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Kui Wen
Erjuan Zhu *Editors*

Report on Development of Beijing, Tianjin, and Hebei Province (2013)

Measurement of Carrying Capacity and Countermeasures

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General Report

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Basic Situation of Carrying Capacity of Beijing, Tianjin, and Hebei Province and Development Countermeasures

Kui Wen, Erjuan Zhu, Guixiang Zhang, Tanglin Ye, Qingling Wu, and Hui Zhu

1.1 Research Background and Multiple Perspectives

1.1.1 Background

Globally – The contradiction between the human pursuit for a higher standard of living and the limited resources and environmental carrying capacity of the Earth is growing progressively. With the rapid development of industrialization and urbanization around the world, the development of mega-cities and metropolitan regions has become an irresistible trend. With rapid growth of urban population and rapid expansion of quantity and size of cities, resource environment of cities and regions is facing increasing pressures and serious challenges. In particular, in the context of the global climate crisis, whether development of cities and regions can adapt to the carrying capacity of resources and environment is at stake.

China – In the face of a severe situation of tight resource constraints, serious environmental pollution and ecosystem degradation, achieving sustainable development is a vital objective for its ecological civilization. After the 18th National People's Congress, promoting the construction of an ecological civilization is regarded as a priority for economic and social development to actively promote the transformation of the development mode.

Beijing-Tianjin-Hebei region – There are increasing pressures on the regional resource and environment so that we urgently need to set the foundation, and then explore the valid method to ease the pressure and to enhance carrying capacity. The "Twelfth Five-Year Plan" period is an important phase for Beijing-Tianjin-Hebei

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region to accelerate economic restructuring, industrial upgrading, and to build world-class technology innovation base, advanced manufacturing research and development transformation base, and heavy chemical industry base, and a crucial period of regional industrial integration, spatial optimization, urban and rural integration, eco-building and constructing a city agglomeration with more international competitiveness. With the mass gathering of the modern industry, especially the chemical industry, in coastal areas, the pressure of regional resource and environment is increasing; with the accelerated process of urbanization, more and more population flow into mega-cities such as Beijing and Tianjin, which has brought enormous pressure on urban transportation, resource ecology, and public services. We urgently need to make a basic judgment about the carrying capacity of Beijing-Tianjin_Hebei region, and need to explore effective methods to ease the pressure and to enhance the carrying capacity at the foundation.

1.1.2 Multiple Perspectives

In today's norm of global low-carbon development, the ecological civilization in China is regarded as an objective of sustainable development for the Chinese nation, as well as Beijing, Tianjin, and Hebei, to build eco-livable homes under the guidance of the concept of scientific development, we believe that, when researching and estimating the carrying capacity of a city or a region, and exploring the method of "decompression and increasing capacity," it is necessary to expand the field of research. We not only need to integrate a single element with carrying capacity, urban carrying capacity combined with regional, but also integrate practical carrying capacity with the potential capacity, and absolute capacity and relative capacity. These new perspectives and new understandings help us to grasp the nature, to understand the rule, to broaden our horizons, and to tap into the potential, which provide theoretical guidance for the realization of regional harmonious development between man and environment.

About the studies from carrying capacity of a single element to integrated carrying capacity. Evolution of the concept of carrying capacity experienced the development course from the community carrying capacity, the resource carrying capacity and the ecological carrying capacity to the integrated carrying capacity (See Table 1.1), because the human depends not only on the natural ecological environment, but also complex environments supported by the artificial environment system and socio-economic system. Therefore, it is necessary to expand the studies from a single-element carrying capacity to integrated carrying capacity. Integrated carrying capacity refers to the carrying capacity of a city or a region's natural resources, ecological environment, infrastructure, and social facilities for economic and social activities and urban population. It consists of the carrying capacity of the natural environment and the carrying capacity of the artificial environment, both in regards to the population and it's socio-economic activities, and are influenced and constrained by the socio-economic support system. As for today's large cities, particularly metropolitans, research on single-element natural

Table 1.1 Evolution of the concept of carrying capacity

Name	Background	Meaning
Community carrying capacity	Ecology development	Bearable quantity of ecosystem for communities living in it
Land carrying capacity	Population expansion, shortage of land resources	Productive capacity of land resources in a region, as well as bearable population under certain conditions
Carrying capacity of water, minerals and other resources	Shortage of water, minerals and other resources, population growth, surge in industrial water	Bearable population of water and other natural resources in a region, bearable strength of industrial and agricultural production activities of water and other natural resources in a region
Carrying capacity of environment	Environmental pollution	Holding capacity of regional environmental for pollutants, bearable strength of a regional environmental for human development activities
Carrying capacity of ecology	The integrity of ecosystem damages, functions reduces	Bearable maximum socio-economic activity strength or interference limit of ecosystem
Complex carrying capacity	"Urban disease" of mega-cities	Natural resources and environment, economic and social resources and environment form a complex, multi-level ecosystem; and "human-land system" are opposites

Source: The table is compiled on the basis of precursors' research findings

carrying capacity is clearly not enough. For example, a storm in Beijing on July 21, 2012 exposed the vulnerability and weakness of the urban infrastructure in Beijing – the limit of the carrying capacity of the underground pipe network, which warns us about the city security. Only when perspectives of research expand from the natural carrying capacity to a comprehensive one can our vision, means, and methods to find and solve problems be wider and more in line with the actual development.

About the studies of the carrying capacities from cities to regions. We paid more attention to studies on carrying capacity of a single city in the past, which was necessary at the early stage of single city development. But at the present day of economic globalization and regional economic integration, global resource allocation has changed, and any city is a component part of the urban system in the world, and a highly open system. A city owns limited resources, but through opening to the outside world and exchange, it can obtain and share resources from other regions to achieve sustainable development. Particularly like the capital Beijing, the ultra-mega-city with a population over ten million where it is difficult to bear the burden of its resources and ecological environment, it really needs to have wide regional visual field, and needs to put urban development in a larger region. It is possible for the pressure of a city to be mitigated in a larger region; it is expected that its own "short board" of resources and environment can be extended in a region; it is possible for surrounding areas, with its own resource advantages, to become its resources through functions complementation.

About studies from absolute carrying capacity to relative capacity. The relative carrying capacity can be studied through setting targets of carrying capacity and looking at the relationship between supply and demand of carrying capacity. In the same conditions of resource ecological environment and socio-economic and technology, relative to the different standards of per capita consumption and given life goals, different resources and environments bear different population sizes. "The maximum number of people the earth can support" is very different from "the maximum quality for the people on earth." The former only meets the basic standard of existence, and the latter meets the ideal or optimal goal, such as wealth and environmental livability, and so on. Similarly, from the point of view of supply and demand of resources and environment, the smaller the population size and economic and social activities as carrying objects are, the smaller the fixed carrying pressure of resources and environment is, the stronger the relative carrying capacity is.

About the studies from practical carrying capacity to potential capacity. Practical carrying capacity can be measured according to the "Barrel Theory." If the amount of water in the barrel depends on the shortest slab of the barrel, practical carrying capacity of cities or regions is measured by a minimum practical carrying capacity in individual resources and development conditions, and potential capacity can be obtained through change of impact factors, remedy of the "short board" and then upgrade urban integrated carrying capacity. In fact, there is potential carrying capacity in real life. For instance, through technological progress and efficient use of land, the original land carrying capacity for the population can be greatly improved. If analysis and measure of practical carrying capacity of cities or regions are the important prerequisite to grasp the current status and trends and to find the "short board" of carrying capacity, it is more important for us to attach importance to the studies of potential carrying capacity. We can discover, explore and release potential carrying capacity through analysis of various influencing factors of carrying capacity of resources and environment, and can find an effective way to solve the difficult problems, to break through bottlenecks, to mitigate the pressure, and to improve the carrying capacity.

1.2 Analysis Framework and Indicators to Measure

1.2.1 Theoretical Basis

Mechanics theory – the mechanics theories involved in the studies on carrying capacity include theories of statics in classical mechanics, structural mechanics, fluid mechanics, mechanics of materials, soil mechanics, and rock mechanics, and other sub-disciplines. Among them, the statics mainly concerns how to set up equilibrium conditions of various systems of forces in the system under static conditions. Structural mechanics mainly solves the law of stress and transmission of carrying structural system, as well as how to optimize the existing carrying structure. Fluid dynamics mainly focuses on the law of motion of comprehensive carrying factor in variable conditions.

Ecological theory – ecology is the science of the relationships between organisms and their environments. Its development has manifested three main characteristics: from qualitative studies to quantitative studies, from individual ecological systems to complex ecological systems, and from basic science to applied science. The basic theories about ecology include biological environment, ecological factors, the succession of biotic communities and the ecological system theory.

Economic theory – the application of economic theories in the carrying capacity is mainly manifested in the application of the bifurcation theory in economics including development economics, regional economics, population economics, and environmental economics. Many environmental problems can be described by economic terms, such as allocation of scarce resources, allocation of risks and benefits, competitive benefits, and so on, as well as a lot of environmental damage is also due to economic factors. The economic theory is applied to study the carrying capacity mainly to solve how scarce resource environments and artificial environments achieve the optimum allocation and effective utilization in the development process of cities or regions, and how economy, society and ecology achieve their harmonious development.

Sociological theory – sociology is strongly integrated humanities, is concerned with systems, groups, psychology, security, and structure of human society. The sociological theory is applied in studies on carrying capacity to mainly discover characteristics of social activities of regional social groups, such as behaviors, norms, practices, psychology, and structure and the intrinsic mechanism of influencing the carrying capacity, and effective ways to settle how to mitigate the pressure through changes of influencing factors, such as advances in science and technology, lifestyle, values, social systems, to enhance the carrying capacity.

1.2.2 Analytical Framework

This paper argues that, theoretical analytical framework of integrated carrying capacity of a city or region can consist of carrying objects, the carrier, and external environment. Carrying objects mainly include population size, consumer pressure, human socio-economic activities, and pollutants. The carrier consists of two parts, the carrying capacity of the natural environment and of the artificial environment. Carrying capacity of the natural environment consists of the natural resources system and eco-environmental system; the system of natural resources includes land resources, water resources, mineral resources, and forest resources; eco-environmental system includes air, water, soil, and biological species. Carrying

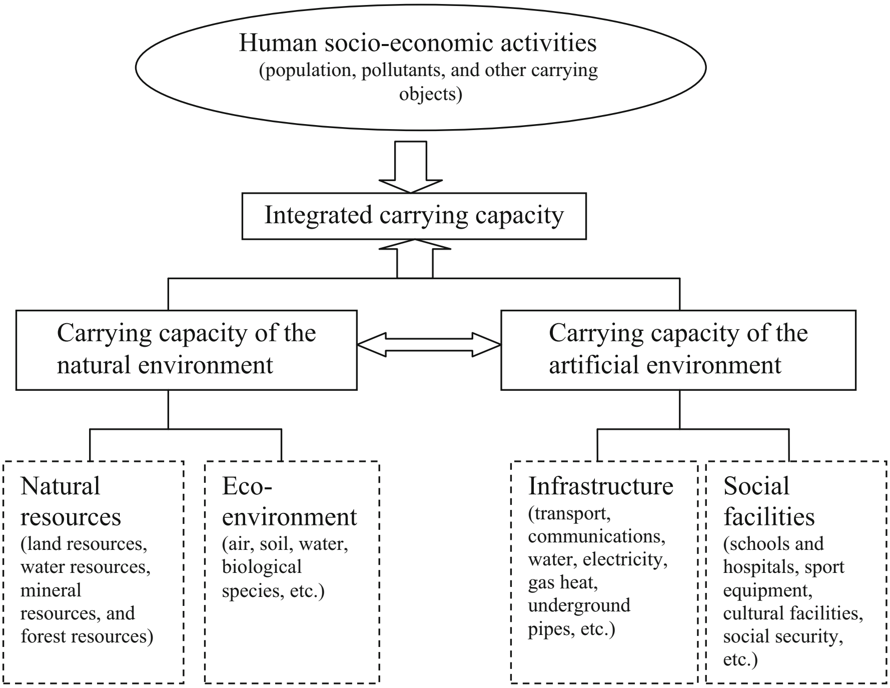

Fig. 1.1 Structure of integrated carrying capacity

capacity of artificial environment consists of infrastructure (such as transport, communications, water, electricity, gas heat, underground pipes, etc.) and social facilities (such as the facilities of science, education and culture and health, including schools and hospitals, public services, social security, etc.). The external environment is the economic and social support system. Whether the carrying capacity of natural environment is the first environmental carrying capacity and the carrying capacity of artificial environment is the second one, all are in economic and social development conditions and environments, and are influenced and constrained by economic hard factors (such as GDP, per capita GDP, financial revenues, etc.) and social soft environment (such as system, culture, management, etc.). See Figs. 1.1 and 1.2.

1.2.3 Interrelation

First one is the relationship of carry and carried and of action and reaction between the carrying capacity of natural environment and the carrying capacity of artificial environment within the carrier. The carrying capacity of the natural environment is also called the first environmental carrier, is the basis of sustainable development of

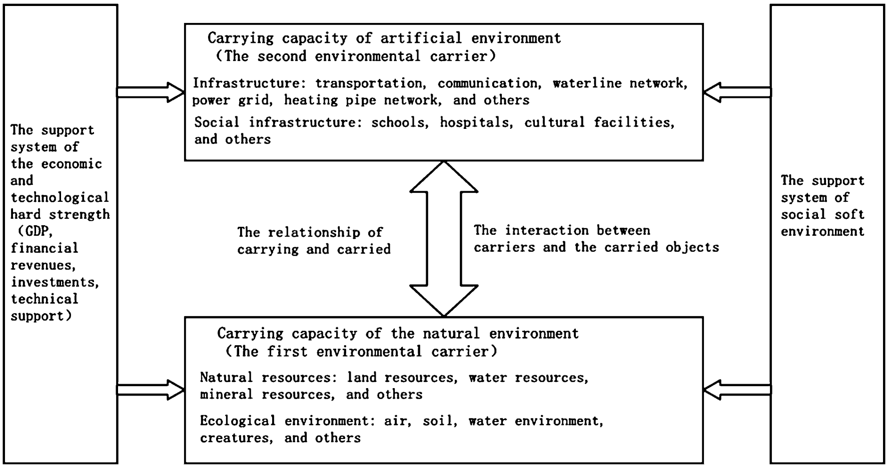

Fig. 1.2 The relationship between carrying capacity and social and economic support system

cities and regions, and it decides the direction, scale, and speed of human activities. The carrying capacity of artificial environment is also called the second environmental carrier, is the indispensable carrier for the normal operation of the human economic and social activities. Carrying capacity of artificial environment has carrying capacity for carrying objects (such as population size, consumer pressure, pollutants, and human socio-economic activities), and has some pressure on the carrying capacity of the natural environment; it is restricted and influenced by the carrying capacity of the natural environment, and its development reacts to the carrying capacity of the natural environment and human economic and social activities.

Second one is the interaction between carriers and the carried objects. Natural and artificial environmental carrying capacities together compose the integrated carrying capacity of a city or region, and jointly support cities, regions, countries, their population, and their socio-economic activities. The carrier and carried objects actually have a supply and demand relationship. The basic path of harmonious development between carrier and the carried object can be found through enhancing the carrying capacity and alleviating the pressure.

Third one is the interaction between the carrier and the external environment. Both the carrying capacity of the natural environment and the carrying capacity of artificial environment is influenced and constrained by it. They are both dependent on the economic and social support system, and are influenced and constrained by the economic and technological hard strength (such as GDP, financial revenues, investments, technical support, etc.) and the social soft environment (such as systems, culture, management, etc.). In general, the stronger the economic strength of a city or region is, the stronger the carrying capacity of the artificial environment. The higher the level of social development is, the stronger the people's consciousness of protecting the environment and energy conservation, and the lower the resource consumption and the environmental pollution.

1.2.4 Indicators to Measure

Integrated carrying capacity of a city or region is composed of a series of self-checks and corresponding development variables and constraint variables: (1) Natural resource environment variables: type, quantity and development capacity of land resources, water resources, mineral resources, and biological resources, as well as self-purification capacity of water, gas, and soil; (2) Artificial environment variables: transportation, communications, and underground pipe network, and other infrastructure variables; school, hospital, social welfare, public service facilities, and social facility variables; (3) Variables of economic and social conditions: population, per capita GDP, per capita disposable income and other economic variables, as well as education of science and technology, system management, cultural awareness and other social variables. If the objects we study are the first two variables, the carrying capacity, the variable of economic and social conditions is an indispensable factor to influence the carrying capacity. This study focuses on six elements of carrying capacity, namely land, water resource, ecological environment, population (object carried), transportation, and other infrastructure, social facilities such as science, education, culture and health, as well as economic and social influencing factors. This study regards the above three variables, namely natural resource environment variable, artificial environment variable, and variable of economic and social conditions as the Level-I indicators, regards the six factors focused on as Level-II indicators, and respectively selects some indicators that can reflect the development variables (namely supply support) and constraint variables (demand pressure) as Level-III indicators, so as to compose the measuring indicator system of integrated carrying capacity. See Table 1.2.

1.3 Analysis of the "Short Blab" of Carrying Capacity in Beijing, Tianjin and Hebei

This study has respectively made empirical analysis to land, population, water resources, ecological environment, infrastructure and social facilities of Beijing, Tianjin and Hebei, and integrated carrying capacity analysis of Beijing, Tianjin and Hebei using integrated carrying capacity evaluating indicators, and has found that the carrying capacity of Beijing, Tianjin and Hebei follows the "short board," which urgently needs to be resolved.

Table 1.2 Evaluating indicator system of integrated carrying capacity of cities and regions

Level-I indicators	Level-II indicators	Indicators of reflecting supply and demand	Level-III indicators	Measurement unit
Carrying capacity of natural resource environment	Carrying capacity of land	Pressure	Population density	Person/sq.km.
			Per capita residential land area	sq.m./person
			Per capita industrial land area	sq.m./person
			Per capita dwelling space	sq.m.
			Land area required GDP per hundred million RMB	sq.km./a hundred million RMB
			Per capita area of land used for building	sq.m./person
		Supporting capacity	Regional land area	sq.km.
			Per capita built-up area	sq.m./person
			Per capita arable area	sq.m./person
			Proportion of unused land	%
			Per capita land area	sq.km./person
			Building floor area ratio	
	Carrying capacity of water resources	Pressure	Per capita water consumption	cu. m./person
			Water consumption of farmland per Mu	cu. m./Mu
			Unit GDP water consumption	cu. m./Mu
		Supporting capacity	Per capita fresh water resources	cu. m./person
			Annual rainfall-water resources	A hundred million cu. m.
	Carrying capacity of eco-environment and energy sources	Pressure	Annual per capita domestic refuse discharge	kg./person year
			Water consumption of ten thousand RMB GDP	cu. m./ten thousand RMB
			Unit GDP energy consumption	ton/ten thousand RMB GDP
			Non-fossil energy proportion	%
		Carrying capacity	Per capita green area	sq.m.
			Built-up area green area percentage of coverage	%
			Percentage of treatment of domestic sewage	%
			Percentage of waste innocent treatment	%

(continued)

Table 1.2 (continued)

Level-I indicators	Level-II indicators	Indicators of reflecting supply and demand	Level-III indicators	Measurement unit
			Percentage of number of good days of city zone at level-II air quality above	%
			Proportion of self-generated energy in current drain (%)	cu. m./person
			Proportion of environment treatment investment in GDP	%
Carrying capacity of artificial environment	Carrying capacity of infrastructure	Pressure	Gross volume of passenger traffic	Ten thousand person-times/year
			Gross freight amount	Ten thousand ton/year
			Unit GDP annual gross freight amount	ton/ten thousand RMB
			Unit area traffic flow	Vehicle/ha.
			Quantity of cars per hundred households	Vehicle/hundred household
			Illegal road use rate of vehicles	%
		Supporting capacity	Urban per capita valid traffic land use area	sq.m./person
			City zone underground mileage density	km/sq.km.
			Car park area density	km^2/sq.km.
			Per capita overall railway mileage	km./ten thousand persons
			Per capita overall highway mileage	km./ten thousand persons
			Urban ponding space density	M^3/sq.km.
			Percentage of urban ponding domain coverage	%
			Urban drainpipe density	km./sq.km.
	Carrying capacity of social facilities	Pressure	Number of students in general colleges and universities	Ten thousand persons
			Proportion of aged population in total population	%
			Percentage of social security coverage	%

(continued)

Table 1.2 (continued)

Level-I indicators	Level-II indicators	Indicators of reflecting supply and demand	Level-III indicators	Measurement unit
		Supporting capacity	Per land employed population and job vacancy	Person/ha.
			Sickbed amount per ten thousand persons	Piece/ten thousand persons
			Number of qualified doctor and nurses per thousand population	Person/thousand persons
			Possible quantity supplied 9-year compulsory education	Ten thousand persons
Economic and social support system	Economic hard strength and social soft environment	Influencing factors	Population size	Ten thousand persons
			Gross GDP	A hundred million RMB
			Per capita GDP	Ten thousand RMB/person
			Per capita disposable financial revenue	Ten thousand RMB/person
			Gross investment in fixed assets	Hundred million RMB
			Proportion of R&D funds in GDP	%
			Number of doctors per thousand person	Ten thousand persons
			Proportion of job-age population in total population	%
			Number of jobholder at end of the year	Ten thousand persons
			Proportion of employed population in total population	%
			Number of college students in per hundred thousand persons	Person
			Number of technologists in ten thousand persons	Person
			Per capita educated fixed number of year	Year
			Annual quantity applied and approved for patents or inventions	Piece

1.3.1 Water Resource Has Become the Biggest "Short Board"

Beijing, Tianjin and Hebei belong to "resource-based" water shortage areas, where per capita water resource is far below the severe water shortage standard accepted internationally. According to findings of research fellow Shi Minjun of the Chinese Academy of Sciences (see the 5th monographic study in this book), Beijing's total water resources was 2.681 billion m^3 in 2011, in accordance with the 20.19 million resident population at the end of 2011, adding about 2.4 million in floating population, per capita share of water resource in Beijing was only 119 m^3, which is far below the severe water shortage standard per capita share of water resources 500–1,000 m^2. (Beijing Municipal Bureau of Water Affairs, 2011). Tianjin's per capita shares of water resources was only 116 m^3. Water resource in most of the municipal districts of Hebei province also faces shortage, and per capita share of water resources is below the severe water shortage international standard. See Fig. 1.3.

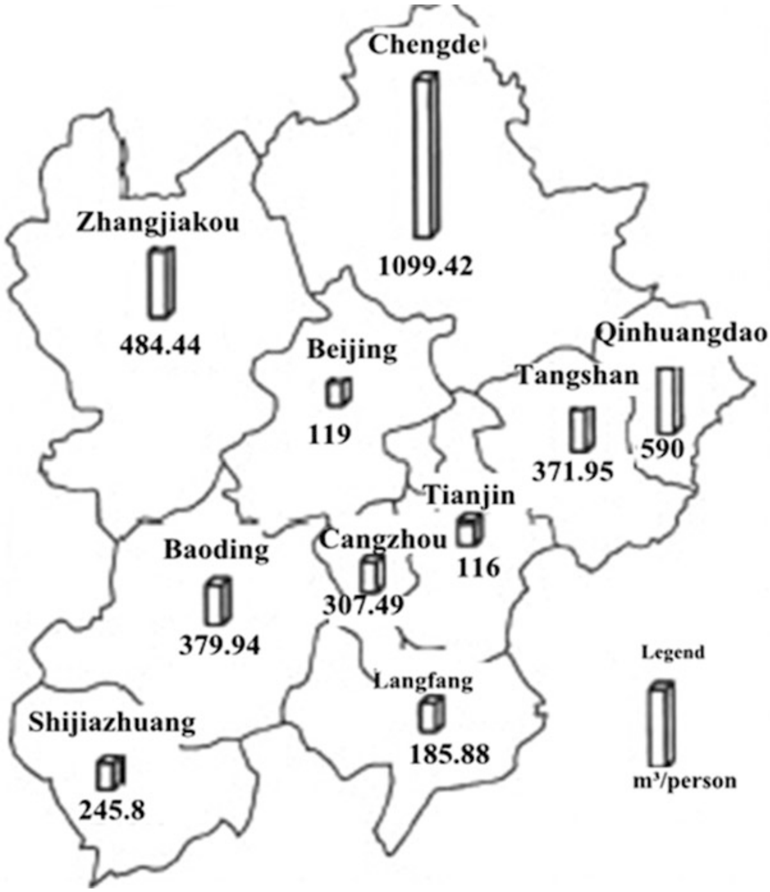

Fig. 1.3 Water resources per Capita in Beijing, Tianjin and Hebei

Water resources in Beijing, Tianjin and Hebei have “two gaps”: one is the gap between local water resources and actual water supply volume; another is the gap between actual water supply volume and the actual water demand. The former is mainly made up through interregional water diversion and groundwater overflow; the latter is mainly solved through net inflow of virtual water outside the region. From the perspective of supply, Beijing’s average amount of water resources was 2.3 billion m^3 for many years, but total amount of water consumption in recent years is about 3.5 billion m^3, in which the gap of water utilization is about 1.2 billion m^3; Tianjin’s amount of water resources was about 1.2 billion m^3 on average, water consumption is about 2.3 billion m^3 in recent years, in which water shortage is about 1.1 billion m^3, and the gap is made up mainly through groundwater overflow and water transfer from neighboring provinces. From the perspective of demand, water consumption of a region actually consists of two parts: one is from “visible” water resources, local water resources, and interregional water diversion; another is the flow of “invisible” virtual water from inter-regional trade in goods and services. Some experts characterize actual demand for water with water footprint. The water footprint of Beijing was 5.748 billion m^3 2007, and 3.152 billion m^3 in Tianjin, in which local amount of water resources was less than half of the water footprint, and actual supply of water was less than the water footprint (water demand). The gap was made up mainly through the net inflow of virtual water from outside the region.

Existing population size of both Beijing and Tianjin has been severely more than the supportable reasonable scale of local water resources. Beijing’s per capita demand of water resources is about 345 m^3, and Tianjin’s per capita demand of water resources is about 279 m^3. From this calculation, Beijing’s local water resources can only support 6.67 million people, which is equivalent to 40 % of the existing population scale; water resources of actual water supply can support about ten million people, which is equivalent to 60 % of the existing population scale; Tianjin’s local water resources can only support 4.31 million people, which is equivalent to 38 % of the existing population scale; water resources of actual water supply can support about 8.39 million people, which is equivalent to 74 % of the existing population scale. This shows that the local amount of water resources in Beijing-Tianjin-Hebei is difficult to support water demand of existing population size and economic and social development.

Although total amount of water resources in Beijing, Tianjin, and Hebei increased, and water consumption slightly reduced in recent years, there is still a serious situation of the groundwater overdraft. According to findings of Professor Wu Yiqing et al. (see the fourth special report in this book), in total water consumption in Beijing-Tianjin-Hebei region, groundwater accounted for 78.47 %, water consumption for agriculture accounted for 71.49 %, 14.55 % for industry, and 18.36 % for domestic water. Relative to average volume of water resources for many years, water resources in Beijing, Tianjin and Hebei region since 2006 have showed an increasing trend due to the growth in volume of rainwater resources, actual water consumption also showed signs of decrease due to structural adjustment and water and energy conservation and other measures, but there is serious groundwater overdraft so that the groundwater depth has increased. According to the data from “Monthly Report on Groundwater Regime in the Plain Terrain of North China” issued by the Ministry of Water Resources in early July 2012, groundwater depth in most of the plain terrain of Beijing was 12–50 m, 1–8 m in Tianjin, on average 12–50 m in Baoding and Shijiazhuang areas of Hebei, and more than 50 m in some parts. In comparison with the same period in 2011, most groundwater depth increased, and groundwater reserves reduced.

1.3.2 Atmospheric Pollution and the Water Environment Has Become an “Achilles Heel”

Ongoing fog and haze exposed a serious problem of air pollution in Beijing, Tianjin, and Hebei. In early 2013, in regions that continuously suffered serious haze and fog, as a result of severe air pollution, the most serious situation was in the Beijing-Tianjin-Hebei region; Beijing, Shijiazhuang, Baoding, Handan, Tianjin, Cangzhou, Langfang, Tangshan, and other cities all issued heavy fog orange warning. Increase of fog and haze reflects worsen air quality and an aggravating hazard.

Urban surface water and groundwater sources are polluted in varying degrees, and the carrying capacity of water to the pollution is close to limit. On one hand, Beijing, Tianjin, and Hebei lack freshwater resources, on the other hand, the water quality worsens because urban surface water and groundwater sources are polluted in varying degrees; some reservoirs have had a phenomena of eutrophication, and show an increasing trend; the number of aquatic animals has obviously decreased in big basins. Because construction of the sewage plants and associated pipelines lag behind, carrying capacity of water body to the pollution is close to limit.

Rapid expansion of the population has largely increased domestic waste of big cities so that “garbage encircles a city.” Taking Beijing as an example, in 2009, the city’s domestic waste reached 6.69 million tons, and produced 18,300 t every day, but the city’s waste treatment capacity is only 12,700 t/day, in which there is a large gap. The main reason is low level of waste reutilization, insufficient recycling, and unreasonable waste treatment structure (mainly landfill, incineration, and very low percentage of biochemical treatment) in Beijing. According to present waste output and landfill speed, most of the city’s landfills will be filled in 4–5 years.

Soil erosion, desertification, sandstorm, and ecological degradation coexist. With the accelerated pace of population expansion in recent years, the natural environment in the Beijing-Tianjin-Hebei region sharply worsens. Soil erosion mainly occurs in east Taihang Mountain and Yanshan Mountain in the west and north and windy weather in North Hebei province largely influences Beijing and Tianjin because resource-depletion development mode of excessive land reclamation and overgrazing have resulted in serious damage of grassland and vegetation, and the natural environment has been caught in a vicious circle. Some industry-dominated urban "ecological overshoot" produce a lot of wastewater, waste gas, and solid waste emissions due to rapid industrial development, resulting in air pollution, and environmental degradation, which damages the ecosystem.

Development of the regional ecological carrying capacity is unbalanced, and Hebei's eco-environment basis is fragile. Beijing's green ecological construction started early, with a high starting point and fast development, and has upgraded from the pursuit of "green" to "beautiful"; Tianjin has good economic base and a large wetland, which has obvious ecological environment advantage; in contrast, Hebei province has obvious gap in green ecological construction due to poor economic strength, such as a low overall green level, insufficient total forest resources, unbalanced distribution, and low quality; there is a large area of sandy land and soil erosion, sharp reduced wetland area, and greatly depressed ecological role of wetland. Beijing and Tianjin also have the same problem.

1.3.3 Overload of Urban Traffic Carrying Capacity, Arduous Mission of Flood Control and Disaster Reduction

Traffic jams have become an outstanding problem that affects the city operating efficiency and the livelihood of residents in Beijing. Due to an excessive concentration of functions in Beijing, "imbalance between vocation and living" causes huge traffic pressures in downtown and tidal traffic flow is obvious. In addition to huge population density, rapid growth of motor vehicle ownership, high convergence of functional zones, unbalanced development of north and south city zones, excessive concentration of good public resources such as schools and hospitals, etc. and large coefficient of variation between vocation and living, low rail traffic density, limited capacity of tridimensional high-speed roads, chaotic parking of non- moving vehicles and random occupancy and use of roads also contribute to traffic jams in Beijing.

The carrying capacity of traffic infrastructure has been severely overloaded in Beijing, and carrying capacity of transit traffic has been saturated. If you simply compare the carrying capacity of traffic infrastructure, then the three metropolitan areas in China, Beijing, Tianjin, and Hebei are ranked first, and Beijing is ranked first in the Beijing-Tianjin-Hebei region, but relative to demand pressures of traffic facilities, Beijing's traffic carrying capacity is seriously overloaded. Motor vehicle ownership has grown rapidly since 2000, peak hour traffic of motor vehicles has seriously surpassed the carrying capacity of urban roads, and transit traffic carrying capacity has been saturated. See Fig. 1.4.

Urban water storage space is limited, drainage facilities have hidden trouble, and flood control and disaster reduction tasks are arduous. A city's major disasters include flood, fire, forest fire, mudslide, earthquake, stampede, pollution exposure, and so on. Beijing's "July 21 flood" in 2012 exposed the limited water storage space in the city, and vulnerable drainage facilities have become the bottleneck affecting urban security.

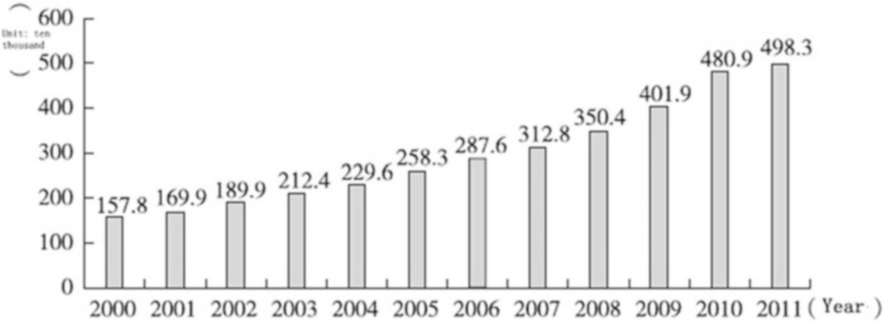

Fig. 1.4 Growth trend of motor vehicle possession (unit: ten thousand)

1.3.4 Continued Increase in Population Size and Aging Structure, Increased Pressures of Public Services and Social Security

Immigration to the megacities continues to increase. Through comprehensive survey to the data in the recent ten years, we discover that, natural population growth was slow in Beijing-Tianjin-Hebei region, natural growth rate of population in Beijing and Tianjin was less than 4 %, and less than 7 % in Hebei province. The immigration increase in Tianjin and Beijing areas is the main reason to the population growth in Beijing-Tianjin-Hebei region. According to future population prediction in Beijing, Tianjin and Hebei by Professor Zhang Yaojun, Renmin University of China (See the second special report in this book), Beijing's net immigration growth is maintained around 500,000 since 2006, assuming that Beijing's net immigration size keeps constant (500,000) every year or continuously increases (calculating by 700,000) in 2010–2020, Beijing's population will be 25.06 million and 26.18 million respectively in 2020. Similarly in Tianjin, Tianjin's net immigration was on average 513,000 each year in 2006–2009, assuming that Tianjin's net immigration size is maintained at 500,000 in 2010–2020 each year or continuously increases (calculating by 700,000), Tianjin's population will be 19.36 million and 19.45 respectively in 2020. By 2020, total population in Beijing-Tianjin-Hebei region will be from 116.8 million and 121.37 million. If considering possible-satisfaction, the following results may appear: if possible-satisfaction is 0.6, considering various indicators (including economy, society, natural resources, etc.) that affect population can be met synchronously, the population carrying capacity in Beijing, Tianjin and Hebei region will be 86.2 million people in 2015; considering mutual compensation in internal factors, the population carrying capacity in Beijing, Tianjin, and Hebei region will be 98.07 million people; considering mutual compensation between all elements, the carrying capacity of population in Beijing-Tianjin-Hebei region will be 101.83 million. But total population reached 104 million in Beijing-Tianjin-Hebei region in 2010, therefore population size has overloaded.

Population structure is aging. Through analysis of the regional population structure, percentage of job-age population in Beijing-Tianjin-Hebei region has dropped from 77 % in 2010 to 73 % or 72 % in 2020, the population of children and juveniles (0–14 years old) and aging population (65 years old and over) are a growing trend, which shows increasingly serious aging because the growth of the aging population is significantly faster than the growth of children and juveniles.

The pressure of public services and social security is increasing. Although the job-age population proportion drops in Beijing, Tianjin and Hebei region, absolute number of labors is sufficient since most immigration to Beijing and Tianjin is job-age young adults. It is estimated that, by 2020, labor supply in Beijing-Tianjin-Hebei region will be 84.73–87.94 million, which indicates that Beijing and Tianjin can still enjoy labor bonus over a period under the background of China's accelerated urbanization and transfer of a large number of farmers from rural area to urban area. On the one hand, the labor supply maintains sufficiency in Beijing-Tianjin-Hebei region, and the employment situation remains severe, on the other hand, aging is intensifying, and the pressure of public services and social security is increasing. Therefore, solving the issues of employment in the working population and "age before it gets rich" has become a key part of future development in Beijing-Tianjin-Hebei region.

1.3.5 Tension in Urban Land Space Grows, and the Conflict Between Land Used for Building and Basic Farmland Protection Becomes Sharp

Population density of mega-cities continuously increases so that the contradiction between people and land has become increasingly prominent. In 2011, resident population reached 20.186 million in Beijing, and population density increased from 766 persons/km^2 in 1999 to 1230 persons/km^2 in 2011; continuous decrease of per capita land use area and per capita area of land used for building reflects continuous increase of population bearing pressure of land resources in Beijing. See Fig. 1.5.

The conflict between land used for building and basic farmland protection becomes sharp. With social and economic development and the advancement of urbanization, the strength of land development and construction is growing. As shown in Fig. 1.6, the proportion of Beijing's area of land used for building in total area is on average increasing by 0.4 % every year, but per capita tillable field is continuously reducing. Beijing has extensive mountainous areas, and land used for ecological purpose has big demand, therefore, potential land resources have been very limited.

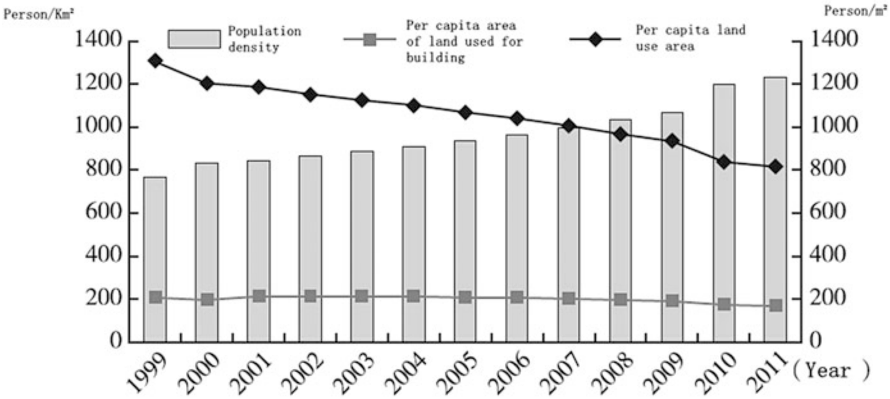

Fig. 1.5 Population density and growth of tension in urban land space of Beijing from 1999 to 2011

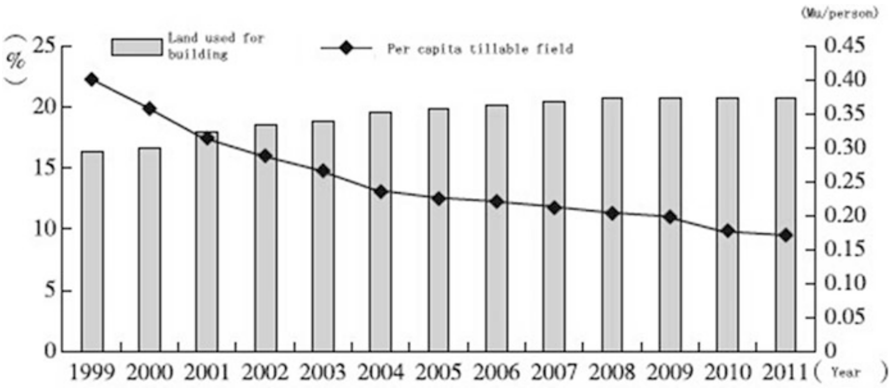

Fig. 1.6 Proportion of Beijing's area of land for building in total area (per capita)

Land resources in Hebei province have still bigger potential for development. Hebei's total land area is 187,693 km^2. Though Hebei's population density also continuously increased from 328 persons/km^2 in 1990 to 386 persons/km^2 in 2011, and per capita land use area also constantly declined from 3,047 m^2/person in 1990 to 2,592 m^2/person in 2011, in comparison with Beijing and Tianjin, its population density is relative smaller, per capita land use area is relative larger, and its land resources has still bigger potential for development (See Fig. 1.7).

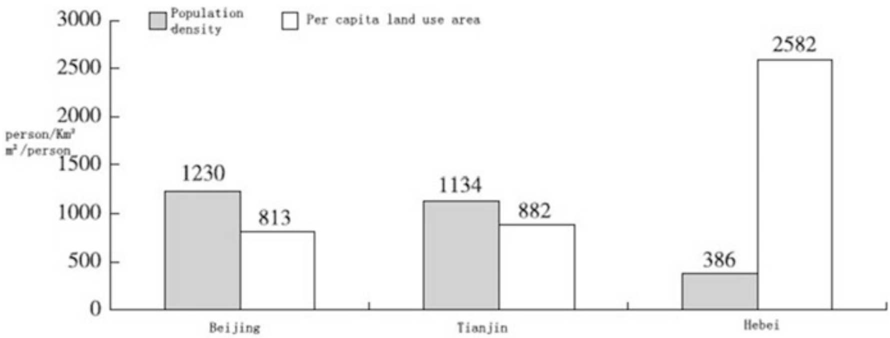

Fig. 1.7 Population density and land use per Capita in Beijing, Tianjin and Hebei

1.4 Methods and Countermeasures of Improving the Carrying Capacity of Beijing-Tianjin-Hebei Region

1.4.1 General Thought: Exploring the Ways Around "Energy Increase and Pressure Reduction"

As evident in our analysis above, carrying capacity of any city or region is subject to the influence of supply supporting capacity and demand pressures. By some measures, reducing pressures on demand means relative enhancement of supply supporting capacity. We can start from both supply and demand of carrying capacity to explore the valid ways of energy increase and pressure reduction. We can enhance the regional carrying capacity through many ways, including improve performance and efficiency by tapping into the latent power through progress of science and technology, by making up the investment in the short board, by regional complementary capacity expansion, and by opening the region wider to the outside world and energy gathering; we can also mitigate the pressure on resource and environment through mitigation of city functions, transformation of the development mode, optimization of space layout, and improvement of management level (See Fig. 1.8).

1.4.2 Fundamental Ways: Optimizing Urban Spatial Layout, Building a Low-Carbon, Ecological and Green House

To give priority to advancing urbanization, speeding up construction of new cities, and building scientific and rational pattern of urbanization that big, medium, and small cities coexist and interact. Practices and development of big cities domestically and abroad prove that excessive expansion of big city size and excessive

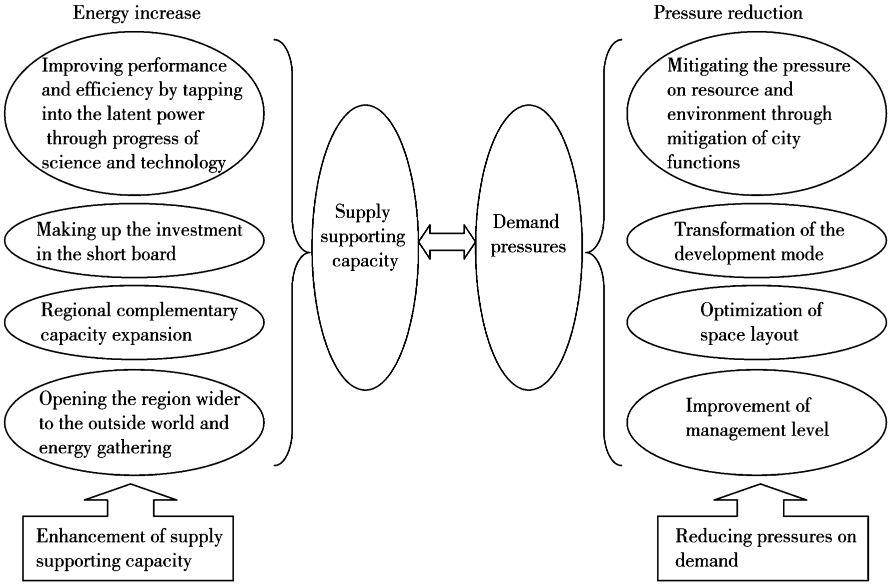

Fig. 1.8 Regional carrying capacity's influence of supply supporting capacity and demand pressures

concentration of urban functions can result in "big city disease" including traffic jam, environmental degradation, tight housing and excessive pressure of public services, and so on, thus the bearing pressure of central cities is generally mitigated through construction of new cities domestically and abroad. For actual development of Beijing-Tianjin-Hebei region, on the premise of scientific planning, in the course of promoting strategy of country principal function area and regional integration, the construction of small cities and towns should be actively promoted, particularly construction of new cities around metropolis and development of medium and small cities should be sped up to strengthen their industrial development, public services, employment attraction, and population aggregation function. In this way, chaotic spread of the center city can be effectively restrained, some functions of the center city zone can be promoted and organically dispersed, and big cities' bearing pressure on resource environment would be mitigated; in the process of industrial transfer and upgrading, core status of center cities can be further strengthened, peripheral new cities and medium and small cities can be cultivated into multiple growth poles to drive economic and social development of the entire region through convergence, proliferation, and linkage effect of growth poles; spatial structure can be further optimized to promote intensive and high efficiency of production space, and livable moderate life space and beautiful eco-space according to the principles of balanced population resources and environment and the integration of economic and social ecological benefits. Thus more repair spaces can be left to nature, and a beautiful home of blue sky, green land, and clear water can be left to posterity.

To change the way of development, to develop a circular economy, and to build low-carbon, ecological, green houses. Changing the way of development and building a resource-saving and environment-friendly society are fundamental safeguards and radical prerequisite to achieve low-carbon, green, recycling, and sustainable development. Changing the way of development must start from the intensive use of land, and highly efficient use of water resources and energy. Although there is severe shortage of water in Beijing, Tianjin, and Hebei region, there is still untapped potential. According to the principle of economical use, optimum utilization of good quality water and recycle, we should achieve joint operation and optimizing regulation of water sources. The intensive use of land should be to guide rational distribution of industry and population based on regional differences of the intensity of land development, including insisting on industrial agglomeration, concentration of layout and highly effective utilization; full utilization of advantages of old town location and society, tapping land-use potential of old city zones, enhancing economic viability and land carrying capacity in old cities; at the same time, paying attention to the intensive utilization of new city land, and considering more economic use of land resources through the approach of "fertile backfill." By undertaking functions of central area, scientific planning and layout, improving public services, and so on, the attractiveness of new cities may be further enhanced. Development of a circular economy is to make comprehensive utilization of waste produced as a resource in accordance with the principles of "reduction, reuse, recycle" to achieve waste reduction, recycle, and harmlessness. In the social consumption link, green consumption should be strongly advocated. Promotion of green development is to speed up the urban green belt and regional forest ecological construction and perfection based on the current ecological environment situation of Beijing-Tianjin-Hebei region to provide a steady stream of "oxygen bar" and forest "carbon sink" for the Beijing-Tianjin-Hebei region, thus to achieve prevention and cure of regional pollution of air, water, and solid waste. Advancement of low carbon development is to promote industrial upgrading and change generation, and to gradually reduce the energy consumption per unit output value and water consumption. The proportion of new energy should be increased to achieve low carbon and clean utilization of energy. Low-carbon traffic, construction and consumption mode should be advocated to build a low-carbon society.

1.4.3 Countermeasures Suggestion: Taking Multi-pronged Approach for the "Short Board", and Upgrading Overall Efficiency of Regional Carrying Capacity

1. Developing carrying capacity of water resources from "raising sources" and "reducing expenditure"

"Raising sources" means water transfer, including both interregional water resource transfer and virtual water transfer of commodity-based trade; "reducing expenditure” refers primarily to the control of the growth of per capita water footprint or even to reduce the per capita water footprint, and the principal means including improving water use efficiency through the progress of science and technology, and adjusting industrial structure, consumption structure, and urban space layout.

As for Beijing, structural water-saving is significant for control of the water footprint growth and enhancing carrying capacity of water resources. Interregional water transfer such as north – south water transfer engineering will directly increase Beijing’s available water resource volume, but after all it is its supplementary water source; enhancing Beijing’s carrying capacity of water resources through technical progress and improvement of utilization efficiency of water resources has limited potential, and expected marginal cost will rise in different degrees; and structural water saving (including optimization of industrial structure, consumption structure and city spatial structure) has major significance for enhancing Beijing’s carrying capacity of future water resources. Industrial structure adjustment has played an important role in the control of Beijing’s water footprint growth, but water-saving effect of consumption structural adjustment is not yet fully realized. In order to achieve future economic development strategies and indicators of population control in the condition of existing water resources, Beijing needs to unceasingly promote industrial restructuring and optimization of consumption structure, and gradually build a water-saving industrial system. In the future, Beijing should pay more attention to strengthening the integration of infrastructure construction with peripheral areas, and promoting the spread and integration of industries and functions to surrounding areas.

Tianjin should place importance to the implementation of virtual water strategy; technical progress and structural adjustment are main ways to restrain the per capita water footprint growth. Building-up and water delivery of the “north – south water transfer” eastern line engineering has played a positive role in alleviating the shortage of water resources and enhancing the carrying capacity of water resources in Tianjin. Technical progress has made significant progress in the establishment of water-saving in Tianjin. It is possible for the steady development of epigenetic water utilization and seawater desalination technology to become new supplementary water source of Tianjin in the future. Through the adjustment of industrial structure and consumption structure in the future, restraining the growth of the water footprint has great potential. Tianjin should attach great importance to the virtual water strategy for the future, and should further expand the transfer of products from the sectors of higher water footprint content to enhance the carrying capacity of water resources in the future development of Tianjin.

