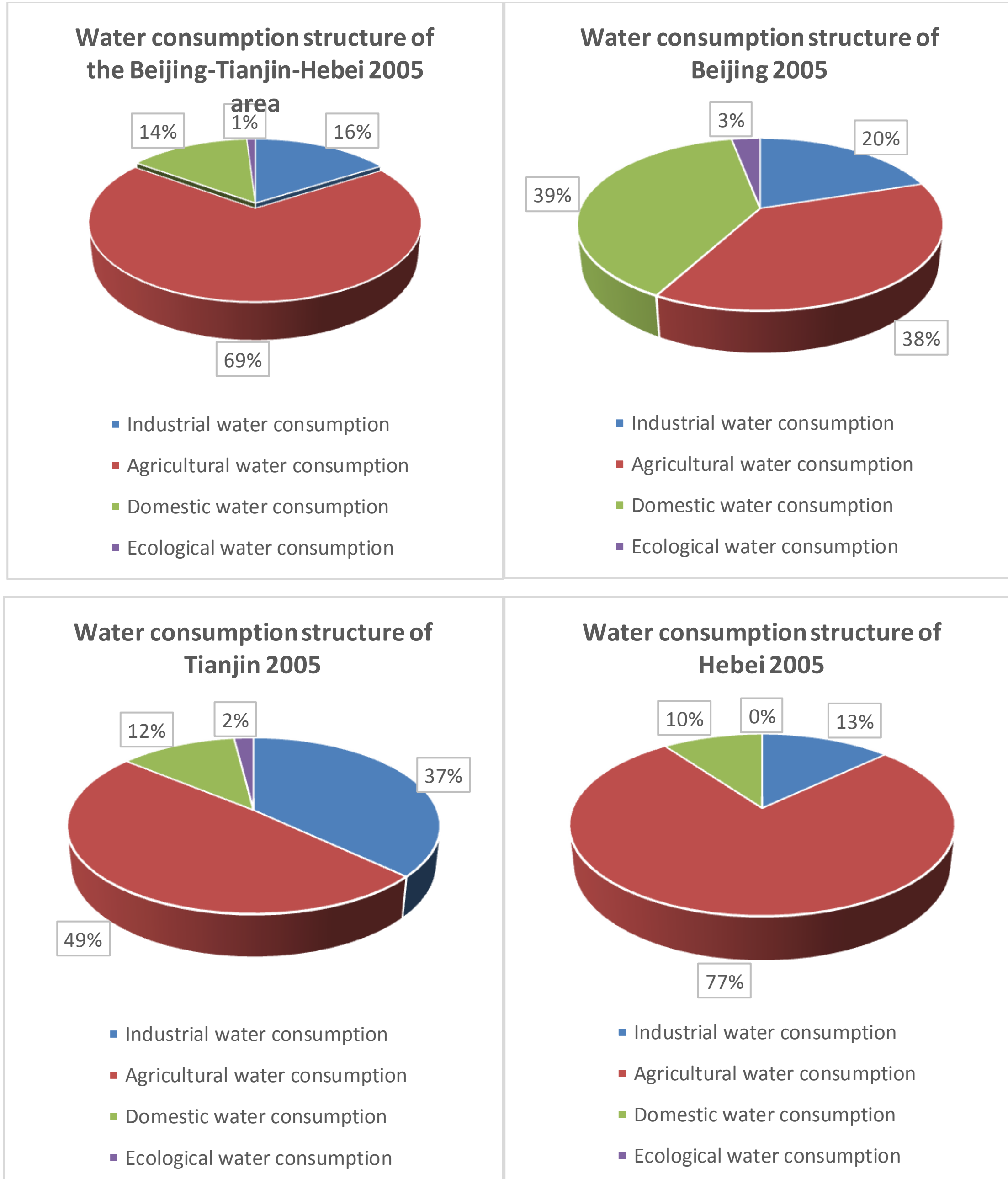

Figure 2-3 Water Consumption Structure of Beijing-Tianjin-Hebei Region

Source: 2005 China Water Resources Bulletin, 2005 Beijing Water Resources Bulletin, 2005 Tianjin Water Resources Bulletin, 2005 Hebei Water Resources Bulletin, The Ministry of Water Resources of the People's Republic of China

2.3 The land resources situation related to the water resource issues in the Beijing-Tianjin-Hebei Region

In addition to the conditions of water resources, the land resources is also very important and must needed to be taken into account when thinking about the water shortage problems since land is always have very close relationship with water. The geological conditions of land could determine the trend and distribution of rivers on this land, the time and space distribution of rainfall, the underground water level, etc. So the conditions of land resources will also be discussed later.

The total area of the Beijing-Tianjin-Hebei Region is 213,600 km^2, including Beijing of 16,300 km^2, Tianjin of 11,700 km^2, and Hebei of 185,600 km^2. This area faces the sea with the hills behind, is an important channel from the inland of the north of China to the sea, the only connection for East China, Northwest China and North China to Northeast China, and an important node for the economy of China to expand from east to west and from south to north. Landform types from southeast to northwest is in the transitional ladder-like distribution. The northwest area consists of plateaus, mountains and hills, which accounts for 56% of the total land area; the southeast area is the Beijing-Tianjin-Hebei plain, including piedmont plain, low plain and coastal plain, and those accounting for 44% of the total land area. The climate in the Beijing-Tianjin-Hebei Region belongs to the temperate continental monsoon climate, which has a sufficient sunlight condition and an average annual rainfall between 300mm and 800 mm. However, the water condition of these areas have an uneven distribution, with the Sea Lump Mountain as a boundary, the south area belongs to sub-humid areas, and the north area belongs to semi-arid area(China academy of urban planning and design, Department of planning of the Ministry of Housing and Urban-Rural Construction of the People's Republic of China, 2014).

2.4 Constraints of water resource environment for the development of the Beijing-Tianjin-Hebei area in recent years.

After the discussion about the conditions of water resources and related land resources in the Beijing-Tianjin-Hebei Region, now it is time to discuss the constraints of water resource environment for the development of the Beijing-Tianjin-Hebei area. In the recent 20 years, the rapid development of the economy and society of the Beijing-Tianjin-Hebei Region brought huge pressure on regional water resources and the environment to support it. Currently, the contradiction between the region's rapid economic development and population swelling, and the water and land resource constraints, is serious and significant. The problems in the ecological protection and poor areas and the rapid urbanization in urban and rural areas as a whole, and regional development as a whole in North Hebei, have and still restrict the Beijing-Tianjin-Hebei urban development. Current problems for resources and the ecological environment in the development of towns in this area are embodied in the following aspects, which includes the water quality pollution and the shortage of governance effect, the over-exploitation of groundwater, the serious land degradation situation exacerbated the pressure of land resources and ecological carrying, and the lack of effective regional and interregional ecological environment coordination mechanism(China academy of urban planning and design, Department of planning of the Ministry of Housing and Urban-Rural Construction of the People's Republic of China, 2014). Let's start with the water quality pollution and the shortage of governance effect.

2.4.1 Water Quality Pollution and the Shortage of Governance Effect

The Beijing-Tianjin-Hebei Region is densely populated with developed industries which led to the huge demand for water resources from towns and industrial and mining enterprises. While the excessive development of water resources, the industrial waste water and sewage emissions dramatically increased at the same time, leading to a sharp deterioration of the water environment in the basin starting in the 1980s. Water pollution has expanded from downstream to upstream, from urban to rural, and from surface water to the groundwater. The water pollution has expanded from local to the entire Beijing-Tianjin-Hebei region. This region located in the Hai River basin, and the waste water and the sewage emissions in the whole basin increased year by year. The waste water and sewage emissions equaled 2.77 billion tons in 1980, and more than 74% was industrial waste water. The waste water and sewage emissions in 1998 had risen to 5.56 billion tons, and more than 69% was industrial waste water. The ratio of the polluted river to the whole basin had risen from 28% in 1980 to 75% in 1998. The deterioration of the water environment of the river basin was mainly led by the discharge of untreated waste water from industrial and mining enterprises and domestic sewage. The industrial pollution in the Hai River basin was mainly from chemical industry, papermaking, thermal power, food, and metallurgical industries, which accounted for more than 50% of the amount of waste water discharge of industry.

Since the 1990s, the water quality of the Hai River and major tributaries has been dominated by Class V water and worse. The pollution in the segments of Tianjin and Cangzhou of the North Canal and the South Canal, the Zhangweixin River, the Xihai

River and the Majia River are the most serious parts of the whole Hai River basin because of the industrial structure of Hebei Province, which is dominated by energy and raw materials, coupled with the discharge of wastewater pollution in large quantities from the township enterprises and "15 kinds of small businesses"(ruled by the Chinese government). On the other hand, the river runoffs of the rivers above are tiny, and their self-purification capacity is weak. In addition, the Sanggan River and the Yang River also have been seriously polluted by the industry of Zhangjiakou City and Xuanhua County, which led to serious deterioration of water quality of the Guanting Reservoir. The State Council approved the implementation of "The Hai River Basin Water Pollution Prevention Plan" in March 1993. Until the end of 1999, of all the 1,591 industrial key sources on pollution in the Hai River Basin, 794 had already met the governance standards, 166 had completed the treatment project and were waiting to be tested for acceptance, 204 were in construction to try to meet the governance standards, 276 were shut down, and 156 had not been constructed. The initial governance outcome was the discharge of waste water, and sewage amount been reduced by 200 million tons in 1998 compared to 1995. But the result of the monitoring of water quality from 171 monitoring sections showed that water resources with quality of the Class V and worse than Class V still accounted for 49.7% of all water resources. Until 2000, the total amount of the industrial wastewater and urban sewage that was discharged in the Hai River Basin was up to 5.39 billion tons, and 87% of that was untreated sewage that was discharged into the rivers and reservoirs. There are more than 10 major rivers/segments for discharging of sewage is currently in the basin. These rivers/segments have poor water quality, and the pollutant concentration in the water is much higher than the national surface water quality standards. Not only has the surface water been polluted, but also the groundwater basin plain areas (especially shallow groundwater) have been subject to a certain degree of pollution. The deterioration of water quality reduced the safety of drinking water. The surface water and groundwater sources in cities are subject to different degrees of pollution, and eutrophication has appeared in part of reservoirs and is exacerbating the trend.

Until the end of 2004, the severe pollution was thorough in the Hai River Basin. Among the 67 water quality monitoring sections of 44 rivers, there are only two sections belonging to Class I, accounting for 3.1%; 7 sections belonging to Class II, for 10.4%; 8 water sections belonging to Class III, about 11.9%; 9 sections present in Class IV of water quality standard, accounting for 13.4 %; Class V has 3, for 4.5%; sections with poorer than Class V has 38, almost 56.7%. Compared with the previous year (2003), the water quality of Dou River in Tangshan, Juma segment in Baoding, the Baiyang Lake, and the Zhang River in Handan have improved; the water quality in the segment of Yongding River in Beijing and the south canal segment in Cangzhou declined slightly. The water quality of those monitoring rivers was essentially flat as shown in Figure 2-3 and Table 2-1.

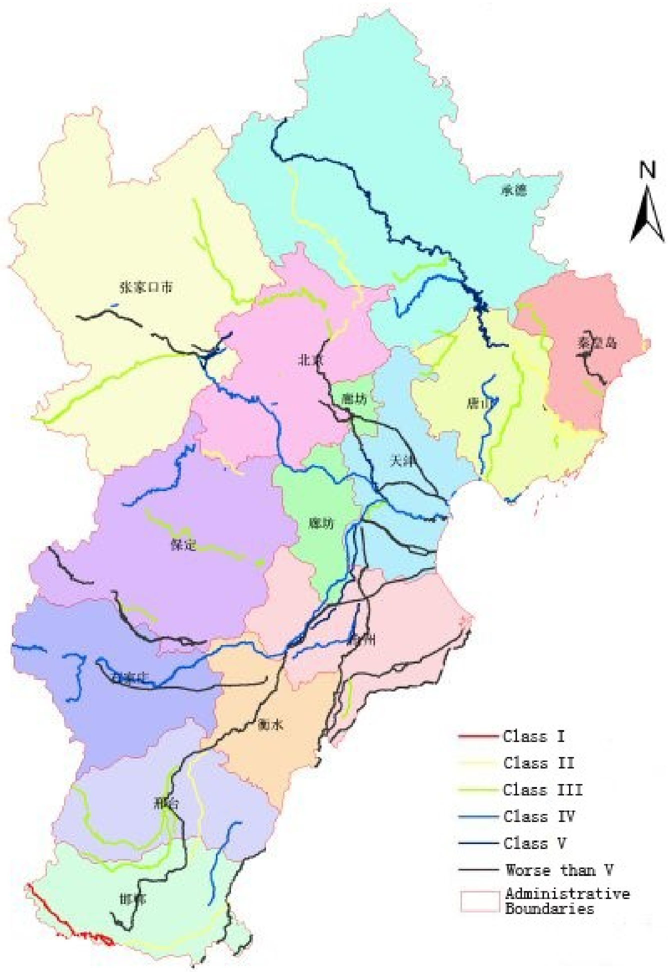

Figure 2-4 Surface Water Environment in Beijing, Tianjin Region

Table 2-1 Beijing-Tianjin-Hebei region water Environment Statistics in 2004

Region	Tertiary Basin	Water Pollution Index	Water Quality Class, 2004	Water Quality Class, 2003
Beijing	Chao River（tributary of Luan River）	1.95	II	II
	North Canal（North San River）	70.06	Poor V	Poor V
	Yongding River	5.255	Poor V	V
	Daqing River	1.9	II	I
Tianjin	Luan River	11.86143	II	II
	Hai River	10.1	IV－Poor V	IV－Poor V
	North Canal （North San River）	17.11	V	V
	Ziya River	9.73	IV	IV
	Daqing River	30.8	Poor V	Poor V
	Heilonggang River (located in Yundong plains and Heilonggang)	12.01	V	V
Shijia Zhuang	Ziya River	11.39	IV－Poor V	IV－Poor V
Tang Shan	Dou River (tributary of Luan River)	2.68	IV	IV
Qinhuang Dao	Yang River (tributary of Luan River)	6.02	Poor V	Poor V
Han Dan	Zhang River (located in Zhang Wei River plain and the outlet of Yuecheng Reservoir)	2.3	1	3
	Zhang River (located in Zhang Wei River plain)	2.6	2	2
	Wei River (located in Zhang Wei River plain)	29.71	Poor V	Poor V
	Ziya River	11.44	Poor V	Poor V
Xing Tai	Weiyun River (located in Heilonggang and Yundong plains)	178.49	Poor V	Poor V
	Ziya River	207.08	Poor V	Poor V
Bao Ding	Juma River (tributary of Daqing River)	4.8	IV	Poor V
	Fu River (tributary of Daqing River)	52.31	Poor V	Poor V
	Baiyang Dian	3.86	III	V
Zhangjia Kou	Luan River	3.15	III	III
	Yang River (segment of Yongding River)	29.09	Poor V	Poor V
	Sanggan River (segment of Yongding River)	3.6	III	III
Cheng De	Luan River	3.92	IV	IV
Cang Zhou	South Canal (located in Heilonggang and Yundong plains / Shandong - Hebei section)	32.315	Poor V	Poor V
	South Canal (located in Heilonggang and Yundong plains / Hebei- Tianjin section)	Data missing here	III	II
	Ziya New River	70.22	Poor V	Poor V
	Cha River (located in Heilong gang and shipped east plains)	40.2	Poor V	Poor V
Lang Fang	North Canal (segment of North San Rver)	49.92	Poor V	Poor V
Heng Shui	Ziya River	67.79	Poor V	Poor V