As for Hebei and the whole Beijing-Tianjin-Hebei region, it is imperative and significant to optimize the allocation of regional water resources, and to establish a regional integrated water resources management system, including consummation of a basin water allocation program, gradual establishment of a water rights system and water conservation compensation system of trans-provincial rivers; construction of safe water sources protection mechanism, establishment of emergency response systems, implementation of emergency water supply mechanism of groundwater; implementation of a strict system of water resources management, establishment of three control red lines including controls of total utilization of water resources, water use efficiency, and limited pollutants of water function zones in the Beijing-Tianjin-Hebei region.

2. Focus on treatment of air pollution and water environment to reverse the deterioration of the ecological environment

Development of green, low-carbon, and a circular economy is a fundamental way. Green, circular, and a low-carbon economy should be actively developed, and should be integrated into the development planning of governments at all levels so as to form a spatial pattern, industrial structure, production mode and lifestyle of saving resources and protecting environment, which reverses the trend of deterioration in the ecological environment from the source to create a good living environment for the people.

Comprehensive measures should be taken to treat air pollution. For the cause that easily forms haze and heavy fog in the winter, a radical way is to take a drastic measure to reduce the intensity and concentration of pollutants in the region, including strictly controlling possession quantity of motor vehicles in Beijing, Tianjin, and other extra cities within the region, encouraging public transportation and other green models, and reducing exhaust emissions, encouraging purchase of new-energy car, improving oil quality, rigorously enforcing exhaust emission standard, focusing on living and industry supporting in city planning, reducing trip rate of urban population, and levying a high environment tax on trans-city zones and long-distance work, reducing urban invalid traffic; implementing the engineering of coal modifying into oil and coal modifying into gas for winter heating within region, encouraging concentrated heating and concentrated processing of heating exhaust and emissions, through industrial restructuring and upgrading, reducing emissions from industrial production, and so on.

Water environmental governance and testing should be strengthened, and the construction of regional joint defense and control mechanism should be enhanced. Water quality monitoring of water sites and main lakes and rivers should be strengthened; construction of urban rainfall and sewage diversion, sewage interception and diversion works should be strengthened; the sewage treatment rate and sewage network coverage should be increased. In terms of pollution control, the promotion of carrying capacity of eco-environmental improvement is also a big system where many links, domains, and sectors closely cooperate, which must establish joint defense and joint control mechanism.

Urban living environment should be improved to advocate a "green roof plan," and water saving project of ecological communities should be constructed to advocate and implement low-carbon consumption patterns. The construction of urban sewage and garbage treatment facilities, urban green development and water bank economic zones should be accelerated, and the wetland should be emphatically protected. Urban dwellers' sense of crisis regarding resources, energy, and environment should be enhanced to change consumers' consumption behaviors and lifestyle, and to establish healthy cities and eco-livable home should be regarded as the emphasis of ecological civilization construction. Mild water recycle facilities should be further popularized. Rainfall in roofs, roads, and green space should be collected to be used for flushing toilets, washing cars, fighting fires, irrigating greenery, and washing clothes. Water permeability materials should be first used in construction, and the speed of rainwater collection at the surface should be decelerated to effectively impound rainwater resources so as to expand urban water sources. Developers should be encouraged to take ecological community water-saving projects, to implement dual water supply, to use dual water quality drainage, where sub-quality water is used in sanitary cleaning, greenery irrigation, road cleaning, car washing, and so on; water seepage floor should be built, and groundwater should be conserved as compensation for landscape water bodies and groundwater to dilute salinity in the groundwater.

3. Emphasizing comprehensive governance of traffic jams, optimizing structure of the traffic network, improving carrying capacity of infrastructure

Multiple measures should be taken to comprehensively govern traffic jams in big cities, including encouraging public means of transportation, such as bus and subway, inhibiting rapid growth of private car ownership. Under the situation of unchanged existing number of vehicles, through control of passenger number, reducing stop sites, improving punctuality rate and upgrading intelligent service level, and so on, more people may be attracted to take mass transit; Bike and pedestrian traffic space should be guaranteed so that more people can take walk and bike in due range; according to consumption levels, mass transit supply differences should be achieved through corresponding rise of fare and increase of comfortable degree to meet personalized needs so as to attract more private car owners and taxi passengers to take public transportation. Beijing should continue to insist on controlling the growth of motor vehicles, and should change from existing administrative ballot-drawing intervention to license auction. Only when a car is discarded as useless can a new license be auctioned; then the quantity of cars can really be controlled, and high-emission, high-energy cross-country vans should be levied an environment tax, and new energy vehicles should be given a policy of unlimited number, free travel restriction, and tax exemption to promote rapid development of the new-energy auto industry. The management of vehicles should be strengthened to reduce the phenomenon of parking on the road, and so on. Traffic hub stations should achieve joint-less integration of various transport modes as soon as possible. The region should promote the construction of traffic hub and transit center stations to form integrated a tridimensional traffic system that regards transfer stations as the nodes and linking-up of various transportation modes (such as plane, train, coach, subway, bus, etc.) as soon as possible, and plans to build a large underground and above-ground tridimensional parking facilities in transport hub areas.

The structure of the traffic network should be optimized. The region should improve the microcirculation system of regional roads, increase the density of urban road net, establish reasonable road net structure, open dead end highways in city zones; strengthen the construction of tridimensional transport systems, pay attention to construction of supporting facilities (such as construction of the car parks), and fully use underground spaces. We suggest planning and constructing large underground and above-ground tridimensional parking facilities in transport hub areas. For example, Beijing has more than 200 subway stations. By building 5,000 underground parking spaces (P + R car park) in every subway station, one million passenger cars above ground can be moved into the underground space, which will greatly reduce the phenomenon of parking on road, widen the actual width of roads, reduce traffic jam, reduce emissions of PM2.5, guarantee traffic space of bicycles and pedestrians, and ease traffic pressure. The government can give appropriate subsidies for parking fee, encourage and lead people to take the subway after driving their car and arriving at the subway stations. Underground spaces can also be equipped with supporting food services and shopping centers because bustling passenger flow carries with it huge consumer demands, thereby it will boost consumption, and promote regional employment.

The region should build a highly efficient transport network between the central cities and new cities to strengthen the accessibility of intercity transportation between the center cities such as Beijing and Tianjin and the surrounding cities. Consummation of public service facilities of new cities and medium and small cities and construction of shortcut traffic infrastructure should be organically integrated. In accordance with equalization principle of basic public services, high-quality resources of center city zones' public services should be actively promoted and transferred and diffused to the suburbs so that new cities' residents can also enjoy high-quality public services based on enjoying basic public services, which has important significance for enhancing new cities' attraction and mitigation of center city population.

International and private capitals should be attracted to invest in the infrastructure construction so as to improve and enhance the carrying capacity of urban water supply and drainage systems. International experiences indicate that infrastructure construction should not be monopolized by the governments, and the best way of investment and financing is the government-led and encouraging international and private capitals to invest in infrastructure development, and reduction and exemption of taxes should be given to those enterprises which reinvest the profits from infrastructure operations into new infrastructure projects. As a megalopolis that regards constructing it into a world city, Beijing should raise the standard for design of water supply and drainage system to gradually line up with the international standard; strengthen international cooperation of science and technology, strive for international advanced water conservancy standards and experiences of design and management; consult with water supply and drainage design of mega-cities similar to the regional environment, make integrated planning of the entire urban equipment pipeline layout, and coordinate the joints of regional pipelines; predict the impact of extreme weather on water supply and drainage system in Beijing, gradually upgrade and replace the current drainage pipes of design flood with recurrence interval of 1 year for the city zones into that of 3–5 years, and improve the pipeline standards in special sections. Urban water supply and drainage pipe should be laid by grading; management and maintenance should be separated, professional maintenance team should be established to check, drain contamination, and perform maintenance on schedule.

4. Alleviating population bearing pressure through function mitigation, industrial upgrading, urban–rural integration, and layout optimization

Non-core functions and some industries of Beijing, Tianjin, and other mega-cities should be transferred around so as to achieve harmonious development between population and regional elements. Excessive concentration of population in center zones should be restrained, and construction of new cities and medium and small cities should be promoted to form a reasonable pattern of intercity organic integration, which may increase the carrying capacity of the regional population; mega-cities' traffic jam should be solved, concentrated emission of automobile exhaust and pollutants from winter heating should be reduced, which will help reduce fog and haze and other extreme weather phenomena.

Industrial upgrading in the region should be promoted, and the absorbability of regional industries to low-end population should be reduced to optimize the structure of population. Labor elements should be promoted to freely flow within the region, including eliminating system barriers, and realizing the integration of labor markets within the region; speeding up the reform of the household registration system and the reform of the employment system, and establishing a unified labor skill certification system within the region.

Urban and rural integration should be promoted so that more of the rural population can be stabilized in the region. Governments should make great efforts to create conditions that can be fused into urban society as soon as possible. Inflow and outflow of population is a dynamic equalization process, which facilitate not only urban management, but also economic and social harmony between population and resources and environment.

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Part II
Special Reports

Chapter 2
Studies on Population Carrying Capacity of Beijing, Tianjin and Hebei

Yaojun Zhang, Shuo Li, Yanyu Sun, Yang Chen, and Minmin Zhang

In predicting future population development in Beijing-Tianjin-Hebei region, the bearable population size of resource, environment, economy, society, and other relevant factors of Beijing-Tianjin-Hebei region may be studied through the method of possibility – satisfaction degree, and finally corresponding countermeasure suggestions on promoting population size and regional carrying capacity can be given.

2.1 Beijing-Tianjin-Hebei Population Development Trend and Forecast

2.1.1 Analysis of the Factors Affecting Population Size and Trend

There are three main factors that affect population size, namely natural growth of population, mortality, and migration growth.

The natural growth of the population in Beijing, Tianjin, and Hebei is slow. Over the past decade, the natural growth rate of population for Beijing and Tianjin was less than 4 %, and less than 7 % in Hebei province. In 2010, the natural growth rate of population of Beijing, Tianjin and Hebei was respectively 3.1 %, 2.8 % and 6.81 %, and total fertility rate was respectively 0.71, 0.91, and 1.31, which are far less than the replacement level. At such a low fertility level, there is limited space for further decline of the total fertility rate in the Beijing-Tianjin-Heibei region.

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Death is one of the factors that influences population change. For the Beijing-Tianjin-Hebei region, due to more stable changes in mortality, in fact the influence of mortality on regional population change is not big.

The main cause that affects the population sizes of Beijing and Tianjin are immigration population growth. Since entering the new century, the net immigration population in Beijing and Tianjin increase each year; on average in the recent 5 years annual net immigration population of these two cities have been closer to 500,000. Transfer of population in Hebei did not seriously affect its population size, and increased less than 1.1 million total within 10 years from the fifth census to sixth census.

According to population migration theory, the growth of immigration population size always has close relations to the employment demands of social and economic development in relocated areas. As the location of a country's capital and the third engine of regional economic development, the Beijing-Tianjin-Hebei region, especially Beijing and Tianjin have rapid economic development, and provide a large number of employment opportunities so that they play a non-negligible role in the growth of floating population, particularly in the growth of these floating population who regard obtaining employment as the main purpose.

2.1.2 Selection of Forecast Methods

Three main factors affect population size, namely population natural growth, mortality, and migration growth. This prediction uses the cohort-component method. The essence of cohort-component method is population equilibrium equations, population is divided into various cohorts of different ages and sexes, and population changes are divided into components of birth, death, and migration. Cohort-component method can forecast not only the size of the population, but also population structure, which is the method most widely used for population forecast. That is why this study uses this method.

This forecast used DemProj, a population projection software developed by the Futures Group; DemProj is the fundamental part of the policy planning software, the Spectrum System, to forecast the population, and is also the most important part.

2.1.3 Analysis of Forecast Results

The forecast results showed that the population size in the Beijing, Tianjin, and Hebei region will largely increase in the next decade (See Table 2.1). It is estimated that, by 2015, total population in the Beijing-Tianjin-Hebei region will be 111.42 million in accordance with the low program (Situation 1), 112.57 million with the middle plan (Situation 2), and 112.66 million with the high program (Situation 3), which will respectively grow 7.02, 8.17, and 8.26 million people more than the ones

Table 2.1 Forecast result of population development trend in the Beijing-Tianjin-Hebei region (million persons)

Year	Situation 1	Situation 2	Situation 3
2010	10,440	10,440	10,440
2011	10,589	10,596	10,597
2012	10,734	10,757	10,759
2013	10,874	10,921	10,925
2014	11,010	11,088	11,094
2015	11,142	11,257	11,266
2016	11,265	11,421	11,440
2017	11,382	11,576	11,615
2018	11,490	11,723	11,789
2019	11,589	11,859	11,964
2020	11,680	11,987	12,137

in 2010, and growth rate is respectively 6.72 %, 7.83 % and 7.91 %. By 2020, in accordance with the low program (Situation 1), total population will be 116.8 million, 119.87 million with the middle program (Situation 2), and 121.37 million with the high program (Situation 3), which respectively grew by 12.4, 15.47, and 16.97 million people than that in 2010, and the growth rate is respectively 11.88 %, 14.82 % and 16.25 %. Main cause of population growth in Beijing-Tianjin-Hebei region is the increase of immigration population in Beijing and Tianjin.

In the proportion of population of various ages, the proportion of the job-age population will decline, and the level of those ageing will increase. The population will continue to grow in the Beijing-Tianjin-Hebei region in the next decade, and the age structure of the population will change. In the three situations, the population of children and juvenile (0–14 years old) and aging population (65 years old and above) have a growth trend, the growth speed of the aging population is obviously faster than the growth speed of children and juvenile, in which aging is serious. At the same time, the proportion of the job-age population in the Beijing-Tianjin-Hebei region will continuously decline from 77 % in 2010 to 73 % or 72% in 2020, about a 4 % or 5 % drop (See Table 2.2).

In sight of the absolute number of labors, by 2020, labor supply in the Beijing-Tianjin-Hebei region will be 84.73–87.94 million people, in which labor supply will be sufficient (See Table 2.3).

Forecast results above indicate that, on one hand, aging will continue to increase in the Beijing-Tianjin-Hebei region in the next decade, on the other hand, labor supply will still be adequate because urbanization accelerates in China, and a large number of farmers move away from the countryside to provide a large number of laborers for the cities. In the short term, the employment situation remains critical in the Beijing-Tianjin-Hebei region, and ageing accelerates, therefore, the problem of a large number of the laboring population ageing before getting rich must be solved for the future development of the Beijing-Tianjin-Hebei region.

Table 2.2 Pro rata trend of population age structural changes in the Beijing-Tianjin-Hebei region (%)

Year	Situation 1			Situation 2			Situation 3		
	0–14	15–64	65+	0–14	15–64	65+	0–14	15–64	65+
2010	14	77	8	14	77	8	14	77	8
2011	14	77	9	14	77	9	15	77	9
2012	15	77	9	15	77	9	15	76	9
2013	15	76	9	15	76	9	15	76	9
2014	15	75	10	15	75	9	15	75	9
2015	15	75	10	15	75	10	15	75	10
2016	15	74	10	15	74	10	16	74	10
2017	15	74	11	15	74	11	16	74	11
2018	15	73	12	15	73	11	16	73	11
2019	15	73	12	15	73	12	15	73	12
2020	15	73	13	15	73	12	15	72	12

Table 2.3 Per capita trend of population age structural changes in the Beijing-Tianjin-Hebei region (ten thousand persons)

Year	Situation 1			Situation 2			Situation 3		
	0–14	15–64	65+	0–14	15–64	65+	0–14	15–64	65+
2010	1,505	8,063	873	1,505	8,063	873	1,514	8,063	873
2011	1,528	8,150	910	1,531	8,156	910	1,539	8,156	910
2012	1,565	8,218	951	1,571	8,236	952	1,581	8,236	952
2013	1,608	8,269	996	1,619	8,304	998	1,634	8,304	998
2014	1,652	8,309	1,049	1,670	8,367	1,051	1,686	8,366	1,052
2015	1,688	8,344	1,109	1,716	8,430	1,113	1,735	8,429	1,112
2016	1,716	8,373	1,178	1,751	8,488	1,182	1,777	8,494	1,182
2017	1,731	8,398	1,253	1,777	8,540	1,257	1,807	8,560	1,258
2018	1,736	8,421	1,332	1,792	8,592	1,337	1,831	8,630	1,339
2019	1,733	8,447	1,410	1,800	8,643	1,417	1,846	8,709	1,420
2020	1,722	8,473	1,484	1,798	8,697	1,493	1,846	8,794	1,497

2.2 Measuring Population Carrying Capacity in the Beijing, Tianjin, and Hebei Region

2.2.1 Principal Factors That Affect Population Carrying Capacity in the Beijing, Tianjin, and Hebei Region

Starting from the definition of population carrying capacity, and principal influencing factors of population carrying capacity include the following classes:

1. Natural resource environment factors
   This includes natural resources consumed for human survival and development, such as water, energy, and other resources, also includes level of pollutant that the environment can absorb and process, such as water environmental pollution and solid waste pollution, and so on.
2. Economic and social factors
   This includes the economy, technical conditions, employment, infrastructure, and etc. of human social development, in which the economic development has an especially large influence on population carrying capacity.
3. Setup of standards and objectives
   Under some resources environment and economic and social conditions, different setups of per capita consumption standard and living objective measure different regional carrying capacities. For example, if only considering maintaining the most basic living needs, and meeting the basic standards of living, a maximum number of supported population can be achieved in a region; if achieving an ideal or optimal objective, being affluent and with environmental livability, then only a moderate number of supported population can be achieved, and this number must be the maximum number of population to meet the living standards.
4. Spatial mobility of population and resource factors
   Spatial mobility of resources can make effective allocation of resources to fully utilize the resources, which can consequentially enhance the population that is supported by the resources.

2.2.2 Selection of the Measuring Method of the Population Carrying Capacity in the Beijing-Tianjin-Hebei Region

This study selects possible-satisfiability method founded by Wang Huanchen, one of the founders of population system engineering according to the principles and methods of systems engineering. In the decision-making process, people generally consider them from two aspects of "demand" and "possible" in face of practical problems. The former reflects subjective wishes and expectations, and the latter reflects objective conditions of admissibility and feasibility. If relevant quantitative value that expresses "possible" is defined as the possibility, and quantitative value that expresses "demand" is defined as satisfiability, quantitative value merged by possibility and satisfiability is called possible-satisfiability, hence the method is named.

In terms of the projection of population carrying capacity, possible-satisfiability method has its advantages. Its main advantages are not only reflected in its ability to join the demand and supply factors in population development, but it can also comprehensively consider different roles of various factors in population development.

2.2.3 Measurement of Population Carrying Capacity in the Beijing-Tianjin-Hebei Region

1. Measurement period and data source of population carrying capacity in the Beijing-Tianjin-Hebei region
   This paper regards 2010 as the base year to forecast population carrying capacity of Beijing, Tianjin, and Hebei in 2015. The data used is mainly from overall planning in the "Twelfth-Five-Year Plan" and various special planning in the "Twelfth-Five-Year Plan" of Beijing, Tianjin, and Hebei province, *Beijing Municipal Statistical Yearbook (2011)*, *Tianjin Municipal Statistical Yearbook (2011)*, and *Hebei Provincial Economy Yearbook (2011)*, water resources bulletins of Beijing, Tianjin, and Hebei province in 2011, and China environment and economic databases.
2. Establishment of measuring index system of population carrying capacity in the Beijing-Tianjin-Hebei region

   (a) Principles of index selection
   First, the typical principle. The selected indicators must be able to have an influence on the population carrying capacity, and must be a good representative of the natural resource environment, social resources, and economic development in the Beijing-Tianjin-Hebei region.

   Second, the principle of scientificity. The index system of various subsystems must be based on the actual situation of the Beijing-Tianjin-Hebei region, and index concepts must be clearly defined, and must reflect the interrelation between the population carrying capacity and indicators as well as the constitutive relation within the system. The index system should be an appropriate size, with standard measuring methods and normative statistical calculation methods, and specific indicators that reflect the connotation of population and influencing factors to ensure authenticity and objectivity of evaluation results.

   Third, the dynamic principle. The index system needs to be developmental and changeable, and can change along with the economic and social development in different periods to adapt to the characteristics of different periods, and can more flexibly reflect the relationship between indicators and supported population in a dynamic process.

   Fourth, the general principle. The index system that reflects the population carrying capacity should have broader coverage, and must comprehensively reflect the population carrying capacity, which is a whole system.

   Fifth, the principle of accessibility. The index system should first hit the problems that need to solve, should be technically effective and feasible, and should have a sufficient scientific basis, and the relationship between indicators and problems must be clear. The index system should be easy to calculate and easy to access, as simple as possible, and setup of indicators should use existing statistical indicators as much as possible.

(b) Value and forecast of indicators

About the value of satisfiability: minimum value is per capita standard, and is achievable; for the maximum, it consulted relevant planning of in various regions, combined with the standard of living in developed countries to express that people feel the most satisfied in the maximum value. In addition, some data that were not given in the planning this study got them through linear fitting based on the data in recent 5 years. For specific indicators and data, as shown in Tables 2.4, 2.5, and 2.6.

3. Measuring results and analysis of population carrying capacity in Beijing-Tianjin-Hebei region

Various factors of the population carrying capacity are combined to calculate the population carrying capacity, that is, various factors can compensate each other, and make up relative "poor" indicators with relative "rich" indicators of carrying capacity, namely using weighted average of each factor. Because each selected indicator has a big influence on the population carrying capacity, here we set different weightings for different factors according to various circumstances, and sub-factors in every factor is weighted the same, in which there are four different weighting schemes as follows:

Scheme I: economic factor, social factor, and resource environmental factor can be complementary, namely these three factors are equally important, totaling formula of its total moderate population is:

$$\text{Total moderate population} = (1/3) * \text{economic population} + (1/3) * \text{Social population} + (1/3) * \text{environment population};$$

Scheme II: economic factor is more important than the other two factors, namely the weight of the economic factor is bigger than that of the other two, and totaling formula of its total moderate population is:

$$\text{Total moderate population} = (1/2) * \text{economic population} + (1/4) * \text{social population} + (1/4) * \text{environment population};$$

Scheme III: social factor is more important than the other two factors, namely the weight of the social factor is bigger than that of the other two, and totaling formula of its total moderate population is:

$$\text{Total moderate population} = (1/4) * \text{economic population} + (1/2) * \text{social population} + (1/4) * \text{environment population};$$

Table 2.4 Beijing's possible-satisfiability indicators and critical values

			Beijing	
Factors	Name of sub-factors	Character	Min.	Max.
Economic factor	GDP aggregate (hundred million RMB)	Possible	13,777.90	27,712.30
	Per capita GDP (ten thousand RMB)	Satisfiability	8.04	12.92
	Total investment in fixed assets (hundred million RMB)	Possible	5,493.50	10,121.42
	Per capita investment in fixed assets (ten thousand RMB)	Satisfiability	2.80	4.51
Social factor	Number of jobholders at end of the year (ten thousand persons)	Possible	1,031.60	1,295.57
	Proportion of employed population in total population (%)	Satisfiability	52.58	49.00
	Land used for building (ten thousand ha.)	Possible	33.77	36.47
	Per capita land used for building (sq.m.)	Satisfiability	150.00	180.00
	Number of students in general colleges and universities (ten thousand persons)	Possible	124.79	160.80
	Number of college students every hundred thousand persons (person)	Satisfiability	6,367.00	6,700.00
	Number of sickbeds (piece)	Possible	92,764.00	100,000.00
	Number of sickbeds every thousand persons (piece)	Satisfiability	4.70	5.00
	Number of doctors (person)	Possible	66,000.00	96,000.00
	Number of doctors every thousand persons (person)	Satisfiability	3.37	4.00
	Urban population (ten thousand persons)	Possible	1,686.40	1,926.90
	Urbanization rate (%)	Satisfiability	86.00	90.00
Resource environmental factor	Aggregate of water resources (hundred million cu. m.)	Possible	21.84	23.18
	Per capita water resource volume (cu. m.)	Satisfiability	126.61	150.00
	Water consumption for daily life (ten thousand cu. m.)	Possible	161.10	170.00
	Per capita water consumption for daily life (liter)	Satisfiability	82.00	85.00
	Daily processing capacity of domestic waste (ten thousand tons)	Possible	16,680.00	30,000.00
	Per capita daily output of domestic waste (kg.)	Satisfiability	0.88	1.12
	COD discharge aggregate (ten thousand tons)	Possible	9.19	9.67
	Per capita COD discharge (kg.)	Satisfiability	4.60	4.93
	Energy consumption aggregate (ten thousand tons coal equivalent)	Possible	6,954.10	8,576.85
	Per capita energy consumption (ton coal equivalent)	Satisfiability	3.55	4.08

Table 2.5 Tianjin's possible-satisfiability indicators and critical values

			Tianjin	
Factors	Name of sub-factors	Character	Min. value	Max.
Economic factor	GDP aggregate (hundred million RMB)	Possible	9,108.80	18,319.40
	Per capita GDP (ten thousand RMB)	Satisfiability	7.04	12.40
	Total investment in fixed assets (hundred million RMB)	Possible	6,511.42	13,095.95
	Per capita investment in fixed assets (ten thousand RMB)	Satisfiability	5.03	8.11
Social factor	Number of jobholders at end of the year (ten thousand persons)	Possible	714.00	922.00
	Proportion of employed population in total population (%)	Satisfiability	56.62	53.00
	Land used for building (ten thousand ha.)	Possible	36.82	41.43
	Per capita land used for building (sq.m.)	Satisfiability	230.00	250.00
	Number of students in general colleges and universities (ten thousand persons)	Possible	47.00	50.00
	Number of college students every hundred thousand persons (person)	Satisfiability	4,500.00	4,700.00
	Number of sickbeds (piece)	Possible	63,228.00	99,200.00
	Number of sickbeds every thousand persons (piece)	Satisfiability	4.89	6.20
	Number of doctors (person)	Possible	37,394.00	52,800.00
	Number of doctors every thousand persons (person)	Satisfiability	2.89	3.30
	Urban population (ten thousand persons)	Possible	1,029.23	1,300.00
	Urbanization rate (%)	Satisfiability	79.55	83.00
Resource environmental factor	Aggregate of water resources (hundred million cu. m.)	Possible	15.24	18.30
	Per capita water resource volume (cu. m.)	Satisfiability	126.79	150.00
	Water consumption for daily life (ten thousand cu. m.)	Possible	95.62	108.77
	Per capita water consumption for daily life (liter)	Satisfiability	74.00	85.00
	Daily processing capacity of domestic waste (ten thousand ton)	Possible	9,680.00	17,410.00
	Per capita daily output of domestic waste (kg.)	Satisfiability	0.80	1.00
	COD discharge aggregate (ten thousand tons)	Possible	11.44	13.29
	Per capita COD discharge (kg.)	Satisfiability	8.17	10.30
	Energy consumption aggregate (ten thousand tons coal equivalent)	Possible	5,236.14	8,377.82
	Per capita energy consumption (ton coal equivalent)	Satisfiability	4.06	4.93

Table 2.6 Hebei's possible-satisfiability indicators and critical values

Factors	Name of sub-factors	Character	Hebei Min. value	Max.
Economic factor	GDP aggregate (hundred million RMB)	Possible	20,449.12	30,748.46
	Per capita GDP (ten thousand RMB)	Satisfiability	2.80	4.05
	Total investment in fixed assets (hundred million RMB)	Possible	15,083.35	30,000.00
	Per capita investment in fixed assets (ten thousand RMB)	Satisfiability	2.11	3.73
Social factor	Number of jobholders at end of the year (ten thousand persons)	Possible	3,865.14	4,156.11
	Proportion of employed population in total population (%)	Satisfiability	53.73	55.00
	Land used for building (ten thousand ha.)	Possible	179.42	190.87
	Per capita land used for building (sq.m.)	Satisfiability	230.00	250.00
	Number of students in general colleges and universities (ten thousand persons)	Possible	113.70	122.40
	Number of college students every hundred thousand persons (person)	Satisfiability	1,540.00	1,700.00
	Number of sickbeds (piece)	Possible	249,295.00	299,440.00
	Number of sickbeds every thousand persons (piece)	Satisfiability	3.46	3.94
	Number of doctors (person)	Possible	122,847.00	170,000.00
	Number of doctors every thousand persons (person)	Satisfiability	1.71	2.24
	Urban population (ten thousand persons)	Possible	3,150.00	3,800.00
	Urbanization rate (%)	Satisfiability	43.79	54.00
Resource environmental factor	Aggregate of water resources (hundred million cu. m.)	Possible	141.16	161.00
	Per capita water resource volume (cu. m.)	Satisfiability	201.32	250.00
	Water consumption for daily life (ten thousand cu. m.)	Possible	523.29	600.00
	Per capita water consumption for daily life (liter)	Satisfiability	74.00	85.00
	Daily processing capacity of domestic waste (ten thousand tons)	Possible	18,576.71	35,000.00
	Per capita daily output of domestic waste (kg.)	Satisfiability	0.30	0.50
	COD discharge aggregate (ten thousand tons)	Possible	51.24	56.20
	Per capita COD discharge (kg.)	Satisfiability	7.32	7.92
	Energy consumption aggregate (ten thousand tons coal equivalent)	Possible	27,531.11	36,683.50
	Per capita energy consumption (ton coal equivalent)	Satisfiability	3.88	4.70

Scheme IV: resource environmental factor is more important than the other two factors, namely the weight of the resource environmental factor is bigger than that of the other two, and totaling formula of its total moderate population is:

$$\text{Total moderate population} = (1/4) * \text{economic population} + (1/4) * \text{social population} + (1/2) * \text{environment population.}$$

While sub-factors of every factor can be complementary, population carrying capacity of the three factors in Beijing, Tianjin, and Hebei are respectively shown in Figs. 2.1, 2.2, and 2.3.

It can be seen that, when possible-satisfiability is low, the population carrying capacity of the three areas has larger constraints from the resource environmental factor and social factor, and population carrying capacity of both declines slowly along with the growth of the possible-satisfiability value. In the case of high

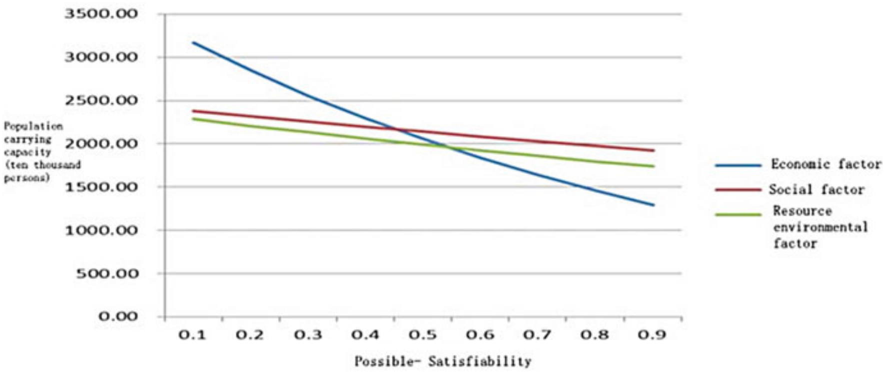

Fig. 2.1 Beijing's population carrying capacity after merging three factors in 2015

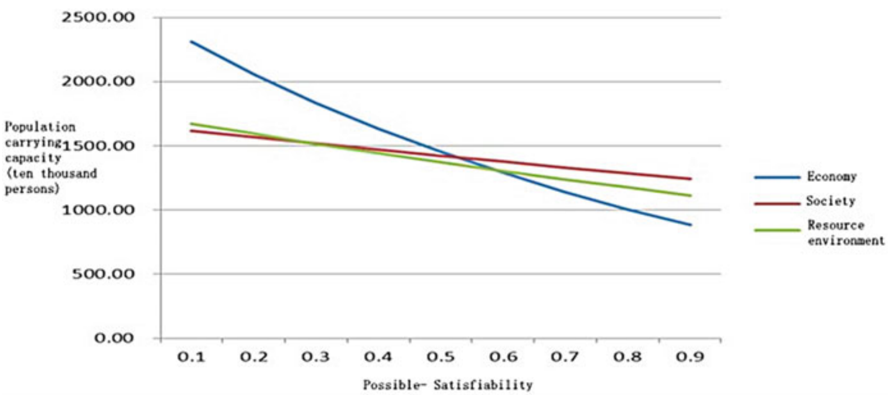

Fig. 2.2 Tianjin's population carrying capacity after merging three factors in 2015

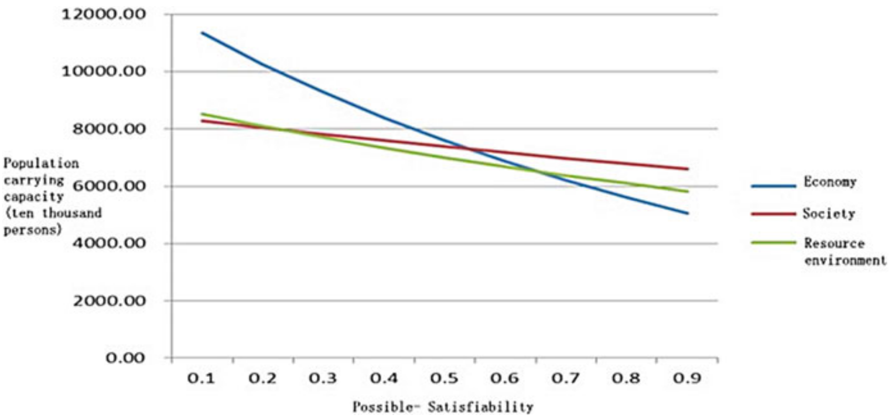

Fig. 2.3 Hebei's population carrying capacity after merging three factors in 2015

possible-satisfiability, the population carrying capacity has larger constraints from the economic factor, and the constraint is bigger that of the social, resource, and environmental factors, which indicates that economic life still maintains a stronger constraint on the population.

Further, when there is mutual compensation between the factors, the comprehensive population carrying capacity of the Beijing, Tianjin and Hebei region in 2015, the following figure is achieved. When possible-satisfiability values 0.6, comprehensive population carrying capacity of Beijing will be 19.5 million people in 2015, 13.22 million people in Tianjin, and 69.11 million in Hebei province, total population carrying capacity of the Beijing-Tianjin-Hebei region will be 101.83 million people, as shown in Fig. 2.4.

The above total population carrying capacity of the Beijing-Tianjin-Hebei region is based on the hypothesis of mutual compensation between all factors, namely all three factors are thought equally important, and the weight of various factors are equal. On the premise of different considerations, when the value of the possible-satisfiability is different, the population carrying capacity of the Beijing-Tianjin-Hebei region in 2015 is calculated as shown in Table 2.7.

As shown in Table 2.7, in the forecast of population carrying capacity in Beijing-Tianjin-Hebei region in 2015, in Scheme I in which economic, social, and resource environmental factors are regarded as equally important, the changing scope of the population size measured is 85.62–138.61 million people under different possible-satisfiability values. In Scheme II in which economic factor is regarded more important than the other two factors, the changing scope of the population size measured is 82.32–146.01 million people under different possible-satisfiability values. In Scheme III in which social factor is regarded more important than the other two factors, the changing scope of the population size measured is 88.64–134.68 million people under different possible-satisfiability values. In Scheme IV in which resource and environmental factor is regarded more important than the other two factors, the changing scope of the population size measured is 85.91–135.15 million people under different possible-satisfiability values.

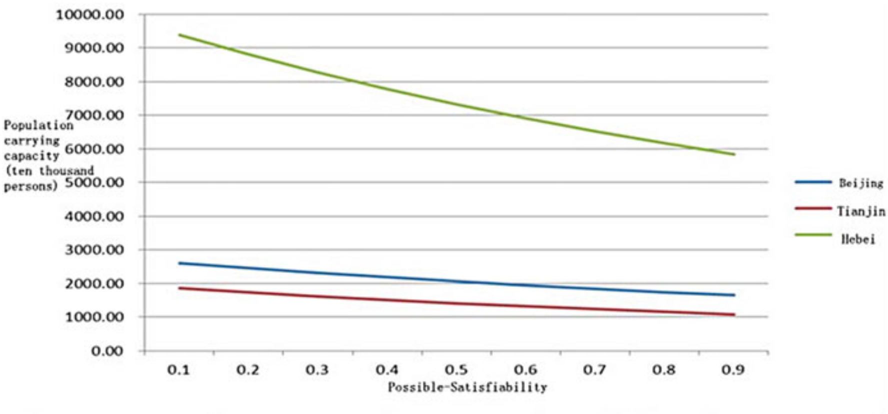

Fig. 2.4 Comprehensive population carrying capacity of the Beijing-Tianjin-Hebei region in 2015

In addition, when possible-satisfiability is 0.6, namely at the acceptable level, population size reaches maximum at this point, which may be called moderate population size. In the four schemes, the moderate population forecasted in Scheme III (namely focus on social factor) is maximum, 102.98 million people; in Scheme IV (namely focus on resource environmental factor) it is minimum, 101.15 million people. In Scheme II (namely focus on economic factor) it is 101.4 million, which is slightly higher than that in Scheme IV. In Scheme I (namely all factors can be complementary) it is 101.84 million. It is observed that economic and resource environmental factors play a limited role in improving the moderate population size of the Beijing-Tianjin-Hebei region. As shown in Fig. 2.5.

4. Conclusion

   By integrating the above calculation and analysis of population carrying capacity, the conclusions are as follows:

   (a) In factors that restrict population carrying capacity of Beijing, Tianjin, and Hebei region in 2015, when possible-satisfiability is higher, economic factor has more obvious constraint force than the other factors; when possible-satisfiability is lower, resource factor, mainly water resource, is representative, and environmental factor, mainly garbage disposal capacity, is representative becomes the main confinement factor.
   (b) In 2015, considering all indicators synchronously, when possible-satisfiability is 0.6, population carrying capacity of Beijing-Tianjin-Hebei region is 86.2 million people, in which Beijing can bear 15.9 million people, Tianjin, 10.43 million people, and Hebei province, 59.87 million people.
   (c) In 2015, considering internal mutual compensation of each factor, when possible-satisfiability is 0.6, population carrying capacity of the Beijing-

Table 2.7 Population carrying capacity of the Beijing-Tianjin-Hebei region in 2015 with different considerations and with different possible-satisfiability values

Scheme	Considerations			Population carrying capacity with different considerations and with different possible-satisfiability values in 2015 (ten thousand persons)								
	Economic factor	Social factor	Resource environmental factor	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
I1	Complementary all factors			13,861	12,992	12,200	11,474	10,804	10,184	9,607	9,068	8,562
I2	Economic factor is more important than other two factors			14,601	13,530	12,563	11,684	10,879	10,140	9,456	8,822	8,232
I3	Social factor is more important than other two factors			13,468	12,728	12,049	11,422	10,840	10,298	9,790	9,313	8,864
I4	Resource environmental factor is more important than other two factors			13,515	12,718	11,988	11,315	10,693	10,114	9,574	9,067	8,591

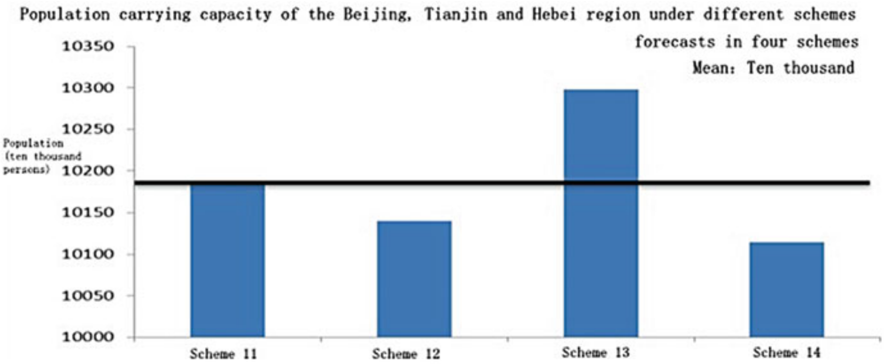

Fig. 2.5 Moderate population size of Beijing, Tianjin and Hebei region in 2015 with different considerations

Tianjin-Hebei region is 98.07 million people, in which Beijing can support 18.41 million people, Tianjin, 12.88 million people, and Hebei province, 66.78 million.

(d) In 2015, considering mutual compensation of factors, when possible-satisfiability is 0.6, population carrying capacity of the Beijing-Tianjin-Hebei region is 101.83 million people, in which Beijing can support 19.5 million people, Tianjin, 13.22 million, and Hebei province, 69.11 million.

2.3 Population Development Trend of Beijing, Tianjin, and Hebei and Comparative Analysis of Carrying Capacity

2.3.1 Overview

According to population development trend forecasted in the low program in the Beijing-Tianjin-Hebei region, it is estimated that the population will reach 111.42 million in 2015. Under different possible-satisfiability values, comprehensive population carrying capacity of the Beijing-Tianjin-Hebei region will be 85.63–138.62 million people in 2015. Corresponding carrying capacity of population forecasted is about 0.45 when possible-satisfiability is 0.4–0.5. With the rise of satisfiability, population carrying capacity declines, and overload of population will be more serious. When possible-satisfiability is 0.6, population overloads by 9.58 million people, when satisfiability is 0.9, population overloads by 25.79 million people (See Table 2.8).

Table 2.8 Low population growth program and population carrying capacity under different possible-satisfiability values

Population forecast		Forecast of population carrying capacity		Gap between population forecast and carrying capacity (ten thousand persons)
Growth program	Population (ten thousand persons)	Possible-satisfiability	Population (ten thousand persons)	
Low program	11,142	0.1	13,862	2,720
		0.2	12,992	1,850
		0.3	12,200	1,058
		0.4	11,474	332
		0.5	10,805	−337
		0.6	10,184	−958
		0.7	9,607	−1,535
		0.8	9,068	−2,074
		0.9	8,563	−2,579

Note: Negative value is overloading population, positive value is supported population

According to forecast of population development trend in the middle program of the Beijing-Tianjin-Hebei region, it is estimated that population will reach 112.57 million people in the region in 2015. Under different possible-satisfiability values, comprehensive population carrying capacity in the Beijing-Tianjin-Hebei region will be 85.63–138.62 million people in 2015. Corresponding carrying capacity of the population forecasted is possible-satisfiability 0.4–0.5, at about 0.46. Population overloads by 10.73 million when possible-satisfiability is 0.6, and population overloads by 26.94 million people when possible-satisfaction is 0.9 (See Table 2.9).

According to forecast of population development trend in the high program of Beijing-Tianjin-Hebei region, it is estimated that population will reach 112.66 million people in the region in 2015. Under different possible-satisfiability values, comprehensive population carrying capacity in the Beijing-Tianjin-Hebei region will be 85.63–138.62 million people in 2015. Corresponding carrying capacity of population forecasted is possible-satisfiability 0.4–0.5, at about 0.47. Population overloads by 10.82 million when possible-satisfiability is 0.6, and population overloads by 27.03 million people when possible-satisfiability is 0.9 (See Table 2.10).

It is observed that, population in 2015 obtained according to different programs on population forecast does not change much when possible-satisfiability of the Beijing, Tianjin and Hebei region is 0.4–0.5. It is obvious that, although the population carrying capacity in the region can basically meet demand of population growth, overall population growth size exceeds population carrying capacity, and in comparison with the situation of acceptable possible-satisfiability (0.6), population will overload by about 10 million people in the Beijing-Tianjin-Hebei region in 2015.

Table 2.9 Population carrying capacities under the middle program on population growth and different possible-satisfiability values

Population forecast		Forecast of population carrying capacity		Gap between population forecast and carrying capacity (ten thousand persons)
Growth program	Population (ten thousand persons)	Possible-satisfiability	Population (ten thousand persons)	
Middle program	11,257	0.1	13,862	2,605
		0.2	12,992	1,735
		0.3	12,200	943
		0.4	11,474	217
		0.5	10,805	−452
		0.6	10,184	−1,073
		0.7	9,607	−1,650
		0.8	9,068	−2,189
		0.9	8,563	−2,694

Note: Negative value is overloading population, positive value is supported population

Table 2.10 Population carrying capacities under the high program on population growth and different possible-satisfiability values

Population forecast		Forecast of population carrying capacity		Gap between population forecast and carrying capacity (ten thousand persons)
Growth program	Population (ten thousand persons)	Possible-satisfiability	Population (ten thousand persons)	
High program	11,266	0.1	13,862	2,596
		0.2	12,992	1,726
		0.3	12,200	934
		0.4	11,474	208
		0.5	10,805	−461
		0.6	10,184	−1,082
		0.7	9,607	−1,659
		0.8	9,068	−2,198
		0.9	8,563	−2,703

Note: Negative value is overloading population, positive value is supported population

2.3.2 Comparative Analysis of Population Forecast and Carrying Capacities of Factors

1. Population carrying capacity of economic factors has the most elasticity, and corresponding possible-satisfiability of population forecast is the highest

Corresponding population carrying capacity of economic factors under different possible-satisfiability values had larger variable range, corresponding population

Table 2.11 Different population growth programs and population carrying capacity of economic factors

Forecast of population carrying capacity		Population forecast			Gap between population forecast and carrying capacity (ten thousand persons)		
Possible-satisfiability	Economic factor	Low program	Middle program	High program	Low program	Middle program	High program
0.1	16,819	11,142	11,257	11,266	5,677	5,562	5,553
0.2	15,146				4,004	3,889	3,880
0.3	13,654				2,512	2,397	2,388
0.4	12,315				1,173	1,058	1,049
0.5	11,105				−37	−152	−161
0.6	10,007				−1,135	−1,250	−1,259
0.7	9,005				−2,137	−2,252	−2,261
0.8	8,086				−3,056	−3,171	−3,180
0.9	7,241				−3,901	−4,016	−4,025

Note: Negative value is overloading population, positive value is supported population

carrying capacity is 72.41–168.19 million people when possible-satisfiability is 0.1–0.9, and corresponding possible-satisfiability of population forecasted in different population forecast programs is close to 0.5, in which population carrying capacity overloads by 370,000 people when possible-satisfiability is 0.5 in the low program. The carrying capacity of population in the low, middle, and high programs respectively overloads by 11.35, 12.5, and 12.59 million people than that when satisfiability is 0.6 (See Table 2.11).

2. Population carrying capacity of social factors has the least elasticity, and corresponding possible-satisfiability of population forecast is higher

Corresponding population carrying capacity of social factors under different possible-satisfiability values has the least variable range amongst the three factors, corresponding population carrying capacity is 97.69–122.88 million people when possible-satisfiability is 0.1–0.9, corresponding possible-satisfiability of population forecasted in the low program is 0.4–0.5, close to 0.45; corresponding possible-satisfiability of population forecasted in the middle and high programs is 0.4. The population carrying capacities in the low, middle, and high programs respectively overloads by 5.02, 6.17, and 6.26 million people than that when the satisfiability is 0.6 (See Table 2.12).

3. Population carrying capacity of resource environmental factors has smaller elasticity, and corresponding possible-satisfiability of population forecasted is the least

Corresponding population carrying capacity of social factors under different possible-satisfiability values has smaller variable range, corresponding population carrying capacity is 86.78–124.78 million people when possible-satisfiability is 0.1–0.9; corresponding possible-satisfiability values of population forecasted in the

Table 2.12 Different population growth programs and population carrying capacity of social factors

Forecast of population carrying capacity		Population forecast			Gap between population forecast and carrying capacity (ten thousand persons)		
Possible-satisfiability	Social factor	Low program	Middle program	High program	Low program	Middle program	High program
0.1	12,288	11,142	11,257	11,266	1,146	1,031	1,022
0.2	11,935				793	678	669
0.3	11,595				453	338	329
0.4	11,266				124	9	0
0.5	10,948				−194	−309	−318
0.6	10,640				−502	−617	−626
0.7	10,341				−801	−916	−925
0.8	10,051				−1,091	−1,206	−1,215
0.9	9,769				−1,373	−1,488	−1,497

Note: Negative value is overloading population, positive value is supported population

low, middle, and high programs all are 0.3–0.4, in which it is 0.34 in the low program, and close to 0.3 in the middle and high programs, and resource environmental factors has the most pressure on the population. Population carrying capacities in the low, medium, and high programs respectively overloads by 12.36, 13.51, and 13.6 million people than that when the satisfiability is 0.6 (See Table 2.13).

In brief, in various factors, resource environmental factor has a more obvious limit to the population carrying capacity, rapid economic development makes Beijing-Tianjin-Hebei region capable of supporting more population within a short time, and social factors can maintain the most stability on the development of Beijing-Tianjin-Hebei region.

2.4 Appropriate Countermeasures on Population and Carrying Capacity of the Beijing-Tianjin-Hebei Region

2.4.1 *Promoting Labor Movement Within the Region*

Under strained relations between the population and ecological resources, the best solution is promoting a labor movement and transfer within the region, namely "local urbanization." This can avoid inflow of a great number of population outside the region which would further exacerbate the tense relationship between the population and resource environment, and can absorb surplus farm labors within the region, which would be killing two birds with one stone. To pursue this,

Table 2.13 Different population growth programs and population carrying capacity of resource environmental factors

Forecast of population carrying capacity		Population forecast			Gap between population forecast and carrying capacity (ten thousand persons)		
Possible-satisfiability	Resource environmental factor	Low program	Middle program	High program	Low program	Middle program	High program
0.1	12,478	11,142	11,257	11,266	1,336	1,221	1,212
0.2	11,896				754	639	630
0.3	11,352				210	95	86
0.4	10,841				−301	−416	−425
0.5	10,361				−781	−896	−905
0.6	9,906				−1,236	−1,351	−1,360
0.7	9,476				−1,666	−1,781	−1,790
0.8	9,067				−2,075	−2,190	−2,199
0.9	8,678				−2,464	−2,579	−2,588

Note: Negative value is overloading population, positive value is supported population government departments in Beijing, Tianjin, and Hebei need to take a series of strong measures, which should at least include:

- Improving the quality of labors, and cultivating modern new-style industrial workers from within. Beijing and Tianjin should fully use their high-quality education resources to improve training efficiency to peasant workers in the region and to substantially improve overall quality of rural workers so as to enhance their competitive power in the labor market in the Beijing-Tianjin-Hebei region.
- Eliminating institutional obstacles to achieve labor market integration within the region. The reform of the household registration system and employment system should be quickened, to eliminate various institutional obstacles that restrict population movement, and to promote free flow of labor elements within the region.
- Establishing unified labor skill certification system within the region, and improving the employment information services. To achieve integration, to promote labor movement and balance within the region, Beijing, Tianjin, and Hebei must guarantee the establishment and implementation of systems, such as mutual acceptance of training certificates within the region, and mutual provision of timely accurate employment information.

2.4.2 Promoting Social Integration so that More Rural Population Can Be Stabilized in the Region

The essence of urbanization is the process in which hundreds of millions of peasants move from the rural area to urban area and ultimately become townspeople. After peasant workers find work in the city, the governments should make greater efforts to create conditions so that they can adapt to life in the city and integrate into urban society, and ultimately become townspeople settled in the cities. In other words, governments should create conditions for the education of floating population's children, residence, employment, protection of rights and interests for farmers to integrate into the city, rather than raising the threshold, keeping thousands of farmers out of the city, and only admitting a few "elite" peasant workers.

2.4.3 Constructing a Reasonable Urban System, and Promoting Organic Linkage Between Cities

The reasonable urban system has also become a standard to weigh regional strength. As for the Beijing-Tianjin-Hebei region, it needs to form the following urban system.

1. Level-I core city circle. Beijing and Tianjin are the core of the region, play an important leading role in promoting the “dual-core” space layout to regional development, and the group-metropolitan region is more dynamic, has strong radiation and influence. Beijing and Tianjin should be further closely linked, with complementary advantages, and complementary features.
2. Level-II core city circle. Regional sub-core cities plays a connecting key role to a city circle, simultaneously also have a positive effect on mitigating excessive influx of population to core cities. Currently, Tangshan, Shijiazhuang, and Handan are all such cities. Tangshan has good industrial basis, superior location, and can really effectively bear and transfer industries of Beijing and Tianjin, which should be cultivated into a core city in North Hebei area; Shijiazhuang is capital of Hebei, has obvious political advantage, convenient traffic and better policy conditions, which has the ability to become a core city in North Hebei area; Handan has more developed industries in the Hebei province, and is adjacent to four provinces, Hebei, Shangxi, Henan, and Shangdong, making it a transit hub gem; it has potential to develop into a center city in South Hebei area, and may cooperate with Shijiazhuang to promote accelerated development of central and southern Hebei areas.
3. Level-III core city circle. Other cities (towns) in the region should also actively develop themselves to become sub-center cities to some regard, for example, Qinhuangdao should use its port advantage and tourist resource advantage, and utilize its position to play a role as a coastal open city, and Hengshui, Cangzhou, and Zhangjiakou cities should also develop into sub-center cities in their areas.

2.4.4 Promoting Balanced Development of Population, Achieving Harmony Among Population and Regional Elements

“Demographic balance” includes “internal balance of the population” and “external balance of the population.” “Internal balance of the population” refers to the balanced development of population, from “birthrate” and “mortality.” “External balance of the population” refers to the harmonious development between the population and society, economy, resources, and environment, from “carrying capacity of natural resource environment” and “carrying capacity of socio-economic system.” In social practices, supply and demand of the population show a trend of constant adjustment and mutual adaptation. Population demand over supply means that the economic development power is insufficient, valuable resources cannot be effectively developed, social productive capacity cannot be fully used, and economic development efficiency is lower, which promote population supply and restrain resource consumption; population supply over demand means excessive development resources, excessive use of existing equipment, low welfare guarantees, and social overload so as to restrain population supply and to promote changes of growth way. The population should be promoted towards balanced development, which lay the foundation for sustainable development of population, resources, environment, economy, and society.

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Chapter 3
Studies on Land Carrying Capacity of Beijing, Tianjin, and Hebei Province

Wenying Peng and Qingling Wu

3.1 Connotation and Evaluation Methods of Land Integrated Carrying Capacity

3.1.1 Connotation of Integrated Land Carrying Capacity

In the studies of productive capacity of land resources in China, land carrying capacity means "the productive capacity of land resources in certain living conditions and supported population under certain standards of living." It contains four key components: production conditions, land productivity, standard of living, and limits of the supported population. Lǚ Yifeng (2001) defined it as "a dynamic estimate of natural potentials of the land production in certain areas and the ratio of aggregate producible food in a certain input condition to the sum of a certain per capita consumption, namely the population carrying capacity of land." Wang Shuhua and Mao Hanying (2001) defined integrated land carrying capacity as bearable scale of various human activities and intensity threshold on land resource in a period of time, region of space, in social, economic, ecological, and environmental conditions. The carrier is not only population, but also various human social and economic activities. The Chinese Academy of Land and Resources Economics (2005) noted it as, in a certain period of time, a certain space and a certain condition of economy, society, resources and environment, bearable scale and intensity of various human activities on land resources. It is obvious that land carrying capacity is a comprehensive concept, and has multiple objectives.

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3.1.2 Evaluation Method of Integrated Land Carrying Capacity the Beijing-Tianjin-Hebei Capital Economic Circle

1. Research field

In accordance with the national "Eleventh-Five-Year Plan" and Beijing Municipal "Twelfth-Five-Year Plan," consulting existing studies on the capital economic circle, aiming at the social, economic, and ecological connections of Beijing and Tianjin, taking into account that Shijiazhuang city is the political and economic center of Hebei province, and is the regional development core of this province, this research field determines Beijing, Tianjin, and Hebei capital circle as "7+2" mode, excluding Shijiazhuang city of Hebei province.

2. Research methods

Regional evaluation of land carrying capacity includes regional evaluation and analysis of the carrying capacity of development and construction of land resources, of the carrying capacity of social resources of land resources, of the economic land carrying capacity and of the eco-environment land carrying capacity.

3.2 Present Situation of Land Utilization of the Beijing-Tianjin-Hebei Capital Economic Circle

Beijing, Tianjin, and Hebei have clear regional distribution characteristics of land resources and utilization. The north mountainous area is dominated by grassland and forest, is supplemented by undeveloped lands, and the south plains is dominated by arable lands, is supplemented by lands used for building, in which there is still certain potential in development and utilization of regional land resources.

3.2.1 Utilization of Land Resources in Beijing

Beijing's total land area is 16,410.54 km^2, and the mountainous area accounts for about 62 %. As of 2011, the resident population reached 20.186 million. As shown in Fig. 3.1, the area of land used for building was 3,377.15 km^2, which was 20.58 % of total land area. Per capita cultivated land was only 0.17 Mu, which was far lower than the 1.38 Mu level of the whole country. Forest coverage was 37.6 %, and forest resources were concentrated in the mountainous areas. In the period of the "Eleventh-Five-Year Plan," mountain forest coverage reached 50.97 %, and forest coverage in plain areas was only 14.85 %, and ecological quality in plain areas was

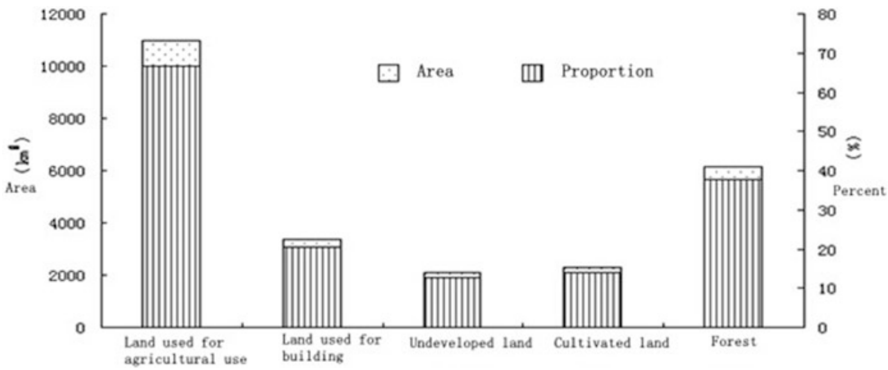

Fig. 3.1 Utilization of land resources in Beijing

poor. Undeveloped land accounted for 12.63 % in the whole city, and mostly belonged to the hard use of land, in which exploitable reserved land resources is insufficient.

3.2.2 Utilization of Land Resources in Tianjin

Tianjin's total land area is 11,916.88 km^2, and mountainous area is about 5.75 %. As of 2011, the resident population was 13.5458 million. As shown in Fig. 3.2, the area of land used for building was 3,881.94 km^2, which was 32.58 % of total land area. Per capita cultivated land was 0.83 Mu, which was lower than the level of the whole country. Forest coverage was only 11.93 %, which was lower than the level of the whole country, and ecological quality was poor.

3.2.3 Utilization of Urban Lands Around Beijing and Tianjin

As shown in Table 3.1, the lands of Hebei province around Beijing and Tianjin cities is 154,127 km^2, and total population is 51.0043 million. Land used for building is 13,212 km^2, and is 8.57 % of total area, in which its utilization is lower. Cultivated land is 453.05 km^2, which covers 29.39 % of total area, in which per capita cultivated land is 1.33 Mu/person, and is in line with the national average. Total area of forest land is 41,192 km^2, and forest land coverage is 26.73 %.

Regional difference of urban land resources utilization around Beijing and Tianjin is prominent. The middle Hebei area has a high socio-economic development level, the percentage of agricultural land is the lowest, and level of per capita cultivated land is the lowest, at 1.04 Mu/person; in the north Hebei area, cultivated land area accounts for a low percentage in total area, but level of per capita

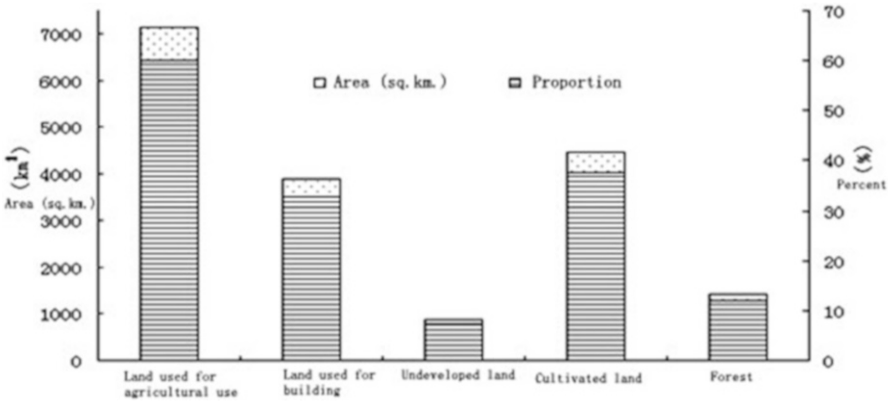

Fig. 3.2 Utilization of land resources in Tianjin

Table 3.1 Utilization of urban lands around Beijing and Tianjin

Cities		East Hebei area Qinhuangdao, Tangshan, Cangzhou	Middle Hebei area Shijiazhuang, Baoding, Langfang	North Hebei area Zhangjiakou, Chengde
Total area	km^2	35,048	42,658	76,421
Population	Ten thousand persons	1,771.58	2,546.36	782.49
Agricultural land	Area km^2	24,410	25,277	56,510
	%	69.65	59.26	73.95
Cultivated land	Area km^2	15,599	17,617	12,089
	%	44.51	41.30	15.82
Forest land	Area km^2	4,220	4,421	32,551
	%	12.04	10.36	42.59
Land used for building	Area km^2	5,480	5,552	2,180
	%	*15.64*	*13.01*	2.85

Note: Data from "*Hebei Provincial Land Use Planning (2006–2020)*" and the China City Statistical Yearbook

cultivated land is the highest, at 2.32 Mu per person. In the east and middle Hebei areas, woodland coverage is lower than the national average, and in the north Hebei area forest coverage rate is 42.69 %. Under the influence of socio-economic conditions, regional natural environment and other factors, utilization of land used for building in the north Hebei area is the lowest, at only 2.85 %. It is obvious that, land used for building, ecological land, and cultivated land resources all have obvious spatial differentiation characteristics.

3.3 Evaluation of Integrated Land Carrying Capacity in Beijing, Tianjin, and Hebei Capital Economic Circle

3.3.1 Evaluation System and Methods

3.3.1.1 Evaluation System Structure

Based on the connotation of integrated land carrying capacity and the requirements for upgrading, according to the formation and features of regional land resources, and by consulting existing research method, the evaluation system of integrated land carrying capacity in Beijing, Tianjin, and Hebei contains three layers: target layer, status layer, and indicator layer, and 15 evaluating indicators, as shown in Table 3.2.

Table 3.2 Evaluating indicator system of integrated land carrying capacity in Beijing-Tianjin-Hebei capital economic circle

Target layer A	Status layer B	Indicator layer C	Character
Integrated land carrying capacity A	Carrying capacity of development and construction B_1	Per capita water resources (cu. m./person)C_1	Benefit-type
		Per capita cultivated land resources (Mu/person)C_2	Benefit-type
		Per capita land used for building (sq.km./ten thousand persons)C_3	Benefit-type
		Land use rate (%)C_4	Cost-type
	Carrying capacity on social resources B_2	Population density (person/sq.km.)C_5	Moderate
		Natural growth rate of population (‰)C_6	Moderate
		Urbanization level (%)C_7	Benefit-type
		Proportion of expenditures for science and technology in regional fiscal expenditures (%)C_8	Benefit-type
	Economic carrying capacity B_3	GDP per land (hundred million RMB/sq.km.)C_9	Moderate
		Investment per land in fixed assets (hundred million RMB/sq.km.)C_{10}	Benefit-type
		Grain yield of per unit area (kg./ha.)C_{11}	Benefit-type
	Eco-environment carrying capacity B_4	Forest coverage (%)C_{12}	Benefit-type
		Undeveloped land rate (%)C_{13}	Benefit-type
		GDP energy consumption per ten thousand RMB (ton coal equivalent/ten thousand RMB)C_{14}	Cost-type
		Per capita public green space area (sq.m./person)C_{15}	Benefit-type

Integrated land carrying capacity resources is the target layer, is the highest layer of the overall evaluating indicator system, and reflects integrated land carrying capacity resources in Beijing, Tianjin, and Hebei region. The status layer reflects the connotation of the integrated land carrying capacity resources, and includes carrying capacity of land development and construction, social carrying capacity of land, economic carrying capacity of land, and ecological carrying capacity of land. The indicator layer is the representative operable indicator, and it is divided into benefit, moderate, and cost indicators.

3.3.1.2 Calculation Method

(a) Standardization indicators

Integrated land carrying capacity resources relates to population, building size, socio-economy, ecological environment, and other factors, the evaluating indicators have different attributes, significances, and units of measure, therefore, in order to facilitate calculation with a uniform method, they need to be dimensionless. In evaluating indicators, attribute values of benefit indicators show positive correlation with carrying capacity, and cost indicators show negative correlation. Attribute values of moderate indicators have a limit, in view of the development of Beijing-Tianjin-Hebei region, this class of indicators are disposed in accordance with benefit indicators. After standardization, the decision matrix is Y = (yij) n ∗ m, obviously the bigger Y value is, the better it is. The methods are as follows:

Benefit indicators:

$$y_{ij} = \frac{x_{ij} - \min_{1 \le i \le n} x_{ij}}{\max_{1 \le i \le n} x_{ij} - \min_{1 \le i \le n} x_{ij}} (1 \le i \le n, 1 \le j \le m)$$

Cost indicators:

$$y_{ij} = \frac{\max_{1 \le i \le n} x_{ij} - x_{ij}}{\max_{1 \le i \le n} x_{ij} - \min_{1 \le i \le n} x_{ij}} (1 \le i \le n, 1 \le j \le m)$$

(b) Determination of multi-indicator weighting and calculation of evaluation values

For weightings in this overall evaluating indicator system, the indicator layer uses mean-square deviation decision weighting method, the target layer uses the weighting method variance weighting, and the status layer uses combination of mean-square deviation objective weighting method and expert subjective weighting method to make objective and overall evaluation to the integrated land carrying capacity in Beijing-Tianjin-Hebei capital economic circle. The basic thought is: based on the evaluating indicators as random variables, dimensionless attribute value of the programs under the indicators is the value of this random variable, after getting the mean of random variables, and then the mean-square deviation of the indicator set is calculated, and mean-square deviation is normalized, its results are weighting coefficients of indicators, and finally we sort and decide on the indicators.

3.3.2 Evaluation of Integrated Land Carrying Capacity

According to the calculation method, weighting coefficients of indicators after made dimensionless are shown in Table 3.3, and the collection of carrying capacity of land development and construction, carrying capacity of social resources, economic carrying capacity, and carrying capacity of ecological environment in Table 3.4. The weight coefficients of the status layer are synthetically confirmed by mean-square deviation objective weighting and expert weighting, as well as existing research findings. In the status layer, the weighting order of four support systems is eco-environment carrying capacity > carrying capacity of social resources and carrying capacity of development and construction > economic carrying capacity; their weight coefficients as shown in Table 3.5. Using linear weighting sum function method, total score of carrying capacity of regional integrated land resources is calculated, as shown in Table 3.6.

Table 3.3 Weight coefficients of evaluating indicators of integrated land carrying capacity

Indicators	Mean	Mean-square deviation	Weight coefficients
Per capita water resources C_1	0.15184	0.21291	0.22516
Per capita cultivated land resource C_2	0.18183	0.22268	0.23550
Per capita land used for building C_3	0.18067	0.22906	0.24224
Land use rate C_4	0.35490	0.28093	0.29709
Population density C_5	0.14473	0.26419	0.20217
Natural growth rate of population C_6	0.48629	0.27014	0.20672
Urbanization level C_7	0.50535	0.35516	0.27177
Expenditures for science and technology in regional fiscal expenditure proportion C_8	0.71797	0.41732	0.31934
GDP per land C_9	0.09240	0.23487	0.28968
Investment per land in fixed assets C_{10}	0.18226	0.27856	0.34357
Grain yield of per unit area C_{11}	0.65285	0.29735	0.36674
Forest coverage C_{12}	0.43629	0.28211	0.26450
Undeveloped land rate C_{13}	0.35490	0.28093	0.26339
GDP energy consumption of ten thousand RMB C_{14}	0.66534	0.26444	0.24793
Per capita public green space area C_{15}	0.31305	0.23911	0.22418

Table 3.4 Collection on carrying capacity of land development and construction, carrying capacity of social resources, economic carrying capacity, and ecological environmental carrying capacity

Areas	Carrying capacity of development and construction	Carrying capacity of social resources	Economic carrying capacity	Eco-environment carrying capacity
Dongcheng district	0.016210	0.79873	0.54201	0.282245
Xicheng district	0.014964	0.84584	0.59368	0.247933
Chaoyang district	0.044638	0.74523	0.57034	0.427733
Fengtai district	0.099744	0.73089	0.34233	0.416451
Shijingshan district	0.057758	0.78011	0.15000	0.401521
Haidian district	0.035609	0.75794	0.46990	0.454615
Fangshan district	0.249593	0.56747	0.29238	0.337612
Tongzhou district	0.126618	0.58584	0.33929	0.278179
Shunyi district	0.196323	0.54580	0.34138	0.427566
Changping district	0.103545	0.68922	0.25613	0.482864
Daxing district	0.123028	0.66019	0.35785	0.346285
Mentougou district	0.533175	0.57040	0.09055	0.536412
Huairou district	0.293182	0.54089	0.30284	0.645958
Pinggu district	0.207243	0.45416	0.30259	0.550064
Miyun county	0.359344	0.45293	0.27842	0.701186
Yanqing county	0.265470	0.40415	0.36796	0.704215
Tianjin city	0.175681	0.40335	0.31173	0.311084
Qinhuangdao city	0.390403	0.18607	0.30790	0.574444
Tangshan city	0.354339	0.20191	0.34881	0.326505
Cangzhou city	0.183812	0.22449	0.28415	0.319546
Baoding city	0.400697	0.21991	0.33200	0.502996
Langfang city	0.163725	0.26306	0.32182	0.347595
Zhangjiakou city	0.562729	0.13700	0.15011	0.396300
Chengde city	0.428537	0.14804	0.23739	0.636993

Table 3.5 Weighting of integrated land carrying capacity

Indicator factors	Carrying capacity of development and construction (B1)	Carrying capacity of social resources (B2)	Economic carrying capacity (B3)	Eco-environment carrying capacity (B4)
Integrated weighting	0.2487	0.2527	0.1685	0.3301

Table 3.6 Integrated land carrying capacity

Areas	Integrated carrying capacity	Areas	Integrated carrying capacity
Dongcheng	0.39037	Huairou district	0.47386
Xicheng district	0.39934	Pinggu district	0.39887
Chaoyang district	0.43672	Miyun county	0.48220
Fengtai district	0.40466	Yanqing county	0.46261
Shijingshan district	0.36932	Tianjin city	0.30083
Haidian district	0.42963	Qinhuangdao city	0.38562
Fangshan district	0.36619	Tangshan city	0.30570
Tongzhou district	0.32853	Cangzhou city	0.25581
Shunyi district	0.38541	Baoding city	0.37720
Changping district	0.40247	Langfang city	0.27616
Daxing district	0.37203	Zhangjiakou city	0.33068
Mentougou district	0.46907	Chengde city	0.39426

Evaluating values of carrying capacity are 0–1, the higher the value is, the bigger the integrated land carrying capacity resources is. Integrated land carrying capacity resources is evaluated by the classification evaluation method, namely evaluation scores from 0 to 1 are divided into four levels, scores >0.8 are the highest level, 0.8–0.6 are higher level, 0.6–0.4 are the medium level, 0.4–0.3 are the lower level, and the scores <0.3 are the lowest level.

1. Evaluation of carrying capacity on land resources development and construction

According to the evaluation results, land carrying capacity development and construction in Beijing-Tianjin-Hebei capital economic circle is at a low level, and level differences are also very clear. Zhangjiakou City, at the highest level is 36 times that of Dongcheng District of Beijing. Figure 3.3 shows regional differences of the land carrying capacity development and construction. It is observed that its spatial variation shows obvious increase from the core area to the periphery,

Fig. 3.3 Regional differentiation of carrying capacity of land resources development and construction in Beijing-Tianjin-Hebei capital economic circle

especially increasing to the West, to the East and to the North. Zhangjiakou City, Mentougou District, Chengde City, and Baoding City have the biggest development potential because of rich soil and water resources in these areas, or due to lower land-use rate, or smaller populations. The higher the level of per capita land use is, the bigger the carrying capacity of development and construction. Xicheng, Dongcheng, Haidian, Chaoyang, Shijingshan and Fengtai districts in Beijing have the lowest carrying capacity of land development and construction because of excessive development of land, and at present the population carrying capacity on the land has reached a state of beyond-saturation. Land resources development should be impelled to those areas with big potential, and give priority to intensive use in order to save.

2. Evaluation of carrying capacity on land resources and social resources

The carrying capacity on land resources and social resources in Beijing-Tianjin-Hebei capital economic circle is at the highest level and medium-high level, which reflects its function of political and cultural center. The carrying capacity of social resources has big differences. Dongcheng District of Beijing, the highest level is five times that of Zhangjiakou City of Hebei province, the lowest level. Figure 3.4 shows the regional differences of carrying capacity on social resources, it is observed that the highest level is in the capital core area, and southern areas are higher than northern areas. High carrying capacity of social resources is in Xicheng, Dongcheng, Shijingshan, Haidian, Chaoyang, and Fengtai districts, and the low one is in Zhangjiakou, Chengde, Qinhuangdao, Tangshan, Baoding, Cangzhou, and Langfang cities, and the medium level in Tianjin City. The land used for high-end services and technological research and development should be clustered in those areas with high carrying capacity of social resources.

3. Evaluation of economic carrying capacity on land resources

Economic land carrying capacity in Beijing-Tianjin-Hebei capital economic circle is at relatively low level, Xicheng District of Beijing, the highest level is five times that of Mentougou District of Beijing, the lowest level. Figure 3.5 shows regional differences of economic carrying capacity, it is observed that in addition to the core area, economic carrying capacity level features the spatial variation of decrease from east to west; economic carrying capacity in Mentougou District and Shijingshan District of Beijing is low because Mentougou District is almost solely mountainous area, and GDP per land and grain yield of per unit area are low, and because Shijingshan District has no first industries, and second and third industries are still at a low level; other lower economic carrying capacity is in Zhangjiakou City, Chengde City, Changping District, Miyun County, Cangzhou City, and Fangshan District, and the high level is Xicheng, Chaoyang, Dongcheng, and Haidian districts; Tianjin is at a medium level. Redevelopment of land resources and urban land consolidation should focus on those areas with high economic carrying capacity.

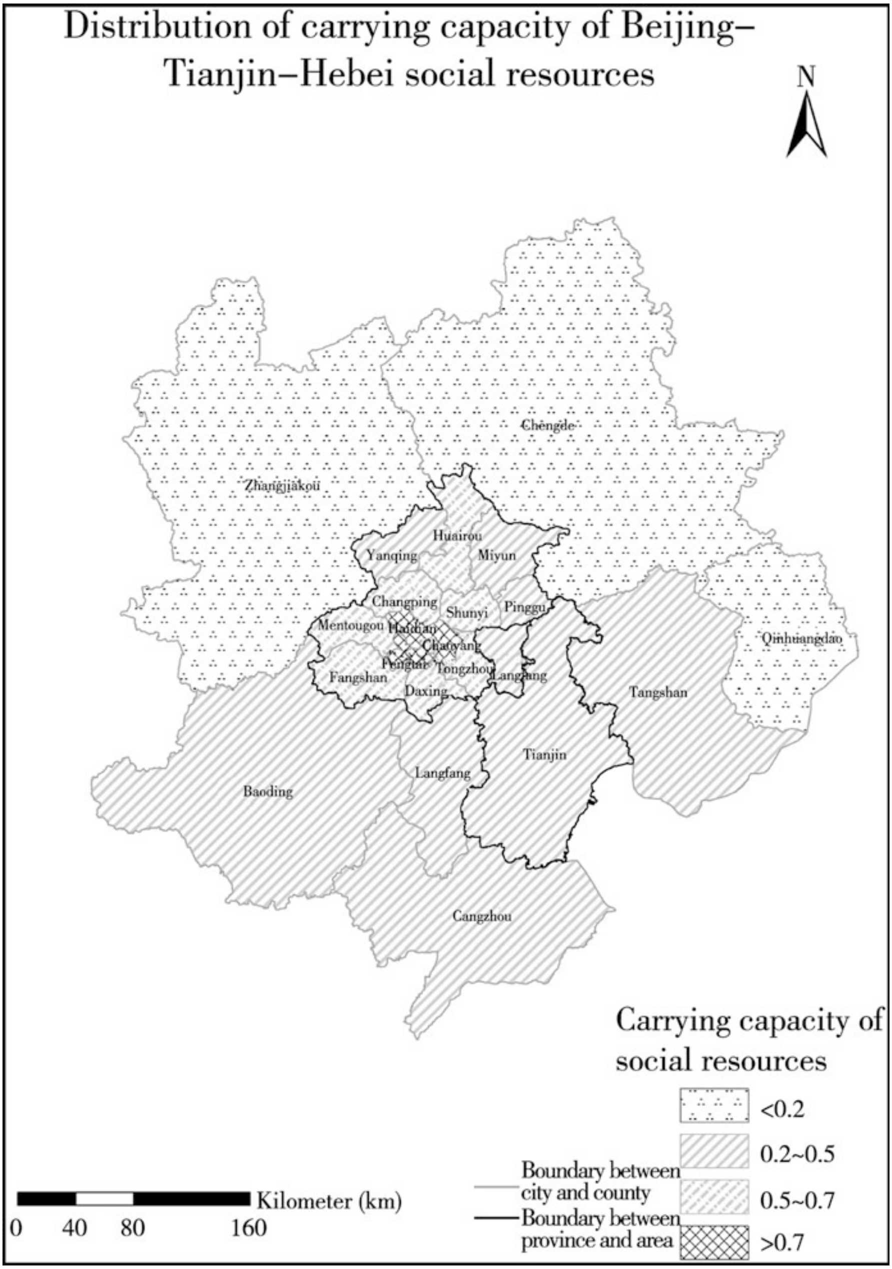

Fig. 3.4 Regional differentiation of social carrying capacity on land resources in Beijing-Tianjin-Hebei capital economic circle

Fig. 3.5 Regional differentiation of economic carrying capacity on land resources in Beijing-Tianjin-Hebei capital economic circle

4. Evaluation of ecological environmental carrying capacity on land resources

Eco-environmental carrying capacity on land resource in Beijing-Tianjin-Hebei capital circle is at the low-medium level; Yanqing and Miyun Counties, at the highest level is nearly twice that of Xicheng District of Beijing, at the lowest level. Figure 3.6 shows regional differences of ecological environmental carrying capacity, it is observed that it is a decreasing spatial variation from the periphery to the core area, and the north area is higher than the south area; the highest level is in Yanqing County, Miyun County, Huairou District, and Chengde City, the higher level is in Qinhuangdao City, Pinggu District, Mentougou District, and Baoding City; the lowest level is in Xicheng, Tongzhou, and Dongcheng districts, and the lower level is in Tianjin City, Cangzhou City, Tangshan City, Fangshan District, Daxing District, Langfang City, and Zhangjiakou City. Low carrying capacity is caused either because of insufficient public green space and relatively high energy consumption of GDP per ten thousand RMB, such as Zhangjiakou City; or because of lower unused land rate reflecting a weaker natural ecological system, such as Langfang and Tianjin. In those areas with low eco-environmental carrying capacity, ecological land should be guaranteed as far as possible, and ecological construction should be vigorously promoted; in those areas with high eco-environmental carrying capacity, the ecosystem should be restored and conserved to better play a role of ecological barrier.

5. Evaluation of integrated carrying capacity on land resource

Overall evaluation of land resources in Beijing-Tianjin-Hebei capital economic circle is 0.3832, at a relatively low level. Beijing has the highest integrated land carrying capacity, at a medium level; Tianjin City and cities in Hebei province around Beijing and Tianjin are relatively consistent, at a relatively low level. Figure 3.7 shows the regional differentiation of integrated carrying capacity, it is observed that the high level is at the northeast – southwest central axis, and the lower level is at the southeast and northwest areas. Medium integrated carrying capacity is in Miyun County, Huairou District, Mentougou District, Yanqing County, Chaoyang District, Haidian District, Fengtai District, and Changping District; the low level is in Cangzhou and Langfang cities, and the rest are at relatively low level. Integrated carrying capacity is caused by complex influencing factors, land development and construction, social resources, economic and environmental factors; generally the higher the social and economic carrying capacities are, the lower the eco-environmental carrying capacity is, so that whole regional integrated carrying capacity level is not high. When there is space-optimizing configuration of land use, the carrying capacity of various status layers should be analyzed respectively.

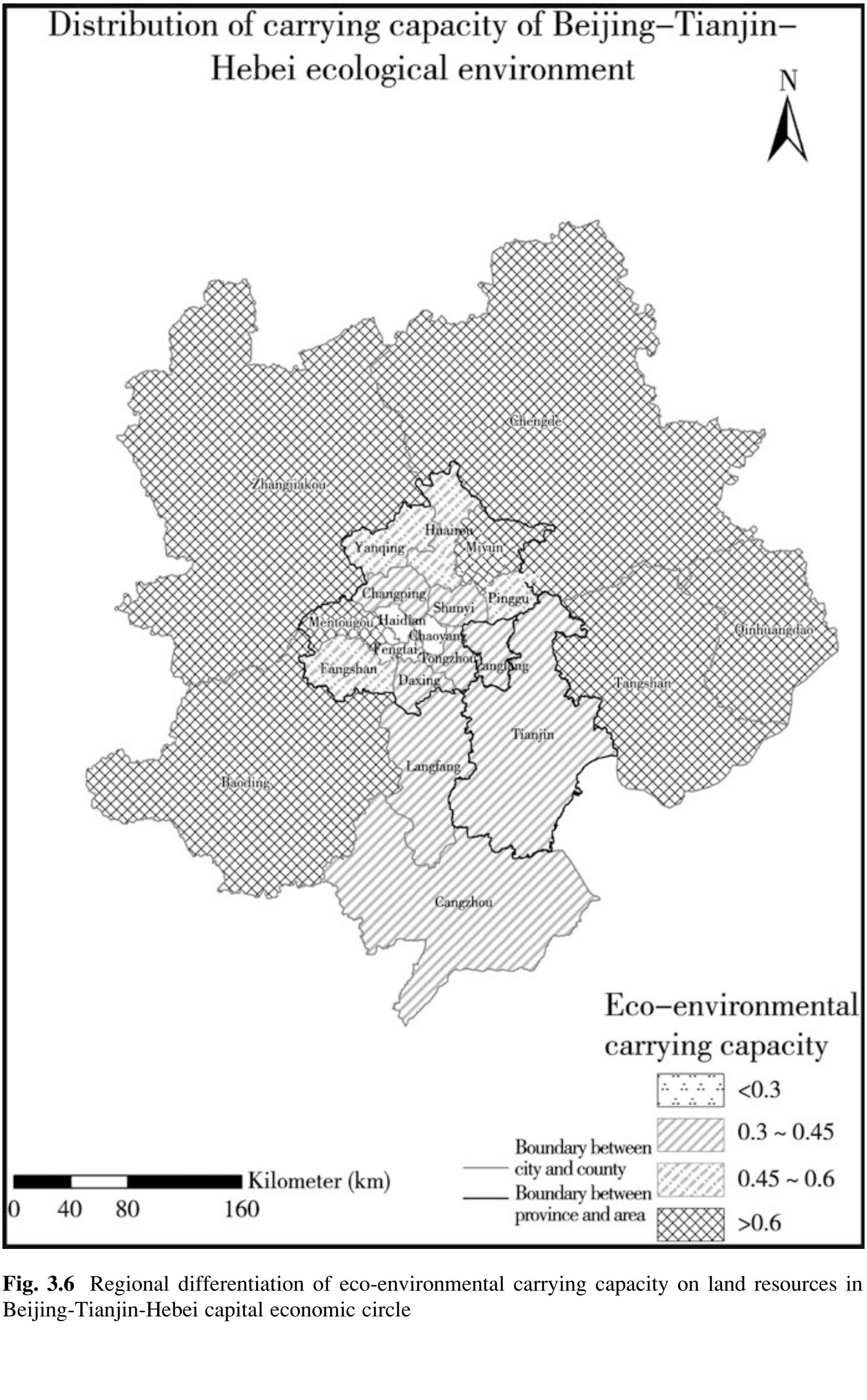

Fig. 3.6 Regional differentiation of eco-environmental carrying capacity on land resources in Beijing-Tianjin-Hebei capital economic circle

Fig. 3.7 Regional differentiation of integrated carrying capacity on land resources in Beijing-Tianjin-Hebei capital economic circle

3.4 Suggestions on Increasing Land Carrying Capacity in Beijing-Tianjin-Hebei Capital Economic Circle

3.4.1 Promoting Regional Harmony, Forming Spatial Patterns of Rational Land Utilization

1. Ecological barrier construction area in the north capital economic circle

The north capital economic circle includes seven cities and districts: Zhangjiakou, Chengde, Yanqing, Huairou, Miyun, Pinggu, and Mentougou. Land use in the region should give priority to ecological land, the region should greatly increase areas of ecological land, fully uses barren hills, slopes, and ravines for forestation, strengthen treatment of sand source in Beijing and Tianjin, protect forest construction and soil and water conservation, and improve the land eco-environment to further improve eco-environmental land carrying capacity.

The region should increase the land used for buildings, speed up the reclamation of wasteland, and guarantee demands of the land used for building for the development of major cities and small towns; strictly protect high-quality cultivated lands and basic farmlands, strengthen agricultural land consolidation and rational distribution of rural residential areas, vigorously develop characteristic agriculture and eco-economic industries, and promote green production and consumption.

2. Urban functions optimizing areas in central capital economic circle

The central capital economic circle includes Beijing's capital core area, and its functional development areas, development of new areas, Tianjin core area and its functional development areas, West Beijing and Tianjin joint development area, and the north area of Langfang city in Hebei province. The region should further intensify its role of capital center to highlight the status of political, cultural, business, and trade services in the whole country. The direction of land use in the region should focus on urban land used for city agglomeration, it should strongly increase the degree of intensive land used for building, guarantee necessary infrastructure, public service facilities, and ecological land, attach importance to ecological service function and landscaping of land, and keep the balance of lands used for living, production, services, and ecology.

The region should integrate various classes of land use through land-use planning, industrial configuration, residential area development, and other measures, reasonably disperse the population and transfer industry, guide cluster development of land use in cities and towns, compress scale of land used for rural residential areas, increase construction of green space, prevent the spread of urban development, and form a rational distribution of towns, industrial optimal allocation, and international urban areas with efficient eco- services.

3. Metropolitan population of the industrial coastal agglomeration in the east capital economic circle

The east capital economic circle includes Binhai, the new area of Tianjin, namely Tanggu District, Hangu district, and Dagang administrative areas and a part of Dongli district and Jinnan district, Qinhuangdao and Tangshan of east Hebei province, and the east area of Cangzhou. The region relies on Beijing, Tianjin, and Hebei, which face the Bohai Sea, and is the gateway of north China to foreign trade, and is the coastal agglomeration of population and industries in the east capital economic circle.

The region is main area of land used for new buildings in the capital circle; and strengthens the regulation of land use planning and regional coordination, accelerates infrastructure construction, increases land consolidation and land conservation strength, in particular obsolete land consolidation and protection of coastal wetlands, protects land used for key industries and construction of green belts in various areas, and enhances the land carrying capacity as much as possible.

4. Optimizing area of green space in the south capital economic circle

The south capital economic circle includes most part of Baoding and Langfang, and the west area of Cangzhou in Hebei province. The area is the development area of key towns of Hebei province in the capital circle, is an important grain production base, and is an optimizing area of green space in the south capital economic circle.

The area should continuously improve the ecological environment of land, strengthen ecological construction of water conservation areas in mountainous area, speed up agricultural land consolidation, medium and low yield field reformation, attach importance to the rectification of land used for key project construction, synthetically plan for green space including cultivated land, maintain the balance between industrial development and livable construction, and guarantee the eco-environmental carrying capacity of the land.

3.4.2 Strengthening Economical and Intensive Use of Land, Improving the Carrying Capacity of Land Development and Construction

1. Vigorously developing the social economy, strengthening social and economic carrying capacities

Social and economic carrying capacities of the Beijing-Tianjin-Hebei capital economic circle is not yet high, and regional differences are large, and cities in Hebei province around Beijing and Tianjin have lower social and economic carrying capacities. Currently, the region should make unified planning, quickly improve economic strength of new urban development areas and ecological conservation area in Beijing and Tianjin, vigorously develop the economy of cities in Hebei province around Beijing and Tianjin, and accelerate the construction of economic and social carrying capacity in those cities around Beijing and Tianjin, which would lay a foundation for a reasonable layout of the population and industries in the capital circle.

2. Consolidating land used for building, improving carrying capacity of the land used for building

The carrying capacity of land resource development and construction is still low in the Beijing, Tianjin, and Hebei capital economic circle, especially extensive use of land used for building has appeared, and intensive land utilization efficiency is low. To improve carrying capacity of regional land development and construction, the carrying capacity of the existing land used for building must be upgraded. Urban development areas around Beijing and Tianjin and cities around Beijing and Tianjin should give priority to cluster development to improve the volume rate to provide a foundation of land carrying capacity in the spread of the population and industries in central urban areas. In mountainous areas in the capital economic circle, the reclamation of waste lands should be further promoted, rural residential areas should be renovated in order to have rational distribution, and the latent power of existing land used for building in the countryside should be fully tapped, which will provide the foundation of land carrying capacity for the development of green industries.

3. Strictly protecting cultivated land and basic farmland, increasing comprehensive benefits of farmland

In the Beijing-Tianjin-Hebei capital economic circle, cultivated land resources are very limited, currently agricultural land planning and consolidation planning in the capital circle should be compiled as soon as possible to strictly protect plateaus and cultivated land resources in plain areas and mountainous areas in the capital circle, to support grain production and construction of characteristic agricultural product bases, to lead non-agricultural land used for building to develop urban agriculture, ecological services, leisure and recreation, and to increase social, economic, and ecological comprehensive benefits of agricultural lands.

3.4.3 Strengthening Management of Water Resources, Enhancing Carrying Capacity on Water Resources

1. Enhancing optimal allocation of land and water resources, regulating space layout of population and industries

Soil and water resources in the Beijing-Tianjin-Hebei capital economic circle have big spatial variation, soil erosion in mountainous areas and land desertification and land subsidence in the plain are prominent, groundwater exploitation is excessive, and population and industrial distribution is not rational. Currently, the capital circle should further optimize and improve integrated planning of water resources, enhance optimal allocation of land and water resources, and agricultural, industrial, and urban integrated configuration, set regional and industrial thresholds for water consumption, regulate population and industrial spatial distribution, and guarantee regional balance of water and land resources.

2. Strengthening technological support, improving utilization efficiency of water resources

First, the region should speed up to promote utilizing reclaimed water, especially should increase the check of reclaimed water reclamation in new cities, new residential areas in cities of Hebei province around Beijing and Tianjin, and business areas; second, the region should reduce the proportion of industrial water, improve rate of recycling industrial water; thirdly, the region should increase appraisal indicators for water use efficiency in regional examination, residential area appraisal, industrial performance, and acceptance of related projects to comprehensively improve utilization efficiency of water resources.

3. Attaching importance to broadening the sources of income and reducing expenditure, improving carrying capacity on water resources

To broaden the sources of income, in addition to scientific configuration of reasonable water diversion for soil and water resources, first is to implement rain collection and utilization projects as soon as possible for ecological water utilization and agricultural water utilization; second is to promote seawater desalination for industrial water utilization as far as possible; third is to improve sewage resource-processing rate, especially in new cities and new development zones, rural areas and other areas with low sewage resource-processing rate. To reduce expenditure, first is to strengthen publicity and education and advocate habits of water saving; second is to strongly develop rural technology, promote comprehensive promotion of agricultural water saving technology, such as promotion and implementation of drip irrigation, controlled irrigation, zero tillage coverage and other technology; third is to attach importance to construction of water conservancy works, strengthen the research of advanced technology for construction of water conservancy works, and upgrade the level of water conservancy construction; fourth is to transform and upgrade technological process and replace equipment, to reduce industrial water consumption, and to construct water-saving industries.

4. Increasing protection strength, controlling shortage of pollution-type water resources

First is to increase protection of water sources by rationally drawing up planning of soil and water resources in the capital economic circle; second is to improve quality of agricultural irrigation water by rationally using fertilizer and pesticide, strengthening land pollution treatment, and controlling pollution of surface source; third is to strictly limit industrial wastewater emission, strengthening sewage resource-processing, achieving a target of “zero” emission; fourth is to improve recycled water technology and construction capacity, to consummate the recycled water design and water quality standard and other specifications and systems, and to improve sewage processing capacity so that there is “zero” domestic water pollution in the water environment.

3.4.4 Improving Quality of Ecological Environment, Guaranteeing Carrying Capacity of Land Eco-environment

1. Taking suitable measures to implement environmentally friendly land utilization mode, guaranteeing sustainable land utilization

   (a) Speeding up to build an environmentally friendly land eco-economic utilization system
   The level of society, economy, and science and technology in Beijing, Tianjin, and Hebei capital circle and capital eco-environment requires that it actively explore and build an environmentally friendly land eco-economic utilization system.

   First is to promote the development of a circular economy in the industrial park, especially in new development districts of the cities and in industrial support areas of the cities around Beijing and Tianjin, and building a cluster of circular economy so as to achieve harmony between industrial development and ecological environment.

   Second is to enhance the industrial threshold in mountainous areas and the hilly country to develop green cleaning industry, namely actively exploring sustainable development of environmental protection and clean and sustainable production.

   Third is to vigorously develop modern urban eco-agriculture, vigorously promote the research and development of agricultural technology and eco-technology by fully using the ecological principle and eco-technology in agricultural production, to develop towards facility, intensive, landscaping, technological, and green industries under a market-oriented direction, to guarantee sustained and steady agricultural production capacity, and to highlight the ecological protective barrier and entertainment function.

   Fourth is to accelerate the development of environmentally friendly services; based on full development, to use political and cultural resources of the Beijing-Tianjin-Hebei capital economic circle, to accelerate the development of services in favor of reducing the intensity of resources and energy consumption for socio-economic development, and in favor of building an economical society.

   (b) Actively promoting the differentiation of land use modes
   First is differential urban and rural land use mode. In accordance with requirements of efficient conservation, ecological health and an orderly environment, urban areas should emphatically guarantee demand of ecological land, tap into the internal latent power, strictly control the scale of land used for building, and enhance intensive utilization efficiency of land used for building. In accordance with requirements for cultivated land protection, ecological conservation, environmental improvement, rural

areas should vigorously develop modern highly-efficient agriculture and control the scale of rural land used for collective construction, and maximize the ecological benefits of agricultural land and landscape service function to continually promote an orderly rural appearance.

Second is differential land use mode in the plains and mountainous areas. The plain areas should insist on the principle of cultivated land protection and economical and intensive use of land used for construction, and build the mode of urban and rural unified planning of land use according to the mode of "Trinity" land use development and consolidation, including town layout and urban construction, industrial parks, and rural residential areas. Mountainous areas should adhere to the principles of ecological priority and appropriate exploitation, pay attention to ecological conservation and water conservation, carefully organize harmony of natural and human landscapes, carefully arrange land used for farming, forestry, animal husbandry and fruit planting, and reasonably configure the land used for villages, tourism, public services, and characteristic industries, and build land use mode of the best ecology, the most beautiful environment, affluent society, and stable industries.

Third is differential land-use mode of core and peripheral areas. Core areas of the capital circle under the jurisdiction of Beijing and Tianjin have large population density, high social and economic aggregation, and rich historical and cultural resources, therefore the areas should pay attention to developing integration of updating and protecting heritage, mitigating and optimizing the functions of core areas, and emphatically guarantee the land used for international activities and world enterprise headquarters. They also must strongly develop technological research and development and world high-end services, and should build green network system based on urban forest construction to form ecological, social, and economic integrated benefits efficient land utilization pattern. The cities of Hebei province around Beijing and Tianjin, in accordance with strict requirements for economical and intensive land use, should meet demands of promoting land used for urbanization and industrialization to lay a good foundation of land resource for undertaking the population and industrial transfer from core areas; strengthen the protection of farmland resources, and guarantee supply of agricultural products; repair and maintain the eco-system, and enhance the ecological barrier function. Those cities should take a comprehensive view of the overall situation, and emphasize on the differences, make optimizing configuration of land use in Beijing-Tianjin-Hebei capital circle to form land-use spatial optimizing configuration mode of rational population distribution, geographical division of industries, and ecological civilization pattern as soon as possible.

2. Making integrated planning of land eco-system conservation, promoting land eco-environmental construction

The land eco-system refers to an organic complex with energy flow and material cycle composed of terrestrial soil, topography, hydrology, and atmospheric environmental medium and some appropriate biotic communities. Beijing-Tianjin-Hebei capital circle has a fragile land eco-system and evident regional differences, and land eco-system protection planning should be researched and drafted as early as possible. Based on regional differentiation, land eco-system can be roughly divided into urban construction compact district, urban agricultural area in the plains, northern grassland, mountain and hill forest zones, and the eastern tidal flat area. Different systems of eco-environmental have different construction emphases.