Source: 2004 National Environmental Quality Report, the State Environmental Protection Administration

For coastal waters, the area of the coastal waters of the Bohai Sea in Tianjin is approximately 3000 km2, which is divided into seven environmental functional areas, and the "Sea water quality standards" had been applied to those areas with Ⅰ, II, III, IV standards separately. In 2004, the statistic result of 10 observation points indicated for Tianjin coastal sea waters showed that the water with Class II and III was 10% and 40% respectively; the sea water with poorer than Class IV accounted for 50% of sea water; and the water qualification rate was only 38%. The sea water near Tangshan, Cangzhou and other off shore cities was seriously polluted: the quality of water in two monitoring points in Tangshan was belonging to poorer than Class IV; the monitoring point in Cangzhou is also inferior to Class IV.

2.4.2 Over-exploitation of Groundwater

The direct representation of the exploitation and utilization for water resources beyond the water resource carrying capacity is the deterioration of the water ecological environment, such as a wide range of land subsidence, the atrophy of lakes and wetlands, and discontinuous flow, as well as the serious water pollution in large areas. In front of the Taihang Mountain plains and the Taihang mountain basin, the layout of urban and industrial and mining areas is relatively dense, and that makes water consumption large and concentrated, which leads to a serious situation from the over-exploitation of shallow groundwater and has formed the over-exploitation of the area with a scope of 28,000 km^2, and the water level near the city has dropped to below 20-30 m. The over-exploitation of the area of groundwater in the eastern plains is 51,000 km^2, and the level of the center of the funnel-shaped groundwater distribution level in Tianjin and Cangzhou has even decreased to 100 m underground. Due to the fall of underground water levels, land subsidence and seawater intrusion in coastal areas have happened in Beijing, Tianjin and Cangzhou city, which deteriorate the water quality of the freshwater layers and scrap water wells.

The social and ecological problems caused by the over-exploitation of groundwater are mainly the damage to the surface structure from land subsidence and ground cracking, as well as the human body health damage led by high fluoride and low iodine groundwater as drinking water, etc. At the end of 2000, the level of the center of the Ningbailong funnel (the funnel shape of groundwater distribution in Ningbailong is called “the Ningbailong funnel”, and that is also applied to other “funnels” with the same shape of ground water distribution, and this name is usually used in the documents from Chinese government), which located in the plain of the south branch of the Hai River and is relatively large, had an area of 1000 km^2, and its center buried depth is 40 m. Owing to the ground water level drops in large areas, the several deep water “funnels” in the Heilonggang area has even the piece. For some serious deep drawdown “funnels”, for example, the Cangzhou funnel and the Jizaoheng funnel, their ground water depth are respectively 85.77 m and 95.17 m, and the funnel area continues to expand while their buried depth continues to fall. The falling of ground water level in Hebei province every year caused the water yield decrease in the past years, which led to the scrapping of motor-pumped wells, the upgrading of the machine pumps, the low efficiency to pump water, the increasing of energy consumption and so on that to form a direct economic loss of about 2.16 billion yuan, which led to serious damage for industrial and agricultural production and the urban and rural residents lives. On the other hand, drinking underground water with high fluorine content will lead to fluorosis, and that is the most serious social problem in the Beijing-Tianjin-Hebei Region which is caused by the shortage of water resources and groundwater. High fluoride water is mainly distributed in Cangzhou, Langfang, and the large areas of central and coastal plains. According to related statistic results, there are 60 counties with disease in the Beijing-Tianjin-Hebei area with a population that has reached 5.472 million, including 932 thousands of people with fluorine spot tooth and 58 thousands of people with skeletal fluorosis, which accounted for 19.33% and 0.78% respectively. Dividing by the fluoride level of drinking water, slight (fluoride level 1-2 mg/l) area of illness accounts for about 55.78% of the area of illness, and the medium and serious illness area (fluoride level is greater than 2 mg/l) accounts for about 44.22%. Since the 1990s, the area of fluorosis illness showed a trend of expansion. Among them, Langfang is a main area because of the intercepting of a large amount of surface water in Beijing (located in the upstream of Langfang) since the 1980s, and it made many districts of Langfang use high fluoride groundwater as a drinking water source instead of low fluorine groundwater, which increased the number of people who drink high fluoride water.

2.4.3 Serious Land Degradation Situation Exacerbated the Pressure of Land Resources and Ecological Carrying

This desertification of the land area has reached 44167.2 km^2. Among it, the degradation area of grassland area is 12970 km^2, which accounts for 48.4% of the total area of actual pasture; the degradation area of the primeval forest area is 7330 km^2, which accounts for 78% of the primeval forest area; the desertification area of land is 26820 km^2, which accounts for 14.9% of the total land area. Due to long-term human activities, in the north and the west of the east side of the Taihang mountain and the whole Yan mountain, the vegetation of the Beijing-Tianjin-Hebei Region has been damaged, which led to low forest coverage in these areas coupled with the relatively dry climate, the speed vegetation restoration process is slow, and because summer often has heavy rain, the flushing strength on the surface of the earth is strong, causing serious land problems in the mountainous area, and sometimes triggering landslides. The regional soil and water loss area is 5.8 km^2, which accounts for 31.7% of the total land area. Soil and water loss could not only reduce farmland areas, decrease the fertility of soil, lead to sedimentation in reservoirs, trigger floods and mudslides, but also form the pressure of flood discharge and water supply of the Guanting reservoir and Miyun reservoir.

2.4.4 The Lack of Effective Regional and Interregional Ecological Environment Coordination Mechanism

For vital regional ecological environment problems, it is not usual to consider the cooperation from the regional level in the Beijing-Tianjin-Hebei area, and a cooperation consultation coordination mechanism at a high political level has not yet been established in China. There is also a lack of the consideration about how to jointly strive for national support for regional ecological environment construction and protection, and how to do the industry layout of a macroscopic plan as a whole from the perspective of regional between three provinces and cities. Especially for the lack of effective resource development in the development and utilization of water resources – the ecological compensation mechanism is the most obvious problem, for example, in 2000, 2001, 2002 and 2003, which were the dry years of the Luan River, in order to guarantee the water supply for Tianjin, all the water that was used as a supply from the capacity of the Panjiakou reservoir of Luan River was transferred to Tianjin, while the Tangshan City of Hebei didn't get the corresponding compensation at that time. Meanwhile, to ensure Tianjin's quantity and quality of water supply, China transferred the water of the Yellow River to supply Tianjin and ordered Cangzhou City of Hebei to block all of its water drain doors along the river three times in 2000, 2002, and 2003. That delayed the water supply for Cangzhou City, and the water shortage caused by that also was not compensated in time.

2.5 Summary

In summary, although we mainly focus on the water shortage issues in this thesis, it is hard to think about those issues without other related and important issues, for example, the soil issues, the society issues, etc. According to the background information we have presented above, the development of the Beijing and Tianjin Tang Zone which located in the Beijing-Tianjin-Hebei area was bound by the conditions of water resources and other issues, such as soil condition, population, forest coverage rate, etc., and by ecological protection and the environmental issues of the development and utilization of soil and water resources. Water and soil resources are the most basic resources which support human beings' survival and reproduction, and economic and social sustainable development. As representing the elements of production and life, the time and space distribution of water and soil resources plays a decisive role that impact the speed and degree of urbanization. Water is a kind of sustainable resource, and as long as there is reasonable use, it can be used sustainably without drying up. But the finiteness of water resources leads to the limitations of development and utilization on water resources. Therefore, the finiteness of water resources has a fundamental constraint with its development and utilization, so its development and utilization only can be done by a limited amount of resources. This needs to happen while trying to play the largest role to provide a reliable material basis for sustainable development, in order to meet the needs of the population growth and the economic and social development.

Chapter 3 Literature Review and Methodology

Water shortage, also called water scarcity, is the lack of sufficient available water resources to meet the demands of water usage within a region. To find the issues that impact the water shortage for industry and the corresponding solutions, people have done a lot of work in different view.

3.1 The History of the Research on the Water Shortage Problem in the Beijing-Tianjin-Hebei Region

The research about water shortage problems in regional scope and giving some corresponding solutions can effectively improve the degree of regional water resources security, so the research about water shortage problems in regional scope has been paid more and more attention, and both the international and the Chinese scholars have got a series of achievements from both the theory and the methodology area.

According to the article “Water management in Spain: an example of changing paradigms” (Garrido and Llamas, 2006) and “Challenges to manage the risk of water scarcity and climate change in the Mediterranean” (Iglesias et al, 2006), comparing with the city scope, to evaluate the regional water shortage risk is more complex. One of the reasons is, because of the inequality of regional social economic development level, the economic loss lead by water shortage is difficult to be calculated by quantitative calculation. In addition, because the system of regional reservoir-supply-consume is so complex that the influence from water resources allocation to regional water shortage risk level is hard to evaluate in quantitative method. The related research from the international area is mainly using the analysis for the issues that may lead to water shortage problems to do the qualitative analysis for the evaluation of the risk level of water shortage problems.

The research about water shortage problems in regional scope in China started in recent years. Ruan, Han and other scholars[3 4 5 6 7] are the earliest researchers to discuss the

[3] Benqing Ruan, Yuping Han, Hao Wang, et al. Fuzzy comprehensive evaluation for water shortage risk, Journal of Hydraulic Engineering, 2005, 36(8): 906-912

[4] Benqing Ruan, Yuping Han, Research of the economic loss from water shortage risk. Journal of Hydraulic Engineering, 2007, 38(10): 1253-1257

assessment water resources shortage risk. They believed that water shortage risk is the ratio and the related loss of the happened water shortage in regional water resource system, which is led by the uncertainty of both water reservoir and water use under the specific space and time conditions. Based on this, they used the area around the Beijing City as a case to research the fuzzy comprehensive evaluation method for the water shortage risks, and they developed the multiple objective risk decision model for the regional water shortage on the basis of water shortage risk analysis and evaluation. Ma and other scholars (2008) [8] developed the water shortage risk assessment indicator system, which used the fuzzy analytical hierarchy process (FAHP) to evaluate the regional water shortage risk of all the two-grade district division of water resources of China, and that work revealed the spatial distribution pattern of water shortage situation in China. Liu developed the water shortage risk index on the basis of the water resources carrying capacity theory, and that evaluated the water shortage risk in the urban agglomeration of Beijing, Tianjin and Hebei.

It is commonly believed that the water shortage problem has close relationship with the economic loss, but the related research about that relationship is limited, and it is hard to develop the water shortage risk vulnerability curve, and that lead to the difficulties to do the quantitative calculation for the economic loss from water shortage in the research of water shortage risk in regional scope. CALVIN is an economic-engineering optimization model for the entire water system of California, which is developed by the University of California. [9][10][11][12][13][14] The model operates facilities and allocates water so as to maximize

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[5] Yuping Han, Zhengmin Xu, Research of regional water shortage risk control. Journal of Hebei University of Technology, 2007, 24(4):81-84

[6] Yuping Han, Zhijie Li, Qingmin Zhao, Research of regional water shortage risk decision. Journal of North China Institute of Water Conservancy and Hydroelectric Power, 2008, 29(1):1-3

[7] Yuping Han, Benqing Ruan, Dangxian Wang, Research of the multiple objective risk decision model for the regional water shortage. Journal of Hydraulic Engineering, 2008, 39(6): 667-673

[8] Dengwei Liu, Risk assessment of water resources shortage in Beijing, Tianjin and Hebei metropolitan area. Water Resources Development Research, 2010, 10(1):20-24

[9] Draper A J, Jenkins M W, Kirby K W, et al. Economic -engineering optimization for California water management. Journal of Water Resources Planning and Management, 2003, 129(3): 155-164

[10] Newlin B D, Jenkins M W, Lund J R, et al. Southern California water markets: Potential and limitations. Journal of Water Resources Planning and Management, 2002, 128(1): 21-32.

statewide agricultural and urban economic value from water use. It worked in the practical application in California, but, because of the amount of the indicator in this model is so much that the practical applications in other regions are limited. Because the research about the relationship between water shortage problem and economic loss is limited, there has obvious difficulty to use the CALVIN model or other quantitative model in China. So the related assessment about that relationship can only use the qualitative analysis indicators.