(a) About the urban construction compact district. The district is mainly the land used for urban residential areas, business services, independent industries and mines, and traffic. The eco-system features strong humanistic attribute and weak natural attribute, its ecological construction emphasizes on green space planning, disintegrates heat island effect from urban construction concentration, and digests atmospheric pollutants from production and life, which create a livable environment.
(b) Urban agricultural area in the plain is mainly agricultural land and the land used for woodlands, gardens, grasslands, and aquaculture sites in rural areas. The eco-system features reasonable land use having a function of ecological services, and unreasonable land use resulting in surface-source pollution that causes huge harm. Its ecological construction focuses on farmland shelter-belt construction, soil improvement and pollution abatement, water resource supporting facilities, and rural land consolidation based on agricultural land standardization and village reformation.
(c) The northern grassland area is mainly the land used for grass ecological barrier and green animal husbandry. The eco-system features a natural and semi-natural state with natural ecological functions, but it has large interference from human activities, and needs special protection and management. Its ecological construction focuses on rehabilitation and maintenance of the grassland eco-system, reasonable bearing of population and industries, and prevention and cure of grassland degradation and desertification.
(d) The mountainous and hilly soil and water conservation district is mostly woodland, grassland, and undeveloped land. The eco-system features natural and semi-natural state with natural ecological functions, but it also needs special protection and management. Its ecological construction focuses on preventing and curing soil erosion, managing the watershed, and strengthening the construction and preservation of forest, and protecting biodiversity.

In short, the Beijing-Tianjin-Hebei capital circle still has large potential in development and construction of land resources, but has limited water resources, and is constrained by vulnerable ecological environment system in the north as well as restricted by regional administrative fragmentation, which have seriously affected the upgrading of land integrated carrying capacity. Currently, the Beijing-Tianjin-Hebei capital circle should strengthen unified leadership, promote regional coordination, and form a space pattern of reasonable land use as soon as possible; strongly carry out land consolidation, strengthen land economical and intensive utilization, improve carrying capacity of land development construction; increase publicity education and technological support, strengthen water resources management, upgrade carrying capacity on water resources; carry out the concept of ecological civilization and green development, improve eco-environment quality, and guarantee land eco-environmental carrying capacity to ensure sustainable development of the capital economic circle.

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Chapter 4
Studies on Carrying Capacity of Water Resources in Beijing, Tianjin, and Hebei

Yiqing Wu and Guanghui Zhang

4.1 General Thoughts

The “Beijing-Tianjin-Hebei” region refers to the region under the jurisdiction of Beijing, Tianjin, and Hebei province, the area is 200,300 km^2, in which there is 190,500 km^2 of mountainous areas, and 90,800 km^2 of plains, which respectively accounts for 54.67 % and 45.33 % in total area of the region. In the Beijing-Tianjin-Hebei region, Beijing accounts for 8.39 %, Tianjin 5.95 %, Hebei 85.68 %. In the Hebei area, mountainous area and plain area are respectively 49.12 % and 36.54 % in total area of the Beijing, Tianjin, and Hebei region. Prefectural and municipal administrative divisions in Hebei Province adjacent to Beijing and Tianjin are Zhangjiakou, Chengde, Tangshan, Langfang, Baoding, and Cangzhou, and the area is 132,500 km^2, which account for 77.21 % of total area in Hebei. Carrying capacity of water resources is volume of freshwater which is objective and renewable in the natural environment, and which can be used by men on the premise of without natural ecosystem deterioration.

The concept of “carrying capacity on water resource” began in the late 1980s, and there is only a but of research done on it abroad and it typically only touched upon in literatures about sustainable development. Domestic research findings mainly focus on the discussion of concept, connotation, and evaluation methods of the carrying capacity on water resources. “Carrying capacity on water resources” is still a concept with blurry denotation and unspecific meaning, and it has three general types. First is “theory of water resource development scale,” the theory says, at a certain social technology and economic stage, based on gross water resources, “carrying capacity on water resources” is obtained through rational

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allocation and effective utilization, and is the largest scale of water resource development and utilization of the most reasonable social, economic, and environmental coordinated development. Second is “theory of water resource bearing maximum population,” the theory says “carrying capacity on water resources” is the maximum population carrying capacity of regional social and economic development at a specific stage of development, on the basis of foreseeable technological, economic, and social development level, based on a sustainable development principle, on the premise of maintaining sound development of the ecological environment, in the condition of rational distribution and efficient utilization of water resources. Third is “theory of capacity of water resources bearing social and economic system sustainable development,” the theory says “carrying capacity on water resources” is the maximum carrying capacity of water resources in a area to social and economic development in the area through reasonable optimizing configuration, at a specific historical development stage, on the basis of foreseeable technological, economic, and social development level, based on a sustainable development principle, in the condition of maintaining ecological environment sound cycle and development.

Essentially, carrying capacity on water resources is the volume of freshwater that is objectively exists and is renewable in the natural environment, and which can be used by men on the premise of without natural ecosystem deterioration. As it is used for agriculture and animal husbandry, industry and life, quantity or scale of urban artificial maintenance of ecological environment, namely how many population and what economic and social scale it can maintain, and whether it is sustainable, all relate with the natural quality of carrying capacity of water resources, but it belongs to the category of social development concept water civilization, water culture and social and economic property, and it is how human society adapts to the natural environment. Using the same amount of per capita water resources or amount of water resources per land and other indicators, measurement of carrying capacity on natural water resources in different climatic regions or in areas with different development levels has subjective connotation, including accepting the identification of low-efficiency and high consumption of water resources.

As for a complete water resource system region, how much water resource can be used mainly depends on local rainfall condition. The same amount of water resources, in different climatic regions or areas with different development levels, is able to maintain different population sizes or scales of economic and social development. The higher the water civilization and water culture are, the bigger the same amount of water resources can maintain and vice versa, and the more serious the water is wasted. Of course, the utilization of regional water resources is on the premise of ecological and environmental sound development, excluding the amount of water that is needed to maintain the natural eco-environment.

In this paper, “carrying capacity on regional water resources” refers to the amount of water resources which is derived from local natural conditions, and which can be on average utilized for many years based on a time-scale hydrological cycle (generally not less than 10 years). Average annual amount of rainwater resources for many years, total amount of water resources, amount of surface water resources, amount of groundwater resources, average annual amount of water consumption for many years or amount of groundwater production involved in the paper, all are based on corresponding mean values from 1998 to 2010, their present amount uses mean values from 2006 to 2010, and the data from the *Bulletin on Water Resources of Haihe River Basin* from 1998 to 2011, and from the bulletin on corresponding provincial and municipal water resources.

4.2 Amount of Water Resources and the Present Situation

4.2.1 Average Amount of Water Resources for Many Years

The average amount of water resources for many years refers to the ratio between the sum of annual amount of water resources in a balanced period of time (generally not less than 10 years) and the number of years in relevant period of time; it is generally divided into the amount of rain water resources, total amount of water resources, the amount of surface water resources, and the amount of groundwater resources. Total amount of water resources is composed of the sum between the amount of surface water resources and the amount of groundwater resources and deducting the repeat amount of both in the calculation. Average annual rainwater resources is a characteristic indicator, in which its formation ability of water resource in an area is the expression of carrying capacity of local climate condition to water resources, and leads the carrying capacity of water resources in the area.

From 1998 to 2010, average amount of rainfall resources in Beijing, Tianjin, and Hebei region was 97.7 billion m^3/a, and total amount of water resources was 16.13 billion m^3/a, in which amount of surface water resources was 6.78 billion m^3/a, amount of groundwater resources, 12.5 billion m^3/a, and repeat amount of surface-water and groundwater resources 3.15 billion m^3/a.

In Beijing, average annual amount of rainwater resources was 8.13 billion m^3/a, and total amount of water resources was 2.26 billion m^3/a, in which amount of surface water resources was 820 million m^3/a, amount of groundwater resources 1.77 billion m^3/a, and repeat amount 330 million m^3/a. Total amount of water resources per unit area (modulus) was 134,600 m^3/(a.km^2), and amount of groundwater resources (modules) 105,300 m^3/(a.km^2).

In Tianjin, average annual amount of rainwater resources was 5.94 billion m^3/a, total amount of water resources was 990 million m^3/a, in which amount of surface water resources was 640 million m^3/a, amount of groundwater resource 450 million m^3/a, and repeat amount 100 million m^3/a. Total water resource modules per unit area were 82,800 m^3/(a.km^2), and groundwater resource modules were 37,600 m^3/(a.km^2).

In Hebei area, average annual amount of rainwater resources was 83.63 billion m^3/a, total amount of water resources was 12.88 billion m^3/a, in which amount of surface water resources was 5.32 billion m^3/a, amount of groundwater resources 10.28 billion m^3/a, and repeat amount 2.72 billion m^3/a. Total water resource modules per unit area were 75,000 m^3/(a.km^2), and groundwater resource modules were 59,900 m^3/(a.km^2).

Average annual amount of water resources in the prefectural and municipal administrative divisions of Hebei Province around Beijing and Tianjin are shown in Table 4.1. Water resources and groundwater in Tangshan area are relatively abundant; their resource module is respectively 115,100 m^3/(a.km^2) and 103,200 m^3/(a.km^2). Total water resources and groundwater resources in Zhangjiakou, Chengde, and Cangzhou are on the opposite, poor, in which water resource modulus and groundwater resource modulus of Zhangjiakou area are respectively 37,700 m^3/(a.km^2) and 32,300 m^3/(a.km^2), water resource modulus and groundwater resource modulus of Chengde area are respectively 44,800 m^3/(a.km^2) and 30,900 m^3/(a.km^2), and water resource modulus and groundwater resource modulus of Cangzhou area respectively 59,600 m^3/(a.km^2) and 41,000 m^3/(a.km^2), which are only one-third of the water resource modulus of Beijing, and carrying capacity of water resources in the area is weak.

4.2.2 Present Amount of Water Resources

The present amount of water resources refers to the amount of water resources or their mean value in the recent 3–5 years, and mainly reflects the actual water resources in the region of interest in the recent years. When present amount of water resources is larger that the average annual amount of water resources for many years, which indicates a rainy period and increased water resources in the region; when present amount of water resources is less than average annual amount of water resources, which indicates a drought period and reduced water resources in the region.

Relative to the average annual amount of water resources, amount of water resources in Beijing, Tianjin, and Hebei region has showed an increasing trend since 2006. Present amount of rainwater resources is 100.28 billion m^3/a, which increased 2.64 %. Among them, 8.47 billion m^3/a are in Beijing, which increased 4.17 %; 6.43 billion m^3/a in Tianjin, which increased 8.19 %; 85.39 billion m^3/a in Hebei, which increased 2.10 %.

Total amount of water resources is 16.66 billion m^3/a, in which amount of surface water resources is 6.5 billion m^3/a, amount of groundwater resources 13.63 billion m^3/a, which respectively increased 3.29 %, 3.99 % and 9.04 % relative to the annual mean value. In Beijing, total amount of water resources is 2.5 billion m^3/a, in which amount of surface water resources is 820 million m^3/a, amount of groundwater resources 1.97 billion m^3/a, which respectively increased 10.6 %, 0.33 % and 11.28 % relative to that annual mean value. In Tianjin, total amount of water resources is 1.28 billion m^3/a, in which amount of surface water resources is 880 million m^3/a, amount of groundwater resource 580 million m^3/a, which

Table 4.1 Average annual amount of water resources of prefectural and municipal administrative divisions in Hebei Province around Beijing and Tianjin

Administrative divisions	Amount of resources (hundred million m^3/a)				Repeat amount of surface-water and groundwater resources	Resource modulus (ten thousand $m^3/(a.km^2)$)	
	Rainwater resources	Total water resources	Surface water resources	Groundwater resources		Total water resources	Groundwater resources
Zhangjiakou	147.1	13.9	5.5	11.9	3.5	3.77	3.23
Chengde	189.2	17.7	14.6	12.2	9.1	4.48	3.09
Tangshan	72.9	15.5	4.5	13.9	2.9	11.51	10.32
Langfang	31.0	5.1	0.6	4.7	0.2	7.93	7.31
Baoding	107.8	18.2	5.0	16.9	3.7	8.24	7.65
Cangzhou	71.2	8.0	2.6	5.5	0.1	5.96	4.10
Total	619.2	78.4	32.8	65.1	19.5	5.95	4.94

Table 4.2 Present amount of water resources in the prefectural and municipal administrative divisions of Hebei Province around Beijing and Tianjin
Unit: hundred million m^3/a

Administrative divisions	Amount of rainwater resources	Total water resources	Amount of surface water resources	Amount of groundwater resources	Repeat amount of surface-water and groundwater resources
Zhangjiakou	149.8	13.9	5.3	12.2	3.6
Chengde	191.2	16.9	13.3	12.3	8.7
Tangshan	76.4	16.0	4.8	14.5	3.3
Langfang	32.4	5.7	0.8	5.0	0.1
Baoding	113.4	19.8	5.5	18.7	4.4
Cangzhou	75.8	9.9	3.8	6.2	0.1
Total	639	82.2	33.5	68.9	20.2

respectively increased 29.95 %, 38.03 % and 29.69 % respectively relative to the annual mean value. In Hebei, total water resources is 12.87 billion m^3/a, in which amount of surface water resources is 4.8 billion m^3/a, groundwater resources 11.08 billion m^3/a, which respectively increased 0.05 %, 9.70 % and 7.75 % relative to the annual mean value.

Present amount of water resources in the prefectural and municipal administrative divisions of Hebei Province around Beijing and Tianjin is shown in Table 4.2. Relative to the annual mean value of local water resources, amount of rainwater resources in Zhangjiakou, Chengde, Tangshan, Langfang, Baoding, and Cangzhou areas respectively increased 1.84 %, 1.05 %, 4.79 %, 4.54 %, 5.26 %, and 6.45 %; total amount of water resources respectively reduced 0.27 % and 3.50 %, and increased 3.01 %, 11.98 %, 8.73 %, and 23.45 %; amount of surface water resources reduced 3.39 % and 8.69 % and increased 7.77 %, 38.32 %, 9.14 %, and 48.31 %; amount of groundwater resources respectively increased 2.48 %, 0.95 %, 3.72 %, 7.30 %, 10.25 %, and 11.85 %.

4.3 Present Water Consumption and State of Affairs

Present water consumption refers to actual water consumption in the recent 3–5 years, including local surface water supply amount, local groundwater supply amount, water supply amount from water diversion and other water supply amount (such as sea water desalination).

Present situation of water consumption refers to actual situation of water consumption in the recent 3–5 years and its relatively average annual water consumption or change tendency of average annual amount of water resources. When the present water consumption is larger than the average water consumption for many years, and larger than the average annual amount of water resources, it indicates that actual water consumption load in the region of interest is increasing, and is beyond the bounds of water resources, which is adverse to regional economic and social sustainable development. When the present water consumption is larger than the average annual water consumption, but smaller than the average annual amount of water resources, it indicates that actual water consumption load in the region of interest is increasing, which should be paid close attention to.

4.3.1 Present Water Consumption

Relative to average annual water consumption, the water consumption in the Beijing-Tianjin-Hebei region since 2006 showed a decreasing trend. Present total water consumption is 23.65 billion m^3/a, which is less than the annual mean value (25.61 billion m^3/a) by 7.69 %. Among them, it is 3.49 billion m^3/a in Beijing, which reduced 4.36 %; 17.86 billion m^3/a in Hebei, which reduced 9.52 %.

In total amount of water consumption of Beijing-Tianjin-Hebei region, groundwater accounts for 78.47 %, at 18.55 billion m^3/a; agricultural water consumption accounts for 71.49 %, at 16.89 billion m^3/a; industrial water consumption accounts for 14.55 %, at 3.44 billion m^3/a; water for living accounts for 18.36 %, at 4.34 billion m^3/a.

Relative to the annual mean value, present agricultural water consumption increased 3.51 % in the Beijing-Tianjin-Hebei region, in which it increased 12.93 % in Tianjin, increased 3.13 % Hebei, and decreased 8.81 % in Beijing. Present industrial water consumption reduced 1.26 % in the Beijing-Tianjin-Hebei region, in which it reduced 1.48 % in Beijing, reduced 17.86 % in Tianjin, and increased 3.43 % in Hebei. Domestic water consumption increased 12.23 % in the Beijing-Tianjin-Hebei region, in which it increased 17.16 % in Beijing, increased 10.91 % in Tianjin, and increased 9.54 % in Hebei. The three areas' ecological water consumption shows a prominent increasing trend (see Fig. 4.1).

The present water utilization of the administrative districts in the Beijing-Tianjin-Hebei region is shown in Table 4.3. Total agricultural water consumption of Zhangjiakou, Chengde, Tangshan, Langfang, Baoding, and Cangzhou areas is respectively 73.78 %, 70.68 %, 69.95 %, 72.79 %, 79.33 %, and 77.36 % in local total water consumption, relative to the annual mean value, they respectively increased 4.78 %, and reduced 7.43 %, 1.34 %, 3.11 %, 4.77 % and 4.65 %; amount of groundwater mining respectively accounts for 69.34 %, 60.87 %, 71.31 %, 88.63 %, 89.17 %, and 82.66 % of local total water consumption, relative to the annual mean value, they respectively increased 14.41 % and 10.48 %, and reduced 3.81 %, 1.88 %, 5.49 %, and 9.75 %.

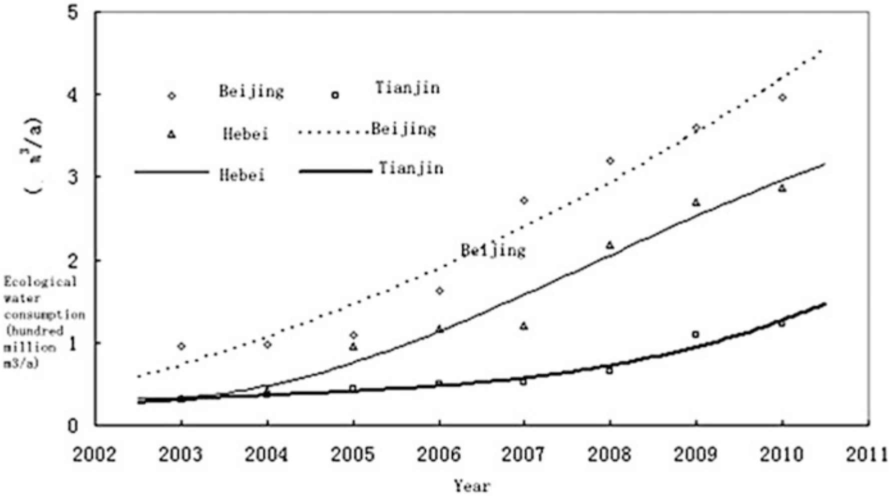

Fig. 4.1 Changes of water consumption for urban eco-environment in the Beijing-Tianjin-Hebei region

4.3.2 Water Utilization

Relative to the average annual total water resources, present water consumption in the Beijing-Tianjin-Hebei region exceeded 46.63 % since 2006, in which Beijing exceeded by 54.7 %, 131.83 % in Tianjin, and 38.68 % in Hebei; the produced quantity in the Beijing-Tianjin-Hebei region overdraft by 48.37 %, in which Beijing has an overdraft of 29.40 %, 41.52 % in Tianjin, and 51.94 % in Hebei.

Overdraft of present water consumption in the administrative districts of Hebei around Beijing and Tianjin is shown in Table 4.4. Relative to the local average total water resources, present water consumption of Tangshan, Langfang, Baoding, and Cangzhou areas respectively had an overdraft of 74.50 %, 80.53 %, 71.01 %, and 31.03 %, amount of groundwater mining had an overdraft of 37.31 %, 82.40 %, 63.76 %, and 73.71 %, respectively. Present total water consumption of Zhangjiakou and Chengde areas and amount of groundwater mining did not overdraft as a whole, but groundwater overdraft in some areas in the plains is more serious.

As for water consumption indicators in various areas, the aggregate of per capita water consumption in Beijing is 200 m^3, 214 m^3 in Tianjin, and 295 m^3 in Hebei. Per capita urban domestic water consumption in the Beijing, Tianjin, and Hebei region is respectively 236, 134, and 147 L/d, and rural and urban per capita domestic water consumption is respectively 203, 88, and 76 L/d. In Beijing, water consumption for GDP of ten thousand RMB and industrial value added is respectively 44 and 35 m^3, respectively 53 and 19 m^3 in Tianjin, and respectively 165 and 57 m^3 in Hebei. Water consumption for farmland irrigation per Mu in Beijing, Tianjin, and Hebei region is respectively 235, 297 and 246 m^3.

Table 4.3 Present water consumption of the prefectural and municipal administrative divisions of Hebei Province around Beijing and Tianjin
Unit: hundred million m^3/a

Administrative divisions	Gross water consumption	Water consumption for agriculture			Amount of groundwater mining		
		Amount	Proportion in total amount (%)	Change rate of relative to mean value for many years (%)	Amount	Proportion in total amount (%)	Change rate of relative to mean value for many years (%)
Zhangjiakou	11.48	8.47	73.78	4.78	7.96	69.34	14.41
Chengde	9.89	6.99	70.68	−7.43	6.02	60.87	10.48
Tangshan	27.92	19.53	69.95	−1.34	19.91	71.31	−3.81
Langfang	10.29	7.49	72.79	−3.11	9.12	88.63	−1.88
Baoding	31.11	24.68	79.33	−4.77	27.74	89.17	−5.49
Cangzhou	13.03	10.08	77.36	−4.65	10.77	82.66	−9.75
Total	103.72	77.24	74.47	−3.04	81.52	78.60	−2.59

Table 4.4 Overdraft of present water consumption in administrative districts of Hebei around Beijing and Tianjin

Unit: hundred million m^3/a

Administrative divisions	Utilization of total water resources			Utilization of groundwater resources		
	Aggregate of average water resources for many years	Aggregate of present water consumption	Overdraft rate (%)	Average amount of groundwater resources for many years	Present amount of groundwater mining	Overdraft rate (%)
Zhangjiakou	13.9	11.48	−17.41	12.2	7.96	−34.75
Chengde	16.9	9.89	−41.48	12.3	6.02	−51.06
Tangshan	16.0	27.92	74.50	14.5	19.91	37.31
Langfang	5.7	10.29	80.53	5.0	9.12	82.40
Baoding	18.2	31.11	71.01	16.9	27.74	63.76
Cangzhou	9.9	13.03	31.62	6.2	10.77	73.71
Total	62.4	72.61	16.36	50.2	53.78	7.13

4.3.3 Groundwater Dynamics in the Plains

Consumers of water resources in the Beijing-Tianjin-Hebei region are mainly distributed in the plains. The groundwater dynamic state in the plains is the actual result of coupling effect between the forming ability of water resource and the strength of water utilization in the Beijing-Tianjin-Hebei region. Reduction of the regional groundwater storage and expansion of groundwater depression cone area indicate that groundwater in the region is overdraft; increase of regional groundwater storage or shrinkage of groundwater depression area indicate that groundwater in the region is being restored.

Since 2006, as the shallow groundwater storage and groundwater depression cone area changes, groundwater in the region of interest has shown signs of restoration, which has something to do with the increase of precipitation and reduction of water consumption for agricultural irrigation in the recent years (see Fig. 4.2). In 2006, shallow groundwater storage was 4.26 billion m^3 less than that of the beginning of the year, and groundwater depression area increased 485 km^2; in 2007, shallow groundwater storage was 3.038 billion m^3 than that of the beginning of the year, and groundwater depression area reduced 1,624 km^2. In 2008, shallow groundwater storage was 648 million m^3 more than that of the beginning of the year, and groundwater depression area reduced 1,268 km^2. In 2009, shallow groundwater storage was 1.591 billion m^3 less than that of the beginning of the year, and groundwater depression area increased 1,948 km^2. In 2010, shallow groundwater storage was 2.544 billion m^3 less than that of the beginning of the year, and groundwater depression area reduced 216 km^2.

According to “Monthly Groundwater Dynamics in North China Plains” issued by the Ministry of Water Resources, in early May 2010, the amount of groundwater in Beijing’s plain area was 10–50 m, 1–5 m in Tianjin, generally 20–50 m in Baoding and Shijiazhuang areas in Hebei plains, more than 75 m (Fig. 4.3a) in some parts, which the amount of groundwater in the plain areas of Beijing-Tianjin-Hebei region had an increase year-on-year in 2009. Until the beginning of May 2011, the amount of groundwater in plain area of Beijing was 12–50 m, 1–8 m in Tianjin, generally 12–50 m in Baoding and Shijiazhuang areas of Hebei, and more than 50 m in some parts. The amount of groundwater in most areas increased year-on-year, and groundwater storage significantly reduced.

In early July 2012, the amount of groundwater in the plain areas of Beijing was 12–50 m, 1–8 m in Tianjin, generally 12–50 m in Baoding and Shijiazhuang areas of Hebei, and 50 m in some parts. In comparison with the same period in 2011, the amount of groundwater in most areas increased, and groundwater storage reduced, as shown in Fig. 4.3b.

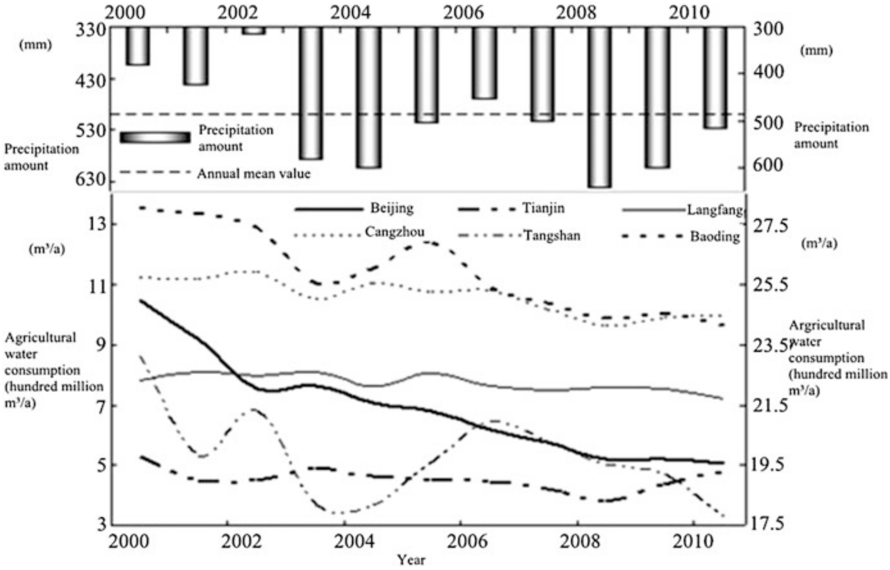

Fig. 4.2 Changes of annual precipitation and agricultural water consumption in Beijing, Tianjin, and Hebei plain areas in the recent 10 years

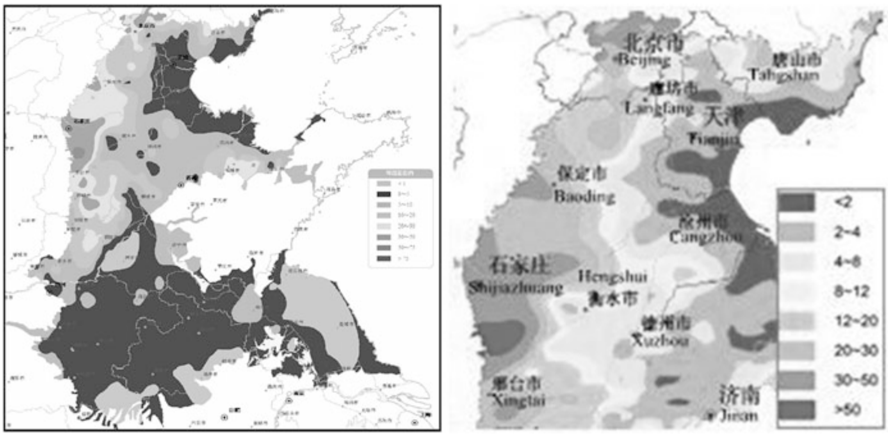

Fig. 4.3 Amount of groundwater in the Beijing-Tianjin-Hebei plains

4.3.4 Future Demand of Water Resources

Domestic water demand includes urban and rural domestic water demands. Urban domestic water demand includes water demand of residential buildings and municipal public water demand, and rural domestic water demand includes domestic water demand of rural population and water demand of livestock. Domestic water demand is closely related to the population, the population is predicted first according to population growth rates of various provinces and cities; then different water use quotas are set for various areas considering the economic development level, finally domestic water demand in Beijing-Tianjin-Hebei plains are achieved, as shown in Table 4.5, in which in 2015, there was 4.378 billion m^3, and in 2020 there was 4.752 billion m^3.

Using the quota unit consumption method, on the basis of economic criteria of industrial water saving, considering new enterprises that use new water-saving technologies and other factors, according to the water-saving level in industrial water saving planning or industrial comprehensive water consumption for output value of ten thousand RMB, industrial water demands of Beijing, Tianjin and Hebei plains in 2015 and 2020 will be 3.704 and 4.094 billion m^3 respectively.

Agricultural water consumption is under the influence of irrigation area and irrigation quota, simultaneously it is constrained by water resources, therefore, irrigation water usage should gradually reduce in the current situation or maintain zero growth, thus, we can obtain agricultural water demands in Beijing, Tianjin, and Hebei plains in 2015 and 2020, which would be 14.301 and 14.089 billion m^3 respectively.

Eco-environmental water demand mainly includes water demands for urban lake and river green spaces, groundwater overdraft suppression, the water course in the plains, and restoration of wetlands and other demands, we can obtain agricultural water demand in Beijing, Tianjin, and Hebei plains in 2015 and 2020, which would be 934 million m^3 and 1.062 billion m^3.

4.4 Emergency Water Sources

Emergency water-supply sources refer to groundwater sources that provide the most basic living conditions to maintain economic and social stability in the Beijing-Tianjin-Hebei region and population concentration in exceptional circumstances such as continuous and extreme drought years, and that can to a large-scale, temporary high-strength supply drinking water, and belong to the basic condition of strategic reserve to ensure the safety of large and medium cities in the Beijing-Tianjin-Hebei region.

4.4.1 Beijing's Emergency Water-Supply Sources

There are four groundwater emergency water-supply sources in Beijing, the two Huairou Rivers, Pinggu, Xishan, and Fangshan emergency water-supply sources, and emergency yield is 830,000 m^3/d (See Table 6.6).

Table 4.5 Water demands of Beijing, Tianjin, and Hebei plains in 2015 and 2020 (China Geological Survey 2009; Xianshao et al. 2007)
Unit: hundred million m^3

Administrative divisions		In 2015					In 2020				
		Domestic water demand		Industrial water demand	Agricultural water demand	Urban environmental water demand	Domestic water demand		Industrial water demand	Agricultural water demand	Urban environmental water demand
		Urban area	Rural area				Urban area	Rural area			
Beijing plains		14.69	0.98	4.78	10.52	4.37	16.45	0.73	4.49	10.20	4.76
Tianjin plains		4.81	1.22	4.96	13.13	1.78	5.14	1.26	5.16	13.44	2.34
Hebei plains		12.06	10.03	27.31	119.36	3.20	13.55	10.39	31.29	117.25	3.52
Areas and cities around Beijing and Tianjin	Zhangjiakou	0.51	0.47	1.45	7.90	0.10	0.53	0.49	1.65	7.55	0.14
	Chengde	0.71	0.59	1.81	6.67	0.08	0.72	0.61	1.79	6.76	0.13
	Tangshan	1.67	1.36	5.75	17.38	0.31	1.87	1.39	6.14	16.98	0.32
	Langfang	1.08	0.74	1.38	6.90	0.26	1.23	0.76	1.53	6.59	0.35
	Baoding	1.59	1.53	2.39	23.64	0.64	1.63	1.61	2.41	23.12	0.66
	Cangzhou	0.76	0.98	1.75	9.85	0.36	0.79	1.03	1.94	9.75	0.47
	Total	6.30	5.66	14.52	72.34	1.75	6.77	5.89	15.46	70.75	2.07
Total demand in Beijing, Tianjin and Hebei region		31.56	12.22	37.04	143.00	9.34	35.14	12.38	40.94	140.89	10.62

The two Huairou rivers emergency and standby water source is located at the Huaihe River alluvial fan, is formed by the superposition of diluvium from the Huaihe River, Shahe River, and Yanqi River, and is adjacent to the Huairou reservoir in the west. Groundwater chemistry type of the water source is HCO_3-Ca · Mg type, in line with national drinking water standard.

Pinggu emergency and standby water source is located at valley mouth- medium bridge area between the Wangdouzhuang Village – Magezhuang Village on the Ju River alluvial fan and Cuo River alluvial fan, and is the joint water source of the quaternary pore water – karst water, and emergency water-supply potential is 27–30 m^3/d.

The Karst water emergency water source in the western suburb belongs to the Ordovician karst fissure water, emergency water supply is 100,000 m^3/d. At present, the karst water emergency exploitation is designed in 15 wells, and average water yield in every well is more than 3,000 m^3/d.

Fangshan emergency water source is the karst water of Fangshan Zhangfang-Changgou area, and emergency water supply reaches 100,000 m^3/d.

4.4.2 Tianjin's Emergency Water Supply Sources

Emergency water-supply sources in Tianjin include four Karst water sources, and emergency water supply is 495,000 m^3/d (See Table 4.6).

West Longhu Valley water source is located at intermountain basin of East Yuqiao Reservoir; main aquifers are composed of Gaoyuzhuang Formation and Wumishan Formation, and are covered by 50–250 m quaternary system flusch sedimentary deposit; groundwater elevation is 18–24 m, groundwater flows from North East to South West, and it is North West-South East direction in the west.

Jixian Chengguan Karst water source is located at clinoplain of southwest Jixian County; its main aquifers are composed of dolomites of Gaoyuzhuang Formation and Wumishan Formation, and are covered by 80–160 m quaternary system flusch sedimentary deposit, and bury of groundwater elevation is 4–12 m.

Baodi lithification karst water source is located at Northeast Baodi County and Southeast Jixian County in Tianjin, it is covered karst water storage structure, the main aquifer is the Middle & Upper Ordovician Majiagou Formation limestone, bury of bedrock layer is 90–200 m, hydrochemical type is HCO3-Ca · Mg, and it may increased yield of 50,000 m^3/d.

Northwest Baodi water source is located at southwest Jixian County, belongs to large-scale flusch concentrated water-supply source, the aquifers of 200–350 m and within 70 m depth are dominated by fine medium sand, sectors of 70–250 m depth are dominated by medium fine sand mingled with gravel, and it is mainly supplied by Xun River basin, emergency water supply is 250,000 m^3/d.

Huangzhuang village depression water source is located at North Tianjin plain, including Southeast Baodi County and Northwest Ninghe County, is the quaternary system diluvium pore water, Aquifer II is dominated by medium fine sand, some

Table 4.6 Groundwater emergency sources of major cities in Beijing-Tianjin- Hebei plains (China Geological Survey 2009)

Area		Location of water source	Emergency available water supply (ten thousand m^3/d)
Beijing		Two Huairou rivers emergency water source	33
		Pinggu emergency water source	30
		Karst water emergency water source in western suburb	10
		Fangshan emergency water source	10
Tianjin		West Longhu valley water source	11.5
		Jixian Chengguan karst water source	6
		Baodi lithification karst water source	5
		Northwest Baodi water source	11
		Huangzhuang village depression water source/Baodi Dazhong village depression water source	16
Hebei	Baoding	Hao village emergency water source	12
	Tangshan	Yanzi river emergency water source	14
		Qingtuoying village emergency water source	16

parts are medium sand, floor bury is 236–285 m, and it is HCO3-Na or HCO3 · Cl-Na water. Aquifer III is medium fine sand, fine sand and silty sand, floor bury is 365–406 m, and it is HCO3-Na · Ca or HCO3-Na water. Mineralization of Aquifers II & III is less than lg/L, and various indicators are able to meet the standards of drinking water.

Baodi Dazhong village depression water source is located in the South-east Baodi County. Aquifers II and III are dominated by fine sand and medium fine sand, it belongs to HCO3-Ca · Na and HCO3 · SO4-Ca · Na water, the mineralization is less than 1 g/L, and various indicators are able to meet the drinking water standards.

4.5 Optimization of Water Resource Allocation and Safeguard

Above analyses indicate that, in recent years, rainwater resources, total water resources, surface water resources, and groundwater resources in Beijing, Tianjin, and Hebei region have increased as a whole, total water consumption and agricultural water consumption reduced, but water consumption for vegetable crop and fruit gardens and parks, living, urban ecological environment, and amount of groundwater mining obviously increased, and bury of groundwater elevation in the most plains increased year after year, and groundwater storage capacity reduced. For the protection of water resource security in Beijing, Tianjin, and

Hebei region, first the allocation of regional water resources should be optimized; second, safe water source safeguard should be constructed; third, the economic utilization of water resources must be intensified.

This region should optimize the allocation of regional water resources. The region should establish a regional system of unified management deployment coordination, and improve the basin water allocation program; increase strategic safe water utilization of Beijing, Tianjin, Shijiazhuang, and other cities through joint deployment among the middle, east, and west water transfer route project of South–north water transfer, and Miyun, Guanting, Cetian, Gangnan and Huangbizhuang, Wangkuai and Xidayang reservoirs; promote allocation optimization of river basin water resources under the new situation, and take into account redistribution of Beijing-Tianjin-Hebei water resources according to water resource module after the South–north water transfer route is dredged; increase strength of ecological water compensation to Daqing River, Chaobai River, Yongding River, Baiyangdian Lake, Hengshui Lake, Nanda Port, Bashang continental river and other rivers; guarantee certain discharge rate of some rivers in Hebei though displacement of the South–north water transfer; and gradually established trans-provincial river water right system and headwater conservation compensation system.

This region should build a safe water source safeguard system. The region should complete the construction of auxiliary projects at the middle route of the South–north water transfer project, and construct Langfang-Zhuozhou, Shijiazhuang-Tianjin, and other intercity trunk canals; consummate the Yellow River diversion project that enters Hebei, and fully promote the construction of the Yellow River diversion project that enters Hebei to compensate the Baiyangdian Lake; actively promote construction of Shuangfeng Temple Reservoir of Chengde and Zhangjiakou Wulahada Reservoir; emphatically strengthen the water quality protection of Guanting reservoir, Yuqiao reservoir, Zhangfang reservoir, and water sources from Luan River and Changjiang River and other water sources; actively promote the seawater desalination project, construct the coastal seawater desalination utilization industrial belts for Tianjin, Qinhuangdao, Tangshan, and Cangzhou and the one along the Baodi, Langfang, and Tongzhou route, give financing and policy support for the construction of seawater desalination supply and distribution project system; establish an emergency response system, and implement emergency groundwater supply mechanism to ensure the safety of water supply of big and medium cities in Beijing, Tianjin, and Hebei plains.

This region should strengthen the economic utilization of water resources. The region should implement the strictest system of water resources management; establish the three red lines for total utilization of water resources in the Beijing-Tianjin-Hebei region (capital economic circle), and establish water use efficiency and pollutant control in water function zones; speed up water saving technical renovation in Shijiazhuang-Tianjin irrigation area, Luanhe River lower reach irrigation area, Sha river irrigation area, Douhe irrigation area, irrigation area of water diversion from Qinglong river, and other large and medium irrigation areas because the maximum potential of water saving is from agriculture; build new irrigation areas of water diversion from Yellow River in Cangzhou, Hengshui, and Langfang along the Yellow River diversion project that enters Hebei to compensate the Baiyangdian Lake to develop highly-efficient water-saving agriculture; develop agriculture of moderate water consumption according to characteristics of irrigation areas to gradually reduce irrigation water consumption, continuously adjust the planting structure and water consumption structure, develop water-saving crops, rationally control the scale of vegetable crop planting and its water consumption; strictly control new projects of high water consumption, encourage enterprises' water-saving technical transformation; increase strength of urban pipe network reconstruction, and reduce the leakage rate of the pipe network; in accordance with the principle "infiltration first, then discharge," build urban rainwater detention storage facilities to increase rainwater utilization efficiency and amount; strengthen the protection of water resources, increase utilization of reclaimed water, construct sewage treatment and reclaimed water pipeline system in new town zones and parks, and gradually promote construction of reclaimed water factories in cities and counties; build water-saving demonstration resident areas, accelerate the promotion and popularization of water-saving appliances, gradually build a water-saving domestic water system; establish a water-saving mechanism, implement differential pricing, and strictly control the waste of water resources.

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Chapter 5
Studies on Carrying Capacity of Water Resources in Beijing and Tianjin: Based on the Water Footprint

Minjun Shi, Zhuoying Zhang, and Dingyang Zhou

5.1 Concept Connotation and Calculation Method of Carrying Capacity of Water Resources

5.1.1 Concept Connotation of Carrying Capacity of Water Resources

Carrying capacity of water resources is a concept with a natural-social dual attribute, not only reflects the capacity of water system to meet demands of social and economic systems, but also is closely related to the degree of social and economic systems' natural water resource system. The concept of carrying capacity originally came from land carrying capacity. The carrying capacity of water resources follows after land carrying capacity in regards to importance in the carrying capacity of resources and environment, and in recent years it has become a research focus and hotspot in the field of water resource science. At present the academic circle has not reach a consensus on the definition of carrying capacity on water resources; different scholars have different opinions. Shi Yafeng and Qu Yaoguang (1992) says, "carrying capacity of water resources refers to the maximum capacity which water resource can carry the agriculture, industry, urban size and population of a region, in a certain stage of development of social history and

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science and technology, without destroying the social and ecological system, and is a comprehensive objective which may change along with social, economic, scientific, and technological development." Cheng Guodong (2002) defines the carrying capacity of water resources as "supporting capacity of water resources to sound development of eco-economic system in a region under the specific stage of historical development, considering foreseeable effects of technological, cultural, institutional, and personal value choices, in a condition of suitable management technology." Feng Zhiming and Liu Dengwei (2006) says, carrying capacity on water resources is "the maximum population or scale of social and economic development which water resources in a region is able to support continuously within a certain period, in economic and technical conditions and standards of living." Duan Qingchun et al. (2010) says, carrying capacity of water resources is "the reasonable size in which regional water resource system can support social and economic sustainable development in a region, in a condition of certain economic, social, and technological development level, on the premise of ecological and environmental healthy development and social and economic sustainable development and coordination." Though different scholars have different definitions about the concept of carrying capacity of water resources, all of the above scholars emphasize the supporting capacity of water resources to economic and social development, and its core is the maximum or reasonable scale of population or economic and social development in which water resource can bear or support.

Based on the above concepts of carrying capacity of water resources, this report has defined the concept of carrying capacity of water resources as follows:

First, the carrying capacity of water resources emphasizes supporting capacity of water resources to social and economic development, and it supplements each other with sustainable development.

Second, the carrying capacity of water resources is objective, and has a limit in a particular historical period, comprehensively reflects comprehensive carrying capacity on water resources to economic and social development, and has a threshold range to measure the constraint of water resources to regional economic and social development. The carrying capacity of water resources is ultimately manifested as "limit size of regional economy or population," in which water resources can support a particular historical period.

Third, the carrying capacity of water resources is dynamic. Over time and changes of conditions, technical progress, and constant improvement of productivity level, on one hand, the capacity of development and utilization of water resources is enhanced; for example, interregional water transfer projects and seawater desalination technology creates more and more available water resources; on the other hand, the utilization efficiency of water resources is enhancing so as to increase the carrying capacity of unit water resource.

Fourth, the carrying capacity of water resources is open. The region is an open system, and factors affecting carrying capacity on regional water resources include internal and external factors; internal factors include quantity and development level of local water resources, scale and structure of economic system, technical progress and productivity level, and consumption level and structure; external factors have inter-regional division of labor and product trade structure.

Based on the above definitions of concept connotation of carrying capacity of water resources, as the threshold to measure constraint of regional water resources to social and economic development, carrying capacity of regional water resources emphasizes supporting functions of water resources to population size under a specific economic and technical level. Population and relevant social system are those supported under the regional water resources; size of carrying capacity of water resources is manifested through the vested social and economic development and the population size under the standard of living. Therefore, the report argues that, the indicator to measure carrying capacity of water resources should be the population size, the supported objects of water resources.

5.1.2 Calculation Method of Carrying Capacity of Water Resources

1. Measuring per capita demand of water resources by per capita water footprint

Because the amount of water resources in a region is relatively stable for some time, computing the population size that can be supported by water resources in a region focuses on confirmation of per capita demand of water resources. Water consumption in a region actually consists of two parts; one part is from "visible" water resources including the local water resources and interregional water transfer; another part is the "invisible" virtual water flow implied in inter-regional trade in goods and services.

Water footprint refers to the amount of water resources required which produces and meets all consumer goods and services within a country, a region, or individual for a time based on meeting human demands. The water footprint in a region actually portrays the real water resources demand of production and living and other human activities in a certain economic structure and mode of consumption in the region. Water footprint includes both direct consumption of water resources, and indirect water consumption, namely the virtual water implied in the commodity production process.

This report measures per capita demand of water resources by per capita water footprint. The per capita water footprint in a region reflects every person's amount of water resources required to maintain current production and living standard under a certain economic structure and consumption mode. Thus, per capita water footprint can comprehensively reflect the demands of water resources for human activities under a specific economic structure and consumption mode. Measuring per capita demand of water resources by per capita water footprint is conducive to be able to comprehensively and objectively analyze the demands of water resources for economic and social development and other human activities in a region in sight of generalized water resources, and the demand includes both demand of local water resources, and demands of interregional water resources transfer and virtual water flow, which has provided new ideas necessary for reexamination of carrying capacity of water resources and improvement of regional carrying capacity on water resources.

2. Calculation method of water footprint based on input–output analysis

Calculation method of the water footprint can use either the bottom-up tracking method, or top-down input–output analysis. The former tracks and calculates water resources consumed for every input in the process of commodity production, bottom-up tracking the source, and then getting water consumption of a product in its entire life-cycle. The latter is, on the basis of input–output model, to calculate entire water consumption induced by the final demand. For the analysis of regional water footprint, the latter is the more popularly used method. This report calculates water footprint and virtual water by the input–output analysis method (Zhang et al. 2011; Zhao et al. 2009).

5.2 Carrying Capacity of Water Resources in Beijing

5.2.1 Water Resources and Water Consumption in Beijing

Beijing is a resource-type region that is severely scarce in water. As an international metropolis, Beijing's shortage of water resources has increasingly aroused widespread concern. In 2011, total water resources were 2.681 billion m^3 in Beijing, in accordance with resident population of 20.19 million at the end of 2011, and floating population of about 2.4 million, per capita share of water resource was only 119 m^3 in Beijing, which were far less than the severely water-scarce standard of the international per capita share of water resources which was 1,000 m^3 (Beijing Municipal Bureau of Water Affairs 2011). Beijing's average annual total water resources is about 2.3 billion m^3, in which surface water accounts for about 30 %, and groundwater accounts for about 70 % (Fig. 5.1). In the south-north water transfer project, emergency water transfer in Hebei showed an upward trend in recent years, and increased from 73 million m^3 in 2008 to 260 million m^3 in 2009–2011 (Beijing Municipal Bureau of Water Affairs 2008–2011).

In 2011, Beijing's total water consumption was 3.6 billion m^3, which increased 80 million m^3 over that in 2010. Among them, water for living was 1.56 billion m^3, which accounted for 43 % of total water consumption; water for environment was 450 million m^3, which accounted for 13 %; water for industry was 500 million m^3, which accounted for 14 %; water for agriculture 1.09 billion m^3, which accounted for 30 %. In the decade from 2002 to 2011, Beijing's total water consumption was on average at about 3.5 billion m^3, which slightly went up. In the changes of water utilization structure, water for agriculture and industry showed a downtrend year after year in the number and proportion, but water for living went up year after year, which has become Beijing's most important component of water utilization (Fig. 5.2).

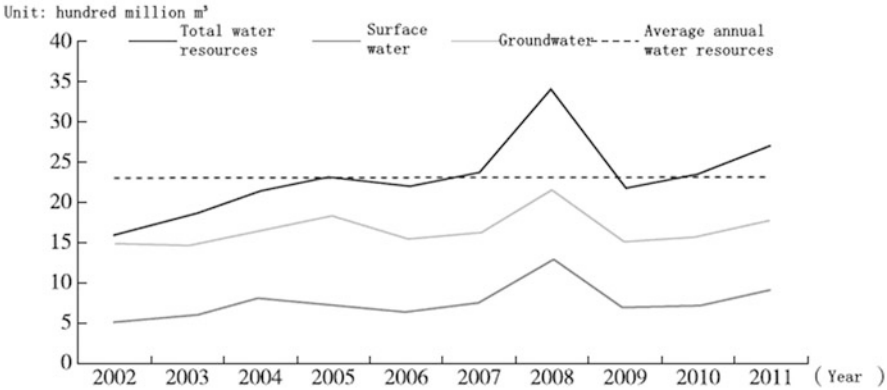

Fig. 5.1 Beijing's changes of total water resource in 2002–2011 (unit: hundred million m^3)

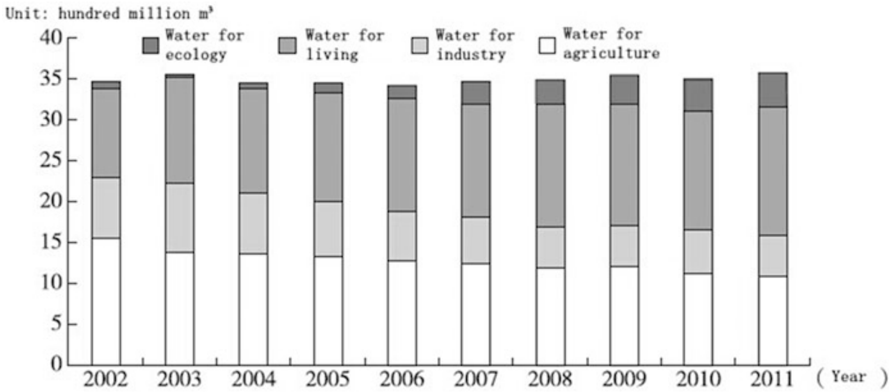

Fig. 5.2 Beijing 2002–2011 water change (unit: hundred million m^3) (Data source: Beijing Water Resources Bulletin 2002–2011)

5.2.2 Water Footprint and Influencing Factors of Water Footprint Changes in Beijing

Based on the input–output tables of Beijing in 1997, 2002, and 2007, the result of Beijing's water footprint showed that Beijing's water footprint for these 3 years was respectively 4.342, 4.406, and 5.748 billion m^3, which showed a clear upward trend, and was prominent from 2002 to 2007. Changes of water footprint reflect the growth of actual water demands. In recent years, Beijing's enhanced economic development, population expansion and demand level resulted in rapid increase of actual water demand. From 2002 to 2007, Beijing's demand for water increased 1.342 billion m^3, however actual water consumption remained at around 3.5 billion m^3, which indicated that Beijing's increase of actual water demand in this period was not entirely met by local water resources.

To distinguish the source of meeting the demand of water resources in Beijing, we further distinguish Beijing's water footprint into internal and external water footprints. Internal water footprint refers to the amount of local water resources consumed for all products and services to meet local consumption; external water footprint refers to out-of-town water resources consumed for all products and services to meet local consumption, namely it is that part that consumes out-of-town water resources to manufacture products in other places, and then is transferred to meet local final demand. The results showed that proportion of Beijing's external water footprint in total water footprint increased from 34 % in 1997 to 50 % in 2007. The result fully reflects the important role of virtual water flow to ease the water crisis and to improve the carrying capacity of water resources in Beijing.

Through calculation and analysis of Beijing's water footprints in 1997–2007, we can see that, for 10 years, Beijing's water resources faced increasing water demands under a background of increasingly fast economic development, growing population size, and increasingly high demands, which fully indicated that the carrying capacity of water resources in Beijing increased within a decade. But Beijing's serious situation of water-shortage cannot be ignored, and how to guarantee the carrying capacity of water resources for Beijing's future development is worth further discussion. It is necessary to understand and analyze the key factors that affect the carrying capacity of water resources in Beijing in order to increase the carrying capacity of water resources in Beijing's future development.

Influencing factors of carrying capacity of water resources in Beijing can be generally divided into two types of internal factors and external factors. So-called internal factors refer to Beijing's local amount of resources and utilization level, scale and structure of economic system, technical progress and productivity level, and consumption level and structure; external factors refer to influencing factors of areas outside Beijing to carrying capacity of water resources in Beijing, such as inter-regional division of labor and product trade structure. In this report, for internal factors, we used a structural decomposition analysis method in the input–output method (Zhang et al. 2012) to divide influencing factors of Beijing's water footprint changes into scale effect, technical effect, structural effect, and economic system efficiency effect; for external factors, we analyzed the important role of external virtual water flow to guarantee Beijing's carrying capacity on water resources using a interprovincial and interregional input–output model in 2002. The results of Beijing's internal influencing factors water footprint changes using the structural decomposition analysis method are shown in Fig. 5.3. In the 10 years from 1997 to 2007, the technical effect and structural effect are the factors that inhibit the growth of water footprint, scale effect and effect of economic system efficiency are the factors that result in the growth of water footprint.

Technical effect is the dominant factor that inhibits the growth of water footprint. From 1997–2002 to 2002–2007, the water footprints under the influence of technical effect reduced to 2.904 and 3.862 billion m^2 respectively. This result is consistent with Beijing's efforts to improve water use efficiency in recent years. Since the late 1990s, aimed at the growing water crisis, Beijing has taken a series of

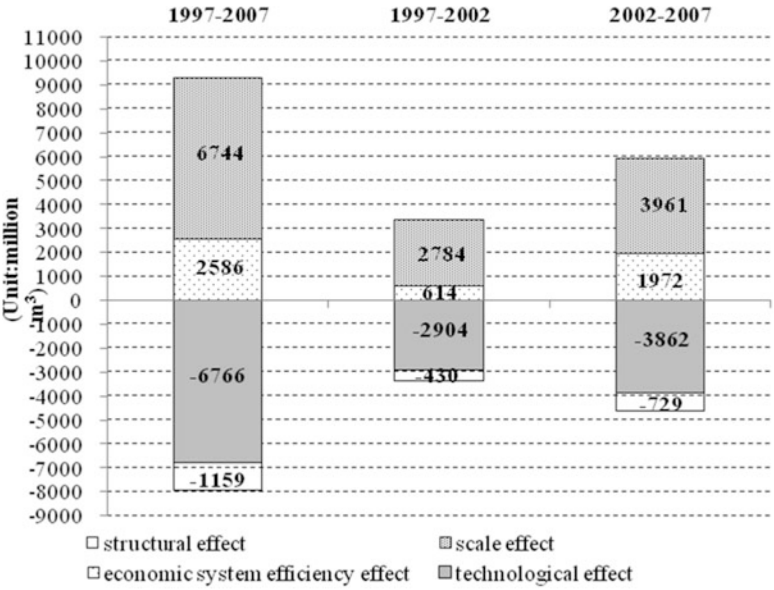

Fig. 5.3 Contributions of four factors in 1997–2002 and 2002–2007 to water footprint changes in Beijing

measures to improve water use efficiency. For example, in urban agriculture, Beijing created a layout that would be water-saving, and vigorously promoted the construction of highly efficient water-saving irrigation projects. By the end of the "Eleventh-Five-Year Plan", water-saving irrigation area of the whole city reached 4.287 million Mu, water-saving irrigation area accounted for 88 % of total irrigated area, recycled water irrigation area reached 580,000 Mu. While increasing engineering construction, Beijing vigorously promoted agricultural measures to improve water-saving benefit. At present, Beijing's efficient utilization coefficient of agricultural irrigation water has raised from 0.65 in 2005 to at present, 0.68, which is higher than the national average by nearly 40 %, and close to the level of developed countries. In industrial water-saving, Beijing accelerated the technical transformation in high water consumption industry, eliminated and updated a number of high water-consumption technology and equipment, and built a series of water-saving facilities. In addition, the reclaimed water recycling in Beijing has been vigorously promoted. Since 2004, Beijing has brought recycled water into the annual water resources allocation plan of the whole city, and determined the recycled water used in the industry, agriculture, urban rivers and lakes, and municipal utilities.

Structural effect has played a role in inhibiting growth of the Beijing water footprint, but it still has potential. From 1997 to 2007, under the influence of the structural effect, water footprint reduced 430 million m^3, in which agriculture, food industry, and electricity heating supply sectors reduced 645 million m^3 of total water demand, water demands of residents and other services, hotel and catering

Table 5.1 Structural changes of the water footprint in Beijing 1997–2007 (unit: hundred million m^3)

	1997		2002		2007	
	Absolute amount	Proportion (%)	Absolute amount	Proportion (%)	Absolute amount	Proportion (%)
First industry	7.38	17	11.02	25	21.27	37
Second industry	26.92	62	23.79	54	27.02	47
Third industry	9.12	21%	9.25	21	9.20	16
Total	43.42	100	44.06	100	57.48	100

industry increased 219 million m^3. From 2002 to 2007, under the influence of the structural effect, the water footprint reduced 729 million m^3, in which water demands of agriculture, food industry, special equipment manufacturing, and other integrated technical services reduced 876 million m^3, and the water demands of wholesale and retail trade, health and sports, and social welfare industries increased 379 million m^3. The role of the structural effect is closely related to residents' consumption structure changes in inhibiting growth of Beijing's water footprint. With an increase in income, the consumption proportion of the third industry with low water use intensity gradually went up. For example, from 1997 to 2007, the proportion of the water footprint in Beijing's agricultural products sector in total regional water footprint dropped from 21 % in 1997 to 16 % in 2007, the proportion of water footprint in the third industry rose from 17 % in 1997 to 37 % in 2007 (See Table 5.1).

External influencing factor of carrying capacity on water resources in Beijing is virtual water flow between Beijing and other provinces based on the product trade. Virtual water amount provided by various provinces for Beijing through inter-provincial product trade is shown in Table 5.2. It is worth noting that the above calculation of water footprint is based on input–output tables of just Beijing, here the table is based on China's interprovincial input–output model in 2002 and Beijing's total water footprints in 2002 are calculated slightly differently, the former is 4.406 billion cm^3, and the latter is 4.689 billion m^3. It is observed that, from the calculation results, Hebei supplied the most virtual water for Beijing. In 2002, Hebei supplied Beijing with 392×10^6 m^3 of virtual water, which accounted for 16 % of the total water footprint from other areas outside Beijing. In addition to virtual water supply, Hebei also provided Beijing visible water resources. From September 2008 to July 2009, the amount of water resources transferred from Hebei to Beijing reached 330 million m^3. As one of the severely water-deficient provinces, Hebei's virtual water supply and water resources transfer to Beijing have effectively eased the pressure on water resources in Beijing, but have worsened the situation of water resource supply and demand which was already severe in Hebei. Besides Hebei, Beijing also obtained virtual water supply from Shandong, Henan, Jilin, Guangdong, and other places.

Table 5.2 Areas providing external water footprint for Beijing (million m^3)

Province code	Province	Virtual water imported to Beijing	Province code	Province	Virtual water imported to Beijing
2	Tianjin	49	17	Hubei	82
3	Hebei	392	18	Hunan	26
4	Shanxi	89	19	Guangdong	147
5	Inner Mongolia	116	20	Guangxi	27
6	Liaoning	107	21	Hainan	5
7	Jilin	268	22	Chongqing	14
8	Heilongjiang	84	23	Sichuan	42
9	Shanghai	120	24	Guizhou	6
10	Jiangsu	84	25	Yunnan	7
11	Zhejiang	76	26	Shaanxi	22
12	Anhui	82	27	Gansu	22
13	Fujian	76	28	Qinghai	23
14	Jiangxi	16	29	Ningxia	7
15	Shandong	143	30	Xinjiang	39
16	Henan	214			

5.2.3 Carrying Capacity on Water Resources in Beijing

In 1997, 2002, and 2007, Beijing's resident population was respectively 12.4, 14.23, and 16.33 million; floating population was respectively 2.42, 3.87, and 4.2 million. Considering the stay of the floating population in relatively short time in Beijing and less consumption of water resources, the floating population quantity multiplies by a coefficient of less than 1. On the assumption that the average stay-time of the floating population in Beijing is about a month, we multiply it by one-twelfth. In this way, through calculation, population sizes borne jointly by Beijing's local water resources and out-of-town virtual water in 1997, 2002, and 2007 were respectively 12.6, 14.55, and 16.68 million, and per capita water footprint were 345, 303, and 345 m^3 (Table 5.3). Considering the relative stability of per capita demands of water resources, per capita water footprint 345 m^3 can be used as the per capita demand for water resources over the past decade.

If the annual amount of water resources in Beijing is calculated to be 2.3 billion m^3, it is calculated that Beijing's carrying capacity on water resources in 1997–2007 was about 6.67 million people. In 1997, 2002, and 2007, total amounts of water consumption in Beijing were respectively 4.17, 3.46, and 3.48 billion m^3, bearable carrying capacities on actual total water consumption in Beijing were respectively 12.08, 10.02, and 10.08 million people (Table 5.4). Beijing's resident population size exceeded the carrying capacity on water resources that the actual total water consumption can bear, if adding floating population, the population size even more so exceeds carrying capacity on water resources. If the population size

Table 5.3 Per capita water footprint in Beijing in 1997–2007

Year	Water footprint (hundred million m^3)	Population size (ten thousand persons)			Per capita water footprint (m^3/person)
		Resident population	Temporary population	Total	
1997	43	1,240	242	1,260	345
2002	44	1,423	387	1,455	303
2007	57	1,633	420	1,668	345

Table 5.4 Changes of carrying capacity on water resources in Beijing in 1997–2007

Year	Total water resources (hundred million m^3)	Total water consumption (hundred million m^3)	Reasonable carrying capacity on water resources (ten thousand persons)	Actual carrying capacity on water resources (ten thousand persons)
1997	22	41.7	667	1,209
2002	16	34.6		1,002
2007	24	34.8		1,008

that local water resources can bear as the reasonable carrying capacity on water resources, Beijing's population size has been two times that of the reasonable carrying capacity on water resources. This shows that Beijing's current population size and economic and social development are borne first through water transfer from other areas and overdraft of groundwater to expand total water consumption, then rely on a large amount of virtual water from other areas.

Means of increasing the carrying capacity on water resources in Beijing in the future includes "tapping new resources" and "economizing on expenditure." "Tapping new resources" means water transfer, including interregional water transfer and virtual water transfer based on commodity trade. The South-North water transfer project and other interregional water diversions will directly increase Beijing's amount of available water resources, which will play a positive role for enhancing the carrying capacity on water resources in Beijing. Virtual water supplies to Beijing from other provinces have also strongly eased the pressure on water resources in Beijing. As for Beijing, virtual water transfer may be an effective way to economize local water resources. But there are some problems worth considering in virtual water trade. Firstly, Beijing's excessive dependence on external high water-consumption products will possibly reduce water use efficiency of its own economic system; Secondly, as for the main sources of Beijing's virtual water such as Hebei, Shandong, and Henan provinces, virtual water trade between these provinces and Beijing has a bilateral effect, on one hand, virtual water trade between these provinces and Beijing possibly promotes economic development of these areas, and stimulates these areas' industrial upgrade and technical progress; on the other hand, virtual water drainage possibly further exacerbates originally severe water situation in these areas. Therefore, virtual water strategy between Beijing and other provinces requires a comprehensive and careful balance.

"Economizing on expenditure" mainly refers to control of growth or reduction of per capita water footprint; mainly means to improve water use efficiency, and restructure and adjust the urban economic spatial layout. The calculation results show that scale effect has played an important role in the growth of Beijing's water footprint. If no measure is taken, it can be expected that, in the future, Beijing's growing population size and higher demand will cause more demand of water resources so as to result in Beijing's overload of water resources into a more precarious situation. Though increasing external water footprint can relieve the pressure on water resources in Beijing, in the long term, reducing internal water footprint may be a more sustainable method to enhance the carrying capacity on water resources in Beijing.

Firstly, in the long term, improving water use efficiency has limited potential in enhancing carrying capacity on water resources in Beijing. The results in this paper show that improvement of water use efficiency is the dominant factor in inhibiting the growth of Beijing's water footprint from 1997 to 2007. However in the future, through technical progress and improvement of water use efficiency does not have enough potential to enhance carrying capacity on water resources in Beijing, and marginal cost is expected to rise in varying degrees. Therefore, it is not enough to improve the carrying capacity on water resources in Beijing by only relying on enhancing water use efficiency.

Secondly, structural water-saving is of great significance in enhancing the carrying capacity on water resources in Beijing for the future. Industrial restructuring has played an important role in inhibiting the growth of Beijing's water footprint, but water-saving effect of consumption restructuring has not fully played its role, therefore consumption restructuring is expected to play a more important role in Beijing's water-saving strategies in the future. In order to achieve future economic development strategies and population control targets in the condition of existing water resources, Beijing needs to continuously advance the industrial restructuring and consumption restructuring, and to develop water-saving industrial system. Within agriculture, Beijing should continue to promote urban agriculture, adjust the planting structure, and reduce until eliminated acres of high-water consumption crops; within the industry, it should continue to support the development of technology-intensive low water-consumption and high-value new industries, and restrict and transfer the development of traditional industries, such as petrochemical and metallurgical industries.

Thirdly, the adjustment of urban economic spatial structure is a long-term solution and inevitable trend to solve the water resource problems in Beijing. Due to the fact that improvement in water use efficiency only has limited potential in reducing the per capita water footprint, structural water-saving effect will become more and more dependent on consumption structural readjustment, and Beijing should pay more attention to urban economic spatial structural readjustment in the future, strengthen the construction of infrastructure and integration with areas around Beijing, and promote spread of industries and functions and integration into surrounding areas.

5.3 Carrying Capacity of Water Resources in Tianjin

5.3.1 Tianjin's Water Resources and Water Consumption

Tianjin is also a resource-type severely water-scarce city. In 2011, total water resources in Tianjin was 1.54 billion m^3, and per capita share of water resources was only 116 m^3, which was about one-fifteenth of the national per capita water resources that year (China Statistical Yearbook 2012). In recent years, under normal yield, Tianjin's total water resources was about 1.2 billion m^3, total water consumption was about 2.3 billion m^3, and the gap between water consumption and water resources was mainly supplemented through the Luan River diversion project and Yellow River diversion project to Tianjin. Tianjin's water supply is mainly surface water (approximately 60–70 %), in which water supply of the Luan River diversion project to Tianjin is about 25–30 % of total water supply; next is groundwater, which is about 30 % of total water supply. In recent years, the supply of surface water increased, and groundwater recharge rate had a downward trend (Fig. 5.4).

With the development of the national economy and the expansion of the city size, Tianjin's overall water consumption slightly increased. In 2011, the city's overall water consumption was 2.31 billion m^3, in which production water supply accounted for 79.7 %, water for living 15.5 %, and water for ecology 4.9 %. In recent years, Tianjin's water consumption showed the following three features: (1) In the case of unceasing reduction of the first industry GDP (1.4 % in 2011), amount and proportion of production water supply in the first industry actually constantly increased, until 2010 which only dropped slightly (consumed 51.1 % in 2011); (2) With gradual increase of the second and third industries GDP, total water consumption in the second and third industries slowly increased, the proportion of water consumption in the second industry showed a downtrend; (3) Although population constantly increased, total amount and proportion of water for living showed a downtrend (Fig. 5.5).

5.3.2 Analysis on the Changes of Water Footprint and Virtual Water Trade

In 2002 and 2007, the calculation results of water footprint showed that Tianjin's water footprint was 1.855 billion m^3 in 2002, and 3.152 billion m^3 in 2007 (Table 5.5), which the water footprint increased 1.297 billion m^3 from 2002 to 2007. Significant increase of the water footprint reflected that the water demand in Tianjin was rapidly expanding. Over the same period, total amount of local water resources in Tianjin only increased 764 million m^3, overall water consumption only increased 341 million m^3, which it is obvious that the increase in water demand was

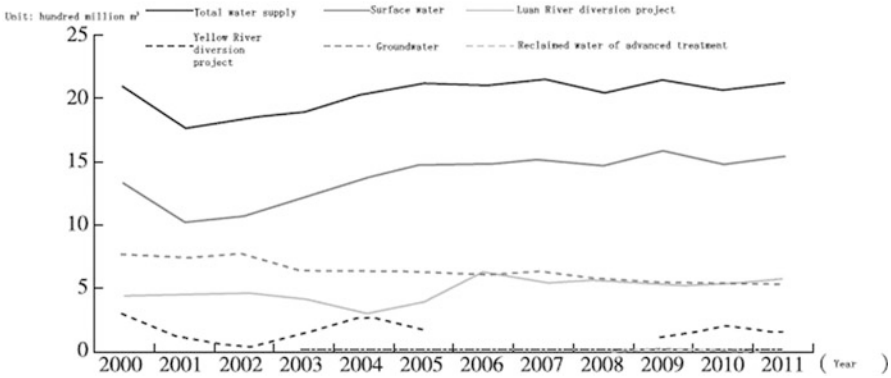

Fig. 5.4 Changes of water supply in Tianjin (unit: hundred million m^3)

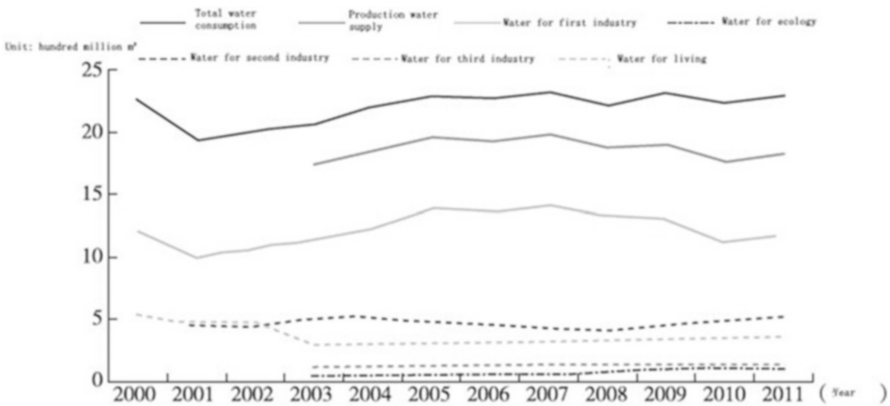

Fig. 5.5 Changes of water distribution in Tianjin (unit: hundred million m^3)

far more than the available amount of water resources and the increase in water supply.

As for the water footprint of sectors in Tianjin, in 2002, other service industries had the highest water footprint, at 634 million m^3, which accounted for 34.2 % of total water footprint; next was in farming, forestry, animal husbandry, and subsidiary business, in which water footprint was 396 million m^3, which accounted for 21.3 % of total water footprint. In 2007, the highest water footprint was in farming, forestry, animal husbandry and subsidiary business, at 999 million m^3, which accounted for 31.7 % of the total water footprint; next was in the building industry, water footprint was 748 million m^3, which accounted for 23.7 % of the total water footprint. Water footprint increased more in the agricultural sector, and increased from 396 million m^3 in 2002 to 999 million m^3 in 2007, and virtual water in the agricultural sector changed from net outflow of 222 million m^3 to net inflow of

Table 5.5 Water footprints and net virtual water outflows of various sectors in Tianjin in 2002 and 2007 (million m^3)

Sectors	2002 year		2007 year	
	Water footprint	Net outflow of virtual water	Water footprint	Net outflow of virtual water
1. Farming, forestry, animal husbandry and subsidiary business	395.6	221.9	999.4	−285.6
2. Coal mining and dressing	0.0	−12.9	0.1	−17.1
3. Petroleum and natural gas mining	0.0	34.7	0.0	72.6
4. Metal mining and dressing	0.0	0.0	0.0	0.0
5. Non-metal ores and other ores mining and dressing	0.0	−62.1	0.0	−42.3
6. Food manufacture and tobacco processing	131.4	−75.5	341.9	−20.5
7. Textile industry	7.6	−8.0	6.0	−7.8
8. Textile wearing apparel, footwear and caps, leather, fur, feather and their products	29.5	61.7	56.6	−9.4
9. Timber processing and furniture manufacture	14.2	6.5	45.6	−61.0
10. Paper manufacture, printing and manufacture of articles for culture, education and sport activity	10.4	0.5	2.3	−9.3
11. Petroleum processing, coking, and nuclear fuel processing	0.6	19.8	1.6	29.5
12. Chemical industry	25.6	129.4	48.6	−68.2
13. Nonmetals mineral products	4.4	−25.9	3.4	−78.6
14. Metal smelting and metal products	4.0	−83.4	3.0	−21.1
15. Universal and special purpose equipment	80.3	−98.0	82.8	−13.6
16. Transport equipment	14.3	26.8	14.3	163.1
17. Electric equipment and machinery	20.1	72.2	21.4	56.4
18. Telecommunication equipment, computer and other electric product	25.0	136.5	18.5	280.1
19. Manufacture of measuring instruments and machinery for cultural activity and office work	5.0	−7.2	4.1	11.9
20. Other manufacture	6.7	−2.7	2.5	−8.5
21. Electric power, heat power, and gas	33.1	−101.7	28.2	−47.1
22. Tap water	73.0	−266.1	26.0	−181.1
23. Construction industry	291.1	−72.2	746.8	−153.6
24. Business transport service	8.8	37.0	34.1	−170.2
25. Lodging and catering services	39.6	11.5	108.4	−57.3
26. Other services	634.2	−202.8	555.9	−244.2
Total	1854.6	−259.9	3151.7	−882.8

283 million m^3, which indicated the rapid urbanization progress in Tianjin has brought a substantial increase for the demand of agricultural products.

As for the sector proportion of water footprint, the water footprint in the second industry was most dominant, and the proportion has increased; the proportion of water footprint in the agricultural sector also increased from 21 % in 2002 to 32 % in 2007; the proportion of water footprint in the third industry reduced from 37 % in 2002 to 22 % in 2007. The structural changes of the water footprint showed an opposite trend against Beijing, which showed that Tianjin is a city dominated by industry, and industrialization also continued development, which indicated the industrialization of Tianjin has driving power to urbanization and the urban economy. The drop in the proportion of water footprint in the service sector and the change of virtual water from net outflow to net inflow indicated that the development of service industry lags in the process of industrialization and urbanization of Tianjin, and the reliance of the service industry on the exterior is deepening.

Analysis of the virtual water trade indicates that Tianjin has become an area of virtual water net inflow, and total net inflows increased from 256 million m^3 in 2002 to 883 million m^3 in 2007, which reflects the importance of virtual water trade in abating the shortage of water resources in Tianjin. In 2002, Tianjin's virtual water flow was about 1 billion m^3, which was 630 million m^3 more than the total water resources of that year; among them, water production and supply industry, other services and production and supply of electric power, heating, power, and gas were main sectors of virtual water net inflow. In 2007, Tianjin's virtual water inflow was about 1.5 billion m^3, which was 370 million m^3 more than the total water resources of that year, in which other services and water production and supply sector were still primary sectors of virtual water inflow, while farming, forestry, animal husbandry and fishery, business transportation, and construction industry also became new main sectors of virtual water net inflow. Farming, forestry, animal husbandry, fishery, chemical industry, business transportation, lodging and catering industry, and other high water-consumption sectors were sectors of virtual water net outflow in 2002, and changed into sectors of virtual water net inflow in 2007, which reflected industrial restructuring has played an important role in alleviating Tianjin's water shortage through virtual water trade. On the other hand, as for the leading industries in Tianjin, such as transportation equipment manufacturing, communication equipment, computers and other electronic equipment manufacturing, and the chemical industry, some maintained net outflow of virtual water, and some changed from net inflow of virtual water in 2002 into net outflow, which reflected the supporting role of water resources in the industrialization and economic growth of Tianjin.

Using structural decomposition analysis, the findings on influencing factors of Tianjin's water footprint changes indicate that, from 2002 to 2007, technical progress and demand structural effects are factors inhibiting the growth of Tianjin's water footprint, demand scale and economic system efficiency effects are factors resulting in the growth of the water footprint (Table 5.6). Among them, technical progress effect is a major factor inhibiting the growth of water footprint. From 2002 to 2007, technical progress effect caused Tianjin's water footprint to reduce by

Table 5.6 Structural decomposition of factors affecting Tianjin's water footprint changes in 1997–2002 (million m^3)

Influencing factors	Technical progress effect		Economic system effect		Demand scale effect		Demand structural effect	
	Absolute amount	proportion	Absolute amount	proportion	Absolute amount	proportion	Absolute amount	proportion
Water footprint changes	−1103.9	−85.1 %	202.1	15.6 %	2275.3	175.4 %	−76.4	−5.9 %

1.104 billion m^3, which was consistent with the results in which Tianjin took a series of legal, economic, and technical means to promote national-class water-saving city construction in recent years. For example, Tianjin eliminated manufacturing technique of high water consumption, low water use efficiency, serious water pollution, and high energy consumption, especially transformed water-saving technological in chemical, metallurgical, textile, printing and dyeing, and other high water-consumption industries, promoted recycled water, eliminated water facilities and products in public buildings which did not meet water-saving standard, and promoted highly efficient utilization of water resources through seawater utilization, sewage transforming into resources, industrial water treatment, film materials and city life, agricultural water saving, and other key technology. Among them, technical progress effects of the construction industry and other services played a huge role in inhibiting the water footprint. Structural effect played a limited role in inhibiting the growth of water footprint, and only reduced it by 76 million m^3. Demand scale effect is the leading factor resulting in the growth of Tianjin's water footprint. Among them, the demands for water in economic development, population expansion, and enhancement of the consumption level resulted in significant increases in farming, forestry, animal husbandry, and fishery, other services, construction industry, food manufacturing, and tobacco processing industry. Economic system efficiency changes also brought about the increase in the water footprint, and these increases were mainly caused by the increase in water demand in the construction industry, food manufacturing, tobacco processing industry, and other service sectors.

5.3.3 Analysis of the Carrying Capacity on Water Resources in Tianjin

In 2002 and 2007, Tianjin's resident population was respectively 10.07 and 11.15 million. It is estimated according to relevant information of the Tianjin Floating Population Office that, in 2002 and 2007, Tianjin's temporary population was respectively one and two million. On the assumption that average stay time of the temporary population in Tianjin is 1 month, it is calculated that, in 2002 and 2007, Tianjin's urban population was about 10.15 and 11.32 million. Thus, Tianjin's per

Table 5.7 Analysis on carrying capacity of water resources in Tianjin

Year	Resident population/ten thousand persons	Temporary population/ten thousand persons	Population size/ten thousand persons	Water footprint/million m^3	Per capita water footprint/m^3/person	Actual carrying capacity on water resources/ten thousand persons	Reasonable carrying capacity on water resources/ten thousand persons
2002	1,007	100	1,016	1854.6	183	1,093	657
2007	1,115	200	1,132	3151.7	279	839	431

capita water footprints was respectively 183 m^3 in 2002 and 279 m^3 in 2007 (Table 5.7), in which per capita water footprint grew about 96 m^3 over the 5 years. Tianjin's per capita water footprint is still lower than that in Beijing, but its faster growth is worth paying attention to. Considering the increasing trend of Tianjin's per capita water footprint, per capita water footprints of those 2 years were respectively as the per capita demand of water resources in 2002 and 2007.

Calculating by Tianjin's annual average amount of water resources under normal yield as 1.2 billion m^3, the population borne by local water resources in Tianjin was respectively 6.57 and 4.31 million in 2002 and 2007. In 2002 and 2007, Tianjin's actual total amount of water supply was respectively 1.996 and 2.337 billion m^3, and carrying capacity on water resources borne by actual amount of water supply was 10.93 and 8.39 million people.

On one hand, current population size has far more than reasonable population size supported by local water resources in Tianjin, and goes beyond the carrying capacity on water resources which actual water supply can support, and carrying capacity of water resources supported by current actual water supply is based on interregional water transfer of the Luan River diversion project and Yellow River diversion project to Tianjin. In 2011, the water supply amount of the Luan River diversion project and Yellow River diversion project accounted for 47.5 % of total water supply. Calculating by 670 million m^3 average annual water supply from Luan River diversion project and Yellow River diversion project to Tianjin in recent years, and by current water use efficiency and demand structure, water amount provided from the Luan River diversion project and Yellow River diversion project was equivalent to support of 3.66 and 2.4 million people of Tianjin in 2002 and 2007, which respectively accounted for 36 % and 21 % of total population in those 2 years, it is obvious that Tianjin's carrying capacity on water resources has a large rate of dependency on interregional water transfer such as the Luan River diversion project and Yellow River diversion project. Tianjin's future development, including industrialization and urbanization, must take into account the constraint of the carrying capacity on water resources. For a time in the future, if there are no emergencies, there should be an increase of water supply from the Luan River and Yellow River diversion projects to Tianjin, and the completion and water transfer in the eastern line project of "South-North water transfer" will have a positive effect to alleviate Tianjin's water shortages and to increase the carrying capacity on water resources. In recent years, reclaimed water utilization and seawater desalination technology have steadily developed, which will possibly become a new supplementary source for Tianjin in the future.

On the other hand, the increase of per capita water footprint has led to a decline in carrying capacity on water resources in Tianjin; with the continued development of urbanization and industrialization, it is expected that Tianjin will face a greater population size and larger water demands in the future, therefore Tianjin must give high priority to restrain the growth of the per capita water footprint. In the long term, technical progress and structural readjustment are main ways to restrain the growth of the per capita water footprint in Tianjin. Technical progress has made notable achievements in the establishment of water-saving type city in Tianjin, the role of consumption structural readjustment are not yet fully reflected in inhibiting the growth of water footprint, therefore there is still potential to inhibit the growth of the water footprint through industrial restructuring and readjustment of the consumption structural in the future.

Just like Beijing, virtual water trade has effectively alleviated Tianjin's water pressure, and has enhanced the supporting capacity of water resources to economic development in Tianjin. In 2007, the communication equipment, computers, and other electronic equipment manufacturing, transport equipment manufacturing, petroleum and natural gas mining industry, and electrical machinery and equipment manufacturing were the leading industries in Tianjin in recent years, and they were industries of virtual water net outflow. These sectors had big production capacity and high economic efficiency, and played an important role to Tianjin's economic development. Since these sectors have low direct water-use coefficient and water footprint and low water-consumption industrial specialization, such interregional trade structure is conducive to effective use of limited water resources. On the other hand, more water-consumption sectors such as farming, forestry, animal husbandry, fishery, food processing, and other services have changed from net outflow of water footprint to net inflow, which has effectively alleviated Tianjin's water shortage, and has enhanced the carrying capacity on water resources. In the future, Tianjin will still need to highly focus on virtual water strategy to further expand the product transfer of those sectors with high water footprint content to alleviate Tianjin's water pressure.

5.4 Conclusions and Implications

Findings in the report show that, firstly, the existing population sizes of Beijing and Tianjin have seriously surpassed the reasonable population size supported by local water resources, and surpassed the carrying capacity on water resources which actual water supply can sustain. Beijing's carrying capacity on local water resources is only 6.67 million people, which is equivalent to 40 % of the current population; carrying capacity on water resources supported by actual water supply amount is only about 10 million people, which is equivalent to 60 % of the current population. Tianjin's carrying capacity on local water resources is only 4.31 million people, which is equivalent to 38 % of the current population; carrying capacity on water resources supported by actual water supply amount is only 8.39 million people, which is equivalent to 74 % of the current population.

Secondly, actual water supply amounts of Beijing and Tianjin are both higher than local water resources, Beijing's water gap is mainly compensated by groundwater overdraft and water transfer from neighboring provinces, Tianjin's water gap is mainly compensated by the Luan River and Yellow River diversion projects. In other words, the carrying capacities on water resources of Beijing and Tianjin supported by their actual water supplies are based on interregional water diversion and groundwater overdraft.

Thirdly, actual water demand of Beijing and Tianjin is met by virtual water. In 2007, local amounts of water resources were equal to only about half of the water footprint, and actual water supply amounts were much less than the water footprint, therefore the gaps between actual water supply and water footprint were compensated by the net inflow of virtual water. In other words, Beijing and Tianjin's amounts of local water resources are difficult to support the demands of existing population size and economic and social development, and the water demand of the existing population size and social and economic development are met through interregional water diversion and virtual water inflow.

As for Beijing, the south-north water transfer and other interregional water diversion projects will bring Beijing an increase of water resources to enhance the carrying capacity on water resources to a certain extent; enhancing Beijing's carrying capacity on water resources through technical progress and improved water use efficiency has not had much potential. Beijing's future development should pay more attention to the spatial arrangement adjustment of the urban economy, improve infrastructure construction and integration with those areas around Beijing, and spread industries and functions and integrate into surrounding areas to reduce the pressure on water resources.

As for Tianjin, on one hand, it needs to explore new compensation water resources, including eastern line project of "South-North water transfer," reclaimed water utilization. and seawater desalination technology, on the other hand, it needs to attach great importance to restraining the growth of the per capita water footprint, to promote technical progress and structural readjustment, and to keep implementation of virtual water strategy so as to alleviate the growth of water demands from economic and social development and population growth.

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Chapter 6
Studies on Ecological Environmental Carrying Capacity in Beijing, Tianjin, and Hebei Region

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6.1 General Situation of the Ecological System in the Beijing-Tianjin-Hebei Region

With the densest population and industrial scale in North China, the best development and most modernized, the Beijing-Tianjin-Hebei region is an important political, economic, and cultural center in China. However, an indisputable fact is that, in recent years, the region bears huge pressure brought by the deterioration of the ecological environment, which has created serious challenges for economic and social sustainable development in the region.

6.1.1 Resources

1. Land resources

Beijing, Tianjin and Hebei region has a total land area of 215,800 km^2, in which, Beijing has an area of 16,800 km^2, Tianjin 11,300 km^2, and Hebei province 187,700 km^2. Land use structure is shown in Fig. 6.1; land use in the Beijing-Tianjin-Hebei region is dominated by farmland, and supplemented by woodland, and land used for building also accounted for a big proportion. In recent years, with the accelerated process of urbanization and the increase in annual investment scale, the demand for land used for building surges, and more and more cultivated lands are used for building.

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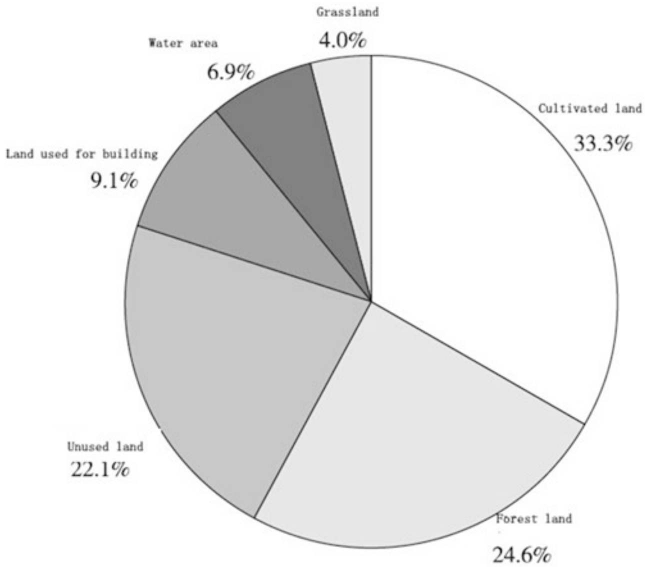

Fig. 6.1 Land use structure in the Beijing-Tianjin-Hebei region

2. Water resources

In 2010, the total amount of water resources in Beijing-Tianjin-Hebei region was 17.824 billion m^3, which accounted for 0.56 % of total water resources of the whole country; per capita water resources was 163.75 m^3, which was less than 20 % of the international per capita share of water resources (1,000 m^3). In water utilization, in 2010, the total amount of water supply in the Beijing-Tianjin-Hebei region was 3.91 billion m^3, in which water for living was 2.082 billion m^3, which accounted for 53.25 %; production water supply was 1.387 billion m^3, which accounted for 35.48 %.

In addition, the city downstream river pollution is still serious in the region. In Beijing, in 2011, total river length of 2,545.6 km was monitored in terms of water quality, in which the length of river with water was 2,194.6 km. 1,003.0 km of the river complied with Class-II water quality standard; 115.6 km of the river met Class-III water quality standard; 131.4 km met Class-IV water quality standard; 44.4 km met Class-V water quality standard; and 900.2 km was inferior to Class-V water quality standard. 1,121.6 km of the river reached the standard.

For large and medium reservoirs, water quality of Guanting reservoir was Class-IV, the other met Class-II – III water quality standards. 16 water reservoirs were monitored in the whole year, average total water storage was 1.43 billion m^3, in which, 87.4 % of total storage capacity monitored fell under reservoirs of Class-II and III; 12.6 % of total storage capacity monitored fell under reservoirs of Class-IV water quality.

Table 6.1 Current ecological construction in Beijing-Tianjin-Hebei region

Unit	Forest land area (ten thousand ha)	Per capita forest land area (Mu)	Forest coverage (%)	Green space area per urban person (m^2)
Beijing	107.00	1.07	36.70	14.5
Tianjin	19.55	0.24	8.24	16.3
Hebei	434.13	0.97	23.25	8.4

Data sources: Tianjin Forestry Bureau, Beijing Forestry Bureau, Forestry Department of Hebei province in 2011

As for lakes, in 7.2 million m^2 of water area monitored, 85.4 % of water area monitored fell under Class-IV and V water quality lakes; 14.6 % of water area monitored were inferior to Class-V water quality lakes. 598.6 m^2 of water areas reached the standard.

For shallow groundwater, 3,293 km^2 of it met Class-III water quality standard, 3,107 km^2 met Class-IV – V water quality standards. Deep groundwater quality was obviously better than shallow groundwater quality, 3,079 km^2 met Class-III water quality standard, and 356 km^2 met Class-IV – V water quality standards.

3. Vegetation and green space system

In the Beijing-Tianjin-Hebei region as a whole, Beijing's green ecological construction started early, had a high starting point, and rapidly developed. At present, the "green" issue has basically been solved, and is upgrading towards "beauty" direction; most areas of Tianjin belong to the plain, and is close to the ocean, therefore its ecological and environmental advantages are obvious. In the indicator of green space area per urban person, in comparison with these two big cities, green ecological construction in Hebei province has a clear gap in both intensity and level, and has become a "short board" in regional ecological construction (Table 6.1).

4. Energy resources

There are rich and various fossil energy resources and metals in the Beijing-Tianjin-Hebei region, main fossil energy resources include coal, oil, and natural gas, in which, the coastal area of Hebei province is the main oil producing area in North China. According to statistics, in 2010, there was 311.9671 million tons of basic oil reserve in Beijing-Tianjin-Hebei region, which accounted for about 10 % of total oil reserves; basic natural gas reserve of 64.796 billion m^3, which accounted for 1.7 % of total reserves; basic coal reserve of 6.735 billion tons, which accounted for 2.4 % of total coal reserves. Metallic mineral resources in this region include iron, manganese, chromium, and vanadium, which are mainly found in Hebei province.

6.1.2 Environment

1. Air quality

According to relevant air quality monitoring results in 13 representative cities in Beijing, Tianjin and Hebei region for many years (total monitored days in Beijing and Tianjin are 2,922 days, and that in Shijiazhuang, Zhangjiakou, Chengde, Qinhuangdao, Tangshan, Langfang, Baoding, Cangzhou, Hengshui, Xingtai, and Handan are 2,358 days). Overall air quality was good, excellent air quality rates were above 60 %, and all have improved to different degrees. Among them, Qinhuangdao had the best air quality, air quality compliance rate reached 97 %; air quality has also gotten better in Hengshui, Tangshan, and Cangzhou, and compliance rates were more than 80 %; Beijing's air quality had the lowest compliance rate, only at 63 %.

2. Key pollutant emission

The results of the key air pollutants of the 13 cities in the Beijing-Tianjin-Hebei region show that, primary pollutants of Zhangjiakou and Chengde are sulphur dioxide, next is inhalable particulate matter; in the other 11 cities, primary pollutant is inhalable particulate matter, and next is sulfur dioxide. In these 13 cities, the percentage of nitrogen oxides as primary pollutant is zero. From 2001 to 2011, concentrations of main air pollutants all showed a downtrend.

3. Environmental governance

Since 2004, Beijing's financial departments at all levels have invested more than three billion RMB each year to implement 17 afforestation projects, and to build three green ecological barriers (green ecological barrier based on three green isolation stalls in urban areas; green ecological barrier based on channel green belts around five rivers and ten roads in plain areas; green ecological barrier based on a wide range of ecological shelter in mountainous areas), which has had some results in concentrated governance to five large sand-afflicted areas in the city. Tianjin also had the goal of "eco-city construction." Since 2008, Tianjin drafted "2009–2012 Tianjin forestry construction plan," launched and implemented six big afforestation projects, in which ecological construction of the whole city has achieved forward development. In 2003, Hebei provincial party committee and provincial government created "Decision on promoting the leap-forward development of forestry," and organized and implemented a number of national key forestry ecological projects, such as returning land for farming to forestry, sandstorm source treatment in Beijing and Tianjin, three-north protection forests, Taihang mountain afforestation, coast protection, forest and wildlife protection, nature reserve construction, wetland conservation, and so on.

6.1.3 Main Issues Faced by Eco-environment in the Beijing-Tianjin-Hebei Region

1. Coexistence of resource scarcity and environmental deterioration

The first issue is the coexistence of water scarcity and water pollution intensification. On one hand, the contradiction between supply and demand of water has intensified, water scarcity has become the short board to constrain regional development. With the population and economic and social development in the upstream area, and acceleration of urbanization process, water consumption in the upstream area has increased continuously, and available water supply is decreasing continuously, on the other hand, the quality of water supply has deteriorated, urban surface water and groundwater sources have been polluted to different extents; some reservoirs have had a phenomena of eutrophication and are intensifying, and the number of aquatic animals in big basins has markedly decreased.

The second issue is the coexistence of soil erosion, land desertification, sandstorms and environmental pollution, and ecological degradation. Soil erosion occurs mainly in east Taihang mountain and Yanshan mountain, and sandstorms from North Hebei province has a big influence on Beijing and Tianjin; with the accelerated pace of population expansion in recent years, the natural environment in the Beijing-Tianjin-Hebei region has had dramatic deterioration and resource-exhausted unsustainable development, such as excessive land reclamation and excessive pasturage in grassland which have resulted in serious damage of grassland and vegetation.

2. Imbalanced regional development, inadequate overall eco-system, low ecological protection capacity

Imbalance of ecological carrying capacity in the Beijing-Tianjin-Hebei region is manifested by asynchronous ecosystem construction resulting in different ecological protection capacities. Beijing's green ecological construction started early, had a high starting point, rapid development, and has upgraded from pursuit of "green" to "beauty" direction; Tianjin's ecological environment has obvious advantages based on better foundation and larger area of wetland, and currently construction of ecological city has increasingly sped up; in comparison with these two big cities, Hebei's green ecological construction has a bigger gap, and has become the "short board" in regional ecological construction. Firstly, some issues are very prominent, such as low levels of overall afforestation, lack of total forest resources, unequal distribution, and low quality. Forest coverage in about half of the counties (city) is less than 10 %; per capita forest area is less than half that of the national average. Secondly, the ecological management task is arduous. According to the monitored results, existing desert land in Hebei province has reached 2.4 million hectares, which account for 12.8 % of total area of the province. Two big sandstorm areas, six drought areas, five sand beaches and nine sandstorm channels in Bashang and around Beijing and Tianjin have even a greater impact on eco-environment in

Beijing and Tianjin. Existing area of soil and water erosion has reached 60,000 km^2 in the whole province, at 51.2 % of mountainous areas, which not only has led to the reduction of productivity of cultivated land, but has also posed a threat to Miyun, Guanting, and Panjiakou reservoirs and the South–north water transfer and other water conservancy facilities.

3. Overall advancement of the regional ecological mechanisms are inadequate, there is significant constraints
   (a) The ecological safety of Beijing, Tianjin and Hebei region is not only the ecological security in the region, but is also a major political issue regarding national security and national image. Accordingly, the ecological construction of Beijing-Tianjin-Hebei region should be treated as a special region and vital one in overall planning. In recent years, although sand source management and sustainable use of capital water resource in the twenty-first century in Beijing and Tianjin have started, overall planning on ecological construction in Beijing-Tianjin-Hebei region has not been drafted, therefore the support in green ecological construction is not enough yet; there is still not comprehensive regional ecological coordination or a management body.
   (b) As for the Beijing-Tianjin-Hebei region, Beijing, Tianjin, and Hebei do not yet have a unified common understanding on constructing an overall regional green eco-system, and have not yet established a convenient and effective communication and collaboration mechanism. In green ecological construction, each does their own thing in most cases, and the three areas lack effective communication and coordination, and have yet to carry out comprehensive high-level cooperation.

6.2 Evaluation of Ecological Carrying Capacity in the Beijing-Tianjin-Hebei Region

Ecological carrying capacity is a relative concept, namely eco-system is supporting capacity against activities of human society. Therefore, this paper evaluates ecological carrying capacity in the Beijing-Tianjin-Hebei region using the index method to fully reflect the supporting capacity of ecosystem on economic and social development in the region.

6.2.1 Construction of the Evaluating Indicator System

Through comprehensive consideration of the characteristics of ecological carrying capacity, in accordance with the above principles of construction, the indicator

Table 6.2 Evaluating indicator system of ecological carrying capacity

Level-I indicator	Level-II indicators	Level-III indicators	
		Pressure indicators	Supporting capacity indicators
Ecological carrying capacity C	Resource carrying capacity C_1	Unit GDP water consumption C_1p_1	Per capita water resources C_1s_1
		Land area used for unit GDP C_1p_2	Per capita arable area C_1s_2
		Per capita land used for building C_1P_3	Area of built-up areas C_1s_3
		Per capita integrated water consumption C_1p_4	Clean energy productivity C_1s_4
		Unit GDP current drain C_1p_5	
	Environmental carrying capacity C_2	Quantity of wastewater effluent C_2p_1	Compliance rate of air environment quality C_2s_1
		Smoke and dust discharge amount C_2p_2	Per capita greenbelt area C_2s_2
		Exhaust emission amount C_2p_3	Forest coverage C_2s_3
		Proportion of environmental investment in GDP C_2p_4	Built-up area afforestation rate C_2s_4
	Carrying capacity on social systems C_3	Population C_3p_1	GNP C_3s_1
		Number of students in universities and colleges C_3p_2	Investments in science and education C_3s_2
		Quantity of private cars C_3p_3	Road paving area C_3S_3

system established in this paper includes a Level-I indicator, 3 Level-II indicators, and 23 Level-III indicators, as shown in Table 6.2.