Because of the shortage of the related quantitative research about the water shortage problem, especially in China, this thesis will be a good attempt to try to provide the basis for future research, since it has quantitative research in it. In addition, it also correlated the findings of the previous research and the recent data when the thesis does the analysis for the dominant issues, existing problems and suggested solutions water shortage problems, which will fit for the current status of the Beijing-Tianjin-Hebei Region. At last, since it uses the Region as a case study, it could provide the support for people who is also thinking and trying to make decisions to solve the water shortage problems in the Region, so it has certain practical significance.

3.2 The Source of Original Data and Information

Most of the background information about the Beijing-Tianjin-Hebei Region in chapter 2 are mainly collected from the book *The planning of the coordinated development of Beijing-Tianjin-Hebei city cluster (2008-2020)*, which was written by China academy of urban planning and design, which belongs to the department of planning of the Ministry of Housing and Urban-Rural Construction of the People's Republic of China, and the book itself was published by The Commercial Press (Beijing) in 2014.

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[11] Jenkins M W, Lund J R, Howitt R E, et al. Optimization of California's water system: Results and insights. Journal of Water Resources Planning and Management, 2004, 130(4): 127-136.

[12] Null S, Lund J R. Re -Assembling hetch hetchy: Water supply implications of removing O'Shaughnessy Dam. Journal of the American Water Resources Association, 2006, 42(4): 395-408.

[13] Harou J J, Pulido -Velazquez M, Rosenberg D E, et al. Hydro -economic models: Concepts, design, applications, and future prospects. Journal of Hydrology, 2009, 375(3): 627-643.

[14] Medellin-Azuara J, Mendoza-Espinosa L G, Lund J R, et al. Virtues of simple hydro -economic optimization: Baja California, Mexico. Environmental Management, 2009, 90(11): 3470-3478.

Chen (2000) mentioned some basic information about the serious water shortage situation about the total amount of water resources in the Beijing-Tianjin-Hebei Region's location--the Hai River Basin. Zhang and Jia (2003) and the article from WWW.SOHU.COM (2002) mentioned the contradiction between the high GDP and the low local water resources per capita amount in the Beijing-Tianjin-Hebei Region. The background information about the population issue in chapter 2 are mainly collected from the book *Report on China's migrant population development*, which was written by National Health and Family Planning Commission of the People's Republic of China., and the book itself was published by China Population Publishing House in 2014.

The figures in chapter 2 were edited according to the data from the *2005 China Water Resources Bulletin*, the *2005 Beijing Water Resources Bulletin*, the *2005 Tianjin Water Resources Bulletin*, and the *2005 Hebei Water Resources Bulletin*, which were edited and posted by The Ministry of Water Resources of the People's Republic of China.

The Chinese Statistical Yearbook from the year 2004 to 2013, which is posted by the Chinese government in each year, provided the statistical data of the original water resource data in the Beijing-Tianjin-Hebei area, which support the model analysis in chapter 4 and 5 in this thesis.

3.3 The Selection of Model to find the Main Issues of Water Shortage

There have developed many econometrical models mentioned in literatures. According to the book Using Econometrics-A Practical Guide 5th Edition (Studenmund, 2005), the most widely used model is the linear regression model. But, because of some of the issues we collected have very high similarities between them, which might lead to very multicollinearity, and that will definitely and significantly damage the reliability of the result of model if people use the linear regression model. Based on that, we need to find a better model for data which have very close relationship and could lead to problems of multicollinearity. After the study of the features of the PCA model from the article "Introduction to the principal component analysis", it is easy to find that this model could work well with the data picked for analysis. So the PCA model was chosen to use in this thesis. The features of the data and the PCA model will be discussed more in chapter 4.

3.4 The selection of the methods to find the solutions for water shortage

After analyzing the relationship between the issues and the water shortage problems, the solutions for those problems could be found and the best solution could be recommended. In this thesis, the internal solutions are found into 5 views: the water carrying capacity, the optimization of the industrial structure, the discharge control and governance for sewage, the control and management of population size, and the establishment of a regional unified control system.

The evaluation of the water resources carrying capacity is a mature method to do the evaluation of water resources shortage. There have large amount of researches in the water resources area all over the world, but the amount of the specialized research for the water resources carrying capacity are tiny, and most of them are included into the Theory of Sustainable Development. For example, Joadror (1998) did the related research for the water resources carrying capacity of urban in the view of water supply. Rijiberman (2000) used the carrying capacity as the benchmark of the security assurance of urban water resources when they did the research of the evaluation and the managerial system of urban water resources. Harris (1998) focused on the agricultural water resources carrying capacity in agricultural production area, and then use it as a benchmark for evaluating the regional development potential. The URS company (2001) did the research on the carrying capacity of the Keys Basin in Florida, which include the definition, the research method, and the quantitative methods of model for carrying capacity.

Liu and Wang (2008) introduced the basic concept about the COD and its role when judge the water pollution level. Wei (2006) used the discharge of COD, ground water volume, underground water volume, total water resources volume, etc., as the influencing issues, and then build the multi-objective model to evaluate the water resource carrying capacity, and use its result to evaluate the regional water resources status and then provide evidence for the water resource planning and the optimization of industries.

Wang and Zhao (2008) used the data from the year 1997 to 2006 and the stochastic frontier approach (SFA) to evaluate the technical efficiency of the agricultural production and the efficiency of irrigation water. The result showed that the average efficiency of agricultural water usage is just 0.49, which means that the total water consumption of agriculture could decrease by almost 50% to get the current production of grains while other conditions keep the same. So the increase of agricultural water use efficiency could help with solving the water shortage problems.

Yang (2013) analyzed the main water pollution problems in the industrial enterprises and suggested the possible solutions that could help with the deduction of the discharge of sewage and the recycle and reuse of sewage. That could help with protect the total volume of local available water resources.

Kai(2013) started his research from the evolution of the current population policy in China to try to reveal the causes and effects of the current population policy, and restore the process and the starting point of the formulating of those policies from the view of history. To meet those requirements, he used literature method, comparative method, and interview method to analysis the impacts of the current population policy that was made on China's economic and social development with giving priority to the analysis of the problems lead by policies. For example, the unusual rapid decline in fertility rate that was caused by family planning, the neglect of population quality led by the excessive controlling of population, sex ratio imbalance led by the strictly limit of the number of birth population, the aging problems, are all the threats to the population security of China. Considering the existing problems, the author used the theory of optimum population and the population optimization theory to analysis problems from the global level and the perspective of long-term development to put forward the advices for appropriate raising the retirement age and eliminate the diversity of the retirement age for men and women creatively. In addition, he also put forward countermeasures and advices for the two-child policy, the stability of the one-child family structure, and the establishment of the social old-age security system.

Xie and Liu (2009) expounded and proved the necessity, urgency and feasibility of the establishment of the cross-regional coordination mechanism of water resources protection and utilization in the process of the promotion of the regional integration of the Beijing-Tianjin-Hebei region, and described the guiding ideology, principles, organization form, job responsibilities and problems that are needed to be focused while establish a cross-regional coordination mechanism according to the basic rule of watershed management and requirements.

In addition to the internal solutions, the external solutions also need to be suggested. Shen (2014) used a long-distance water diversion project as a case to expounds the research status of both overseas and domestic long distance water diversion projects, and he also did a preliminary analysis for the difficulties and problems need to be solved in the current long-distance water diversion engineering from both water quantity and water quality aspects; then he discussed the main influencing factors in the water diversion project, include the management operation and technical factors, water quality factors, economic benefit factors and ecological environment factors preliminarily, and then he discussed the economic model of long-distance water diversion project, and developed the preliminary analysis model for the costs and benefits of the long distance water diversion project; he also introduced the fuzzy comprehensive evaluation model and used it to discuss the economic evaluation index of long distance water diversion project from both the economic evaluation and the financial analysis aspects preliminarily.

There also have other solutions that might not as directly as the internal and the external solutions mentioned above, but they also could be important when working with the water shortage problems in the Beijing-Tianjin-Hebei Region. Ma, Gong, Hu and Yu (2003) summarized the research status of the relationship among the regional precipitation situation, the forest coverage, and the soil and water loss on the basis of large numbers of related research data in China and among the international scope, and then discussed the future direction and trend of research. The result is that, forest coverage rate should have impact on the water recycle in nature, so the forest coverage rate should be taken into account when thinking about the water shortage problem in a specific area.

3.5 Methodology of this thesis

The methodology of this thesis is presented as follows: first, trying to use the result of the PCA model analysis as the standard of to judge for which issue have the significant and obvious impact on the water resources shortage. Second, use the result of model analysis and other issues that cannot be used in quantitative analysis from the background information to summarize the problems that related to those issues and could lead to water shortage quickly. Third, find the solutions corresponding to those problems and then give the evaluation of those solutions one by one at last.

Chapter 4 PCA Model Analysis

In this chapter, the background information will be used to find issues and related data that are believed some or all of the issues could be possible causes to the water shortage problems in the Beijing-Tianjin-Hebei Region, and then we will use the principal components analysis (PCA) model to find those factors which really worked for the water shortage problem and which of them could be the main factors that lead to those problems. Those significant issues will then be focused to when we are trying to find the solutions for the water shortage problem, which will be presented in Chapter 5.

4.1 Issues to be analyzed

According to the background information mentioned and based on the study of the book *The planning of the coordinated development of Beijing-Tianjin-Hebei city cluster (2008-2020)* in chapter 2, the following issues and related data are found and picked since those are believed that some or all of them could be possible causes to the water shortage problems in the Beijing-Tianjin-Hebei Region.

4.1.1 Gross Domestic Product (GDP)

GDP is commonly used as an indicator of macroeconomics for economic analysis, and, because of the close connections and interaction effect between agriculture, industry and tertiary industry, so the agricultural GDP, the industrial GDP and the tertiary industrial GDP are picked as issues to be analyzed.

4.1.2 Population

Population is usually an important indicator when evaluating the economic situation. In this case, the size of the population can impact the demand of water directly, as it is known that the more people an area has, the more water it will consume.

4.1.3 Forest Coverage Rate

Forest coverage rate is an important issue that is related to water resources. According to the article "Summary of the Studies on Relation between Forest Coverage and Water and Soil Conservation"(Ma et al, 2003), forests could make the soil preserve more water and for a longer time than usual, and it also can increase and maintain the amount of precipitation and the surface water discharge among the area nearby it. So the forest coverage rate is picked as an issue.

4.1.4 Water Supply

The water supply volume is consisted of the annual precipitation, the surface water volume, and the underground water volume, so it is needed to pick all of those three issues as factors to evaluate the water shortage problem. On the other hand, since those three factors could impact each other and their amounts are nearly unavoidable to be repeatedly computed to some extent. So the total water resources volume was also picked as another issue.

4.1.5 Water consumption

Water consumption is consisted of agricultural water consumption, industrial water consumption, domestic consumption and ecological water consumption. The first three issues come from agriculture, industry and other humanity activities. Ecological water consumption comes from the amount of ecological water needed for maintaining or improving the balance of existing ecosystem of plant communities, animal and abiotic parts, or it could be simply understood as "the water amount needed by livings and others except human beings"

4.1.6 Water pollution

Water pollution could directly impact the amount of available water volume, and it also can reflect the efficiency of water usage. The discharge of sewage was picked by year, as well as so do the discharge of chemical oxygen demand (COD) and sewage treatment capacity. Discharge of sewage could impact the quality of water resources. According to the article "The definition and the emission standards of COD", COD is the amount of oxygen that is used for the chemical oxidation of materials that can be oxidized, and it is generally presented by the number of milligrams per litre of water consumption of oxygen. It is the basic comprehensive index of water quality monitoring, which is the lower the COD is, the better the water quality should be (Yufeng Liu and Dongying Wang, 2008).

4.2 Concepts and properties to the PCA Model analysis

When processing information, when a certain correlation between two variables exists, it can be interpreted as those two variables reflect the information in the subject and has a certain overlap. For example, as mentioned earlier in this chapter, industrial GDP, agricultural GDP and tertiary industrial GDP tend to have a higher correlation among them. Such kind of variable information with height of overlapping and highly relevance will bring obstacles for the application of statistical method

In order to solve these problems, the most simple and direct solution is to cut down the number of variables, but it could lead to problems such as loss of information and incomplete information. Therefore, people hope to explore a more effective solution, which can greatly reduce the number of variables involved in data modeling, and also won't cause the loss of information at the same time.

4.2.1 Introduction of PCA model

PCA model, also known as principal component analysis model, is a kind of method that could reveal large sample and multivariate data or the internal relations between samples. In order to get the main information, it aims at using the ideas of dimension reduction, which means converting multiple indexes into a few more comprehensive indicators so that it reduces the dimension of the observation space. Here is used it to analyze the issues that are possibly related to water shortage problems, as presented earlier

4.2.2 Strengths and Weaknesses of the PCA Model

From the results, six factors that influence the water deficit are extracted. Obviously, that helps a lot when try to find out the main reason to analyze. Although the PCA analysis is helpful in this model, there also exist weaknesses in choosing this method.

(1) Strengths of the PCA Model

As mentioned earlier, the PCA model is helpful and effective to extract factors. So there has much strength for using PCA analysis in this special case.