6.2.2 *Evaluation Methods*

Starting with defining the connotation of ecological carrying capacity, this paper evaluates and analyzes the ecological carrying capacity in the Beijing-Tianjin-Hebei region using the index method. The evaluation methods are introduced below.

1. Index of ecological carrying capacity

   Index of ecological carrying capacity is expressed as:

$$CPS = CP/CS$$

Among them, CP is ecological pressure index, the expression is:

$$CP = \sum_{i=1}^{n} P_i w_i$$

P_i is standardization value of ecological pressure indicators, w_i is corresponding weighting.

$$CS = \sum_{ij1}^{n} S_j w_j$$

S_j is standardization value of ecological supporting capacity indicators, w_j is corresponding weighting.

$CPS < 1$ indicates that the pressure from social and economic activities is within bearable capacity on ecological system, meaning that the ecological system is healthy; $CPS = 1$ indicates that the pressure from social and economic activities is adapted to supporting capacity on ecological system, meaning that the ecological system is basically steady; $CPS > 1$ indicates that the pressure from social and economic activities exceeds bearable capacity on ecological system, and the bigger the value is, the bigger the overload is, the bigger the possibility of harming the ecological system.

2. Standardization of indicators

In the process of evaluating the ecological carrying capacity in the Beijing-Tianjin-Hebei region, because the indicators have different dimensions, for purposes of convenient comparison, we standardize the indicator value first, also, to ensure the comparability between pressure index and supporting capacity index, we standardize indicators using the standardization method. The standardization formula of indicators is:

$$u_{ij} = \left(v_{ij} - \min v_{ij}\right) / \left(\max v_{ij} - \min v_{ij}\right),\ i = 1, 2, \cdots, m, j = 1, 2, \cdots, n$$

u_{ij} is indicator value after standardization, v_{ij} is original indicator value.

3. Confirmation of weighting

   In this paper, the indicator weighting is confirmed by a grey correlation analysis, and the basic steps are as follows:

   (a) Confirmation of virtual ideal indicator sequence and actual comparative sequence

   The evaluating indicator system of ecological carrying capacity in Beijing-Tianjin-Hebei region consists of three levels, and is concerned with two levels, indicator level and guideline level of virtual ideal indicator sequence. For the pressure indicators, this paper selects the sequence composed of minimum standardization values of all indicators of the same index in the same year (area) as the virtual ideal indicator sequence of the index, and standardization sequence of all indicators of the same index as actual comparative sequence of the index; for supporting capacity indicators, this paper selects the sequence composed of maximum standardization values of all indicators of same index in the same year (area) as the virtual ideal indicator sequence of the index, standardization sequence of all indicators of the same index as the actual sequence. Similarly, so does the virtual ideal indicator sequence of the guideline level.

(b) Calculation of grey correlation coefficients

For every indicator sequence of the same index, the grey correlation coefficient of the actual comparative sequence i and the virtual ideal indicator sequence in j year is:

$$\xi_{ij} = \frac{\min_i \min_j \left|u_{0j} - u_{ij}\right| + \eta \max_i \max_j \left|u_{0j} - u_{ij}\right|}{\left|u_{0j} - u_{ij}\right| + \eta \max_i \max_j \left|u_{0j} - u_{ij}\right|}$$

Among them, $i = 1, 2, \cdots, a$; $j = 1, 2, \cdots, t$, a is the number of indicators in the same index, u_{ij} is the standardization value of actual comparative sequence i of the index in j year, u_{0j} is the standardization value of virtual ideal indicator sequence of the index in j year. $\eta \in (0, 1)$ is recognition differential, $\eta = 0.5$ in this paper. Similarly, so does the calculation of the grey correlation coefficient in the guideline level.

4. Calculation of grey correlation degree

For every indicator sequence of same index, the grey correlation degree (Zheng Yisheng et al. 1998; Cai Xiaoming 2000; Ebenezer Howard 2002) between actual comparative sequence i and virtual ideal indicator sequence is:

$$\zeta = \frac{1}{t} \sum_{j=1}^{t} \xi_{ij}$$

Among them, $i = 1, 2, \cdots, a$, a is the number of indicators in the same index. Similarly, so does the calculation of grey correlation degree in the guideline level.

5. Calculation of normalized weight values

For the indicator level, normalized weight value of i indicator in the same index is:

$$w_i = \frac{\zeta_i}{\sum_{i=1}^{a} \zeta_i}$$

Among them, a is the number of indicators in the same index. Similarly, so does the calculation of normalized weight values in the guideline level.

6.2.3 Empirical Researches on the Evaluation of Ecological Carrying Capacity in the Beijing, Tianjin, and Hebei Region

This paper divides the evaluation of ecological carrying capacity in Beijing, Tianjin, and Hebei region into two levels. Firstly, we evaluate longitudinally the ecological carrying capacities in Beijing, Tianjin, and Hebei region from 2001 to 2010 to find the changes of ecological carrying capacity in this period, and then study its development trend; secondly, we horizontally compare the ecological carrying capacity of 13 cities in Beijing, Tianjin, and Hebei region, classify these 13 cities by carrying capacity, and make diagnostic analysis to the differences of ecological carrying capacity in different cities.

1. Data sources and description

In this paper, the data used for empirical research is from the following two ways:

First, directly available data comes from the "2002–2011 China Statistical Yearbook for Regional Economy:" statistical bulletins of Beijing, Tianjin, and Hebei in 2001–2010; official websites of agriculture, forestry, land and resources, and other sectors of Beijing, Tianjin, Hebei.

Second, missing data are found by the moving average method, linear regression method, weighting method, and other methods.

2. Changes of ecological carrying capacity in the Beijing-Tianjin-Hebei region

This paper calculated ecological pressure, ecological supporting capacity, and general condition of ecological carrying capacity in the Beijing-Tianjin-Hebei region from 2001 to 2010 using the evaluating indicator system in Table 8.2 and index method. According to data analysis and calculation results, the ecological pressure indicator, ecological supporting capacity indicator, and ecological carrying capacity indicator in the Beijing-Tianjin-Hebei region from 2001 to 2010 are shown in Table 6.3.

From Table 6.3, it is observed that, in the 10 years from 2001 to 2010, the overall ecological carrying capacity in the Beijing, Tianjin, and Hebei region was good. Among them, in 6 years (in 2003, 2004, 2006, 2008, 2009, and 2010), the ecological carrying capacity indicators are less than 1, which indicates the pressure from social and economic activities on the ecological system is within bearable capacity of the natural ecological system, and overall ecological system is healthy; in 4 years (in 2001, 2002, 2005, and 2007), the ecological carrying capacity indicators are more than 1, which indicates the pressure from social and economic activities on the ecological system exceeds bearable capacity of natural ecological system.

For a more intuitive analysis of the results in Table 8.6, we show the changes of the ecological pressure indicator, ecological supporting capacity indicator, and ecological carrying capacity indicators in the Beijing-Tianjin-Hebei region from 2001 to 2010 in Fig. 6.2.

Table 6.3 Indicators of ecological carrying capacity in the Beijing-Tianjin-Hebei region

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Pressure indicator	0.2783	0.3254	0.3662	0.4075	0.4875	0.4338	0.5075	0.5764	0.4204	0.4668
Supporting capacity indicator	0.2158	0.3048	0.3840	0.4735	0.4842	0.5084	0.4846	0.6457	0.7246	0.7600
Carrying capacity indicator	1.2900	1.0676	0.9537	0.8605	1.0068	0.8533	1.0473	0.8927	0.5801	0.6142

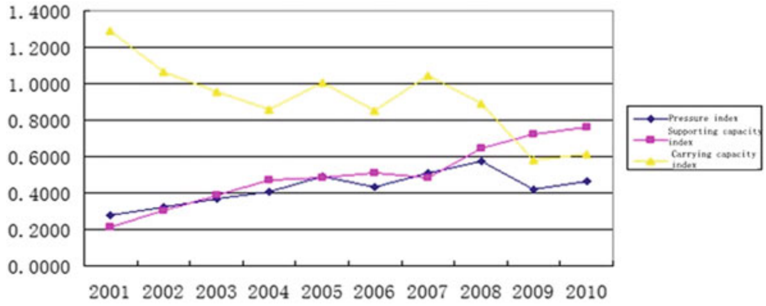

Fig. 6.2 Changes of ecological pressure, ecological supporting capacity, and ecological carrying capacity in the Beijing-Tianjin-Hebei region in 2001–2010

From the figure above, it is observed that the eco-environment in the Beijing-Tianjin-Hebei region shows changes in stages and development characteristics.

(a) From 2001 to 2010, in Beijing, Tianjin, and Hebei region, the ecological pressure index showed an upward trend overall, and specific situations can be divided into two stages; at stage I, it showed an upward trend each year from 2001 to 2005, which indicates that in this period, the ecological pressure in Beijing, Tianjin, and Hebei region increased; at stage II, from 2006 to 2010, it fluctuated in a "drop-rise-drop-rise" alternate manner, and reached its peak in 2008, namely the pressure from social and economic activities on the ecological system reached its maximum. It is possible that, after entering the new century, there has been rapid economic and social development in the Beijing-Tianjin-Hebei region to gradually increase consumption and damage to the ecosystem so that the pressure on the eco-system continually increased. In the "Eleventh-Five-Year Plan," a series of measures on energy conservation and emission reduction is drafted to increase rectification strength to the environment so that resource consumption for social and economic activities dropped, and environmental damage was also reduced, which are the factors to promote a drop in the ecological pressure. However, because the domestic policies on ecological protection started later, and is still at an exploratory stage, fluctuations are inevitable.
(b) From 2001 to 2010, in the Beijing-Tianjin-Hebei region, the ecological supporting capacity index showed an upward trend overall, which indicates that in this period, ecological supporting capacity in Beijing-Tianjin-Hebei region enhanced. With social and economic development, ecological security has gained universal attention. Compared with other domestic regions, resource reserves in the Beijing-Tianjin-Hebei region are not rich, and it is a dense area of population and industrial activities, thus damage to the ecosystem is more serious, and the capacity to bear economic and social development is limited. But, in recent years, the Beijing-Tianjin-Hebei region continues to increase investment in environmental management and ecological protection; implementation of a series of measures such as water conservation, wetland

protection, reforestation, energy conservation, and environmental protection has effectively restrained the trend of ecological deterioration, and has restored ecological environment to a certain extent so as to enhance the supporting capacity of ecosystem to social and economic activities.

(c) From 2001 to 2010, the ecological carrying capacity index of Beijing, Tianjin, and Hebei region showed a downtrend overall, and specific situations can be divided into three stages: at stage I, from 2001 to 2004 it showed a downtrend each year, which indicates that in this period, ecological carrying capacity in Beijing, Tianjin, and Hebei region improved year after year; there was ecological overload in 2001 and 2002, and carrying capacity overload changed into healthy carrying capacity by 2003 and 2004 mainly because of the implementation of measures on environment governance and ecological protection which caused the ecological system to resume, and supporting capacity constantly enhanced so that ecological carrying capacity improved despite constantly increased pressure from social and economic activities; at stage II, from 2005 to 2007, it was instable; besides ecological carrying capacity index being less than 1 in 2006 showing a healthy ecological state, ecological carrying capacity indicators were more than 1 in 2005 and 2007, which indicated that the pressure from social and economic activities on the ecological system in Beijing, Tianjin, and Hebei region exceeded supporting capacity of the ecological system in those 2 years mainly because the ecological pressure in Beijing, Tianjin, and Hebei region showed obvious fluctuation and an upward trend in this period, and the development trend of ecological supporting capacity was more gentle so that overall ecological carrying capacity overloaded; at stage II, from 2008 to 2010, it showed an overall downtrend, and ecological carrying capacity indicators were less than 1 in these 3 years, which indicated that, since 2008, ecological carrying capacity in the Beijing-Tianjin-Hebei region clearly entered good development of ecological health. With the accelerated development of the integration trend of the Beijing-Tianjin-Hebei region, the effect of many measures on ecological environmental integration (such as Bashang eco-agricultural engineering project and landscape engineering projects around the capital) has gradually emerged.

3. Comparative studies on ecological carrying capacities of 13 cities in the Beijing-Tianjin-Hebei region

This paper calculated the general condition of ecological pressure, ecological supporting capacity, and ecological carrying capacity of 13 cities in the Beijing-Tianjin-Hebei region in 2010 using the evaluating indicator system and index method in Table 6.3. According to data analysis and calculation results, the ecological pressure indicators, ecological supporting capacity indicators, and ecological carrying capacity indicators of these 13 cities in 2010 are shown in Table 6.4.

As shown in Table 6.4, the ecological carrying capacities of the 13 cities in the Beijing-Tianjin-Hebei region are obviously different. For an intuitive analysis, we regard the ecological pressure index and ecological supporting capacity index as the

Table 6.4 Ecological carrying capacity indicators of 13 cities in the Beijing-Tianjin-Hebei region in 2010

	Beijing	Tianjin	Shijiazhuang	Tangshan	Qinhuangdao	Handan	Xingtai	Baoding	Zhangjiakou	Chengde	Cangzhou	Langfang	Hengshui
Pressure indicators	0.55	0.48	0.39	0.46	0.13	0.35	0.33	0.29	0.20	0.23	0.10	0.10	0.15
Supporting capacity indicators	0.63	0.34	0.30	0.36	0.43	0.27	0.22	0.25	0.20	0.40	0.23	0.23	0.19
Carrying capacity indicators	**0.88**	**1.42**	**1.29**	**1.28**	**0.29**	**1.27**	**1.52**	**1.15**	**1.00**	**0.58**	**0.41**	**0.43**	**0.79**

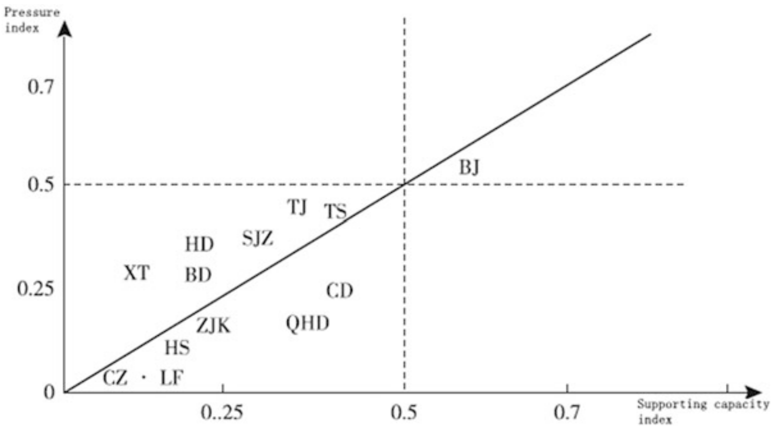

Fig. 6.3 Ecological pressure and ecological supporting capacity of 13 cities in Beijing, Tianjin, and Hebei region

coordinate axis to express ecological pressure and ecological supporting capacity of 13 cities in the Beijing, Tianjin, and Hebei region in the quadrantal diagram, as shown in Fig. 6.3.

From Fig. 6.3, it is observed that the ecological pressure and ecological carrying capacity of 13 cities in Beijing, Tianjin, and Hebei region show the following three situations:

(a) Ecological overload. It is manifested as ecological pressure index > ecological supporting capacity index, namely ecological carrying capacity index >1, the red marks on the top left of the oblique line shown in Fig. 8.3. Six cities Tianjin, Tangshan, Shijiazhuang, Handan, Baoding, and Xingtai fall under this situation. The pressures from social and economic activities of these cities on the ecosystem goes obviously beyond the carrying capacity of the ecosystems, in which Xingtai's ecological overload is the most serious. The ecological overload in these six cities was caused mainly because industrialization was dominant in their economic development, the proportion of the second industry in the gross regional product was close to or over 50 % (statistics, 2010), in which the highest was in Xingtai, the proportion of the second industry in GDP reached 55.61 %, and the lowest proportion of the second industry in GDP was in Shijiazhuang, at 48.63 %. Rapid industrial development has caused a lot of waste water, waste gas, and solid waste to be emitted, resulting in air pollution and environmental degradation so as to destroy the ecosystems. Adding on the increasing pressure of rapid development on the ecosystems and the pressure from social and economic activities on the eco-system has exceeded the carrying capacity of ecosystem.

(b) Ecological suitability. It is manifested as ecological pressure index = ecological supporting capacity index, namely ecological carrying capacity index = 1, the blue mark on oblique line shown in Fig. 8.3. Only Zhangjiakou falls under this category.

(c) Ecological health. It is manifested as ecological pressure index < ecological supporting capacity index, namely ecological carrying capacity index <1, the black marks in the low right of oblique line shown in Fig. 8.3. Six cities Beijing, Chengde, Qinhuangdao, Hengshui, Cangzhou, and Langfang fall under this situation. Among them, the best ecological carrying capacity is in Qinhuangdao. Although these six cities belong under the situation of ecological health, their reasons are different. As the capital, Beijing always attaches importance to ecological environmental protection and management. In recent years, most of Beijing's industries were moved out, the proportion of the second industry in GDP continuously dropped, only 24.01 % in 2010, and the services were dominant in economic development, therefore destruction to the ecological environment was smaller. In addition, in recent years, Beijing continued to increase the investment strength in ecological environment management and construction so that ecological environment has markedly improved, thus achieving healthy development of the ecosystem. Qinhuangdao and Chengde are famous tourist cities, and are well known, domestically and abroad, as good eco-environment, in particular, water and vegetation are relatively abundant. Hengshui, Cangzhou, and Langfang do not have strong supporting capacity of ecosystem, but comparatively, they have less pressure on the ecosystem, therefore overall ecological conditions are relatively healthy.

6.3 Countermeasure Suggestions on Upgrading the Carrying Capacity on Ecological Environment in Beijing, Tianjin, and Hebei

Through empirical analysis of developed countries to upgrade carrying capacity on ecological environment, and based on the practical circumstances of Beijing, Tianjin, and Hebei, this paper suggests the following to upgrade the ecological carrying capacity in Beijing, Tianjin, and Hebei:

6.3.1 Speed Up Building Cyclic Economic Development Mode

The law of world development process indicates that, when per capita GNP of a country or a region is at the development stage of 500–3,000 US dollars, it often is in the period of most serious contradiction between economic development and ecological environment. Since reform and opening up for more than 30 years, China's economy is rapidly developed, the economy in the Beijing-Tianjin-Hebei region has seen rapid development, but the contradiction between economic development and resource environment is increasingly intensified. Only by developing a cyclic economy, and reducing production of pollutants and emission of solid contaminants from the sources can establish economic development that the ecological environment can bear, and can settle the persistent contradiction between economic development and ecological environment so as to achieve coordinated development between economic development and ecological environment.

6.3.2 Advocating and Implementing Low-Carbon Consumption

As the world population grows, the society transforms from production-oriented to consumption-oriented, and changes from seller's market to buyer's market, the consumption pattern and lifestyle have more and more obvious effect on the coordinated development between economic development and ecological environment, therefore change of consumer behaviors will have a significant effect on settling environmental issues. By blindly imitating the pattern of developed countries to excessively waste resources, an unprecedented huge pressure will be brought to the resources and environment. Only implementation of a sustainable consumption pattern can reduce waste of resources from the consumer sector, thus promoting coordinated development of economic development and ecological environment. As a populous and large energy consuming power, gradual implementation of a progressive sustainable low-carbon consumption pattern is the general course of development for China. Therefore, to improve the carrying capacity on ecological environment, the Beijing-Tianjin-Hebei region should also implement sustainable low-carbon consumption plans.

6.3.3 Unceasingly Controlling Population Growth

At present, the population size of Beijing, Tianjin, and Hebei have reached 104 million, Beijing and Tianjin have respective resident population of 19.61 and 12.94 million. Population density in the Beijing-Tianjin-Hebei region is as much as 484 per square kilometer, which is almost four times that of the national average population density. As pressure from the growing population on natural resources gradually increases, human economic behaviors will begin to cause scarcity of resources and ecological environmental deterioration. Rapid population growth is the root of eco-environmental deterioration for developing countries; excessive population and rapid population growth not only devours the fruits of economic development, posing a threat to sustainable use of resources and environment, but also causes many social problems to affect harmonious development between economic development and ecological environment. Therefore, controlling population growth is the key to harmonious development between economic development and ecological environment for developing countries.

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Chapter 7
Studies on Carrying Capacity of Beijing-Tianjin-Hebei's Infrastructure and Social Facilities

Mingyue Miao, Zixiang Qi, and Mengxin Zhang

7.1 Basic Understanding of Urban Traffic Carrying Capacity and Quantitative Model

This paper uses the concept of carrying capacity in urban infrastructure, and studies megalopolis Beijing as an example.

7.1.1 Basic Understanding of Carrying Capacity of Urban Road Network

At present, studies on urban traffic carrying capacity has made some achievements, which are mainly manifested in: urban traffic jam and traffic capacity, studies on urban traffic planning and management based on sustainable development, studies on carrying capacity of urban traffic environment, and studies on carrying capacity of urban traffic population. This paper mainly studies the traffic carrying capacity of the road network and transit passenger traffic system.

As shown in Fig. 7.1, changes in land usage have directly led to changes in resident trips and traffic demand. With economic development and the accelerated process of urbanization, the change is generally manifested by the surge in traffic demand. To meet increased traffic demands, the government has to improve traffic facilities and to enhance road accessibility so that land price in the region rises, thus more developers will be inclined to enter, which improves the density of land development, so as to change regional traffic demand again. Repeatedly as such,

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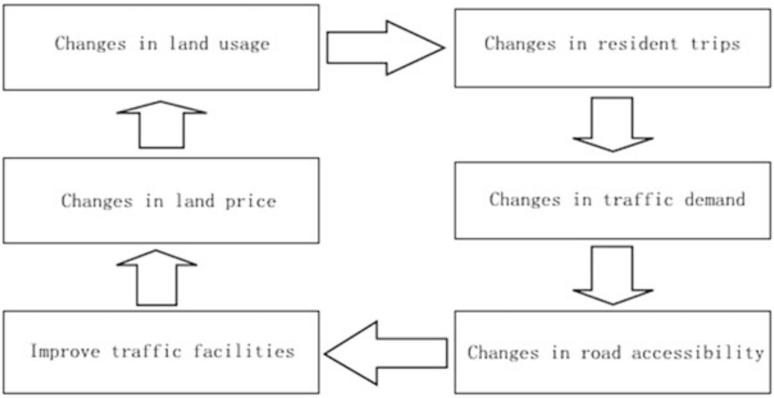

Fig. 7.1 Interaction between traffic and land usage

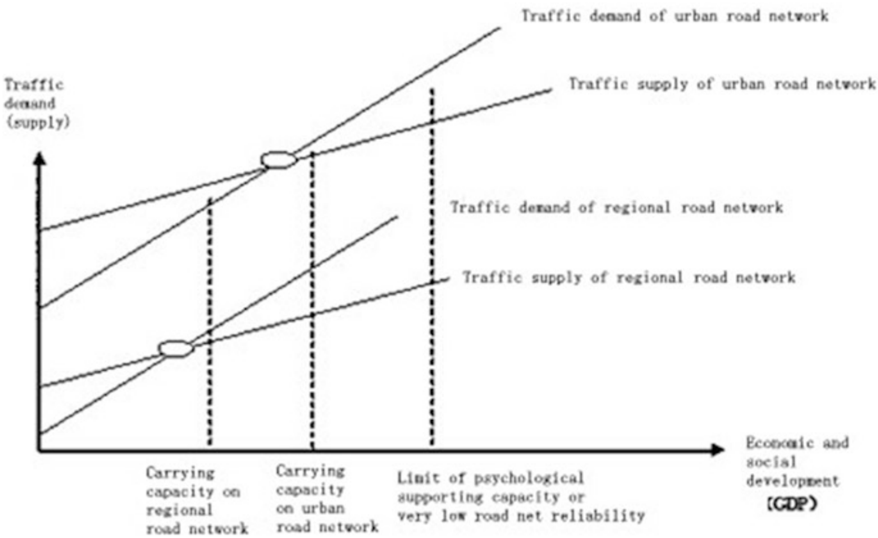

Fig. 7.2 Carrying capacities on regional and urban road networks

land and real estate prices inevitably continue to rise which increases the difficulty of road construction and relocation, and promotes underground transportation (subway) development. Meanwhile, motor vehicle traffic flow continues to increase, and in some road sections traffic flow exceeds design capacity so that traffic jams progressively intensifies.

From the above analysis, it is observed that, if not control, the interaction between land development and traffic will gradually limit carrying capacity on ground traffic. Due to planning and other reasons, traffic of roads have different carrying capacities, local traffic jams will first appear in areas of larger traffic flow, namely reach or exceed the carrying capacity on the regional road network (see Fig. 7.2). With continued increase of traffic flow, traffic jams continually spread, widespread traffic jam in the whole city will be inevitable, hitting the limit of

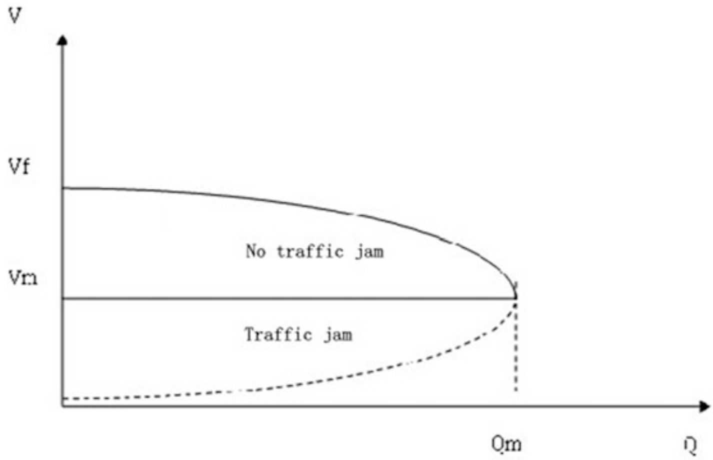

Fig. 7.3 Velocity- quantity of flow (V-Q) relationship

carrying capacity on the urban road network. Since then, average operating speed of vehicles in the urban road network starts to decrease, in terms of simple traffic network, the limit of carrying capacity is the limit of social psychological supporting capacity or the situation which has very low road network reliability, and thus is extremely easy to have large-scale gridlock, which cannot fix itself. For convenient calculation and quantization, generally the basic road capacity characterizes the extreme carrying capacity.

Based on the characteristics of traffic flow, velocity-density model as a linear type, above figure can be drawn (Fig. 7.3).

Among them, *Vm* is velocity when maximum quantity of flow is *Qm*, and *Vf* is navigated speed. When the vehicle flowrate gradually increases, the average velocity of a vehicle drops, and after the vehicle flowrate increases to a certain stage, reaching the maximum quantity of flow *Qm*, since then due to increase in traffic density, the velocity drops, the quantity of flow begins to decline, and the road is congested. Thus, for a single section, it can be considered the road capacity is *Qm*, namely maximum flow rate per hour. Generally the carrying capacity in *i* section is measured by the gross number of vehicles (number of vehicles GN), and the carrying capacity can be characterized by maximum number of vehicles in *i* section in a day:

$$\text{GNi} = \text{Qm} \times 24 \tag{7.1}$$

7.1.2 Quantitative Model of the Carrying Capacity on Road Net

At present, studies on the carrying capacity of the urban road network are regarded as part of the studies on carrying capacities of urban traffic environment and energy, and due to limited data, it is limited in its macroscopic study to serve urban planning and transportation planning.

Hou Deshao (2008) calculated and obtained optimal maximum carrying capacity of the road network as the carrying capacity on urban road network using the graph theory on the basis of existing OD survey data, through the establishment of a bi-layer planning model, regarding maximized carrying capacity on the road network and the least average trip time as the target, and established seven models according to difference of the objective functions.

Zhan Xinye et al. of Peking University (Zhan et al. 2008) thought the carrying capacity on the road network resource is decided by the gross capacity of the road network and the space-time consumption of models of vehicles (Formula (7.2)):

$$\mathrm{VCi} = (\mathrm{Ci} \times \mathrm{C})/\mathrm{Si} \tag{7.2}$$

In the formula, *VCi* is the maximum number of operating vehicles (unit) of *i* model of vehicle limited by the road network capacity; *Ci* is the distribution coefficient (dimensionless); *C* is the gross road net capacity (unit); *Si* is the ratio between space-time consumption of standard model of single vehicle and space-time consumption of *i* model of single vehicle (standard · vehicle-1). *C* is decided by the road network structure and the average speed of vehicle (Formula (7.3)), and the road net structure consists of the length and traffic capacity of various types of roads (Formula (7.4)).

$$\begin{aligned}\mathrm{C} = {} & \mathrm{C(expressway)} + \mathrm{C(arterial\ road)} + \mathrm{C(secondary\ main\ road)} \\ & + \mathrm{C(branch\ way)} + \mathrm{C(street)}\end{aligned} \tag{7.3}$$

$$\mathrm{Cn} = (\mathrm{Ln} \times \mathrm{Un})/\mathrm{Vn} \tag{7.4}$$

In the formula, *Cn* is gross capacity of *n* type of road (vehicle number); *n* is the sum of expressway, arterial road, secondary main road, branch way and street; *Ln* is gross length of *n* type of road (km); *Vn* is average speed (km · h-1); *Un* is actual traffic capacity of standard model of vehicles in *n* type of road (vehicle number · h-1). *Un* is affected by types of vehicles and roads and other factors (Formula (7.5)).

$$\mathrm{U} = \mathrm{u} \times \eta \times \mu \times 2 \tag{7.5}$$

In the formula, *u* is theory traffic capacity of the standard model of vehicles (104 vehicles · h-1); η is driveway correction coefficient (dimensionless); μ is correction coefficient of road type (dimensionless); *2* is bi-directional driveway coefficient (dimensionless).

Hou Deshao's method reveals the formation mechanism of carrying capacity on the road network from the micro-level: for the same network, the channels or minimum intercepts of different OD points are different, therefore the network carrying capacity varies. Thus, in actual road network, the calculation of carrying

Table 7.1 Design standards of all classes of highways (Kelly 1998)

Indicators	Transporting velocity (km/h)	Rush hour departure interval (min)	Length of line (km)	Station spacing (km)	Passenger capacity (person-time/h)
Railway	25–50	3–5	>15	>1.0	25,000–50,000
BRT	>25	4–8	>15	>1.0	30,000
Trunk line	18–20	4–10	10–15	0.5–0.8	5,000
Branch line	15–20	4–10	<8	0.3–0.5	3,000

capacity measured by the road capacity will be very complicated, on one hand we must consider road capacity and junction traffic capacity on any OD path, on the other hand we also need to consider reducing road capacity value on OD path after superposition of traffic flow from different directions. Zhan Xinye's method takes a more macro approach, and is easy to calculate, but it neglects the junction node limit and other factors, and the calculation results are generally far bigger than actual carrying capacity of the road network.

Usually road section capacity increased value and the intersection spacing have a linear relationship, in the case where intersection spacing is equal to or less than 200 m, intersection affecting correction coefficient is the green ratio []. On the assumption that the intersections are spaced 200 m, and all are two-phase signal control, and for road *i*, fixed value of the green ratio between it and road *j* intersection is $\frac{C_i}{C_i+C_j}$. Thereby, Formula (7.2) can be changed into:

$$\begin{aligned} C_{\text{Road network}} = {} & C_{\text{Express-way}} + C_{\text{Trunk line}} \times \left(\frac{C_{\text{Trunk line}}}{C_{\text{Trunk line}} + C_{\text{Inferior line}}}\right) \\ & + C_{\text{Inferior line}} \left(\frac{C_{\text{Inferior line}}}{C_{\text{Trunk line}} + C_{\text{Inferior line}}}\right) \\ & + C_{\text{Branch line}} \left(\frac{C_{\text{Trunk line}}}{C_{\text{Branch line}} + C_{\text{Inferior line}}}\right) \end{aligned} \tag{7.6}$$

In accordance with Table 7.1, if C_{railway}, C_{BRT}, C_{transit} are respectively *n* railways, *m* BRTs and *k* transit lines, the limit of traffic carrying capacity is:

$$C_{\text{railway}} = \text{n}50,000 \text{ person} - \text{times/h} \tag{7.7}$$

$$C_{\text{BRT}} = \text{m}30,000\text{person} - \text{times/h} \tag{7.8}$$

$$C_{transit} = m30,000 person - times/h \quad (7.9)$$

7.1.3 *Calculation of Carrying Capacities on the Road Network and Public Transportation Passenger Traffic System in Beijing*

According to the contents of *Traffic Engineering* compiled by Ren Futian et al. (Baldwin et al. 2003), traffic capacity of one-way 4-lane expressway is calculated as (Table 7.2):

$$U_{Expressway} = 1,900 \times 0.97 \times 4 = 7,372_{veh/h} \quad (7.10)$$

Reference to Tables 9.2, takes Vn = 40 km/h, then two-way expressways are:

$$C_{Expressway} = (262.9 \times 7,372 \times 2)/40 = 96,905_{veh}$$

In a similar way: $C_{Trunk\ line} = 495,828.6veh$, $C_{Inferior\ line} = 180,300veh$, $C_{Branch\ line} = 449,626.4veh$

From the formula (7.9), we can get $C_{Road\ network} = 829,525.3veh$

According to formulas (7.7), (7.8) and (7.9): $C_{railway}$ = 750,000 person-times/h, C_{BRT}=90000人次 / *h*, $C_{Tram\ and\ Bus}$=3745000人次/ h. (Table 7.3). The sum of the three is: $C_{Transit}$ =4585000人次/ h. Considering the number of vehicles and the scheduling, actual carrying capacity C_{actual} of the transit system will be far less than this value.

$$C_{Actual} = \bar{n}_s \times n_1 \times n_v \times \theta \times C_{persons\ per\ single\ bus} \quad (7.11)$$

In the formula, $\bar{n}_s$ is average sites passed in unit time (1 h), which relate to bus speed and site spacing; n_1 is total number of lines; n_v is working vehicles, which relate to departure time interval, total number of vehicles and operation time

Table 7.2 Beijing's urban road mileage

Type of road	Expressway	Arterial road	Secondary road	Branch way and below
Mileage (km)	262.9	867.7	630.9	4,494.6

Data: 2012 Beijing annual report on traffic development (Krugman 1991)

Table 7.3 Some indicators of Beijing's public traffic operation

Type of transit	Number of lines	Vehicles in service
Railway	15	2,850
Tram and bus	749	21,628
BRT	3	–

Data: Beijing annual report on traffic development 2012 interval; $\overline{\theta}$ is average transfer rate, which relate to the number of transfer; average maximum fixed number of persons per single bus $\overline{C_{\text{persons per single bus}}}$.

7.2 Analysis of the Carrying Capacity on the Road Network in Beijing

7.2.1 Rush Hour Traffic Flow of Motor Vehicles Has Exceeded the Carrying Capacity of the Urban Road Network

From Fig. 7.1 and Table 7.1, it is obvious that, in the morning rush hour (7:00–8:00), quantity of working minibus reached 1.05 million (minibuses accounted for 87.7 % of all motor vehicles), regardless of other types of vehicles, apparently the quantity is larger than the carrying capacity on the road network (829,000 vehicles/h), therefore widespread traffic jams are inevitable (Table 7.4). See Figs. 7.4 and 7.5.

7.2.2 Big Traffic Pressure in City Center, and Obvious Tidal Traffic Flow

Excessive function convergence and "imbalance between vocation and living" have caused the most congestion in the core area within the 2nd ring road, according to monitoring results (Fujita et al. 1999), daily working motor vehicles within the 2nd ring road reached 915,000, namely 27.6 % of daily motor vehicles on the road in the whole city run within the 2nd ring road (road length of original four city districts only accounted for 2.6 % of total length in the whole city), so

Table 7.4 Proportion of trip quantity as morning and evening rush hours in all-day trip quantity

Indicators	Evening rush hour Proportion in all-day trip quantity (%)	Morning rush hour Proportion in all-day trip quantity (%)
Trip aggregate	19.3	14.7
Tram and bus	15.4	15.7
Railway	28.4	17.9
Taxi	10.7	8.1
Car	23.8	19.8
Bicycle	19.4	17
Walk	17.7	8.4

Data source: Beijing annual report on traffic development 2012

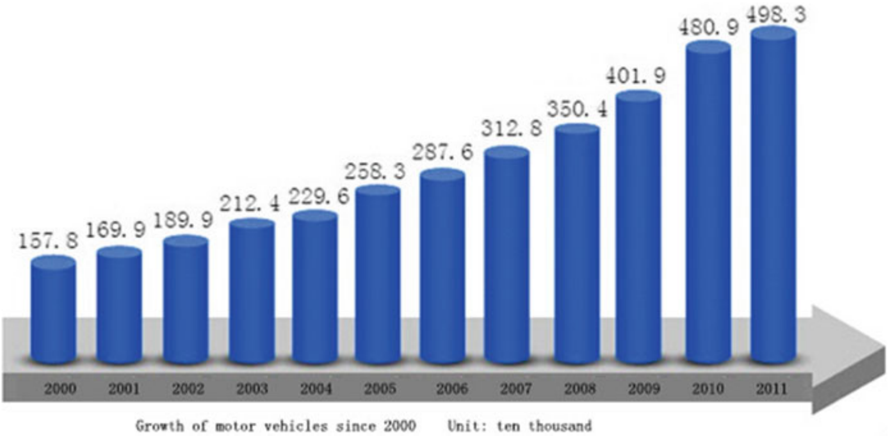

Fig. 7.4 Growth of motor vehicles since 2,000 unit: ten thousand (Data source: Beijing Traffic Management Bureau of Public Security Department)

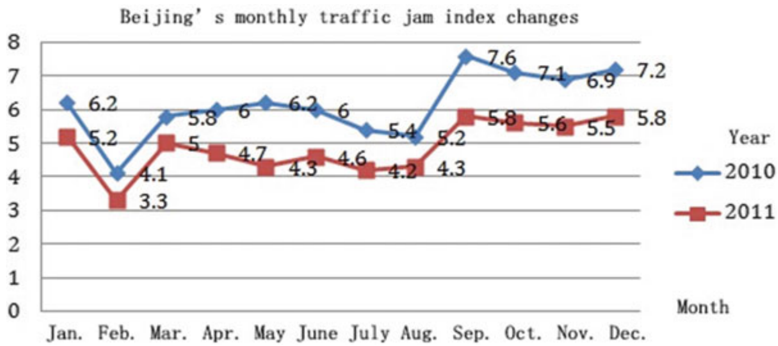

Fig. 7.5 Beijing's monthly traffic jam (Data source: Beijing Traffic Development Research Center)

that the zones within the 2nd ring road are the most congested zones in the whole city. At present, the speed in some sections are at a relatively low level, for example, rush-hour speed in north 2nd ring road is 28.4 km/h, rush-hour speed in west 2nd ring road is 30.1 km/h, in east 2nd ring road 31.5 km/h, and in east 3rd ring road 33.4 km/h. Traffic in the central area within the 5th ring road is relatively congested, and the range of congestion is expanding. Although a "five-day system" was implemented starting October 2008 to limit traffic flow, and stagger rush hour was implemented starting April 2010, and other comprehensive measures to mitigate congestion, traffic flow has been reduced and balanced to a certain extent, with the rapid growth of motor vehicle possession, the trend of decreasing traffic speed is still obvious.

7.2.3 Obvious Differences in Traffic Carrying Capacities on the South and North Road Networks

This paper regards subway Line 1 as the boundary that divides the area within the sixth ring road of Beijing into the north and south parts for comparison; in economic development (Baldwin 2001), in the sight of per capita economic indicators, the gap between the north and south urban areas has obviously increased. In 2001, per capita GDP in the north urban area was 1.5 more than that of the south urban area, from 2001 to 2009 per capita GDP in the north urban area on average annually grew 14.87 %, and per capita GDP in the south area on average annually grew only 8.72 %, which was 6.15 % lower than that of the north area, and resulted in per capita GDP in the north area to be 2.4 times that of the south area in 2009. In transportation infrastructure, we further study the number and area of various units distributed in the north and south areas, it can be discovered that accessibility and road infrastructure construction of the north and south urban areas had drastic differences (Figs. 7.6 and 7.7).

7.2.4 Saturated Traffic Carrying Capacity in the Transit System Exceeds Actual Carrying Capacity

Above $C_{BRT} = 4,585,000\text{person} - \text{times/h}$ is the theory carrying capacity calculated only considering the lines, and without consideration to the number of vehicles and vehicles scheduling; actually, in accordance with cruising data in the "2012 Beijing Annual Report on Traffic Development," trip quantity of buses (and electric buses) were 8.11 million person-times/day within the 6th ring road at the end of 2011, and trip quantity of railway were 3.95 million person-times//day. According to Tables 9.3 and 9.1, in accordance with formula (7.11), trip quantity of buses within the 6th ring road in the morning rush hour was 1.216 million persons-times, on the assumption that buses on all lines run on roads in 5-min departure intervals, in the morning rush hour each working bus on average takes trip quantity of 135 person-times, but it was crowded for passengers, even on larger buses GJ113 (length: 10–12 m, fixed number: $\leq$110 persons).

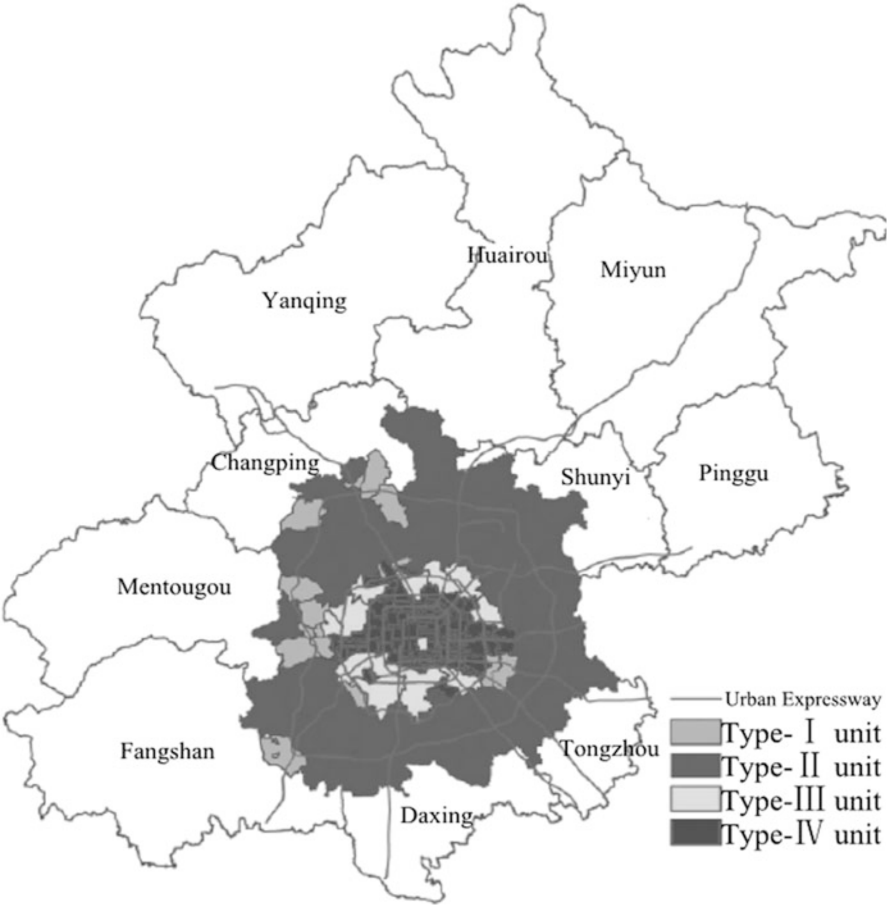

Fig. 7.6 Space distribution of the types of street (Baldwin 2001)

Notes: 1. Type I, road infrastructure construction within the area is better, but the accessibility is poor relative to the center area;

2. Type II, road infrastructure construction within the area is bad, and the accessibility is poor relative to the center area;

3. Type III, road infrastructure construction within the area is bad, but the accessibility is excellent relative to the center area;

4. Type IV, road infrastructure construction within the area is better, and the accessibility is excellent relative to the center area

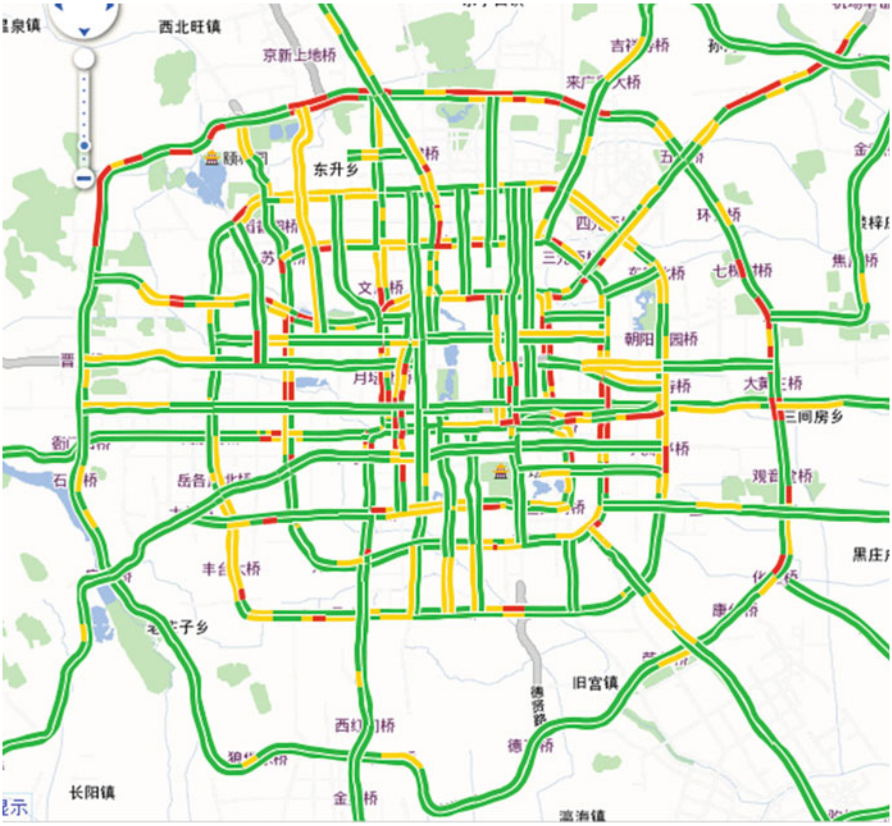

Fig. 7.7 Highway conditions on Friday rush hour (Data source: Beijing Traffic Management Bureau of Public Security Department)

7.3 Comparison of Carrying Capacities on the Regional Traffic Infrastructure

7.3.1 Comparison of Beijing, Tianjin, and Hebei

Factor analysis is a multivariate statistical method to simplify multivariables, and it can be regarded as a generalization of master component analysis (Table 7.5). Factor analysis is the method to find this internal relation. The factor analysis model is as follows:

And satisfies

⊖m $\leq$ p ⊜ $Cov(F, \varepsilon) = 0$ $Cov(F, \varepsilon) = 0$ ⊛D(F)= $\begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} = I_m$即$F_1 \cdots F_m \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} = I_m$即$F_1 \cdots F_m$
are uncorrelated, and variance = 1.

Table 7.5 Indicator evaluation system for the carrying capacities on regional traffic infrastructure (Beijing, Tianjin, and Hebei)

Area	Bus passenger capacity (ten thousand persons-times)	Per capita road length (km/ten thousand persons)	Per capita transit line length (km/ten thousand persons)	Per capita railway line length (km/ten thousand persons)	Road network density (km/ every hundred sq. km)	Railway traffic capacity (ten thousand persons-times)	Per capita private car quantity (vehicle /ten thousand persons)	Quantity of operating transit vehicle at end of the year (vehicle)	Traffic jam degree on expressway	Traffic jam degree on national highway
Beijing	505,144	9.16	9.56	0.17	128.66	184,645	1,908.16	24,011	0.731	0.710
Tianjin	108,810	11.23	9.52	0.06	124.64	6,568	970.35	7,413	0.378	0.639
Hebei	195,949	15.66	3.33	0	82.23	0	101.12	14,630	0.375	0.793

Data sources: China statistical yearbook for regional economy 2011, and China traffic statistical yearbook 2010

This paper selected 10 indicators in Table 9.1, they are respectively bus passenger capacity, per capita road length, per capita transit line length, per capita railway line length, road network density, railway traffic capacity, private car quantity, quantity of operating transit vehicle, and traffic jam degree on expressway, and traffic jam degree on national highway, to compare the carrying capacities on traffic infrastructure in the Beijing-Tianjin-Hebei region (Table 7.6).

Variance accumulative total contribution rate of the factor 1 reaches 72.525 %, variance accumulative total contribution rate of factor 2 reaches 27.485 % in which these two factors cover all the above 10 indicators (Tables 7.7 and 7.8).

The formula to calculating factor score is as follows:

$$\text{Factor Fi} = \sum_{P=1}^{10} \mathrm{a_{ip}} X_p$$

$$\text{Integrated score} = 0.72515 * \text{F1} + 0.27485 * \text{F2}$$

$$\text{Beijing's integrated score} = 0.72515 * 1.09787 + 0.27485 * 0.3578 = 0.89$$

$$\text{Tianjin's integrated score} = 0.72515 * (-0.8588) + 0.27485 * 0.77188 = -0.41$$

$$\text{Hebei's integrated score} = 0.72515 * (-0.23907) + 0.27485 * (-1.12968) = -0.48$$

7.3.2 *Comparison of the Beijing-Tianjin-Hebei Region, the Yangtze Delta, and the Zhujiang River Delta*

In a similar way, we calculate and compare the integrated scores of carrying capacities of the traffic infrastructure in the Beijing-Tianjin-Hebei region, the Yangtze Delta, and the Zhujiang River Delta (Tables 7.9, 7.10, 7.11 and 7.12).

$$\text{Integrated score of the Beijing-Tianjin-Hebei region} = 0.697 * .96225 + 0.303 * (-0.63828) = 0.48$$

$$\text{Integrated score of the Yangtze Delta} = 0.697 * 0.07164 + 0.303 * 1.15248 = 0.40$$

$$\text{Integrated score of the Zhujiang River Delta} = 0.697 * (-1.03389) + 0.303 * (-0.51420) = -0.88$$

7.3.3 *Comparative Conclusions*

Through factor analysis, the conclusions from the above table are drawn: in ranking of carrying capacities on traffic infrastructure in Beijing, Tianjin, and Hebei, Beijing ranks first, Tianjin second, and Hebei third; comparing traffic infrastructure in three big economic circles, Beijing-Tianjin-Hebei region ranks first, the Yangtze

Table 7.6 Total variance explained

Components	Initial eigenvalue			Extracted sum of squares loads			Rotated sum of squares loads		
	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %
1	7.251	72.515	72.515	7.251	72.515	72.515	5.286	52.864	52.864
2	2.749	27.485	100.000	2.749	27.485	100.000	4.714	47.136	100.000
3	0	0	100.000						
4	0	0	100.000						
5	0	0	100.000						
6	0	0	100.000						
7	0	0	100.000						
8	0	0	100.000						
9	0	0	100.000						
10	0	0	100.000						

Table 7.7 Rotated component matrix

	Components	
	1	2
Bus passenger capacity	0.995	0.104
Per capita road length	−0.502	−0.865
Per capita transit line length	0.212	0.977
Per capita railway line length	0.784	0.621
Road network density	0.283	0.959
Railway traffic capacity	0.941	0.340
Per capita private car quantity	0.685	0.729
Operating transit vehicle quantity at the end of the year	0.991	−0.133
Traffic jam degree on expressway	0.948	0.317
Traffic jam degree on national highway	0.267	−0.964

Table 7.8 Score coefficient matrix of components

	Components	
	1	2
Bus passenger capacity	0.224	−0.084
Per capita road length	−0.022	−0.173
Per capita transit line length	−0.059	0.235
Per capita railway line length	0.116	0.077
Road network density	−0.041	0.223
Railway traffic capacity	0.184	−0.015
Per capita private car quantity	0.080	0.117
Operating transit vehicle quantity at the end of the year	0.249	−0.146
Traffic jam degree on expressway	0.189	−0.022
Traffic jam degree on national highway	0.171	−0.286

Delta second, and the Zhujiang River Delta third (Table 7.13). Although Beijing ranks first in carrying capacities on traffic infrastructure in the Beijing, Tianjin and Hebei region, part III of this paper has proven overload of Beijing's traffic carrying capacity so that the capital economy cannot run with Pareto optimality. Above analysis shows that simply improving the traffic infrastructure is only a temporary solution for promoting carrying capacity; we construct roads if there is congestion, add subways if there are too people on the ground, which is nothing but stop-gap measures, while it is necessary, it cannot fundamentally solve the present situation of traffic jam in Beijing, and cannot reduce the negative effects from the congestion.

Infrastructure can be divided into three classes; class-1 is traffic infrastructure, such as high-speed railway, expressway, subway, airport, and port; class-2 is knowledge overflow infrastructure, such as colleges and universities, technology exchange, satellite and wireless network, information highway network, and information integration institutions; class-3 is public service infrastructure, such as sewerage treatment facilities, and waste recycle systems, hospitals, kindergartens,

Table 7.9 Indicator evaluation system for the carrying capacity on the traffic infrastructure (Beijing-Tianjin-Hebei region, the Yangtze Delta, and the Zhujiang River Delta)

Area	Bus passenger capacity (ten thousand persons-times)	Per capita road length (km/ten thousand persons)	Per capita transit line length (km/ten thousand persons)	Per capita railway line length (km/ten thousand persons)	Road network density (km/every hundred sq. km)	Railway traffic capacity (ten thousand persons-times)	Per capita private car quantity (vehicle / person ten thousand)	Quantity of road operating vehicles (ten thousand vehicle)	Traffic jam degree on expressway	Traffic jam degree on national highway
Beijing-Tianjin-Hebei region	809,903	13.89	5.26	0.04	111.84	191,213	862.14	104.97	0.495	0.714
The Yangtze delta	1,006,873	17.44	7.37	0.03	147.85	209,866	610.32	125.22	0.491	0.584
The Zhujiang river delta	584,784	33.86	12.91	0.05	106.88	134,373	601.59	90.27	0.470	0.656

Data sources: China statistical yearbook for regional economy 2011, China traffic statistical yearbook 2010, some data are from authors' calculation

Table 7.10 Total variance explained

Components	Initial eigenvalue			Extracted sum of squares loads			Rotated sum of squares loads		
	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %	Total	Variance %	Accumulation %
1	6.970	69.700	69.700	6.970	69.700	69.700	5.144	51.440	51.440
2	3.030	30.300	100.000	3.030	30.300	100.000	4.856	48.560	100.000
3	0	0	100.000						
4	0	0	100.000						
5	0	0	100.000						
6	0	0	100.000						
7	0	0	100.000						
8	0	0	100.000						
9	0	0	100.000						
10	0	0	100.000						

Table 7.11 Rotated component matrix

	Components	
	1	2
Bus passenger capacity	0.584	0.811
Per capita road length	−0.957	−0.290
Per capita transit line length	−0.982	−0.190
Per capita railway line length	−0.553	−0.833
Road network density	0.172	0.985
Railway traffic capacity	0.764	0.645
Per capita private car quantity	0.849	−0.528
Quantity of road operating vehicles	0.474	0.880
Traffic jam degree on expressway	0.952	0.307
Traffic jam degree on national highway	0.389	−0.921

Table 7.12 Score coefficient matrix of components

	Components	
	1	2
Bus passenger capacity	0.059	0.143
Per capita road length	−0.193	0.018
Per capita transit line length	−0.208	0.045
Per capita railway line length	−0.050	−0.152
Road network density	−0.052	0.224
Railway traffic capacity	0.116	0.086
Per capita private car quantity	0.244	−0.208
Quantity of road operating vehicles	0.027	0.170
Traffic jam degree on expressway	0.190	−0.014
Traffic jam degree on national highway	0.175	−0.261

Table 7.13 Ranking of carrying capacities on the regional traffic infrastructure

Areas	Factor score	Ranking	Areas	Factor score	Ranking
Beijing	0.89	1	Beijing-Tianjin-Hebei region	0.48	1
Tianjin	−0.41	2	The Yangtze delta	0.40	2
Hebei	−0.48	3	The Zhujiang river delta	−0.88	3

Data from authors' calculation based on the SPSS

primary and secondary schools, power production and distribution facilities, petroleum transportation facilities and leisure facilities, and so on. Improvement of the traffic infrastructure can no doubt reduce the interregional trade cost, including transportation cost, time cost, and opportunity cost, but can also improve freedom of trade or economic openness, and can speed up the exchange of goods and the circulation production factors, but if local governments only improve regional traffic infrastructure, a polarization effect will be produced causing inter-regional differentiation. In this way, Krugman (Krugman 1991) proved this point by building the "core-periphery" model. French economist Francois Perroux (1950) introduced the concept of growth pole. He said that economic space is always around the polar nucleus in the growth process, economic growth does not appear in all places at once, but first appears on some growth poles with different intensities. Growth pole has polarization and spread effects. Professor An Husen of Nankai University (2009) said, improvement of infrastructure conditions in favor of interregional trade does not show obvious effect before the threshold level is reached, but if it goes beyond the threshold level, regional differentiation will occur. All in all, the better Beijing's infrastructure is, the more attractive it becomes for population agglomeration, the more pressure on carrying capacity is brought so that traffic infrastructure overloads.

7.4 Suggestions on Improving Urban Traffic Carrying Capacity

7.4.1 Strengthening the Accessibility of Regional Traffic to Alleviate Traffic Pressure on Core Cities

The main city in the Beijing-Tianjin-Hebei urban circle is Beijing. Beijing also has the most pressure in the capital circle, congestion costs have had a marked negative external effect, excessive population concentration and excessive operating vehicles slow down social operating efficiency, and reduce economic operating efficiency, and Pareto optimality cannot be reached. Beijing should insist on controlling the growth of motor vehicles, and should change from the existing administrative intervention of drawing lucky numbers in license auction which tallies more so with market economy. A license plate should only be auctioned if a car is discarded, thus the quantity of cars can really be controlled.

7.4.2 Strengthening Function Mitigation of Center City, Strengthening Organic Cooperation Among Knowledge Overflow Infrastructure, Public Service Infrastructure, and Traffic Infrastructure

The knowledge overflow infrastructure not only can produce a spread effect, and its spread effect can reverse the polarization effect produced by traffic infrastructure to become the spread effect in the game between it and the polarization effect produced by traffic infrastructure once it breaks through a critical value, if and only if expenditure share of industrial products in underdeveloped areas or edge areas is big enough, which will cause regional convergence, and the two effects work together to reach regional economic integration; as does the public service infrastructure.

Industries transfer, population can only spread, and bearing pressure on the central city can only be relieved, therefore the function mitigation of central city zones and the equalization of public services are the prerequisite for industrial transfer. The governments of Beijing, Tianjin, and Hebei should make overall plans, in collaboration with the relevant ministries, lead colleges and universities in Beijing and Tianjin to establish branches in Hebei province, encourage major hospitals in Beijing and Tianjin to make interregional operation and establish branches in Hebei province.

7.4.3 Strengthening the Deployment of Carrying Capacity: Developing Individualized Public Traffic, Improving the Level and Quality of Transit Services

Center cities should recover the differential public transport supply to attract more private car owners. In the case of same existing vehicle quantity, these cities should increase more comfort buses, and proportionally increase the ticket price to control the number of passengers, and attract more car drivers by reducing the stop sites, by increasing the punctuality rate, and by upgrading the level of intelligent services, rather than simply attracting bike riders and squeezing out car drivers; develop the expressway, high-speed road, direct shuttle-bus based on interregional services to quickly mitigate traffic flow pressure on central areas. Traffic hubs like the Beijing Railway Station, Beijing West Railway Station, and Beijing South Railway Station, and the roads around tourist spots such as the Forbidden City and Summer Palace are focal areas of vehicle flow and people flow, people should be quickly transported out of those areas with fast, large-capacity, and direct buses; Beijing's center city zones cover a large area and have concentrated functions, thereby they have an obvious tidal-type traffic feature in which large numbers of motor vehicles go to town in the morning rush hour and go out of town in the evening rush hour, especially under the influence of large residential areas such as Daxing, Changping, and Tongzhou, and this feature is particularly prominent in the south, north, and east areas. According to statistics [Beijing Traffic Management Bureau, *City Running Report*], during the morning rush hour, motor vehicles going into town are 1.4 times more than that of vehicles going out of town, in which it reached 1.85 times in the south, 1.35 times in the north, 1.26 times in the east, and 1.13 times in the west. During evening rush hour, motor vehicles going out of town are 1.85 times more than vehicles going into town, in which it reached 2.31 times in the south, 2.13 times in the east, 1.68 times in the north, and 1.27 times in the west. Some destinations are in the city center, within the 2nd or 3rd ring roads, and some are traffic flow through the city. Development of expressways, highways, direct shuttle buses and selecting routes based on congestion attracting private car owners to take public transport to reduce the pressure on the center zones, are in favor of keeping low density green areas between new cities and center zones.

7.4.4 Attracting International and Private Investments in Infrastructural Construction

The experiences of developed countries indicated that infrastructural construction should not be monopolized by the governments because monopoly is one of the least efficient ways of resource allocation; but cannot be completely provided by the market, because this will result in insufficient supply of public goods. Best way of investment and financing in infrastructural construction is government-led, integration of international capitals and private capitals.

7.4.5 Strengthening the Construction of the Mega-city Tridimensional Traffic System, Fully Using the Underground Space

Many cities often only focus on infrastructural construction, but ignore the construction of supporting facilities. For example, some cities blindly develop highways, but neglect the construction of underground car parking lots, resulting in private cars parking randomly on the public roads which seriously hampers traffic; traffic carrying capacity has no obvious improvement so that the financial funds the government invests in infrastructure does not fulfill its role to its capacity, therefore constructing supporting infrastructure facilities are equally important with infrastructural construction. The governments should increase the use of underground space, both above-ground and underground spaces supplement each other to jointly upgrade carrying capacity on the infrastructure.

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Chapter 8
Studies on Social Carrying Capacity of the Beijing-Tianjin-Hebei Region

Wen Zhao, Hui Liu, and Li Gong

8.1 Definition and Research Significance of Social Carrying Capacity

With China's accelerated urbanization process, the huge urban cluster effect causes more and more people to centralize in national-level center cities such as Beijing, Shanghai, and Guangzhou. On the one hand, Beijing's urban population development scale has increased, the peak population reached 30 million; on the other hand, the conflict between construction of urban sustainable development capacity and rapid population expansion is increasingly prominent. In the context of building a global city, the process of integration between Beijing, Hebei, and Tianjin and other neighboring areas is accelerating.

"Social carrying capacity" is defined as the carrying capacity on regional public good resources, namely public service capacity and other conditions, to existing population growth and economic development. In the process of developing the economy, society, population, resources, and environment in the capital and the Beijing-Tianjin-Hebei region, along with the enhancing the ability of governments to provide public service products, the population size and living quality that the region can bear will improve. For this reason, on the basis of urban areal natural and economic carrying capacities that link up with the population, the studies bring the meaning of "social carrying capacity" into the evaluation framework of integrated carrying capacity in Beijing and the Beijing-Tianjin-Hebei region so that the urban or areal carrying capacity becomes a comprehensive concept including natural, economic, and social carrying capacities. It is observed that the concept of social carrying capacity is the inevitable outcome of city (especially mega-cities) development entering the post-industrialization stage, urbanization developing to mega-cities as the core city circle, and the urban agglomeration development stage. If the

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contradictions between urban population expansion and corresponding demand for social public goods cannot be handled well, it is possible to aggravate internal polarization in the urban areas and to bring a series of social, economic, and environmental issues. It is necessary for the city government to create livable environments in terms of enhancement of social welfare, social security, public services, and social management capacity in its own area based on the level of social carrying capacity and being people-oriented, so as to promote comprehensive, healthy, and sustainable development of the local economy, society, and environment.

8.2 Indicator System and Measurement for Social Carrying Capacity

On the basis of the principles of data attainability, and representativeness and comparability of indicators, the evaluating indicator system for social carrying capacity in Beijing-Tianjin-Hebei region is determined. It includes, (1) public service facilities, which contain medical services and healthcare, culture technology and education, and housing, to measure residents' quality of life and development conditions; (2) social security, which contains employment (entrepreneurship) capacity, human resources level, and social security degree (social and medical insurances, social relief, and social welfare), to measure social welfare and social security conditions; (3) social management, which contains public security management, environment management, traffic management, government services, and city emergency capacity. They measure social operating conditions and order.

8.2.1 Evaluating Indicator System for Urban Social Carrying Capacity in the Beijing-Tianjin-Hebei Region

Considering the actual operability, because Beijing, Tianjin, and Hebei are on the same administrative level, the areas in these three cities and province are compared according to the comparability of appropriate indicators for administrative divisions (see Table 8.1).

8.2.2 Evaluation Methods

Weight determination: when the differences in the importance of indicators are not explicit, the weighting of indicators at the same level is averaged as far as possible to avoid the influence of human factors on the scores of indicators; for indicators

Table 8.1 Evaluating indicator system for social carrying capacity in the Beijing-Tianjin-Hebei region

	Level-II indicators	Level-III indicators	Beijing	Tianjin	Hebei	Standard value
Public services	Medical services and healthcare	Number of doctors every ten thousand persons	34.6	22.5	17.3	40
		Number of sickbeds every ten thousand persons	43.4	30.7	37.4	64
		Proportion of medical services and healthcare expenses in fiscal expenditures	4.9	5.0	8.56	12
	Culture and education	Quantity of books in libraries every ten thousand persons	25,012	10,000	2,401	26,000
		Proportion of educational expenses in fiscal expenditures	11.4	17.0	18.43	20
	Housing	Per capita urban house building area (m^2)	29.4	32.77	32.21	40
Social security	Employment capacity	Number of students in colleges and universities every hundred thousand persons	5,613	4,329	2,006	6,000
		Population physical constitution (life expectancy)	80.18	78.89	74.97	83
	Social security degree	Proportion of social security expenditure in fiscal expenditure (%)	7.8	9.4	12.05	15
		Urban minimum living security standard	500	480	325	600
Social management	Environmental management	Per capita park green area (m^2)	11.33	10.3	14.26	15
		Percentage of urban landscape coverage (%)	45.6	34.5	42.1	50
		Sewage treatment rate (%)	81.7	86.8	84	90
	Traffic control	Per capita urban road area (m^2)	5.26	17.05	17.48	20
		Public transit quantity every ten thousand persons	22.38	15.19	10.44	25
	Urban emergency capacity	Per capita area of emergency refuges (m^2)	0.7	0.32	0.44	1.0

Data sources: Beijing Statistical Yearbook 2012, Tianjin Statistical Yearbook 2012, Hebei Statistical Yearbook 2012, China Statistical Yearbook 2012 that can distinguish the differences of their importance, they are given different weightings according to its importance. In this indicator system, the weightings of public services, social security, and social management are 50 %, 30 %, and 20 % respectively.

The scores of indicators: all indicators are scored from the comparison of them with standard values. Standard values are determined in three ways, (1) internationally recognized standards as standard values; (2) internationally average standards as standard values; (3) theoretically ideal value of an indicator as a standard value. The score of each quantitative indicator is determined by the index method. For positive indicators, indicator index = actual value of an indicator ÷ standard value of the indicator; for negative indicator, indicator index = standard value of an indicator ÷ actual value of the indicator. Composite scoring method: indices of indicators are multiplied by respective weighting, and then finding the sum (Table 8.2).

8.2.3 Evaluation Results

See Tables 8.3, 8.4 and 8.5.

8.2.4 Conclusions

According to scoring results of integrated indices, the ranking of social carrying capacity in Beijing, Tianjin, and Hebei is in turn Beijing, Tianjin, and Hebei. In the contents of indicators, Beijing, Tianjin, and Hebei all have larger investment in social security, are good in terms of employment security, human resources, and social welfare, and three areas need further improvement in terms of public service level and social management efficiency. Beijing's indicators of the lowest index are mainly traffic management and housing security, which are lower than Tianjin and Hebei. Though the highest quantity of transit per ten thousand people in Beijing, Beijing has the highest population density, and the area per person (vehicle) of land used for the traffic is the lowest, thus traffic scores the lowest. Tianjin's indicator of relatively low score is medical service and healthcare. Hebei's indicators of the lowest score are cultural and educational facilities and employment potential.

Table 8.2 Weighting of evaluating indicator system for social carrying capacity

	Weighting	Level-II indicators	Weighting	Level-III indicators	Weighting
Public services	0.5	Medical services and healthcare	0.5	Number of doctors every ten thousand persons	0.4
				Number of sickbeds every ten thousand persons	0.3
				Proportion of medical services and healthcare expenses in fiscal expenditures	0.3
		Culture and education	0.4	Quantity of books in libraries every ten thousand persons	0.5
				Proportion of educational expenses in fiscal expenditure	0.5
		Housing	0.1	Per capita urban house building area (m^2)	1
Social security	0.3	Employment capacity	0.5	Number of students in colleges and universities every hundred thousand persons	0.5
				Population physical constitution (life expectancy)	0.5
		Social security degree	0.5	Proportion of social security expenditure in fiscal expenditure (%)	0.5
				Urban minimum living security standard	0.5
Social management	0.2	Environmental management	0.5	Per capita green area (m^2)	0.3
				Percentage of urban landscape coverage (%)	0.3
				Sewage treatment rate (%)	0.4
		Traffic control	0.4	Per capita urban road area (m^2)	0.5
				Public transit quantity every ten thousand persons	0.5
		Urban emergency capacity	0.1	Per capita area of emergency refuges (m^2)	1

Table 8.3 Indices of evaluating indicators for social carrying capacity in Beijing, Tianjin, and Hebei

	Level-II indicators	Level-III indicators	Beijing	Tianjin	Hebei
Public services	Medical services and healthcare	Number of doctors every ten thousand persons	0.865	0.5625	0.4325
		Number of sickbeds every ten thousand persons	0.67813	0.47969	0.58438
		Medical services and healthcare expenses in fiscal expenditure proportion	0.40833	0.41667	0.71333
	Culture and education	Quantity of library books every ten thousand persons	0.962	0.38462	0.09235
		Proportion of educational expenses in fiscal expenditure	0.57	0.85	0.9215
	Housing	Per capita urban house building area (m^2)	0.735	0.81925	0.80525
Social security	Employment capacity	Number of students in colleges and universities every hundred thousand persons	0.9355	0.7215	0.33433
		Population physical constitution (life expectancy)	0.96602	0.95048	0.90325
	Social security degree	Proportion of social security expenditure in fiscal expenditure (%)	0.52	0.62667	0.80333
		Urban minimum living security standard	0.83333	0.8	0.54167
Social management	Environmental management	Per capita green area (m^2)	0.75533	0.68667	0.95067
		Percentage of urban landscape coverage (%)	0.912	0.69	0.842
		Sewage treatment rate (%)	0.90778	0.96444	0.93333
	Traffic control 0.4	Per capita urban road area (m^2)	0.263	0.8525	0.874
		Public transit quantity every ten thousand persons	0.8952	0.6076	0.4176
	Urban emergency capacity	Per capita area of emergency refuges (m^2)	0.7	0.32	0.44

Table 8.4 Indices of Level-II indicators for social carrying capacity in Beijing, Tianjin, and Hebei

	Level-II indicators	Beijing	Tianjin	Hebei
Public services	Medical services and healthcare	0.671938	0.493906	0.562313
	Culture and education	0.766	0.617308	0.506923
	Housing	0.735	0.81925	0.80525
Social security	Employment capacity	0.950762	0.835991	0.61879
	Social security degree	0.676667	0.713333	0.6725
Social management	Environmental management	0.863311	0.798778	0.911133
	Traffic control	0.5791	0.73005	0.6458
	Urban emergency capacity	0.7	0.32	0.44

Table 8.5 Indices of Level-I indicators for social carrying capacity in Beijing, Tianjin, and Hebei

	Beijing	Tianjin	Hebei
Public services	0.715869	0.575801	0.56445
Social security	0.813715	0.774662	0.645645
Social management	0.733296	0.723409	0.757887
Integrated indices	0.748708	0.664981	0.627496

8.3 Present Situation of Social Carrying Capacity in Beijing, Tianjin, and Hebei and Analysis of Issues

8.3.1 Outstanding Results of Education Development, and Significant Improvement in Quality of Population

In comparison with the fifth national census data in 2000, in Beijing's resident population in 2011, in total, 16,839 people with higher education level per every 100,000 people rose to 31,499 people; 23,165 people with high-school education level declined to 21,220 people; 34,380 people with junior-high-school education level declined to 31,396 people; 16,963 people with primary-school education level declined to 9,956 people. At the end of 2010, Beijing public libraries had books of 46.13 million volumes, which increased 1.45 million volumes over that in 2009; the income from movie ticket sales reached RMB 1.181 billion, and access rate of wired radio and TV reached 91.68 %, in which people's material and cultural living standards had significant improvement.

Tianjin further increases investment in education in the city's general budget expenditures in 2010, education expenditure increased 25.4 %, which increased 33 % over that of the previous year. Cultural quality of the population has further improved. According to the results of the sixth national census data, there were 17,480 people with college education level and above per 100,000 people in Tianjin, which increased 8,473 people over that of the results of the fifth census; per capita schooling reached 10.45 years, which increased 1.5 years; in which average schooling of immigration resident population was 9.71 years, which increased 1.02 years.

Hebei's education is in healthy development. In 2010 there were 106 general colleges and universities in the whole province, in which there were 48 undergraduate colleges (including 18 independent colleges) and 58 colleges (including 52 vocational and technical colleges). In comparison with the ones in 2005, the number of schools increased by 24, and the number of students recruited increased by 87,400 people, which increased by 36 %. Students increased by 323,200 people, which increased by 43 %.

8.3.2 Further Optimized Health Resources, Continually Improved Health Level

Beijing has formed a multi-level medical insurance. As of 2011, Beijing's number of insured with basic medical insurance reached 11.88 million people, and basic medical insurance fund expenditures were 37.45 billion RMB. Basic endowment insurance for urban employees combined with employees' supplementary medical insurance, coupled with the new rural cooperative medical system and medical insurance for migrants have jointly constituted the medical security system in Beijing.

Tianjin actively promotes the equalization of basic public health services, and has formed a medical insurance system covering all urban and rural residents. In the city, has 3.49 sickbeds per 1,000 people, and 2.25 practicing (assistant) physicians, which are higher than the national average of 3.28 sickbeds and 1.8 physicians, and the capacity of public health services is growing. In 2010, Tianjin pushed the reform of the medical and health system, and strengthened the construction of public hospitals to ensure fairness in basic health services; it improved the basic medical and health service system to give accessible medical care. It raised the treatment of medical insurance for urban employees, average life expectancy of the population reached 80.27 years, and residents' main health indicators remained at the forefront in the whole country.

Urban and rural medical assistance work has deepened in Hebei. By the end of 2011, medical assistance funds of 106 million RMB were appropriated to the rural area, and 36.55 million RMB were appropriated to the urban area. Urban medical assistance outpatient departments and hospitalization rescued 745,000 people in the whole province, and spent 109 million RMB in funds; rural medicaid outpatient departments and hospitalization rescued 1.76 million people, and spent 102 million RMB in funds, in addition, rural medical assistance also supported 1.712 million people to participate in the new rural cooperative medical system, and spent 36.36 million RMB in funds.

8.3.3 A More Consummate Social Security System, and Forming a Social Assistance System

Beijing has initially set up and continuously improved the social security system with characteristics of the capital. Beijing's endowment insurance system reform is steadily operating, its coverage is gradually expanding, insured number is rising, there is a steady increase in financing, and the level of endowment insurance continues to increase. By the end of 2011, Beijing's basic endowment insurance fund expenditures were 56.08 billion RMB and unemployment insurance expenditures reached 2.77 billion RMB. Employment injury insurance fund revenue and expenditure maintained a balance on the whole. Monthly minimum living security standard for urban residents continually increased.

Tianjin's level of social welfare and assistance is improving. Tianjin has a basic social security system for its population, and continues to improve the living security level of low-income groups, and enhance the degree of socialization of old-age services. Tianjin established an employment help system for groups difficult to gain employment. Medical insurance for people who draw unemployment compensation are brought under the basic medical insurance system for urban employees. The number of insured further increased. Tianjin has established the mechanism of enterprises' regular employee pay-rise, and constantly improves the minimum living security standard of urban residents, which promotes difficult groups to further share the fruits of reform and development.

Hebei's social security level has gone to a new level, construction of a social assistance system is constantly improved. By the end of 2010, the province's rural and urban minimum living security standards grew in pace with the national average. Concentrated support capacity for the rural five guarantees almost doubled that of the national average. Hebei has formed the initial basic framework of a new social assistance system which regards medical services and healthcare, education, housing, employment, legal services, and other special assistance as the auxiliary on the basis of the minimum living security standard and the support of the five guarantees, which is supplemented by preferential policies, social mutual aid, and charity donations, and which is adaptable to the level of economic and social development.

8.3.4 Serious Challenges and Main Issues of Social Carrying Capacity

Serious challenges: (1) Beijing and Tianjin, two mega-cities, are faced with enormous population pressure, and there are challenges to medical services, education, employment, housing, and public security. (2) Continuous and rapid population ageing will further increase the payment pressure of pensions and hospitalization costs. For example, the sixth census results of Tianjin in 2010 showed the aging population (age of 65 and above) was 8.52 %, which exceeded the standard of international division of the aging (aging population is 7 % of total population). (3) With rapid improvement in urbanization level, establishment and improvement of urban and rural social security systems are more urgent. (4) The diversification of forms of employment brings challenges. Unlike the traditional employment mode, future employment mode will be diverse, thus there will be more jobholders in the private economy and the flexible employed population will be covered by social security, therefore the traditional social security system is facing challenges.

Main issues: (1) Social vulnerable groups are not fully guaranteed. These vulnerable groups are primarily the low education and low-income population. For example, in Beijing, social income shows a "pyramid" structure with a larger middle-lower layer and a smaller middle layer, a even smaller number of the wealthy is at the top, and a large number of vulnerable groups form the base, in which governments have an important security task. (2) The endowment insurance fund cannot effectively "raise the income." (3) There is inequitable distribution in urban and rural medical resources, and vulnerable groups are unable to have required basic medical security. (4) Limited resources of minimum living security fail to bring maximum value. Assistance standards are average, and ignore the differences of every family in scale, structure, and demand, so that they cannot meet actual demands of "destitute families." (5) There is the gap between rural social security and the well-off society because the rural social security has small coverage and a low level of security.

8.4 Suggestions on Improving the Social Carrying Capacity in Beijing, Tianjin, and Hebei

8.4.1 Increasing Basic Security Strength for Vulnerable Groups

Differential assorted assistance modes should be explored and implemented. Suitable items and services of social security are provided for different vulnerable groups, including minimum living security, minimum education security, minimum medical security, and housing, the individual and family should be discriminatingly considered. For the individual, "long-term assistance" should be provided for people incapable of working, and short-term assistance for capable people to work. As for families, different assistances should be provided for different families according to size, structure, and actual demand degree of families to reflect the humanization of assistance. Multi-level social security system should be established. Different industries, occupations, and income groups have different demands of social security.

8.4.2 Consolidation and Improvement of the Multi-level Social Security System

The social security system, including social insurance, social assistance, social welfare, special care and placement, and social mutual aid, should be fully established. Three levels of medical insurance system including basic medical insurance, enterprise supplementary medical insurance, and market medical insurance, and social assistance should be improved. Temporary remedy, policy support, social mutual aid, family security, and other supporting measures should be improved. Some urgent issues such as endowment insurance, minimum living security, and economic compensation, which have major influence on economic and social development, should be emphatically solved. The social security fund needs to be extended in multiple channels, and new sources of financing should be opened up, such as corporate stock and increment of state-owned assets realized through capital markets, The social security fund holds shares of overseas state-owned listed companies with strong competitive power, and some shares of the incomes from interest tax, inheritance, and gift taxes should be exclusively used in the social security fund. Focusing on cultivating a large number of social "blood donors" (young groups, middle-income groups) is a fundamental policy to break the bottleneck of social security development.

8.4.3 Establishing Social Security System with Urban and Rural Integration

Urban–rural integration development is an inevitable trend of social progress. With the accelerated process of urbanization, new town farmers need more social security than urban employees, therefore urban and rural unified planning of social security system should achieved organic integration. A developed and undeveloped phenomenon coexists in the Beijing-Tianjin-Hebei region; some policies should be moderately inclined to underdeveloped areas to upgrade the level of regional social security as a whole. The region should fully use national preferential policies to further increase the strength of the general and earmarked transfer payment to poor areas, and to emphatically consummate the social security, education, public health, environmental protection, infrastructural construction, special-purpose loan discount interest, and so on. Especially underdeveloped areas around Beijing should actively strive for support of these preferential policies so as to increase the level of local social security.

8.4.4 Improving the Governments' Capacity of Public Administration and Social Services

(1) The region should create an excellent transformation "soft environment." The region should strengthen the building of the legal system, enhance the consistency and transparency of the administration according to law, standardize the market order, and form a unified open competitive and orderly market system; increase the strength of investment and expenditure in science and technology, education, health, culture, and other domains; increase handling capability of emergencies and major security incidents. (2) The region should persist in mostly relying on market mechanisms, and properly playing the role of government. The region should generally adopt the market principle, provide diversified public services, reduce direct intervention in the micro-level, strengthen policy leading to transformation of enterprise, fully play the role of market serving as the basic means of regulating the allocation of resources, and the entry, withdrawal, innovation, and structural readjustment of industries and enterprise restructuring should be mainly decided by the market; the governments should mainly make planning and policies, and create good environment for investment, entrepreneurship and development; governments should increase infrastructural construction, and establish the perfect infrastructure to equip complete infrastructure system for economic development. (3) Governments' capacity of social services should be improved. Governments should abandon the "GDP-only Government" tendency, strengthen the functions of social services, improve the people's livelihood, change the pattern that "places emphasis on management rather than services, emphasis on administrative control rather than public governance," and make great efforts to change into a service-oriented government for more economic development, more perfect democracy, more progressive science and technology, more harmonious society, and a richer living standard.

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Chapter 9
Studies on the Integrated Carrying Capacity of Beijing

Yanjun Li

In 2011 Beijing's regional gross domestic product (GDP) was 1,600.04 billion RMB and resident population was 20.186 million, the population density reached 1,230 persons/km^2, and the population density in the capital core area was as high as 23,271 persons/km^2, in which the population density in Xicheng District was as high as 24,540 persons/km^2, and more than 7,000 persons/km^2 in Chaoyang, Haidian, Shijingshan, and Fengtai Districts. Population growth and urbanization causes urban problems in Beijing, such as environmental pollution, cramped housing, traffic jam, and scarce resources, to be more conspicuous.

According to "Beijing City Overall Plan (2004–2020)," in 2010 urban population would reach 16 million, and 18 million in 2020. When drawing up the Plan, although it considered various factors affecting the concentration of the urban population and its uncertainty, in order to adapt to the rapid capital urban economic and social development, based on dynamic monitoring of the actual rate of development of the city to timely adjust urban infrastructural construction and urban space layout, urban infrastructure and other related indicators were tentatively reserved for 20 million people in planning. But in reality, Beijing surpassed by 10 years the objective that total resident population would be controlled at 18 million in 2020 as proposed in the Overall Plan, and resident population in 2011 exceeded 20 million; the objective that per capita GDP would breach 10,000 USD in 2020 proposed in the Overall Plan was met in 2009.

In the next few decades, with the goal of constructing Beijing as a global city and building up of the capital economic circle, Beijing will have new development opportunities. Beijing's rapid development and population expansion have further increased the pressure on the population, resources, and the environment, and there are serious challenges for integrated carrying capacity and sustainable development of the city.

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The key to achieving sustainable development is to seek a dynamic balance between the environmental protection and the sustainable use of resources. Therefore, studies and evaluation on the integrated carrying capacity of Beijing and understanding the present situation of the integrated carrying capacity of Beijing have important practical significance to Beijing's construction of the global city and capital economic circle.

9.1 Evaluating Indicator System for Integrated Carrying Capacity of Beijing and Model Building

9.1.1 Definition of Urban Integrated Carrying Capacity

Carrying capacity is an ancient concept derived from Greece, and has developed from the initial ecology field to urban field. Generally, carrying capacity is a concept that is closely related to resource endowment, technical means, social choice and values, and that has an ethical feature of relative connotation, and has a non-fixed, non-static, and non-singular relationship. In this paper, urban carrying capacity includes the carrying capacity on the element system and the urban integrated carrying capacity. Among them, the carrying capacity on the elements means the threshold, namely, if the threshold is exceeded, the environment will cause serious, even irreversible, damage, and the sustainable development of the city is affected, which show the short board of the elements of urban development. Urban integrated carrying capacity refers to the maximum load that the city can bear without any damage, namely the carrying capacity on urban resource endowment, eco-environment, and infrastructure to the urban population and economic and social activities.

9.1.2 Building of the Evaluating Indicator System

Urban integrated carrying capacity includes the carrying capacity on a city's resource endowment, ecological environment, and infrastructure of the population and economic and social activities of the city. Land, water resources, traffic, environment, and the population are urban main elements; they jointly form the urban complex system. Based on specific resources and social conditions of Beijing, and by considering operability and representativeness of the indicator choice, this paper builds two levels of the indicator system, in which there are 5 level-I indicators, namely the land carrying capacity, the carrying capacity on ecological environment, the carrying capacity on water resources, the infrastructural carrying capacity and the social carrying capacity. Thirty-five level-II indicators were established under the level-I indicators, such as "area of land used for urban building per ten thousand persons," finally we get the evaluating indicator system for integrated carrying capacity of Beijing (Table 9.1).

Table 9.1 Evaluating indicator system for integrated carrying capacity of Beijing and weighting

	Level-I indicator	Level-II indicators	Weighting
Integrated carrying capacity indicators system	Land carrying capacity (0.178)	Land output capacity (hundred million RMB/km^2)	0.028453
		Built-up area every ten thousand persons (km^2)	0.031201
		Area of land used for urban building every ten thousand persons (km^2)	0.029883
		Resident population density (person/km^2)	0.02873
		Grain yield per unit area (kg/ha)	0.024949
		Per capita arable area (Mu/person)	0.034844
	Carrying capacity on eco-environment (0.232)	Annual & daily means of inhalable particles (mg/m^3)	0.028946
		Annual & daily means of sulfur dioxide (mg/m^3)	0.030083
		Annual & daily means of nitrogen dioxide (mg/m^3)	0.029429
		Energy consumption of unit gross regional products (ton coal equivalent/ten thousand RMB)	0.028169
		Length of sewage conduit every ten thousand persons (km)	0.02885
		Sewage treatment rate	0.032782
		Per capita green area (m^3)	0.030047
		Percentage of built-up area landscape coverage (%)	0.024057
	Carrying capacity on water resources (0.157)	Per capita water resources (m^3)	0.024413
		Per capita annual water consumption (m^3/person)	0.029412
		Overall production capacity of water supply at end of the year (ten thousand m^3/day)	0.022728
		Length of feed piping every ten thousand persons (km)	0.02885
		Water consumption for ten thousand RMB GDP (m^3)	0.02903
		All-year water supply aggregate (hundred million m^3)	0.022889
	Infrastructural carrying capacity (0.208)	Per capita urban road area (m^2)	0.031022
		Transit operating capacity every ten thousand persons (vehicle)	0.025238
		Railway mileage every ten thousand persons (km)	0.02894
		Total investment cost for infrastructure every ten thousand persons (hundred million RMB)	0.032574

(continued)

Table 9.1 (continued)

	Level-I indicator	Level-II indicators	Weighting
		Quantity of private cars per hundred households	0.02815
		Per capita quantity of motor vehicles (vehicle)	0.030658
		Proportion of investment for infra-structure in total investment	0.031597
	Social carrying capacity (0.224)	Urban registered unemployment rate (%)	0.031542
		Per capita house building area (m^2)	0.030992
		Quantity of sickbeds every thousand persons (piece/person)	0.025241
		Resident population growth rate (%)	0.025152
		Ratio between all classes of students and full-time teachers (%)	0.029571
		Total population	0.029198
		Total population dependency ratio (%)	0.024393
		CPI	0.027987

9.1.3 Standardization of Evaluating Indicators

Because there are different dimensions and different units, the data needs to be standardized and dimensionless. Given plan set of in integrated evaluating indicators is $P = \{P1, P2, P3, \ldots, Pn\}$ (Pi is sample number); indicator set is $G = \{G1, G2, G3, \ldots, Gm\}$; attribute value of plan set *P* to indicator set *G* is *yij* (i = 1, 2, . . ., n; j = 1, 2, . . ., m); Y = (yij)n X m expresses "attribute matrix" namely "decision matrix" of plan set *P* to indicator set *G*. According to the character of the evaluating indicators, evaluating indicators are divided into "benefit" indicators and "cost" indicators. Benefit indicators refer to the attribute value and carrying capacity are indicators with positive correlation, and the better it is, the bigger its value is; cost indicators refer to the attribute value and carrying capacity are indicators with negative correlation, and the better it is, the smaller its value is. In the level-II indicators system, "resident population density, annual and daily means of inhalable particles, annual and daily means of sulfur dioxide, annual and daily means of nitrogen dioxide, unit GDP energy consumption, per capita annual water consumption, water consumption for ten thousand RMB GDP, quantity of private cars per hundred households, per capita quantity of motor vehicles, urban registered unemployment rate, ratio between all classes of students and full-time teachers, total population, total population dependency ratio, and CPI;" these 14 indicators are cost indicators.

Standardization method is as follows:

$$\text{Benefit indicators}: Z_{ij}=\left(y_{ij}\text{-}y_{jmin}\right)/\left(y_{jmax}\text{-}y_{\text{jmin}}\right)\ (i=1,\ 2,\ \ldots,\ n;j=1,\ 2,\ \ldots,\ m), \tag{9.1}$$

$$\text{Cost indicators}: z_{ij}=\left(y_{jmax}\text{-}y_{ij}\right)/\left(y_{jmax}\text{-}y_{jmin}\right)\ (i=1,\ 2,\ \ldots,\ n;\ j=1,\ 2,\ \ldots,\ m). \tag{9.2}$$

In formulas (9.1) and (9.2), y_{jmax}, y_{jmin} are respectively the maximum and minimum values of Gj indicator, the decision matrix is $Z = \left(Z_{ij}\right)\ n\ X\ m$ after standardization, so that the data of decision matrix can be directly processed. It is clear that the bigger Z_{ij} is, the stronger its carrying capacity is.

9.1.4 Weighting for Integrated Evaluation

The key of integrated indicator evaluation analysis is determining the weightings of indicators. This paper determines the weightings of indicators by the high precision mean-square deviation objective assignment method. The method regards each single evaluating indicator as a random variable, dimensionless attribute value of each plan Pi under indicator Gj is regarded as the value of the random variable. Firstly, we find out the mean-square deviations of these random variables, then normalize these mean-square deviations, which the results are weighting coefficients of various indicators. Calculation steps are:

$$\text{1. Average value of each random variable}: \frac{\sum_{i=1}^{m} R_i}{mn} \tag{9.3}$$

$$\text{2. Mean-square deviation of } Gj: \ \delta\left(G_j\right) = \sqrt{\sum_{i=1}^{n} \left(Z_{ij} - E\left(G_j\right)\right)^2} \tag{9.4}$$

$$\text{3. Weighting of indicator } \mathrm{W}\left(G_j\right) = \delta\left(G_j\right)/\sum_{j=1}^{m} \delta\left(G_j\right) \tag{9.5}$$

Through the above calculation, weighting of the single indicator of integrated carrying capacity can be obtained. The weighting of level-I indicator is the sum of the weightings of level-II indicators, hereby weightings of level-I and II indicators can be obtained (Table 11.1).

9.1.5 Evaluation Models

Each level-II indicator reflects the development level of the urban carrying capacity from different sides, overall level must have an overall evaluation, therefore we find urban integrated carrying capacity indicators using the multi-objective linear weighting function, and express it by *Ri*; calculation step is as follows:

$$R_i(W) = \sum_{j=1}^{m} Z_{ij} W_j \tag{9.6}$$

From formula (9.6), we can find out Beijing's annual integrated carrying capacity index *Ri*. Clearly, the bigger the Ri scores, the bigger the urban carrying capacity to population, society, and economy. The short board in urban development can be determined through the score of the elements, the lowest score of the elements reflects the short board of urban development, and future urban development will be limited by such elements.

9.2 Evaluation Results of Beijing's Integrated Carrying Capacity

According to related data of the Beijing Statistical Yearbook (2003–2012) and the China City Statistical Yearbook (2003–2012), through calculation, Beijing's integrated carrying capacity in 2002–2011 is obtained (Table 9.2).

From the evaluation results, it can be seen that, index of integrated carrying capacity in 2002 was 0.3929, and it reached 0.5323 in 2011, which shows a clear upward trend during the decade (Fig. 9.1). Rise of the carrying capacity on the eco-environment is the most important influencing factor to drive the rise of the integrated carrying capacity, in which there was an increase in urban landscape rate, decrease in energy consumption and pollutant emission reduction, all improving the carrying capacity on eco-environment, which is a significant achievement made by Beijing in attaching importance to eco-environment after the successful Olympics bid. The carrying capacity on water resources has steadily increased due to changes in supply and demand of water resources.

Table 9.2 Indicators of Beijing's elements and integrated carrying capacity in 2002–2011

Time	Land carrying capacity	Carrying capacity on eco-environment	Carrying capacity on water resources	Infrastructural carrying capacity	Social carrying capacity	Integrated carrying capacity
2002	0.0998	0.0318	0.0095	0.0873	0.1646	0.3929
2003	0.0986	0.0660	0.0227	0.1064	0.1233	0.4170
2004	0.0945	0.0800	0.0430	0.1023	0.1503	0.4702
2005	0.0938	0.0779	0.0376	0.1126	0.1242	0.4461
2006	0.0908	0.1139	0.0772	0.1079	0.1247	0.5146
2007	0.0625	0.1564	0.0846	0.1063	0.1072	0.5170
2008	0.0677	0.1594	0.1025	0.1177	0.1101	0.5575
2009	0.0640	0.1974	0.0809	0.1155	0.1555	0.6132
2010	0.0273	0.1929	0.0847	0.0851	0.1087	0.4986
2011	0.0327	0.2000	0.0921	0.0754	0.1322	0.5323

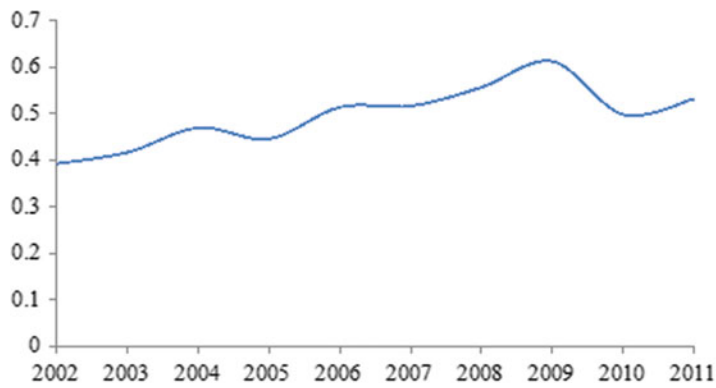

Fig. 9.1 Index of Beijing's integrated carrying capacity in 2002–2011

9.3 Analysis of Beijing's Carrying Capacities of Various Elements

9.3.1 Carrying Capacity on the Eco-environment Has the Maximum Effect on Beijing's Development

In the weighting coefficients of the level-I indicators determined according to mean-square deviation method, it is observed that, the weighting of carrying capacity on the eco-environment is 0.232, which means the carrying capacity on the eco-environment has the maximum effect on Beijing's development, the next is social carrying capacity (0.224), it also has a very important effect on Beijing's development, and then in turn infrastructural carrying capacity (0.208), and land carrying capacity (0.178), and carrying capacity on water resources (0.157) (See Fig. 9.2).

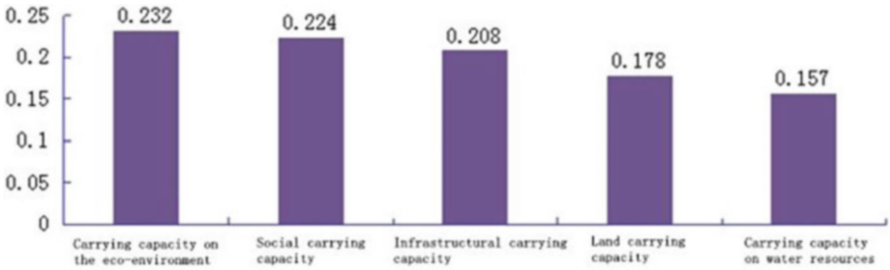

Fig. 9.2 Weighting coefficients of level-I indicators of Beijing's integrated carrying capacity

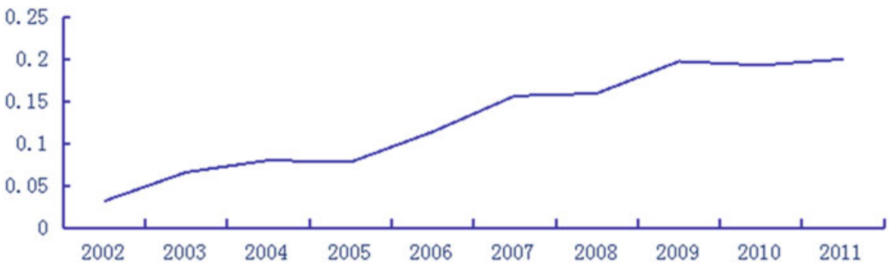

Fig. 9.3 Changes of carrying capacity on the eco-environment in Beijing

From 2002 to 2011, the carrying capacity on the eco-environment in Beijing showed a clear upward trend, carrying capacity on eco-environment in Beijing scored 0.032 in 2002, and 0.200 in 2012. The rise of the carrying capacity on the eco-environment is the most important influencing factor to drive the increase in integrated carrying capacity (Fig. 9.3).