First of all, the PCA model could help to eliminate the influence of those related evaluated indexes. In this case, some indexes are highly related with each other, for example, Agriculture GDP and Industry GDP. Since original indexes could be transformed into those independent principal components by using PCA analysis, and practically, the stronger the relation between each pair of indexes, the better the result of PCA analysis. It can be seen that the relation between Agriculture GDP and Industry GDP is strong enough to be analyzed as one index. Recall the book *Using Econometrics-A Practical Guide 5th Edition*, if it is desired to analyze them separately, the PCA model would help to separate these two indexes and show their relationship. If the linear model—the most widely used model—is used in this case, the problems lead by the multicollinearity of the possible issues that are picked would be unavoidable.

Second, since fewer indexes with more significance will be selected to evaluate and analyze, PCA analysis can help to reduce the workload of selection. Comparing with PCA analysis, other selecting methods are difficult to eliminate the related effects between indexes, so a lot of time will be spent on selecting the main indexes. However, PCA analysis can eliminate the effects as mentioned. Therefore, it will be easier to select indexes which need to be analyzed. From the result, the contribution of some indexes are really close, and PCA analysis can give the coefficient of each index, so that the tiny differences between them can be seen.

Third, PCA analysis is a kind of information-preserving analyzing method to select fewer comprehensive indexes instead of the original indexes under the condition of too many kinds of indexes exists to be analyzed. In this case, there are 16 indexes to be considered. Among them, it can be seen clearly that several indexes are really important to be considered. PCA analysis can order the principal components. During the analyzing, some components are discarded to get several principal components which variances are pretty large. With the help of these principal components instead of the original variables, it reduces the workload a lot. Therefore, it is not necessary to consider all of these 16 indexes, and only several of them are needed to be chosen by getting the principal components.

Fourth, to get a comprehensive score model, the rate of contribution of each principal component is considered. During the comprehensive evaluation, the coefficients of the principal components are the contribution rate of each component. Each coefficient shows the weight of the information of some component to the whole information. Therefore, the coefficients of each indexes in the comprehensive score model will be objective and reasonable. PCA analysis overcomes the weaknesses in other methods. The variances of 10.667, 2.588 and 1.138 are considered, to get the comprehensive score model to evaluate the importance of each index in these three principal components.

Therefore, it is helpful and effective to choose a PCA model to evaluate the importance of these 16 indexes so that the reason of being important in the water deficit can be analyzed.

(2) Weaknesses of PCA Model

Each coin has two sides. Although there are a lot of strengths using a PCA model in this case, there are still some weaknesses while using this method.

First, in PCA analysis, it needs to be checked that that the cumulative rate of contribution of several principal components can reach to a quite high level, i.e. the information has to be highly preserved after dimensionality reduction. In this case, it has been overcome. The cumulative rate of contribution of the first three principal components has reached to be greater than 85%. So the PCA analysis can then be used in this case. However, PCA model is not widely used in every case.

Second, the principal components which are extracted have to be able to give a reasonable and real background and meaning; otherwise the principal components can only represent the information instead of having real meaning. In this case, it is a little bit hard to find out the real meaning for the second principal. In the second principal, Annual Precipitation, Total Water Resources Volume, Underground Water Volume, Surface Water Volume and Industry Water Consumption have larger coefficients. The first three indexes can be concluded as the water volume. However, the last one is the only consumption that needs to be considered in the second component. Other two consumptions should not be included in the second component. However, other two principal components are quite meaningful in this case. Generally, the meaning of the principal components is quite fuzzy. These components are not as clear and exact as the original variables. However, it is required to pay to reduce the dimension. Thus, m extracted principal components should be fewer than the p original variables, otherwise, the strengths of reducing the dimension may not be as significant as the weaknesses of the less meaningful principle components.

In conclusion, it is better to choose PCA analysis in this case than other methods. And several important indexes to analyze the reason of the water deficit can be concluded.

4.2.3 Definition of PCA model

Suppose $X_1, X_2, \cdots, X_p$ are random variables, and denote sample standard deviation as $S_1, S_2, \cdots, S_p$. First of all, let's make a standard transformation:

$$C_j = a_{j1}x_1 + a_{j2}x_2 + \cdots + a_{jp}x_p, \;\; j = 1,2, \cdots, p$$

Here we have the following definitions:

(1) If $C_1 = a_{11}x_1 + a_{12}x_2 + \cdots + a_{1p}x_p$, and $Var(C_1)$ is maximized, then C_1 is call as the first principle component.

(2) If $C_2 = a_{21}x_1 + a_{22}x_2 + \cdots + a_{2p}x_p$, $(a_{21}, a_{22}, \cdots, a_{2p})$ is perpendicular to $(a_{11}, a_{12}, \cdots, a_{1p})$, and $Var(C_2)$ is maximized, then C_2 is called as the second principle component.

(3) Similarly, the third component may also exists, and even more components may exist; but no more than *p* principal components.

4.2.4 Properties of the principal component

Principal component $C_1, C_2, \cdots, C_p$ has the following properties:

(1) If each pair of principal components is unrelated, i.e. for each *i* and *j*, the correlation coefficient of C_i and C_j for each *i* and *j* is given as,

$$Corr(C_i, C_j) = 0, \ \ \forall i \neq j, i \leq p, j \leq p$$

(2) The vector constituted by the combination coefficient $(a_{i1}, a_{i2}, \cdots, a_{ip})$ is the unit vector.

(3) The variance of each principal component is decreasing, i.e.

$$Var(C_1) \geq Var(C_2) \geq \cdots \geq Var(C_p)$$

(4) The total variance remains constant, i.e.

$$Var(C_1) + Var(C_2) + \cdots + Var(C_p) = Var(x_1) + Var(x_2) + \cdots + Var(x_p) = p$$

This property shows that principal components are linear combinations of the original variables. They are reorganizations of the original variable information. Principal components do not increase or decrease the total amount of information; they keep the total amount of information constant.

(5) The correlation coefficient of the principal components and the original variables is given as

$$Corr(C_i, x_j) = a_{ij} = a_{ji}$$

(6) Let the correlation matrix $X_1, X_2, \cdots, X_p$ be R, then $(a_{i1}, a_{i2}, \cdots, a_{ip})$ is the i^{th} eigenvector of the correlation matrix R. Eigenvalue l_i is the variance of the i^{th} principle component, i.e.

$$Var(C_i) = l_i$$

Where l_i is the i^{th} eigenvalue of the correlation matrix R

$$l_1 \geq l_2 \geq \cdots \geq l_p \geq 0$$

4.3 Assumptions of PCA

Before we start to use PCA to analyze the dataset, it is important to make it clear that all assumptions should be met if it is possible. Hereby, some essential assumptions are listed and to be checked.

1. In multivariate PCA, each parameter, or variable should be continuous.
2. Each variable should be selected randomly from the population.
3. The relationship between observed variables should be linear.
4. Each parameter should be able to be assumed normality, in other word, each variable should be normally distributed.
5. In the dataset, the sample size should be large enough.
6. Significant outliers are not allowed in the dataset.
7. The dataset should be able to reduce the number of variables.

All assumptions above are the significant assumptions to do PCA. And based on the dataset we have, we can check whether these assumptions are met.

4.4 Procedure of PCA and Data Analysis

As mentioned before, this thesis considers 16 factors as the possible factors of influence. Table 4-1 shows the values of these factors from 2003 to 2012 that are collected from the statistical data of the original water resource data in the Beijing-Tianjin-Hebei Region in The Chinese Statistical Yearbook from the year 2004 to 2013. Since data are significantly different among factors, we standardize data before getting the results. By using SPSS, the results of PCA based on the data collected in Table 4-1 can be got.

Table 4-1 Original Data

Year	Industry GDP (hundred million)	Agriculture GDP (hundred million)	Service GDP (hundred million)	Population(ten thousand)	Annual Precipitation(mm)	Total Water Resources Volume(hundred million m^3)	Forest Coverage Rate	Surface Water Volume(hundred million m^3)	Ground Water Volume (hundred million m^3)	Agricultural Water Consumption(hundred million m^3)	Industry Water Consumption(hundred million m^3)	Domestic Water Consumption(hundred million m^3)	Ecological Water Consumption (hundred million m^3)	Discharge of Sewage(ten thousand ton)	Discharge of COD(ten thousand ton)	Sewage Treatment Capacity
2003	5452.28	1238.07	7026.44	9236	1195.4	182.1	17.56	58.8	155.4	173.7	38.7	41.4	1.6	367016.4	90.62	690014.2
2004	6916.71	1563.07	8217.5	9326	1145.3	189.89	17.44	79.26	152.76	172.02	37.9	39.02	3.48	353470	92.49	611222
2005	8369.27	1601.06	9853.06	9432	1027	168.38	17.44	72.72	132.64	176.48	36.97	42.15	3.77	369894	92.3	924436
2006	9569.34	1653.96	11635.22	9574	930.4	139.52	17.44	55.39	116.84	178.05	36.85	43.09	3.27	377428	94.1	735510
2007	11259.95	2016.17	14086.91	9734	1011.1	154.91	17.44	54.09	130.75	177.16	34.92	43.33	5.26	387659.2	91	119887
2008	13442.16	2270	16538.45	9936	1227.8	213.5	17.44	88.8	167.1	167.57	34.23	43.6	7.03	409185	83.9	143830
2009	13909.05	2454.48	18652.66	10122	1014	178.24	22.23	64.89	146.06	168.13	33.26	43.81	7.39	445448.8	80.2	77889
2010	16728.87	2832.75	21963.26	10455	1129	171.2	22.23	69.4	136.3	165.57	32.95	44.76	8.06	467154	77	73579
2011	20250.01	3201.72	26065.59	10615	1087.2	199.35	22.23	89.9	152.6	162.24	35.72	47.75	9.18	491167.2	181.78	107932
2012	21928.98	3508.46	29113.17	10770	1085.2[15]	307.97	22.23	162.25	198.95	163.95	35.21	44.35	10.82	528860.4	176.5	66496

Source: The Chinese Statistical Yearbook from the year 2004 to 2013

[15] Original data is missing here. Because the PCA analysis needs the entire table of data, the average of the previous and existed data are used here, as a temporary substitute.

Before we start to do PCA, it is necessary to check the assumptions.

1. Treat each year as an observation, then for each observation, there are totally 16 parameters to be concerned. For each parameter, the data is continuous.
2. According to the description of the dataset (collected from "The planning of the coordinated development of Beijing-Tianjin-Hebei city cluster (2008-2020)", which the parameters inside are collected randomly, mentioned earlier in this chapter), each parameter is selected randomly.
3. In the following part, we will check the linearity of the variables.
4. Assume that each parameter is normally distributed.
5. In the table, there are only 10-year data for us to take as a reference. The sample size is not very large; however, we still could use the method to see the result.
6. If we directly look at the table, there is no significant outlier in the table.
7. In the table, the descriptions of some variables are quite close to each other. It is a foundation for us to think about the reduction of the number of the variables. In the following part, we will complete a test to see whether it is better to reduce the variables.

So the assumptions are met.

4.4.1 Linearity Test

To test the linearity, we can get the plots of each pair of variables.

Figure 4-1 Pair Plots of Variables

Most of pairwise variables show the linear relationship. However, some of them cannot be treated as linearity, especially the relationship between Forest Coverage Rate and other variables. Hereby, we want to consider this variable, so we also take it into consideration.

4.4.2 Bartlett's test of Sphericity

The principal idea of PCA is to reduce the number of observed variables. Then it should be reasonable and meaningful to do PCA on the dataset.

The Bartlett's test of sphericity is usually used to test the null hypothesis that whether the correlation matrix is an identity matrix or not, which would indicate that you variables are not correlated and therefore unsuitable for structure detection. The statistics of the Bartlett's test of sphericity are based on the determinant of correlation coefficient matrix. If its value is large, and its value of corresponding concomitant probability is less than the significance level set by the user, then the null hypothesis should be rejected, and the correlation coefficient matrix can't be an identity matrix. In other word, it should be suitable to do the factor analysis if there have correlation between the original variables, or the factor analysis should not be done. Small values (usually less than 0.05) of the significance level indicated that a factor analysis may be useful with your data. Because this thesis is just use the Bartlett's test of sphericity as a tool, the test itself will not be introduced or discussed too much here.

Since values are various and the range is considerable, the data can be standardized by letting each value divided by the column mean. And then by coding in R, we can easily get the result.

```
 Bartlett's Test of Sphericity

data:  data
X-squared = 767.884, df = 120, p-value < 2.2e-16
```

Figure 4-2 The Result of Bartlett's Test of Sphericity

When construct Bartlett's test of sphericity, the p-value we get is 2.2×10^{-16}, which is far smaller than 0.01, if we set the it as 0.01. Then it means that it is worth to reduce the number of variables.

4.4.3 Using of the PCA model

Now is the time to use the PCA model and the data in table 4-2 to do the following work.

Table 4-2 Standard Matrix for Origin Data

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sewage Treatment Capacity	-0.72	-1.01	0.14	-0.56	1.16	2.04	-0.39	-0.55	0.71	-0.81
Discharge of COD	-0.39	-0.35	-0.35	-0.303	-0.38	-0.57	-0.66	-0.74	1.94	1.81
Discharge of Sewage	-0.88	-1.10	-0.83	-0.70	-0.53	-0.18	0.43	0.79	1.19	1.81
Ecological Water Consumption	-1.47793	-0.84444	-0.74672	-0.9152	-0.24464	0.35179	0.4731	0.69887	1.07627	1.62889
Domestic Water Consumption	-0.84573	-1.89082	-0.5164	-0.10363	0.00176	0.12032	0.21253	0.62969	1.94263	0.44965
Industry Water Consumption	1.57487	1.15893	0.67539	0.613	-0.39047	-0.74922	-1.25355	-1.41473	0.02548	-0.23969
Agricultural Water Consumption	0.55715	0.26583	1.03922	1.31147	1.15714	-0.50583	-0.40872	-0.85264	-1.43008	-1.13356
Ground Water Volume	0.28282	0.16724	-0.71362	-1.40535	-0.79636	0.79505	-0.12609	-0.55338	0.16024	2.18945
Surface Water Volume	-0.65403	-0.00914	-0.21528	-0.76151	-0.80248	0.29155	-0.46207	-0.31992	0.32623	2.60666
Total Water Resources Volume	-0.18126	-0.01328	-0.47712	-1.09945	-0.76758	0.49584	-0.2645	-0.41631	0.19071	2.53296
Forest Coverage Rate	-0.73508	-0.7824	-0.7824	-0.7824	-0.7824	-0.7824	1.16177	1.16177	1.16177	1.16177
Annual Precipitation	0.61554	0.47452	0.14153	-0.13038	0.09677	0.70674	0.10494	0.42864	0.31098	-2.74929
Population	-1.23831	-1.07538	-0.88347	-0.6264	-0.33673	0.02897	0.3657	0.96856	1.25823	1.53884
Service GDP	-1.22585	-1.06867	-0.85282	-0.61763	-0.29407	0.02946	0.30847	0.74538	1.28677	1.68896
Agriculture GDP	-1.31074	-0.883	-0.833	-0.76338	-0.28666	0.04742	0.29022	0.78807	1.27368	1.6774
Industry GDP	-1.32	-1.05	-0.80558	-0.58	-0.27	0.12	0.20	0.71	1.35	1.65

Let $X = (X_1, X_2, \ldots, X_p)^T$ be the random variable, n samples are represented respectively as $x_i = (x_{i1}, x_{i2}, \ldots, x_{ip})^T$, $i = 1,2, \ldots, n, n > p$. Standardizing the sample matrix which is constructed from collected n samples as the following:

$$Z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}, i = 1,2, \ldots, n; j = 1,2, \ldots, p$$

where $\bar{x}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}$, $S_j^2 = \frac{\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}{n}$.

Then we get the standard matrix Z in Table 4-2.

(1) Get the correlation coefficient matrix R based on the standard matrix Z.

$$R = [r_{ij}]_p x_p = \frac{Z^T Z}{n-1}$$

where $r_{ij} = \frac{\sum z_{jk} z_{kj}}{n-1}, i, j = 1,2, \ldots, p$. Table 4-3 shows the result of the coefficient matrix R of 16 factors.

(2) Solve p eigenvalues from the characteristic equation of sample correlation matrix R, $|R - \lambda I_p| = 0$, to get the principle components. The number of principle components can be settled from

$$\frac{\sum_{j=1}^{m} \lambda_j}{\sum_{j=1}^{p} \lambda_j} \geq 0.85$$

where m is the number of principle components. According to the inequality, the information utilization reaches more than 85%. For each $\lambda_j, j = 1,2, \ldots, m$, solve the unit eigenvector b_j^0 from the equation set $Rb = \lambda_j b$.

(3) Variables will become principle components after they are standardized.

$$U_{ij} = z_i^T b_j^0, j = 1,2, \ldots, m$$

U_1 is called as the first principle component, U_2 is the second principle component and so on. U_p is the p^{th} principle component.

(4) Compositely analyze the m principle components.
Get the weighted sum of m principle components, i.e. the final evaluation value. Each weight is the variance contribution of every principle component.

SPSS gives a list of components in Table 4-4. Since a component is treated as a principal component when the variance is greater than 1, then let's compare the variance of each component and select the principle components.

Table 4-3 Correlation Matrix

	Industry GDP	Agriculture GDP	Service GDP	Population	Annual Precipitation	Forest Coverage Rate	Water Resources Volume	Surface Water Volume	Ground Water Volume	Agricultural Water Consumption	Industry Water Consumption	Domestic Water Consumption	Ecological Water Consumption	Discharge of Sewage	Discharge of COD	Sewage Treatment Capacity
Sewage Treatment Capacity	0.145	0.100	0.102	0.093	0.323	-0.230	-0.087	-0.110	-0.034	-0.046	-0.338	0.372	0.181	-0.021	-0.029	1.000
Discharge of COD	0.702	0.685	0.693	0.638	-0.623	0.505	0.670	0.734	0.570	-0.573	0.070	0.568	0.613	0.696	1.000	-0.029
Discharge of Sewage	0.973	0.978	0.985	0.981	-0.612	0.907	0.672	0.705	0.568	-0.856	-0.597	0.780	0.950	1.000	0.696	-0.021
Ecological Water Consumption	0.979	0.987	0.978	0.975	-0.541	0.830	0.658	0.698	0.559	-0.851	-0.720	0.748	1.000	0.950	0.613	0.181
Domestic Water Consumption	0.828	0.787	0.818	0.825	-0.192	0.694	0.199	0.256	0.108	-0.624	-0.582	1.000	0.748	0.780	0.568	0.372
Industry Water Consumption	-0.645	-0.654	-0.649	-0.693	0.100	-0.614	-0.117	-0.127	-0.063	0.508	1.000	-0.582	-0.720	-0.597	0.070	-0.338
Agricultural Water Consumption	-0.829	-0.856	-0.837	-0.849	0.274	-0.823	-0.651	-0.625	-0.655	1.000	0.508	-0.624	-0.851	-0.856	-0.573	-0.046
Ground Water Volume	0.506	0.535	0.518	0.473	-0.600	0.362	0.964	0.878	1.000	-0.655	-0.063	0.108	0.559	0.568	0.570	-0.034
Surface Water Volume	0.684	0.697	0.683	0.634	-0.829	0.461	0.971	1.000	0.878	-0.625	-0.127	0.256	0.698	0.705	0.734	-0.110
Total Water Resources Volume	0.625	0.646	0.633	0.584	-0.764	0.440	1.000	0.971	0.964	-0.651	-0.117	0.199	0.658	0.672	0.670	-0.087
Forest Coverage Rate	0.838	0.864	0.864	0.886	-0.408	1.000	0.440	0.461	0.362	-0.823	-0.614	0.694	0.830	0.907	0.505	-0.230
Annual Precipitation	-0.565	-0.565	-0.578	-0.524	1.000	-0.408	-0.764	-0.829	-0.600	0.274	0.100	-0.192	-0.541	-0.612	-0.623	0.323
Population	0.992	0.993	0.996	1.000	-0.524	0.886	0.584	0.634	0.473	-0.849	-0.693	0.825	0.975	0.981	0.638	0.093
Service GDP	0.998	0.996	1.000	0.996	-0.578	0.864	0.633	0.683	0.518	-0.837	-0.649	0.818	0.978	0.985	0.693	0.102
Agriculture GDP	0.995	1.000	0.996	0.993	-0.565	0.864	0.646	0.697	0.535	-0.856	-0.654	0.787	0.987	0.978	0.685	0.100
Industry GDP	1.000	0.995	0.998	0.992	-0.565	0.838	0.625	0.684	0.506	-0.829	-0.645	0.828	0.979	0.973	0.702	0.145

The correlation matrix shows that some of these factors are related significantly, for example, Industry, Agriculture, Service GDP and Population. The correlation is almost 1.00 between each pair of these factors. However, in spite of the highly relation between the pairs of some factors, the correlations are pretty low. Therefore, choosing a PCA model is effective.

Table 4-4 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**10.667**	**66.672**	**66.672**	**10.667**	**66.672**	**66.672**
2	**2.588**	**16.177**	**82.849**	**2.588**	**16.177**	**82.849**
3	**1.138**	**7.110**	**89.959**	**1.138**	**7.110**	**89.959**
4	.822	5.136	95.095	.822	5.136	95.095
5	.616	3.849	98.944	.616	3.849	98.944
6	.099	.620	99.564	.099	.620	99.564
7	.046	.288	99.852	.046	.288	99.852
8	.020	.126	99.977	.020	.126	99.977
9	.004	.023	100.000	.004	.023	100.000
10	1.655E-15	1.034E-14	100.000			
11	6.149E-16	3.843E-15	100.000			
12	1.317E-16	8.234E-16	100.000			
13	-2.787E-17	-1.742E-16	100.000			
14	-2.227E-16	-1.392E-15	100.000			
15	-3.769E-16	-2.356E-15	100.000			
16	-4.879E-16	-3.050E-15	100.000			

The variance of the first three components was greater than 1, and also, the total cumulative rate of contribution of the first three principal components was 89.959%, greater than 85%, then the three principle components were set. Table 4-5 gives the result of the first three components.

Table 4-5 Component Matrix

Component	F1	F2	F3
Industry GDP(X_1)	.980	-.161	.009
Agriculture GDP(X_2)	.986	-.137	-.024
Tertiary Industrial GDP(X_3)	.985	-.148	-.033
Population(X_4)	.972	-.212	-.073
Annual Precipitation(X_5)	-.637	-.562	.143
Forest Coverage Rate(X_6)	.850	-.207	-.429
Total Water Resources Volume(X_7)	.751	.597	.214
Surface Water Volume(X_8)	.784	.572	.157
Underground Water Volume(X_9)	.652	.593	.300
Agricultural Water Consumption(X_{10})	-.872	.073	-.017
Industry Water Consumption(X_{11})	-.572	.641	.011
Domestic Water Consumption(X_{12})	.738	-.524	.062
Ecological Water Consumption(X_{13})	.972	-.161	.058
Discharge of Sewage(X_{14})	.985	-.069	-.125
Discharge of COD(X_{15})	.734	.335	.089
Sewage Treatment Capacity(X_{16})	.052	-.499	.857

Comparing the values of factors in each component, it can be seen that each component has their own meaning to represent some indexes. To inference the first component, we see that GDP, water consumption and discharge of sewage take a large percentage. Therefore, we may conclude it as the **human influence** on the water resource. The second principal component describes the main effect of water volume at different places, thus, a reasonable conclusion should be the **natural water volume**. As for the third component, it is obvious that the most "outstanding" parameter is **sewage treatment capacity**, so we can use this to name the third one. The relationship of those three are showed below:

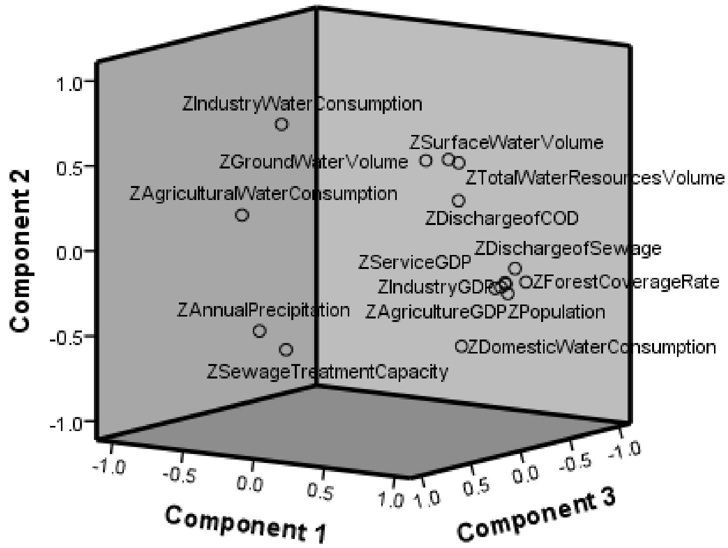


Figure 4-3 Component Graph

From the table of the Component Matrix, we can conclude the weights of factors in each principle component. Considering the rate of contribution of each principal component, we can get a comprehensive score model as the following:

$$Y = 0.2051X_1 + 0.2067X_2 + 0.2045X_3 + 0.1915X_4 - 0.1968X_5 + 0.1380X_6 + 0.2530X_7 + 0.2535X_8 + 0.2365X_9 - 0.1910X_{10} - 0.0573X_{11} + 0.1135X_{12} + 0.2069X_{13} + 0.2065X_{14} + 0.2106X_{15} + 0.1952X_{16}$$

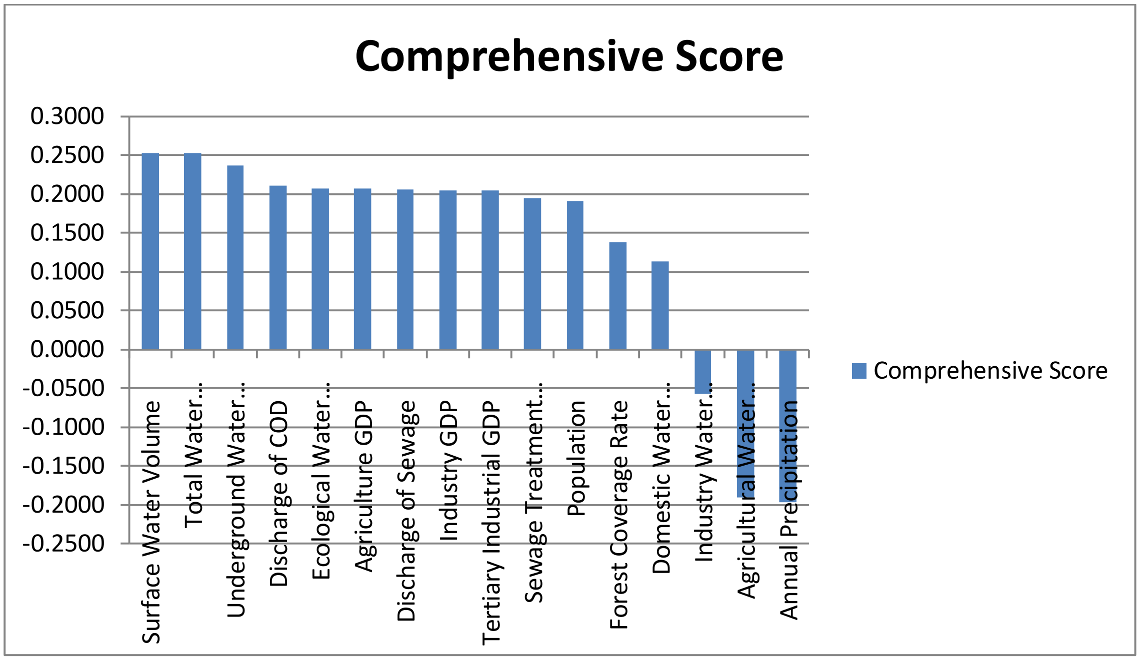


Figure 4-4 the Importance of Each Factor

Therefore, from the comprehensive score model, the issues, include Surface Water of Volume, Total Water Resources Volume, Underground Water Volume, Discharge of COD, Ecological Water Consumption, Agricultural GDP, Industrial GDP and Tertiary industrial GDP, are recommended as the main factors that influence the water deficit.

Chapter 5 Problems Existed and Solutions Recommended

As mentioned in Chapter 4, it is recommended that Surface Water of Volume, Total Water Resources Volume, Underground Water Volume, Discharge of COD, Ecological Water Consumption, Agricultural GDP, Industrial GDP and Tertiary industrial GDP as the main factors that influence the water deficit. So those will be surely taken into account since it is assumed that those issues could surely have significant impact on the water shortage problems.

In addition, according to the background information and the literatures reviewed, because of the huge population and the related population problems in the Beijing-Tianjin-Hebei Region, as mentioned in chapter 2, and the nature of humans' demand for water, it is thought that the Population issue could immediately impact the demand of water resources. On the other hand, similar with the Population issue, it is found that the Forest Coverage Rate could also impact the supply and demand of water resources and even the whole process of water circulation in nature, and the Agricultural Water Consumption is also an important issue because of the high usage of water in the Beijing-Tianjin-Hebei Region and the extensive usage of water in this area. So it is recommend Population, Forest Coverage Rate and the Agricultural Water Consumption be seen as issues which are that related to the water shortage problems.

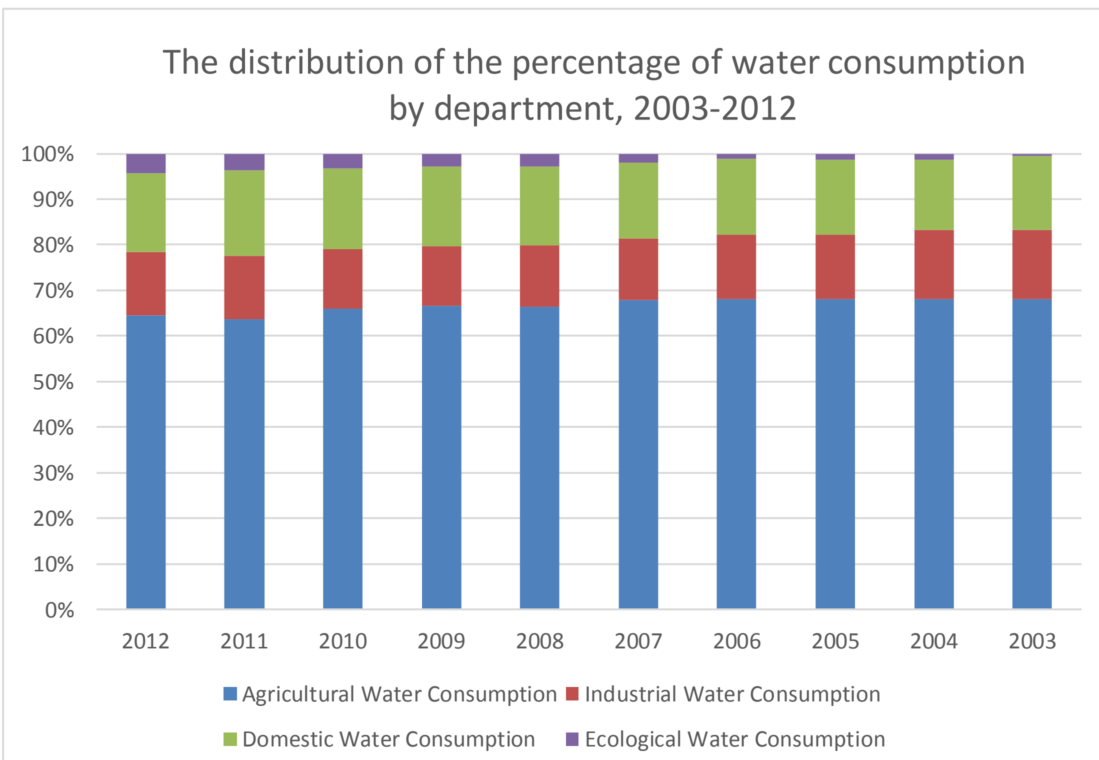
Based on this result, it is time to analyze what problems could those issues lead to, and the different kind of solutions will also be discussed and evaluated, and the recommended solutions will be given for those water shortage problems. The possible responses of all those solutions will also be presented following each of them.

5.1 Analysis for Problems Existed

Because of the high significance of the issues of Surface Water of Volume, Total Water Resources Volume and Underground Water Volume and the low significance of the Annual Precipitation issue, it could be concluded that, in water supplies' view, the water supply in total is not enough to satisfy the demand in the Region, and the shortage of water resources is mainly caused by the shortage of ground water and underground water instead of the atmospheric precipitation (other kinds of water source, for example, recycled water and glacial water, was not accounted because of their tiny amount and the shortage of data). So the Beijing-Tianjin-Hebei Region has natural shortage on supply of local water resources.

On the other hand, the issues of Agricultural GDP, Industrial GDP and Tertiary industrial GDP showed the impact of the division of water resources. The high speed development of the agriculture, industry and tertiary industry led to the huge and fast growth of the water demand. What's worse, the huge amount of the population in the Beijing-Tianjin-Hebei Region will lead to the huge demand on food, which brings great pressure to bear on the productivity of the local agriculture, while agriculture need much more water resources than other industries, and those will be mentioned later. There is no doubt that those limited water supplies have become a "bottleneck" that limited the development of all those three industries. And, to make it worse, to satisfy the local water demand, the excessive groundwater exploitation appears in many regions in the Beijing-Tianjin-Hebei area, and some places even set a limitation on the volume and the time for people's daily use of water. According to the data collected from the China Statistical Yearbook from 2004 to 2013, the distribution the percentage of water consumption is transferred into bar chart showed below:

Table 5-1 the Distribution of the Percentage of Water Consumption by Department, 2003-2012



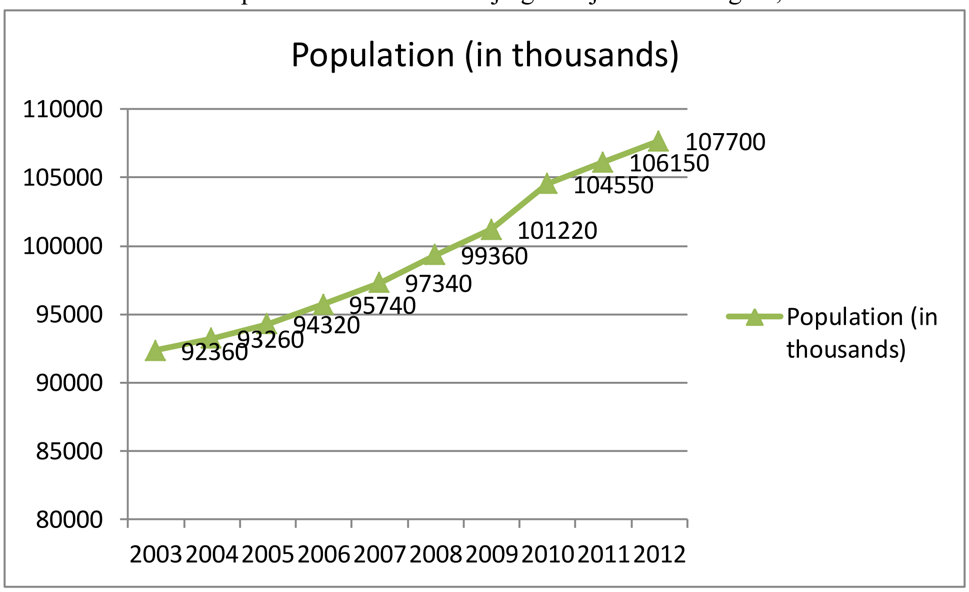
Source: The Chinese Statistical Yearbook from the year 2004 to 2013

It can be observed that the percentage of the water consumption in agriculture accounts for the largest part, which is 64.46%, and industry accounts for 13.84% and the domestic (include the water consumption of the tertiary industry) and ecology relative accounts for 17.44% and 4.25% in 2013. According to the *International Statistical Yearbook 2013*, the water consumption in high income countries in average in agriculture accounts for the only 41%, and industry accounts for 42.2%, and the domestic water consumption accounts for 16.8% in 2009. So it can be known that the Beijing-Tianjin-Hebei Region needs to decrease percentage of the water consumption of agriculture, as a core problem. In addition, the importance of the issue Agricultural Water Consumption for water shortage showed the water shortage problem led by the excess use of water resources for agriculture more clear. This also showed the influence of the utilization efficiency of water resources in agriculture in the Beijing-Tianjin-Hebei Region. All in all, the more water used by the agriculture, the less water left for others including industry.

The issue Discharge of COD showed the significance of another problem, the water pollution problem, to lead to water shortage. The industrial sewage contributed a lot to the water pollution problem in the Beijing-Tianjin-Hebei Region. Recall the background information that mentioned in chapter 2, the water pollution problem is very serious. On the other hand, according to the article "Introduction to industrial wastewater treatment", the industrial enterprise is facing 3 major problems. First of all, the shortage of the technical and managerial personnel and professional and technical equipment for sewage treatment could lead to the water pollution lead by the industrial sewage. The sewage treatment for enterprises is a complex and integrated systems engineering, which requires technical and managerial personnel to track governance to do the integration management and debugging work so that to make sure the rationality and scientificity of the sewage treatment. And comparing with developed countries, China has an obvious gap on the research and development of professional and technical equipment and the related usage experience for sewage treatment, and many enterprises cannot buy advanced equipment to do the sewage treatment, which lead them to failing to meet the pollution discharge standard and the following environmental problems. Second, the enterprises themselves are lacking of the awareness and attitude for the treatment of sewage. Many medium and small industrial enterprises in China only want to focus on its economic benefit and do not want to take the social responsibility, for example, the treatment of their sewage. That kind of opinion has one of the major impacts on the treatment of sewage in China. Third, the shortage of capital is another problem. In China, large industrial enterprises usually have enough capital to invest in the treatment of sewage, while it is too expensive for most medium and small industrial enterprises so that they cannot do it. (Hui Yang, 2013)

Another important issue is Population. It is known that, the larger the population size, the more water resources it will demand. As showed in the following chart, and recall the background information in chapter 2, the population size is huge in the Beijing-Tianjin-Hebei Region, and it grows continuously from 2004 to 2012, as it is showed in table 5-2. So the demand of water resources is continuous growing, and that make the situation of water shortage become more and more serious in this Region.

Table 5-2 the Population Size in the Beijing-Tianjin-Hebei Region, 2003-2012



Source: The Chinese Statistical Yearbook from the year 2004 to 2013

It is surprising that the issue Ecological Water Consumption have significant impact on leading the water shortage problems while the amount of that part could only accounted for approximately 1 %. Recall the definition of Ecological Water Consumption in chapter 4, comes from the amount of ecological water needed for maintaining or improving the balance of existing ecosystem of plant community, animal and the abiotic part, or it could be simply understood as " the water amount needed by livings and others except human beings". The function of the issue Forest Coverage Rate is related to Ecological Water Consumption closely. So it could be concluded that the balance of the ecosystem and the forest coverage rate in the Region are important when thinking about the solutions of water shortage problems.

Based on the analysis result of these issues, the related problems have been founded. Then the solutions to solve those problems will be introduced and then analyzed and evaluated briefly in the following paragraphs.

5.2 Internal Solutions

The internal solutions are mainly founded from the internal dimension of the Beijing-Tianjin-Hebei Region. In this case, based on the issues observed above, the following 5 dimensions of solutions will be mainly focused on: the water resources carrying capacity, the optimization of the industrial structure, the discharge control and governance for sewage, the control and management of population size, and the establishment of a unified control system among Beijing-Tianjin-Hebei region.

5.2.1 Evaluation of Water Resources Carrying Capacity

Before making any plans to solve most kinds of problems, it is important to understand the nature of the problem first, which means that people need to analyze and evaluate the related conditions and statues of the problem. The result of those analysis and evaluations could provide the evidence to support the following actions to work with water shortage problems in the processes include planning, implementation, etc. The literatures showed that the research of water resources carrying capacity is a main way when analyzing and evaluating the related conditions and statues of the regional water resources. Most of those evaluations and analysis for the reason of water shortage is just simply analyzing the trends of numbers and the supply-demand trends of data in China. But the evaluation of regional water resources carrying capacity is a mature way to do that.

According to the article “Optimization of the Industrial Structure Subject to the Water Resources”, there is still no unified definition for water resources carrying capacity, but it is commonly used for evaluating the maximum carrying capacity of regional water resources to support the social, ecological, environmental and economy activities in an acceptable level (Wei, 2008).

To evaluate the water resources carrying capacity in a specific region, it is usually needed to think about 3 issues: 1) the sustainable development, which means that the water resources need to enable not only the current demand, but also the future demand; 2) targeting the maintaining of the virtuous cycle of the ecological system as a goal; 3) trying to maximize the water resource carrying capacity for society and economy. From the definition of the carrying capacity of regional water resources, it is easy to find that the research of it could related to the huge system consisting of issues including society, economy, environment, ecology, resources and many other issues.

In this case, the most important thing is to evaluate and understand the water resource carrying capacity in this area first, and then makes the suitable industrial planning, and executes that plan at last.

Recall the article "Optimization of the Industrial Structure Subject to the Water Resources", there has developed many kinds of methods to evaluate the regional water resources carrying capacity(Wei, 2008), and because this thesis will not focus on how to pick up which one is better, only several methods that are commonly used are presented here.

(1) System dynamics method

Using the system dynamics method to analyze the carrying capacity of water resources is the simulation analysis for a macro system. This method could include large numbers of complex factors as a whole to do the dynamic calculation for the carrying capacity of a specific resource in a region, which have the view of the development of the whole system. The most important feature of this method is that it could use first-order differential equation sets to reflect the relationship between the cause and effect among each module. In practice, it will use the system dynamics model to simulate different developing plans, and predict the decision factors. It will use those factors as the indicator system for water resources carrying capacity and the water environmental carrying capacity, compare them and get the best developing plan and the related carrying capacity.

Analysis and Evaluation:

This method could include nearly all kinds of the data that are collected for evaluation, which could evaluate the water resources carrying capacity in the broadest view without discrimination for different kinds of data, so it could provide the most reliable results comparing with other methods. But, its backward is also obvious: it is commonly need large numbers of different kinds of data which users of this method are hard to collect or easy to ignore some issues that might not as important as others but still have tiny impact on the result of this method. So this method is not fit for personal or small organizations analysis but fit for government and other powerful organizations that have enough capital, time, technical level, experts and labors, etc., to collect and analyze those data to support the using of this method.

(2) Indicator system evaluation method

The indicator system evaluation method is a kind of quantificational model which is generally used, and that includes vector module method, fuzzy synthetic evaluation method, etc. Vector module method is to suggest the water resource carrying capacity and the water environmental carrying capacity as a vector consisted by n indicators with the city developing situation of m developing plans or m periods/regions, with each corresponding to m units of water resource carrying capacity and the water environmental carrying capacity, and then normalize the n indicators of m units of water resource carrying capacity and the water environmental carrying capacity. The module of that normalization is the water resource carrying capacity and the water environmental carrying capacity in corresponding plans, periods or regions

The fuzzy synthetic evaluation method will suppose the evaluation for water resource carrying capacity and the water environmental carrying capacity as a fuzzy synthetic evaluation. Its model is: suppose there are 2 infinite domain of discourse, $\mathbf{U} = |u_1, u_2, \cdots, u_n|$ and $\mathbf{V} = |v_1, v_2, \cdots, v_n|$, while **U** represent set of the factors of evaluation (means the evaluation indicators), and **V** represent the set of comments. So the fuzzy synthetic evaluation is the following fuzzy transformation: **B**=**A*****R**, while **A** is the fuzzy weight vector, which means the relative importance of each evaluation factor or indicator, and **B** is the fuzzy subset of **V**, which means the total subjection of the evaluation subject for the specific comment, and **R** is the fuzzy relation matrix that consisted by v_{ij}, which is the subjection of u_n (each evaluation factor) for **V**, while use r_{ij} (indicate the particular value of the j^{th} variable that is observed on the i^{th} item, or trial) represents a subjection which is evaluated on the fuzzy subset of the v_j^{th} level with respect to factor u_i.. Based on the composite operation above, it could be found that the subjection of the evaluation subject in whole for each level of comments. Then let's select the big or small factor of the vector B, and then we the final comment for the evaluation subject could be known.

Analysis and Evaluation:

It is obvious that the indicator system evaluation method depends on the artificial comments and the comparison of the indicator numbers of different carrying capacity or the comparison of the indicator numbers and the standard numbers, and the results are all dimensionless numbers. So, in fact they are the coordination degrees between the social and economic system and the water system, which is not in the sense of strict concept of the water resources carrying capacity and the water environmental carrying capacity.

(3) Multi-objective optimization method

The multi-objective optimization method is another kind of quantitative method that is commonly used. It uses system analysis with decomposition-coordination method, to divide the water resource, human social and economic system of a specific area into several subsystems, and then use mathematical model to describe. It will use the coordinated relationship variables of the multi-objective core model to connect each subsystem model. If the optimization objective and the limitation conditions that needed are known, with the predicted results in different years of the decisional model and the model simulation, then the developing plan that could satisfy the integral optimal of multiple objectives could be found, and its corresponding population or social and economic developing size is the water resources carrying capacity and the water environmental carrying capacity. The multi-objective core model is usually use the optimization algorithm in mathematical area to solve. It could be find that, the formulation and screening of plans have the decisive significance for the accuracy of the result of the optimization solution. To avoid the plan is decided so early that the second-best solutions are generated, they could use scenario analysis method to screen the alternative plans. That method could only roughly provide some feasible scenarios for decision makers to design the background scenarios, and then use the multi-objective model method to screen the front desk scenario as the direction of planning according to the decision makers' opinion.

Analysis and Evaluation:

Similar with the system dynamics method, the multi-objective optimization method also does the research with looking the research area as a whole system, to analyze the relationship among the factors inside the system and describe it by mathematical model, and use mathematics to plan and analyze the system status and the distribution of each factors when the system want to maximize subjects. The multi-objective optimization method could get the best status of the system under specific backgrounds by using the mathematical planning method, and the adjustments for system are showed when the system intend to maximize subjects. And, of course, multi-objective optimization method still has the problem to choose exogenous variable (also called parameter).

Because of the difficulties of the technology to solve the problem of multi-objective planning, this method is limited in the applications for cases that have small size of models, which cannot take the affecting factors generally into account. But, because of the development of computer science and the mature mathematical planning tools in recent years, analysts could focus more on modeling, planning, and choosing subjects, especially the integrated analysis involves economy, society, resources, and environment factors. So the multi-objective optimization method starts to have new development on the integrated decision making including the water resource carrying capacity.

Conclusion and recommendation of those solutions:

Based on the complex status of the water shortage problem in the Beijing-Tianjin-Hebei Region and the special status and power that are owned by the Chinese government, this thesis recommend the Chinese government use the system dynamics method because the nature conditions in the Beijing-Tianjin-Hebei Region is very complex, and all the issues must be taken into account at the same time, since the decisions will impact the future of this area which is significant in China, and the system dynamics method could satisfy the demand. In addition, the ability of the Chinese government to collect large numbers of data and do the macro planning in this area, and the irreplaceable political and leading role of the government in China to guide the future development in China, could satisfy the specific demand on the collection of large numbers of different kinds of data to use the system dynamics method.

5.2.2 Optimization of the Industrial Structure

The phrase "optimization of the industrial structure" is often used in China, since the current industrial structure has led to a series of problems in different area, and the water shortage problem is just one of them. According to the result of the PCA model, the Total Water Resource Volume, Agricultural GDP, Tertiary Industrial GDP and Agricultural Water Consumption are included in the issues that have significant impact on the water shortage problem. According to the article "China's agricultural water use efficiency and influencing factors", the agricultural water use efficiency is defined as the volume of grain produced by one unit of water resource, and the influencing factors include the local climate, soil and the construction of irrigation and water conservancy infrastructure. Because it is difficult to change the nature factors, which include the local climate and soil, so the only method that need to think and use is the construction of irrigation and water conservancy infrastructure (Wang and Zhao, 2008). After the study of the related literatures and governmental policies, and then summarize and made the modification on the solutions that have been used in China because of the features of the Beijing-Tianjin-Hebei Region and the whole China, the following 4 directions are recommended:

(1) Intensification of propaganda and legislation for water resources, and paying more attention to the overall planning

In China, the Chinese government often plays the most important role in the economic area. In this case, the local government in the Beijing-Tianjin-Hebei Region needs to propagandize the basic information of water resources to enhance people's consciousness of floods, saving water and water resources protection. On the other hand, the Chinese government needs to enhance the legislation for agricultural water conservancy infrastructure. Each region of the Region should formulate the detailed rules and standards for agricultural water conservancy infrastructure and management according to the specific local conditions, and the effects of results should be taken into account of the achievement assessment for local government officers. At last, the overall planning should not only focus on the connection between the economic development and the improving of people's livelihood, but also accelerate the building of a series of the backbone water conservancy project that could motivate the development of economy and society to relive the "bottleneck" for development. In addition, it is also important to pay attention to the connection between the exploitation and the saving of water resources and enhancing the management of water resources according to related law.

(2) Intensification of the government-led diversified investment

Because the construction of water conservancy infrastructure needs large amounts of money and official process, this work should be led by the Chinese government in most of cases. So the government needs to invest more money on the construction of water conservancy infrastructure than before. On the other hand, government also needs to formulate rules and policies to motivate and attract the social capital and private capital to attend to the building and management of the water conservancy infrastructure, for example, provide the priorities or bonus for them, so that the regulation of market economy could work automatically.

(3) Developing the water conservancy of people's livelihood

The water conservancies of people's livelihood are directly related to people's life safety, living security, survival and development, settlement and legitimate interest. First of all, they need to pay more attention on the governance of medium or small rivers, the reinforcement for dangerously weak reservoirs, and the prevention and control of mountain torrent disaster. Second, the construction of rural drinking water safety and the construction of water engineering for drought resistance must be guaranteed to supply people's basic demand for water. At last, planning and implementing the complete set of irrigated areas and the water-saving transformation is also important

(4) Speeding up the change of the pattern of production and developing water-saving agriculture

Currently, the use efficiency of irrigation water is only 46% in China, and the average production of grains with using 1 m^3 water is no more than 1 kg, while many developed countries which using the modern advanced irrigation technology could be higher than 2 kg for average production of grains with using 1 m^3 water. If China starts to use advanced irrigation technology, it could increase the average production of grains with using 1m^3 water to 1.3 kg under the current agriculture water consumption, and, of course, the status of the Region will also be changed. So it is essential to change the traditional agriculture into water-saving agriculture, for example, change flood irrigation into drop irrigation, spray irrigation and drip irrigation under mulch

Conclusion:

In summary, the core problem is to increase the agricultural water use efficiency. Once it worked, the conflicts of water resources shortage among the industries will be relieved. Those 4 solutions recommended above is based on the understanding, modification and summary of the related policies and the current fact of the Beijing-Tianjin-Hebei Region, and all 4 of them should be worked well when they are used at the same time. So this thesis recommends all of them.

5.2.3 Discharge Control and Governance for Sewage

According to the article "Introduction to the treatment of industrial sewage" (Yang, 2013), to solve the water pollution problem led by the industrial sewage, the Chinese government needs to lead it. The most important problem in this case is to solve the backwardness of the technology to treat sewage. The Chinese government not only needs to research and develop its owned related technology, but also can import advanced technology from other countries. In addition, the training of the professional personnel is also important to support the treatment of sewage.

Another important point is to intensify propaganda and legislation for the treatment of sewage so that the owner of the enterprise, employees, and the people who lives near those enterprises will be aware of the danger and harm of industrial sewage. They could help the government officers to supervise the treatment of sewage.

Third, the government need to stimulate related laws and policy to punish the illegal enterprises and reward those enterprises which meet the standard of the treatment of sewage, for example, the government could provide priorities for "good enterprises" like a number of tax deductions and exemptions.

At last, according to the regulation of market economy, the government should focus on the technology of the treatment of sewage that could not only decrease the pollution level, but also can decrease the cost of enterprises' production. That could motivate the owners of enterprises to adjust their business automatically because of benefits.

Although the solutions above need the huge amount of capital investment from the Chinese government, the current water pollution status that lead to the water shortage is forcing them to do so.

Conclusion:

Similar with the solutions for the optimization of the industrial structure, the solutions for industrial water pollution problems recommended above are also based on the understanding, modification, and summary of the related policies and the current fact of the industry in the Region. The focus point should be those industries, and the Chinese government needs to guide, support and rule them to solve the industrial sewage pollution problems.

5.2.4 Control and Management of Population Size

Because the water shortage problem were led by the huge and continuous growing population size according to The Chinese Statistical Yearbook from the year 2004 to 2013, the goal of solving the bad impact from population size to water shortage problem is simply control and management of the population size, which means to limit or decrease the population size in the Beijing-Tianjin-Hebei Region in short. According to the article "The evolution, the problems, and the countermeasures of China's population policy" (Sun, 2013) and after reviewing the population policy in China, the following solutions are recommended.

(1) Family planning

The family planning policies have been implemented in China since early 1970s, and the core issue is the limitation on the maximum number of children each couple could have. Currently, that series of policies are differentiated and specialized based on the local population conditions. Among the Beijing-Tianjin-Hebei Region, the Beijing City is now started to allow couples to have 2 children in maximum if both of the parents of those children are the only child in their families. On the other hand, other regions in the Region still have not been allowed to have the second child no matter what family status are of the couples.

Analysis and Evaluation:

As mentioned earlier, the smaller the population size, the less the water resource will be needed. It is obvious that family planning method have very high efficiency when solving the related water shortage problem. But those series policies could also lead to other kind of social, political, and natural problems, such as the damage for reproductive freedom, the problem of the aging of population, etc. All in all, the family planning method will get effect in short period for water shortage, as administrative means of the government. But the costs and backwards of that method must be evaluated and compared with the benefits and advantages of the family planning method, to see if it really worthwhile.

(2) Control and management of floating population

Because of the advantages of the economy, education, health facilities, etc. comparing with most of the other areas, the Beijing-Tianjin-Hebei Region have attracted large numbers of people moving into the Region especially in the Beijing City and the Tianjin City, and that increased the total population size in the Region, which led to the worsen of the water shortage in this area. Currently, a series of specialized policies for floating population have been implemented in the Beijing City and Tianjin City, which include the limitation on education, purchasing houses, health care, etc.

Analysis and Evaluation:

Similar with the family planning method, the control and management of floating population also have obvious and direct impact on the population size of the Region, and the drawbacks of it are also easy to be noticed: it mainly could damage the freedom of people to move into this Region, and that also lead to a series of social, political and economic problems, for example, the regional discrimination between people who originally live in the Region and people who belong to floating population. So the advantages and backwards of the control and management of floating population also need to be evaluated and compared before implementation.

Conclusion:

In summary, the solutions for control and management of population size requires the government's guide, support and rule, and they have obvious and efficient impact to reach the goal, limit or decrease the population size in the Beijing-Tianjin-Hebei Region, as administrative means of government. And the negative effects are also significant enough to make it essential to take them into account when planning those solutions. But it is still recommended to use those solutions in the Region with specialized modifications according to the regional conditions and features.

5.2.5 Establishment of a Unified Control System among Beijing-Tianjin-Hebei Region

According to the article "The cross-regional coordination mechanism of protection and utilization of water resources in Beijing-Tianjin-Hebei region"(Xie and Liu, 2009), although Beijing City, Tianjin City and Hebei Province belong to different political divisions, they have many similar features: they attach to each other in geological location with similar climate, and their economic advantages have complementation to each other, and, the most important is, most of the areas among Beijing City, Tianjin City and Hebei Province belong to the same rivers and basins, as mentioned in chapter 2. Because of such similar conditions, those three political divisions are usually and should be thought as a whole when discussing the water shortage problem in in this Region. So the establishment of a unified control system among Beijing-Tianjin-Hebei region becomes important and necessary. That system should be established based on the following key points:

(1) Setting up the guiding ideology and principle for a coordination mechanism

Since the unified control system among Beijing-Tianjin-Hebei region is huge and complex, it requires a unified guiding ideology and principle to guide the establishment, development and maintenance of that system. That guiding ideology and principle should holding the manner of breaking the barriers between the resources that belong to different department or areas, planning the usage of those resources from an overall perspective of Beijing-Tianjin-Hebei region, maintaining the idea of sustainable development as core direction, and trying to achieve the highest payoff for all regions or departments as a whole. On the other hand, each department also needs to clear their role and responsibility for each of them and take the conditions of other areas in to account when doing their job.

(2) Setting up a specialized department for coordination mechanism and clear its work objectives and responsibility

The foundation of a specialized department in government for coordination mechanism could help to direct and motivate the treatment of sewage. That department needs to have power and authority in this area. It should be able to use it ability of strengthening the allocation of resources to enhance the coordination function of the protection of basin environment and prevention of pollution, and to play a role as the authority for the protection and exploitation of water resources in Beijing-Tianjin-Hebei region in unified and coordinated way.

Its work objectives should include the planning of water resources protection and saving water, guiding and attend the division of the main functional areas of basins and the objectives for water quality that cross the boundary between different areas or districts, and supervise the actual status of the implementation the contents of those plans that are mentioned above.

Conclusion:

In summary, the establishment of such a unified control system among Beijing-Tianjin-Hebei region is essential and helpful to solve the water shortage problems in the Beijing-Tianjin-Hebei Region. Although that might need more capitals, labors and other kind of costs than before, it is worthwhile.

5.3 External Solutions

The external solutions are mainly focused on the water transformation and the communication related to water resources between the Beijing-Tianjin-Hebei Region and other regions. As we mentioned in Chapter 2, the Beijing-Tianjin-Hebei Region has naturally shortage of water. To satisfy the water demand in this area, the water transformation is an alternative option that has been used by the Chinese government for many years. Currently, the main water transformation projects in this area include the south-to-north water diversion project and the Luanhe-Tianjin water diversion project.

According to the article "The main factors that influence the long distance water diversion project" (Shen, 2014) and base on the current status of the Beijing-Tianjin-Hebei Region, this kind of method could solve the water shortage status in this Beijing-Tianjin-Hebei region from a very large extent, so it is widely used in China. But this method has a series of limitations in real applications, as presented below.

(1) Management, operation and technical limitations

The long distance water diversion projects usually have 3 kind of method for water diversion: open channel, closed conduit and pipeline. Open channel and closed conduit need longtime maintenance work, and they are usually only used for high flow low water quality and seasonal water supply projects. Pipelines need large amounts of capital investment, and the shape and quality of those pipes are diverse to adapt to different local conditions including the flow size, the water pressure level, the capital owned, etc.

(2) Water quality limitation

Because the length of the whole project is usually tens of miles, and the water need to stay in pipe for hours, the change of water quality is nearly unavoidable. The issues lead to such kind of changes might include 1) the possible existed bacteria and other microorganism inside the source of water are not be killed by disinfection treatment, 2) the by-product of disinfection treatment, for example, trihalomethane and haloacetic acid from the common used disinfection treatment with chlorine, 3) the pollution of the incrustation in pipe, 4) the organic matters inside water that easy to feed bacteria, and 5) the chemical reaction between water and pipe.

(3) Economic benefit limitation

The main energy cost of pipeline is the usage of electricity, and that will increase the price of water and the cost of electricity.

(4) Ecological environment limitation

It is easy to image that the change of the local ecological environment conditions lead by the long distance water diversion project. For the areas which supply water resources, the total water volume in those areas will decrease since water have been transferred to other area, which means that the possible flood disaster could be stopped in that area. But, on the other hand, the local ecological water consumption and the local climate might be influenced, and the local ecological balance might be broken, which can impact the breeding of aquatic organisms. In addition, the water volume of downstream will also decrease, which might lead to estuarine sediment deposition and seawater intrusion happen in the downstream of the river in that area. For the area which demand water resources, although there are more advantages than drawbacks, the possibility of the spread of disease and alien species could be new problems for that area. For the areas that the long distance water diversion projects go through, the possibility of land salinization and flooding will also been raised.

Conclusion:

In summary, the long distance water diversion projects have obvious advantages to solve the water shortage problems in the Beijing-Tianjin-Hebei Region, but that need very detailed planning before its establishment and the maintenance when it operating.

5.4 Long-term Cross-regional Solutions

Some of the factors causing water shortage problems are required not only to be solved in local area, but also to be considered in wider scope, even the relationship between them and water shortage problems may not looks as directly as the solutions mentioned above. For example, according to the article "Summary of the Studies on Relation between Forest Coverage and Water and Soil Conservation" (Ma et al, 2003), the forest coverage rate of the upstream of a basin, which is not located in the Beijing-Tianjin-Hebei Region, could lead to the water shortage problem in the downstream of the basin, which the Beijing-Tianjin-Hebei Region is located. This kind of issues need to face more complex conditions in social, natural and political view, and the solutions for the related problems also need to work well with long-term cooperation. To solve such kind of problems, the most important solution is, the Chinese government need to establish of a unified control system, which is similar as those discussed in section 5.2.4, to try to setting up the guiding ideology and principle for a coordination mechanism and a specialized function for the Ministry of Land and Resources or the Ministry of Environmental Protection of China for coordination mechanism and clear its work objectives and responsibility in the whole country scope to focus on the planning, the implementation, the supporting and the supervision for the protection and the planting of forests and for the division and protection for the water resources for ecological system. In addition, the local government of each division needs to implement the decisions and the rules made by that specialized department of Chinese government mentioned above. And the Chinese government needs to solve the contradictions between different regions when those regions have conflicts of interests. Again, the related work of should be similar with those discussed in section 5.2.4. . There might have other issues that are similar with the forest coverage rate of the upstream of a basin when thinking about the issues that leads to the water shortage problems that need to be thought in a large scope, but those will not discuss in this thesis because they also need the Chinese government's similar solutions.

Chapter 6 Conclusion

The goal of this thesis is trying to find the issues that possible lead to the water shortage problem in the Beijing-Tianjin-Hebei Region. And, the related problems led by those issues are analyzed and then the recommended solutions are suggested.

For the possible issues that lead to the water shortage problem in the Beijing-Tianjin-Hebei Region, this thesis find that part of them are some common issues that also lead to the same problem in the whole China scope, since China have the water shortage problems as a whole. In addition, other issues are related to the special conditions of the Beijing-Tianjin-Hebei Region. According to the Chinese government officer's speech (mentioned in chapter 1), the background information of the Beijing-Tianjin-Hebei Region (mentioned in chapter 2) and the related historical research in this area(mentioned in chapter 3), those issues include the ownership of water resources per capita, the contradiction between the supply and the demand of water resources, the method of water resource utilization, the overdeveloped water resources, and the water body pollution, which exist in China as a whole; and the natural volume of both ground water and underground water resources, the rainfall water resources, the time and space distribution of water resources, the local population size, the regional GDP (including industrial GDP, agricultural GDP, tertiary industrial GDP), the water consumption structure(including agricultural water consumption, industrial water consumption, domestic consumption, and ecological water consumption), the land resources situation, the water quality pollution, the shortage of regional and interregional ecological environment coordination mechanism, the over-exploitation of groundwater, and the land degradation situation, and the forest coverage rate, which existed in the Beijing-Tianjin-Hebei Region obviously.

This thesis also shows the process to take two kinds of issues that mentioned above into account to analyze: some of those issues can be used in quantitative analysis (mentioned in chapter 4) while others that can only be taken into account with the result of the qualitative analysis that are used for qualitative analysis (mentioned in chapter 5) to find the reason and the solutions of the water shortage problem in the Beijing-Tianjin-Hebei Region. This process shows the practical application of analysis for different kind of data.

During the process of the quantitative analysis, the thesis using the selected and modified quantifiable data(include industrial GDP, agricultural GDP, tertiary industrial GDP, population, forest coverage rate, annual precipitation, surface water volume, underground water volume, total water resources volume, agricultural water consumption, industrial water consumption, domestic consumption, ecological water consumption, discharge of sewage by year, the discharge of chemical oxygen demand (COD), and sewage treatment capacity) that based on the understanding of the background information and the original data, and the study about the features of different kinds of common models in econometrics (mentioned in chapter 4), and it find that some of those data might be impacted significantly by multicollinear problems, which means that the linear model (the most commonly used model) is not fit for this analysis process. Based on this fact and the research about the features of the possible adaptable models for this analysis, this thesis find that the strength and of the PCA model is fit to be used to analyze the data that might have multicollinear problems in this thesis as a tool, and the weakness of this model is acceptable to a certain extent in this case.

According to the result of the PCA model, this thesis find that, Surface Water of Volume, Total Water Resources Volume, Underground Water Volume, Discharge of COD, Ecological Water Consumption, Agricultural GDP, Industrial GDP and Tertiary industrial GDP are the main factors that could lead to the water shortage problems.

In addition, based on the study of the literatures reviewed and the qualitative analysis for the issues that can only be taken into account with the result of the qualitative analysis, the thesis also got the following result: Population, Forest Coverage Rate and the Agricultural Water Consumption were also seen as main factors since they are commonly and theoretically considered as important factors that lead to water shortage.

Based on the result of the quantitative analysis (using PCA model) and the qualitative analysis, this thesis summarized the problems that related to those issues which could lead to water shortage problems after categorized similar or related issues. Those problems include the natural shortage on supply of local water resources (especially the ground water and underground water), the high agricultural water consumption, the huge and still rising population size, the widely excessive groundwater exploitation, the water pollution, the unbalance of the ecosystem and the low forest coverage rate.

Then this thesis finds the corresponding solutions, include the evaluation of water resources carrying capacity (includes the system dynamics method, the indicator system evaluation method, the multi-objective optimization method), the optimization of the industrial structure (includes the intensification of propaganda and legislation for water resources and paying more attention to the overall planning, the intensification of the government-led diversified investment, developing the water conservancy of people's livelihood, and speeding up the change of the pattern of production and developing water-saving agriculture), the discharge control and governance for sewage(includes maintaining the Chinese government's leader status in the process of the treatment of sewage, the intensification of the propaganda and legislation for the treatment of sewage, the stimulation of the related laws and policy to punish the illegal enterprises and reward "good" enterprises, and the developing the technology of the treatment of sewage that could decrease the pollution level and the cost of enterprises' production at the same time), the control and management of population size (includes the family planning, the control and management of floating population), the establishment of a unified control system among Beijing-Tianjin-Hebei region (includes setting up the guiding ideology and principle for a coordination mechanism, setting up a specialized department for coordination mechanism and clear its work objectives and responsibility,), the water transformation and the communication, and the long-term cross-sectional solutions(need Chinese government's leader status to motivate them).

Based on the study about those solutions, this thesis believed that the system dynamics method is the best method when evaluating water resources carrying capacity. The advantages and drawbacks of the solutions for control and management of population size are both obvious, so they must be used very carefully, and that process need the Chinese government's guide, support and rule. And all of the other solutions are recommended. The Chinese government's role in those solutions should be the most important of all.

The result of this thesis still has weakness on the collection of data because of the shortage of sample size for PCA model, and the result will be more accurate if more data could be collected. In this thesis, the shortage of data cannot be solved because the lack of the source of original shortage, which need other people to fix it in the future. And the possible human factors could impact the integrity, the accuracy and the authenticity of the original data of China, which may also influence the result of the PCA model. In addition, the PCA model still has its own weakness, as mentioned in chapter 3. And, because of the natural drawback of the econometrics models, they can only support the thesis, but they cannot prove it must be right. At last, the author of this thesis still have shortage on the understanding of economic knowledge, which may lead to the limitation when thinking about the problems, for example, some important issues that might also have significant impact on the water shortage problems in the Beijing-Tianjin-Hebei Region, but because the author has the shortage of the understanding of those issues, those are not taken into account in this thesis, as mentioned in chapter 5. Those problems should be solved by others in the future.

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