As for single indicators, since 2002, annual and daily means of inhalable particles, annual and daily means of sulphur dioxide, annual and daily means of nitrogen dioxide, and energy consumption per unit gross regional product showed an obvious downward trend, and length of sewage piping per ten thousand persons, sewage treatment rate, and percentage of built-up area landscape coverage rose significantly. Decline in pollution and enhancement of governance capacity have improved the ecological environment, and eventually drive the increase in Beijing's carrying capacity on the eco-environment (Table 9.3).

9.3.2 Water Resources Constrain Beijing's Development and Are the Short Board

In the evaluation results, the carrying capacity on water resources in Beijing shows a clear upward trend. In 2002, the carrying capacity on water resources in Beijing was 0.009, and rose to 0.092 in 2011 (Fig. 9.4).

Table 9.3 Changes of indicators on Beijing's ecological environment (2002–2011)

	Annual and daily means of inhalable particles (mg/m^3)	Annual & daily means of sulfur dioxide (mg/m^3)	Annual & daily means of nitrogen dioxide (mg/m^3)	Energy consumption for unit gross regional products (equal value) (ton coal equivalent/ten thousand RMB)	Length of sewage conduit every ten thousand persons (km)	Sewage treatment rate (%)	Per capita green area (m^2)	Percentage of built-up area landscape coverage (%)
2002	0.141	0.061	0.072	1.03	1.868	45	10.1	30.94
2003	0.149	0.055	0.071	0.93	1.994	50.1	11.25	40.9
2004	0.142	0.05	0.066	0.85	1.948	53.9	10.49	40.21
2005	0.161	0.053	0.066	0.79	1.639	62.4	12	38
2006	0.148	0.047	0.066	0.73	2.149	73.8	10.68	44.4
2007	0.1222	0.036	0.049	0.64	2.668	76.2	8.57	36.17
2008	0.121	0.034	0.053	0.57	2.630	78.9	8.56	37.15
2009	0.121	0.032	0.057	0.54	2.561	80.29	12.11	47.69
2010	0.121	0.032	0.057	0.49	2.283	81	11.28	55.1
2011	0.114	0.028	0.055	0.43	2.361	81.7	11.33	45.6

Data sources: Beijing statistical yearbooks 2003–2012

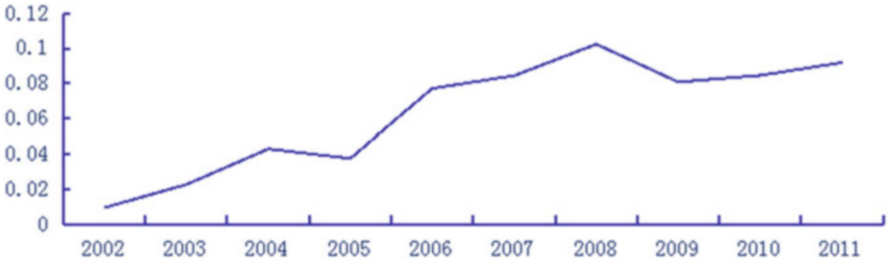

Fig. 9.4 Changes of carrying capacity on water resources in Beijing

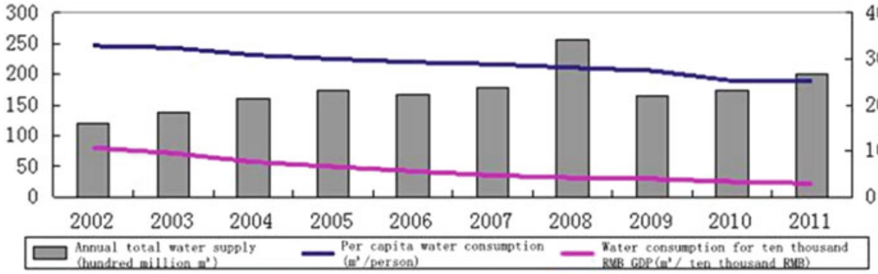

Fig. 9.5 Changes in Beijing's water supply and consumption (2002–2011)

Changes in supply and demand are the fundamental reason for the rise of carrying capacity on water resources in Beijing. Through analysis of indicators of the carrying capacity on water resources, it is observed that, on one hand, Beijing's water supply capability has significantly improved, and annual total water supply and overall water supply productivity at the end of the year have rapidly increased in the 10 years, which have resulted in a significant increase in per capita volume of water resources. On the other hand, water consumption is increasingly decreasing, in recent years, taking root of the concept of resource saving and green development and the transformation of economic development pattern in Beijing, per capita water consumption and water consumption for ten thousand RMB GDP have increasingly declined (Fig. 9.5). Precisely because of the increase of water supply capacity and decreasing demand, carrying capacity on water resources in Beijing is continuously rising.

Though the carrying capacity on water resources has increased, the pressure and constraint of water resources on the development of Beijing have not fundamentally abated. From the calculation results of the indicators of Beijing's elements and integrated carrying capacity in 2002–2011 (Table 9.2), it is observed that, in 2002–2006, the lowest score goes to carrying capacity on water resources in Beijing, which is constraining Beijing's development and is its short board.

In 2011, Beijing's annual total water resources were 2.68 billion m^3, and actual consumption in the same year was 3.6 billion m^3, in which there is a gap of 920 million m^3. The huge difference between actual water consumption and water resources, on one hand, needs to rely on the supply of excessive exploitation of

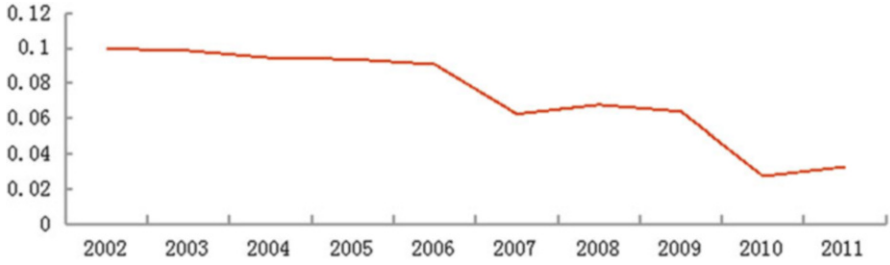

Fig. 9.6 Changes of carrying capacity on land resources in Beijing

surface water and overdraft of groundwater; average annual exploitation rate of water resources for many years reached 90 % as a whole, and was even more than 100 % in some years; this level is much higher than the 60 % stipulated by the United Nations of the ecological vulnerability level; on the other hand, it has to rely on the supply of extraneous water sources; in 2011, south–north water transfer project supplied Beijing water resources of 260 million m^3, which accounted for 10 % of annual total water resources of Beijing. Therefore, tight water resources will continue to constrain Beijing's development and be its short board for quite a while.

9.3.3 Lack of Land Resources Is Becoming a Key Constraint to Beijing's Development

Beijing's carrying capacity on land resources shows a downward trend. In 2002, the carrying capacity on land resources scored 0.100, and decreased to 0.033 in 2011. As of 2007, the score of the land carrying capacity was less than the carrying capacity on water resources; the scarcity of land resources will be the key limiting factor to economic development in Beijing (Fig. 9.6).

In recent years, Beijing's cultivated land area decreased year after year, and dropped from 275,000 ha in 2002 to 232,000 ha in 2008 (Data after 2008 are not counted), which reduced 43,000 ha in 6 years, and on average reduced 2.87 % each year; at the same time, the population rapidly increased, Beijing's resident population was 14.232 million at the end of 2002, and increased to 20.186 million by the end of 2011, which the average annual growth rate increased to 3.96 %. Sharp reduction of arable land area and rapid increase in the population jointly caused the actual population number to constantly be above the carrying capacity on land resources in Beijing in recent years.

Rapid increase of population also increased the per capita area of land used for urban building and population density so that the contradiction between supply and demand of land utilization further intensified (Fig. 9.7). Therefore, making great efforts to improve the efficiency of land use and to control the excessive growth of the population are the key to achieving healthy and sustainable development of resources in Beijing.

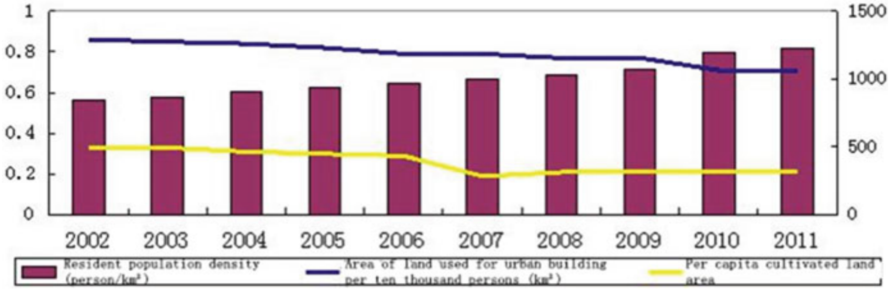

Fig. 9.7 Changes of per capita cultivated land, per capita land used for building and resident population density in Beijing

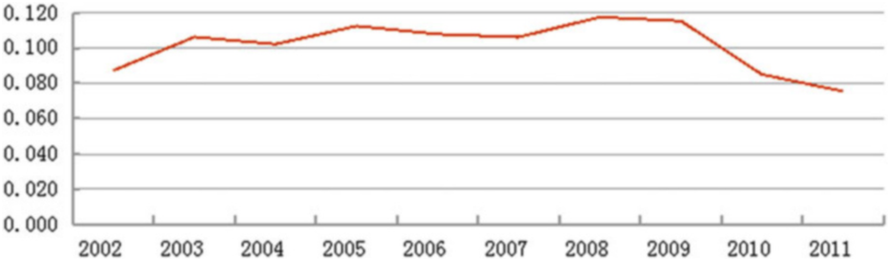

Fig. 9.8 Changes in infrastructural carrying capacity of Beijing

9.3.4 Infrastructural Carrying Capacity Shows Overall Downward Trend

Beijing's infrastructural carrying capacity shows an unceasing downward trend. In 2002 Beijing's infrastructural carrying capacity scored 0.087, increased to 0.118 in 2008, and then continually dropped, especially obviously dropping in 2010 and 2011, and scored only 0.075 in 2011. See Fig. 9.8.

As for indicators regarding the infrastructural carrying capacity of Beijing, on the eve of the Olympics, Beijing's investment in infrastructure and proportion of infrastructure in total investment largely rose, and transit operating capacity and railway transit mileage also quickly increased, which it should be said that the Olympic factor had a clear impact on infrastructural construction in Beijing. But due to rapid increase in private cars and motor vehicles in recent years, plus the rapid population growth, per capita urban road area is still rapidly dropping (Table 9.4).

In 2011, Beijing's per capita urban road area was 5.26 square meters, which was lower than Shanghai (18.44 m^2), Tianjin (14.89 m^2, 2010) and the national average of 13.2 m^2. In the post-Olympic period, as Beijing's investment in infrastructure slowed down, the pressure on Beijing's infrastructure is further intensified and Beijing's infrastructural development still cannot meet the demands of all classes.

Table 9.4 Changes of indicators for infrastructural carrying capacity in Beijing

	Per capita urban road area (m^2)	Transit operating capacity every ten thousand persons (vehicle)	Railway mileage every ten thousand persons (km)	Total infrastructure investment cost (hundred million RMB)	Quantity of private cars per hundred household	Per capita quantity of motor vehicles (vehicle)	Proportion of infrastructure investment in total investment
2002	8.10	11.02	0.0527	0.29	4.00	0.13	22.70
2003	9.60	13.73	0.0783	0.29	7.00	0.15	19.40
2004	9.45	14.54	0.0764	0.31	13.00	0.15	18.30
2005	10.55	13.86	0.0741	0.40	14.00	0.17	21.60
2006	7.40	12.96	0.0721	0.59	18.00	0.18	27.70
2007	5.60	12.57	0.087	0.72	20.00	0.19	29.60
2008	6.21	13.70	0.118	0.68	23.00	0.21	30.20
2009	6.15	13.52	0.1299	0.83	30.00	0.23	30.10
2010	5.57	12.24	0.1713	0.72	34.00	0.25	25.50
2011	5.26	12.13	0.1843	0.69	38.00	0.25	23.70

Data sources: China statistical yearbooks 2003–2012

9.3.5 *Beijing's Social Carrying Capacity Slightly Decreases in Balance*

Beijing has the best level of education and health care in the whole country, the level of basic education ranks the top, per capita education is the highest level in the whole country, and the quantity of hospital sickbeds per thousand persons and the number of doctors and health personnel per thousand persons rank first place in the whole country (Table 9.5).

In recent years, under the guidance of the scientific concept of development, Beijing has paid more attention to people's livelihood, emphatically solved a series of major issues affecting the quality of life in Beijing; registered urban unemployment rate remained at a relatively low level, and per capita housing area continually increased (Fig. 9.9), in which residents' quality of life is continually improving.

But, in recent years, Beijing's population has maintained sustained rapid growth. Due to the rapid population growth in Beijing, from 2002 to 2011, resident population grew 5.954 million in Beijing, and the growth speed reached 5.67 % in 2008 (Fig. 9.10).

Due to the continuous rapid growth in the population, Beijing's social carrying capacity has not significantly improved, but has slowly declined. In 2002, Beijing's social carrying capacity scored 0.165, and dropped to 0.132 in 2011 (See Fig. 9.11).

Table 9.5 Levels of health and service in the whole country and in four municipalities directly under the central authority

	The whole country	Beijing	Tianjin	Shanghai	Chongqing
Quantity of sickbeds in hospitals and health centers per thousand persons (piece)	3.5	6.84	4.46	6.17	3.22
Number of doctors per thousand persons (person)	1.82	5.45	2.98	3.79	1.49
Number of health personnel per thousand persons (person)	4.58	14.2	7.33	9.92	3.61

Data source: China statistical yearbook 2012

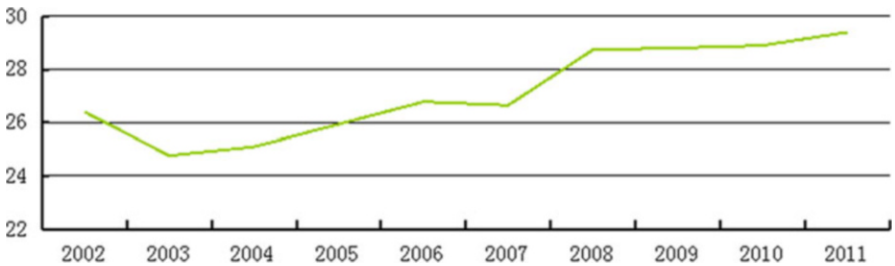

Fig. 9.9 Changes of Beijing's per capita house building area in 2002–2011 (m^2)

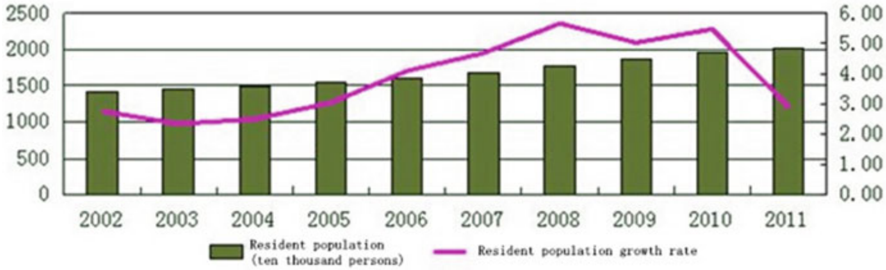

Fig. 9.10 Changes in resident population in Beijing (2002–2011)

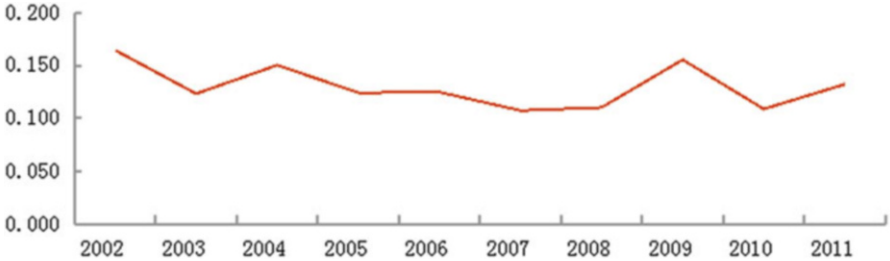

Fig. 9.11 Changes of Beijing's social carrying capacity

The report to the Eighteenth CCP National People's Congress clearly pointed out the need to achieve a comprehensive grand goal of building up a prosperous society by 2020. Under the guidance of this objective, Beijing will also further accelerate the pace of comprehensive construction of a prosperous society in the coming years. Construction of a prosperous society will further raise the level of Beijing residents' income, improve the basic democratic system, protect urban vulnerable groups, narrow the gap in income distribution, improve the living environment, enhance citizens' civilization accomplishment and social civilization degree, strengthen social harmony and stability, and improve residents' quality of life, so as to ultimately improve the social carrying capacity.

9.4 Strategies on Improving Integrated Carrying Capacity of Beijing

9.4.1 Playing the Overall Advantage, Optimizing Structure of Integrated Carrying Capacity

Land, ecological environment, water resources, infrastructure, and social carrying capacity are important components of the urban integrated carrying capacity. Each component has a crucial effect on the integrated carrying capacity, and when one of the elements become the short board, it is difficult to have an overall advantage. Therefore, in terms of improving the integrated carrying capacity, Beijing needs to consider not only the break-through of a single short-board element, but also needs structural optimization in the other elements to improve overall carrying capacity; Beijing also needs to improve land use efficiency through activating land inventory, simultaneously deeply tap into the latent power, and actively utilize unused land; expands traffic infrastructure investment, optimizes road net structure, and improve share rate of highway traffic and railway traffic to mitigate traffic pressure; optimize ecological carrying capacity through control of dirty pollutants, improve pollution treatment capacity and increase urban green area, and improve social carrying capacity through improving residents' life quality, thus enhancing Beijing's integrated carrying capacity.

9.4.2 Breaking Through the Bottleneck of Water Resources by Improving the Contradiction Between Supply and Demand

Water resource is an important short-board factor that restricts the development of Beijing. In 2011, the gap between supply and demand of water resources was 920 million m^3, which accounted for 34.3 % of annual total water supply. For Beijing, paying equal attention to tapping new resources and reducing expenditure, reducing demand of water resources by enhancing water supply capacity, and regulating supply–demand balance of water resources are the fundamental way to break through the bottleneck of water resources.

By analyzing the present demand of water resources, it is observed that there is potential in urban water-saving. Beijing's present proportion of water utilization in living, industry, agriculture, and the environment is respectively 30:14:43:13, if keeping the same structure, adjusting per capita urban domestic water and water consumption for ten thousand RMB GDP will create huge space to release water resources. A decrease of 1 % in per capita domestic water amount will save 16 million m^3 of water resources in Beijing. In recent years, the decrease rate of Beijing's water consumption for ten thousand RMB GDP was at about 10 %, if this downtrend is maintained, at least 360 million m^3 of water resources can be saved each year.

By analyzing the water supply, it is observed that Beijing's water resources supply is single, and has high dependence on groundwater; water pollution has intensified the scarcity of water resources, such as pollution of Miyun and Huairou reservoirs. Thereby according to the principles of high-quality water used in a proper manner, cyclic utilization and repeated use, the city may achieve joint and optimal deployment of all types of water sources. Specific measures include: (1) developing clean production and a cyclic economy, reducing pollution, promoting cyclic utilization of water resources; (2) keeping the existing tube network leakage rate level to avoid reduction; (3) increasing storage and use of rainwater using modern technical means; (4) saving water, unceasingly reducing water consumption for ten thousand RMB production value; (5) unceasingly recycling wastewater using existing technology to reuse wastewater; (6) scientifically determining minable range and minable volume of groundwater; (7) reasonably using water resources from the south–north water transfer.

9.4.3 Improving Efficiency of Stock Land Use, Regulating Regional Land Use Structure

Beijing should activate the stock of land used for construction, deeply tap into its latent power, and actively use unused lands to upgrade total elements of land carrying capacity; should also insists on the principle of industrial agglomeration, layout concentration and intensive land use, reasonably and frugally using the lands; optimize urban spatial layout; tap into the latent power of land used for the old city, enhance the vitality and attraction of the old city relying on the old town location, society, and other factors, and enhance the carrying capacity on land in the old city; advocate reutilization of non-cultivated land resources and urban wasteland to carry on industrial and urban construction, and establish the mechanism for reward and punishment to ensure reasonable and effective development; speed up the ecological construction for unused land that is unsuited for urban construction to actively develop resource cultivation; actively develop and utilize urban underground space resources, and explore the forms of scientific and rational utilization of underground space to fully explore ways to utilize urban land.

9.4.4 Expanding Investment in Traffic Infrastructure, and Optimizing Road Network Structure to Improve Carrying Capacity on Traffic Infrastructure

Beijing should continue to expand the scale of investment in traffic infrastructure, and construct underground parking lots and special-purpose multi-story parking buildings to enhance per capita area of roads; control the growth in the number of cars through economic levers such as restrictions on vehicle license, and jointly upgrade the carrying capacity from both demand and supply.

For the present situation of population expansion and increase in number of trips, increase in quantity of motor vehicles, low transit share rate, slow growth of road length and area, severe lack of parking facilities, and heavy pressure on urban traffic, Beijing should take strong policies on traffic demand management (TDM) to improve urban traffic carrying capacity, including:

1. Expanding the gross capacity of traffic systems, and increasing the strength of railway traffic construction. Before the 2008 Olympic Games, Beijing stepped up the strength of railway traffic construction, and Beijing's railway operating mileage reached 372 km in 2011. The rapid development of railway traffic has eased pressure in Beijing.
2. Optimizing traffic structure, implementing the transit strategy. Optimizing traffic structure is a common policy to relieve traffic jams in big cities of the world, whether in Paris, Tokyo, New York, or London, more than 60 % of the people take public transportation for their trips, and 87 % in Tokyo. In Beijing, 44 % took public transportation in 2012. Therefore, in encouraging people to take public transportation, Beijing still has lots of room for improvement. Average transit cost will fall as passenger capacity increases, and government's subsidies for it can improve the quality of transit services so as to enhance passenger capacity of transit, thereby reduce average costs so as to finally reduce the subsidies required which form a beneficial cycle. Beijing should increase financial subsidies, carry out transit priority, and simultaneously improve the quality of transit services.
3. Limiting and guiding use of cars with economic lever. In Beijing, the quantity of cars grows at a speed of more than 20 %, and there is high utilization rate; Beijing should manage vehicle possession demand and usage demand. Increase of car demand in Beijing, Shanghai, and other big cities is a starting point for increase of nationwide car demand, and driving the growth of car demand is significant for development of China's automobile industry, therefore in this regard, car demand in Beijing cannot be limited. From another point of view, compared with other big cities of the world, the absolute and relative quantity of cars in Beijing is not greater, but the rate is larger. Therefore, Beijing should carry out management of car usage demand.

9.4.5 Moderately Controlling Excessive Growth of Population, Guaranteeing the City's Orderly Development

Attention in urban integrated carrying capacity is ultimately caused by excessive growth of the urban population, and population growth in Beijing is mainly from outside population growth. Due to its special geographical conditions and development advantages, Beijing has been one of the highest concentrated areas of population for a long time, so that Beijing faces huge pressure on resources, environment, and traffic. To raise the urban integrated carrying capacity, Beijing needs to moderate the population size.

First, through administrative measures to control the excessive growth of population. First of all, when drafting Beijing's urban system development planning, Beijing should limit the area of growth and encourage the development of regional growth; to limit the area of growth, Beijing should set urban growth boundaries, and strictly limit any construction and development with city characteristics outside the urban growth boundaries. Urban planning management departments should strictly enforce the planning to faithfully enhance planning implementation strength. After confirming the growth boundary, there should be no longer any new construction outside the boundary. Without public infrastructure, it is impossible for new living areas and new enterprises to exist, thereby expansion can be controlled.

Secondly, through industrial restructuring to control the population growth. Beijing has begun to show characteristics of industrial structure based on modern services, which also coincides with the nature and functions of Beijing. In 2011, the proportion of the service industry was 74 % of the gross employment proportion in Beijing, and the development of services has decided the pattern of employment expansion and even population growth in Beijing. As the information technology equipment enhances the level of service equipment, labor-intensive characteristics of the service industry has continually weakened, and labor productivity of the modern service industry is often higher than the manufacturing. In the relationship between single employment growth and overall employment expansion, it is observed that Beijing's employment structure based on the third industry is in favor of controlling expansion of employment in the whole city, thus in favor of controlling population growth. However, in comparison with other cities, Beijing's services also have their shortcomings, and overall efficiency is not high, therefore there is still a lot of room for improvement. Beijing should diffuse the population through diffusion of industries, simultaneously improving the quality of industrial development through enhancing industrial efficiency, in particular efficiency of service industry, reduce development of industries for employment demand, thereby reducing the employment population growth.

9.4.6 Enhancing the Efficiency of Environmental Governance, Improving Urban Living Environment and Upgrading the Carrying Capacity on the Eco-environment

Beijing should accelerate the construction of urban sewage and garbage treatment facilities, strengthen urban afforestation, and improve the urban environment; actively promote the concession system of urban environmental infrastructure, improve the investment mechanism for environmental facilities, and enhance the operational efficiency of environmental infrastructure. Total emissions of chemical oxygen demand in urban domestic sewage and industrial waste water needs to reduce by 10 %. Beijing needs to strengthen the construction of urban sewage treatment facilities, and comprehensively levy sewage treatment fees, and increase the urban sewage treatment rate.

Simultaneously Beijing needs to strengthen citizen's sense of crisis regarding resources, energy, and environment, to establish the scientific concept of development about resource finiteness, and to change the concept of development that the production supply is decided by demand. Through the implementation of an incentive reward system guide the city, enterprises, and residents' demand-oriented right resources to achieve sustainable development of the city.

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Chapter 10
Studies on Tianjin's Integrated Carrying Capacity

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With rapid urban population growth and rapid expansion of urban scale, the constraint of urban integrated carrying capacity on urban development has increasingly caused widespread concern in the academic circle and government departments. Study on urban integrated carrying capacity will help us to better solve bottleneck problems of that in the environment, resources, and facilities in fast urban development.

10.1 Evaluation of Tianjin's Integrated Carrying Capacity

10.1.1 Connotations of Integrated Carrying Capacity

The connotation of urban integrated carrying capacity is the carrying capacity of a city's eco-environment, resource endowment, public services, and infrastructure to economic and social activities and urban population when urban resources fully play their own functions in the space conditions. It mainly includes the carrying capacities on resources, environment, energy, infrastructure, and society. Urban integrated carrying capacity is a comprehensive concept with a "capacity" connotation, and is not a simple superposition of the carrying capacity on elements, but an organic combination of these carrying capacities. Coordination and mutual promotion of carrying capacities on elements jointly compose the integrated carrying capacity as a whole.

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10.1.2 Construction of the Integrated Carrying Capacity Indicator System

According to the connotations of urban integrated carrying capacity, urban integrated carrying capacity is decomposed into six elements, the carrying capacities on land, environment, energy, water resources, infrastructure, and society. Each sub-element includes a pressure indicator and supporting capacity indicator. Pressure indicator characterizes a city's pressure on demands. Due to limited element resources, the more the city demands of an element, the stronger the constraint of urban development is, the greater the pressure is, the less likely the carry capacity is to be improved. Supporting indicator characterizes the supply capacity of a city. The more the city supplies to an element, the greater the space for urban development is, the stronger the pressure-bearing ability is, the more likely the carry capacity is to be enhanced. Each pressure indicator and supporting capacity indicator contains relevant indicators. Accordingly, the urban integrated carrying capacity indicator system is constructed, and the indicator system is divided into 6 main classes and 44 important indicators (See Table 10.1).

10.1.3 Overall Evaluation of Tianjin's Integrated Carrying Capacity

1. Index model of integrated carrying capacity

According to the indicator system for integrated carrying capacity, the integrated carrying capacity model is established.

$$\mathrm{F} = \mathrm{A}_{\mathrm{Pressure}} / \mathrm{A}_{\mathrm{Supporting}}$$

Among them, F is the score of the integrated carrying capacity, A_{Pressure} is the pressure index of the carrying capacity, $A_{\mathrm{Supporting}}$ is the supporting capacity index of the carrying capacity.

$$\mathrm{A}_{\mathrm{Pressure}} = \sum\nolimits_{i=1}^{n} \mathrm{W_i P_i} \quad \sum\nolimits_{i=1}^{n} \mathrm{W_i P_i}\,(\mathrm{i} = 1,\ 2,\ \cdots \mathrm{n}),\ \mathrm{A}_{\mathrm{Supporting}} = \sum\nolimits_{j=1}^{n} \mathrm{W_j P_j} \sum\nolimits_{j=1}^{n} \mathrm{W_j P_j}\,(\mathrm{j} = 1,\ 2,\ \cdots \mathrm{n})$$

W_i and W_j are respectively the weightings of indicators i & j, P_i and P_j are respectively the standardization values of indicators i & j. The bigger the values of W_i and W_j are, the bigger the index weighting is, the more the contribution of this factor to evaluation system for carrying capacity is.

Table 10.1 Indicator system for urban integrated carrying capacity

Target layer	Guideline layer		Indicator layer
Urban integrated carrying capacity A	Land carrying capacity B1	Pressure indicators	Per capita land used for building (m^2)C1
			Land output capacity (hundred million RMB/km^2)C2
		Supporting capacity indicators	Per capita cultivated land area (m^2)C3
			Per capita built-up area (m^2)C4
	Environmental carrying capacity B2	Pressure indicators	Quantity of industrial sewage effluent for unit industrial output value (ton/hundred million RMB)C1
			Wastewater effluent aggregate (ten thousand tons)C2
			Wastewater COD discharge aggregate (ten thousand tons)C3
			Industrial solid waste output (ten thousand tons)C4
			SO2 discharge amount in exhaust gas (ten thousand tons)C5
			Industrial smoke & dust discharge amount in exhaust gas (ton)C6
		Supporting capacity indicators	Proportion of number of good days of urban area at level-II air quality above (%)C7
			Percentage of urban landscape coverage (%)C8
			Nature reserve area (ten thousand ha)C9
			Proportion of industrial pollution abatement investment in GDP (%)C10
			Product value of three wastes comprehensive utilization (ten thousand RMB) C11
	Carrying capacity on water resources B3	Pressure indicators	Total water consumption (ten thousand m^3)C1
			Per capita comprehensive water consumption (kg)C2
		Supporting capacity indicators	Per capita water resources (m^3)C3
			Urban water supply aggregate (ten thousand tons)C4
			Overall production capacity of urban water supply (ten thousand tons/day)C5
	Energy carrying capacity B4	Pressure indicators	Annual current drain (hundred million kwh)C1
			Unit GDP energy consumption (ton coal equivalent/ten thousand RMB)C2
		Supporting capacity indicators	Electricity productive capacity (hundred million kwh)C3
			Energy production aggregate (ten thousand tons coal equivalent)C4

(continued)

Table 10.1 (continued)

Target layer	Guideline layer		Indicator layer
	Infrastructural carrying capacity B5	Pressure indicators	Quantity of private cars (vehicle)C1
			Annual gross passenger capacity (ten thousand persons)C2
			Annual gross freight amount (ten thousand tons)C3
			Quantity of transit vehicles every ten thousand persons (vehicle)C4
			Per capita road area (sq. m)C5
		Supporting capacity indicators	Per urban person investment in infrastructure (ten thousand RMB)C6
			Quantity of mobile telephones per hundred urban households (piece)C7
			Long-distance lightguide cable link length (km)C8
			Drainpipe density (km/km^2)C9
	Social carrying capacity B6	Pressure indicators	Population natural growth rate (‰)C1
			Social dependency ratio of population (%)C2
			Average number of students shouldered every teacher in colleges and universities (person)C3
			Number of specialized technical personnel per ten thousand persons (person)C4
		Supporting capacity indicators	Total labor resources (ten thousand persons)C5
			Quantity of universities and colleges C6
			Per capita investment in science and education (RMB/person)C7
			Quantity of hospital sickbeds every ten thousand persons (piece/thousand persons)C8
			Quantity of books in public libraries (ten thousand volume)C9
			Patent application amount (piece)C10
			Per capita input in public safety (RMB/person)C11

2. Descriptions to evaluation results

   (a) If $F < 1$, the urban integrated carrying capacity is in sound conditions, the smaller F is, the bigger the city development space is, and the stronger the pressure-bearing ability is;
   (b) If $F = 1$, the urban integrated carrying capacity is on the warning line, the integrated carrying capacity is fully loaded, there is no space for urban development;

(c) If $F > 1$, the urban integrated carrying capacity is in crisis, the integrated carrying capacity is overloaded, and the city's function development is limited.

3. Determining the weighting of indicator system

Urban integrated carrying capacity pressure and indicators of supporting capacity are weighed respectively using a analytic hierarchy process, and the following results are obtained (Tables 12.2 and 12.3), matrix meets $CI = 0.02 < 0.1$, and passing through the consistency check.

Results show that, the carrying capacities on land and environment have maximum contribution rates to the integrated carrying capacity index, the weightings are respectively 0.343 and 0.235; the carrying capacities on infrastructure and society have smaller contribution rates, and the weightings are respectively 0.081 and 0.051; the carrying capacities on water resources and energy are means, and the weightings are 0.167 and 0.123 respectively. Contributions of six elements to the urban carrying capacity are in turn the carrying capacities on land, environment, water resources, energy, infrastructure, and society (See Tables 10.2 and 10.3).

4. Overall Evaluation of Tianjin's Integrated Carrying Capacity

According to the above models and weightings of indicators, Tianjin's integrated carrying capacity in 2007–2011 scored 0.788, 0.838, 0.97, 1.05, and 1.04 respectively. Tianjin's integrated carrying capacity index in 2007–2011 showed an upward trend, which indicates that the integrated carrying capacity has become increasingly severe. The integrated carrying capacity index in 2007–2009 was lower than 1, a good condition, and the city also had some development space; the integrated carrying capacity in 2010 and 2011 was slightly more than 1, and reached the warning line; if there are further deterioration, it will not be able to bear the current population and economic activities.

10.2 Analysis of Tianjin's Carrying Capacities on Various Elements

10.2.1 Land Carrying Capacity

1. Changes in land carrying capacity

From 2007 to 2011, scores of land carrying capacity rose from 1.295 to 2.387, in which the land carrying capacity showed an unceasing downward trend. As economic and social development increasingly speeds up, urban population continually expands, per capita land used for building gradually reduces, and pressure value of land resources rises; meanwhile, urban construction continually seizes agricultural land so that per capita cultivated land area continuously decreases, which causes a reduction in supporting the capacity of land resources.

Table 10.2 Pressure indicator system for urban integrated carrying capacity

Target layer	Guideline layer	Weighting of guideline layer	Indicator layer	Weighting of indicator layer
Pressure indices of urban integrated carrying capacity $A_{Pressure}$	Land carrying capacity B1	0.343	Per capita land used for building (m^2)C1	0.114
			Land output capacity (hundred million RMB/km^2)C2	0.229
	Environmental carrying capacity B2	0.235	Quantity of industrial wastewater effluent for unit industrial output value (ton/hundred million RMB) C1	0.039
			Wastewater discharge aggregate (ten thousand tons)C2	0.039
			Wastewater COD discharge aggregate (ten thousand tons)C3	0.039
			Industrial solid waste output (ten thousand tons)C4	0.039
			SO2 discharge amount in exhaust gas (ten thousand tons)C5	0.039
			Industrial smoke & dust discharge amount in exhaust gas (ton)C6	0.039
	Carrying capacity on water resources B3	0.167	Total water consumption (ten thousand m^3)C1	0.111
			Per capita daily domestic consumption (kg)C2	0.056
	Energy carrying capacity B4	0.123	Annual current drain (hundred million kwh)C1	0.041
			Unit GDP energy consumption (ton coal equivalent/ten thousand RMB)C2	0.082
	Infrastructural carrying capacity B5	0.081	Quantity of private cars (vehicle)C1	0.041
			Annual gross passenger capacity (ten thousand persons)C2	0.020
			Annual gross freight amount (ten thousand tons)C3	0.020
	Social carrying capacity B6	0.051	Population natural growth rate (‰)C1	0.024
			Social dependency ratio of population (%)C2	0.015
			Number of students shouldered every teacher in colleges and universities average (person)C3	0.008
			Number of specialized technical personnel per ten thousand persons (person) C4	0.005

Table 10.3 Supporting capacity indicator system for urban integrated carrying capacity

Target layer	Guideline layer	Weighting of guideline layer	Indicator layer	Weighting of indicator layer
Supporting capacity indices of urban integrated carrying capacity of $A_{Supporting}$	Land carrying capacity B1	0.343	Per capita cultivated land area (m^2)C3	0.257
			Per capita built-up area (m^2)C4	0.086
	Environmental carrying capacity B2	0.235	Proportion of number of good days of urban area at level-II air quality above (%)C7	0.033
			Percentage of urban landscape coverage (%) C8	0.025
			Nature reserve area (ten thousand ha)C9	0.017
			Proportion of industrial pollution abatement investment in GDP (%) C10	0.091
			Product value of three wastes comprehensive utilization (ten thousand RMB)C11	0.069
	Carrying capacity on water resources B3	0.167	Per capita water resources (m^3)C3	0.084
			Urban water supply aggregate (ten thousand tons)C4	0.042
			Overall production capacity of urban water supply (ten thousand tons/day)C5	0.042
	Energy carrying capacity B4	0.123	Electricity productive capacity (hundred million kwh)C3	0.031
			Energy production aggregate (ten thousand tons coal equivalent)C4	0.092
	Infrastructural carrying capacity B5	0.081	Quantity of transit vehicles every ten thousand persons (vehicle)C4	0.009
			Per capita road area (m^2)C5	0.028
			Per urban person investment in infrastructure (RMB)C6	0.020

(continued)

Table 10.3 (continued)

Target layer	Guideline layer	Weighting of guideline layer	Indicator layer	Weighting of indicator layer
			Quantity of mobile telephones per hundred urban households (piece)C7	0.004
			Long-distance lightguide cable link length (km)C8	0.011
			Drainpipe density (km/km^2)C9	0.009
	Social carrying capacity B6	0.051	Total labor resources (ten thousand persons) C5	0.019
			Quantity of universities and colleges C6	0.003
			Per capita investment in science and education (RMB/person)C7	0.009
			Quantity of hospital sickbeds every ten thousand persons (piece/thousand persons)C8	0.005
			Quantity of books in public libraries (ten thousand volume)C9	0.003
			Patent application amount (piece)C110	0.005
			Per capita input in public safety (RMB/person) C12	0.006

2. Prospect of land carrying capacity

In accordance with the objective in the “Twelfth-Five-Year Plan,” it is calculated by per land GDP of land used for building in 2010 that during the “Twelfth-Five-Year Plan,” Tianjin needs to increase land used for construction by 42,061.5 ha. According to the target data in the “Twelfth-Five-Year Plan” for development and utilization of land resources in Tianjin, Tianjin will increase land used for construction by 35,000 ha. There remains a 7061.5 ha gap between both, which needs to be fill for improvement in land use efficiency. Tianjin’s cultivated land area and per capita cultivated land area will be further reduced during the “Twelfth-Five-Year Plan.” In existing unused land in Tianjin, wetlands, rivers, lakes, water, beaches, reed lands, and other lands for ecological functions account for 75.1 %, most of them are ecological land that needs protection, and exploitable reserved cultivated land resources are very little, therefore reserved cultivated land resources are severely deficient. At the same time, in comparison with advanced areas, there is a big gap in intensive level of land, thereby land use efficiency must be further enhanced.

10.2.2 Carrying Capacity on the Eco-environment

1. Changes of carrying capacity on the eco-environment

From 2007 to 2011, the scores of carrying capacity on eco-environment rose from 0.150 to 0.212, and then dropped to 0.207, in which the carrying capacity on eco-environment showed a downward trend as a whole, but got better from 2011. During the "Eleventh-Five-Year Plan," Tianjin regarded townscape environment comprehensive rectification, 3-year action plans for eco-city construction, pollution discharge reduction, special water environment governance, and special industrial pollution rectification as the breakthrough point to increase the strength of eco-environmental protection, in which urban eco-environment gradually has improved.

2. Prospect of carrying capacity on eco-environment

During the "Twelfth-Five-Year Plan," Tianjin will continue to comprehensively build an eco-livable city, and the carrying capacity on eco-environment is expected to gradually improve. Construction and protection of natural ecological environment and important ecological function areas will be fully enhanced, natural ecological deterioration trend will be contained, the quality of air, water and acoustic environment will continue to improve, and solid waste pollution will be fully controlled.

10.2.3 Carrying Capacity on Water Resources

1. Changes of carrying capacity on water resources

From 2007 to 2011, the scores of carrying capacity on water resources fell from 1.160 to 0.018, in which the carrying capacity on water resources showed an unceasing upward trend. As Tianjin's resource-saving society construction, enhancement of water-saving awareness and implementation of water-saving measures have had initial effect, per capita comprehensive water consumption and total water consumption continues to reduce.

2. Problems in Tianjin's carrying capacity on water resources

From 2007 to 2011, Tianjin's per capita water resources was only 115 m^3, thereby Tianjin is one of the provincial-level administrative areas with the scarcest amount of water resources in China, and is seriously lower than the standard of 500 m^3, which is the extreme water-shortage warning line which measures water shortage internationally, in which Tianjin belongs to such an area that desperately needs water transfer from other areas to settle the crisis of the regional water resource. Under average conditions for many years, Tianjin's present annual total water deficit is nearly 1.3 billion m^3, and water deficit is more than 2.4 billion m^3, with 95 % of the water being incoming water, which the water deficit rate is up to 63 %.

3. Prospect of carrying capacity on water resources

In accordance with the population control objective in the "Twelfth-Five-Year Plan," on the assumption that per capita demand of water resources is unchanged, it is calculated by average per capita water resources 115 cu. m in 2007–2011 that, Tianjin's water resources should reach at least 1.84 billion m^3 by 2015. In the case of keeping the average total water resources 1.389 billion m^3 in 2007–2011 as the base number and without any reduction, Tianjin will newly increase external water transfer of 816 million m^3 by 2015 in special water planning of the "Twelfth-Five-Year Plan" for reference, total water resources is likely to reach 2.2 billion m^3 by 2015, which can basically meet economic and social development demand in Tianjin, but severely low per capita water resources still restrict Tianjin's economic and social development.

10.2.4 Energy Carrying Capacity

1. Changes of energy carrying capacity

From 2007 to 2011, the scores of energy carrying capacity fell from 4.102 to 0.731, in which energy carrying capacity showed an upward trend. This mainly profited from vigorously promoting energy construction, improving safeguard capacity of energy supply, and optimizing the energy structure in Tianjin during the "Eleventh-Five-Year Plan." At the same time, Tianjin actively promoted energy conservation, where energy conservation and consumption reduction has had remarkable effect. The energy consumption growth rate has been lower than the economic growth speed, which has achieved low energy consumption to support faster economic growth.

2. Problems in energy carrying capacity

Tianjin's energy supply is strongly dependent, easily affected by external environmental changes of energy supply, and its overall risk resistance capacity is not sufficient. Oil supply mainly depends on the crude oil produced by China National Offshore Oil Corp. (CNOOC) and Dagang Oilfield, and the coal depends entirely on transfer from other provinces and cities, and the transfer amount of raw coal grew at a speed of around 10 % in recent years. Oil and coal are resources that are allocated by the state, and resource supply is not fully guaranteed. In electricity and natural gas supply, due to the relatively slow growth in construction investment, and investment is mainly used for renovation projects, new infrastructure projects are rare in that that the electricity supply gap grows; fuel gas supply is becoming increasingly tight, which has caused economic loss and social impact.

3. Prospect of energy carrying capacity

In accordance with the objective in the "Twelfth-Five-Year Plan," it is measured that, the city's total energy consumption will be equivalent to about 97.60 million tons of coal in 2015, and it is estimated by the growth trend of energy productive capacity in 2007–2011 that energy production will be equivalent to about 97.23 million tons of coal in 2015, in which the gap between consumption and supply is small, and the energy carrying capacity is basically in good condition. Tianjin's task to ensure energy security and aggregate balance is still large; coal is mainly transferred from Shanxi, Inner Mongolia, and Hebei; crude oil mainly depends on Bohai Sea and Dagang oilfields, and imports from the Middle East, Russia, and Africa.

10.2.5 Infrastructural Carrying Capacity

1. Changes of infrastructural carrying capacity

From 2007 to 2011, the scores of infrastructural carrying capacity first dropped from 0.150 to 0.111, and then rose to 0.129, in which the infrastructural carrying capacity showed an upward trend, but the carrying capacity weakened after 2011. Significant changes appeared in Tianjin's urban and rural landscape in recent years, important infrastructures were built up one after another, the status of sea airport hub continually rose, regional channel capability significantly enhanced, which formed a modern comprehensive transportation system, and the carrying capacity to economic and social development steadily improved.

2. Prospect of infrastructural carrying capacity

During the "Twelfth-Five-Year Plan," it is possible for Tianjin to further enhance infrastructural carrying capacity. In infrastructure pressures, the quantity of motor vehicles in the objective of the "Twelfth-Five-Year Plan" will grow to about 3 million, it is calculated according to the average annual increased amount of 240,000 motor vehicles in 2007–2011 which, based on 1.91 million vehicles in 2011, million vehicles will reach about 2.9 million in 2015, which is in line with the planning objective. In the infrastructural carrying capacity, it is estimated according to the average annual increased amount of 1.28 m^2 per capita area of roads in 2007–2011 that the value in 2015 will be 22.17 m^2; it is calculated by the objective of population control in the "Twelfth-Five-Year Plan" that road area of the city will reach 350 million m^2 in 2015; it is roughly estimated by general road width of 20 m that the highway traffic mileage will be about 17,500 km. In comparison with total highway traffic mileage 16,350 km in the “Twelfth-Five-Year Plan”, although there is a gap, there is not much effect on the infrastructural carrying capacity.

10.2.6 Social Carrying Capacity

1. Changes of social carrying capacity

From 2007 to 2011, the scores of social carrying capacity fell from 3.478 to 0.442, and then rose to 0.480, in which the social carrying capacity showed an upward trend overall. In the period of the “Eleventh-Five-Year Plan,” Tianjin made overall social progress; its comprehensive strength and quality of education had continuously improved, the level of investment in science and technology and innovation capacity significantly increased, health resource allocation was further optimized, the public cultural service system formed initially, and social civilization grew.

2. Prospect of social carrying capacity

In the period of the “Twelfth-Five-Year Plan,” there is still room for social development for Tianjin’s social carrying capacity, and the supporting capacity is still strong. Education capacity and quality will continue to improve, and the education indicators will get stronger in comparison with that at the end of the “Eleventh-Five-Year Plan.” In terms of the scientific and technological level, the level of investment in science and technology and talent strength will continue to enhance, and the proportion of R&D expenditures in gross regional product will rise to more than 3 % by 2015. Medical services and healthcare and cultural construction will significantly enhance, the quantity of sickbeds per mille persons in medical institutions will increase to 6.2 beds by 2015, and citizen’s civilization level and urban civilization degree will significantly improve.

10.3 Comparison of Advantages and Disadvantages of Integrated Carrying Capacities in Tianjin with Beijing and Hebei

10.3.1 Comparison of Integrated Carrying Capacity

Indices of integrated carrying capacities in Tianjin, Beijing, and Hebei in 2011 were $F_{Tianjin} = 1.04$, $F_{Beijing} = 1.38$, and $F_{Hebei} = 0.96$. Tianjin’s index of integrated carrying capacity was between Beijing and Hebei; Beijing’s index of integrated carrying capacity exceeded the warning line of 1, which was in crisis; Hebei had the best integrated carrying capacity, score was slightly lower than 1, thereby it still has limited space for development.

Table 10.4 Scores of carrying capacities of various elements in Beijing, Tianjin, and Hebei

Province and city	Environmental carrying capacity	Land carrying capacity	Infrastructural carrying capacity	Energy carrying capacity	Social carrying capacity
Tianjin	0.207	**2.387**	0.129	0.731	0.480
Beijing	0.674	**2.668**	**1.948**	0.668	0.502
Hebei	**1.559**	0.229	**1.547**	**1.330**	**2.214**

10.3.2 Comparison of Carrying Capacities of Various Elements

According to $B = B_{Pressure} / B_{Supporting}$, through calculation of the indices of carrying capacities of various elements, the three areas compared each other have different short boards. Tianjin's land carrying capacity is in crisis; Beijing's indices of carrying capacities on land and infrastructure are in crisis; Hebei's indices of carrying capacities on environment, infrastructure, energy, and society slightly exceeded the warning line (see Table 10.4).

1. Land carrying capacity

In this regard, Tianjin falls between Beijing and Hebei province, the space of development is restricted. Land carrying capacity indices of Tianjin and Beijing are more than 1, at 2.387 and 2.668 respectively. Tianjin is slightly better than Beijing, but both of them are in crisis; Hebei's land carrying capacity index is only 0.229, in which its land resources are richer than Beijing and Tianjin. A prominent contradiction between population and land resources is the problem of both Beijing and Tianjin, and the crisis of land carrying capacity directly causes the slight overload of integrated carrying capacity in Tianjin and Beijing. With fast urbanization and industrialization development, a great deal of population swarms into the two big cities so that the disharmony between population scale of rapid expansion and the cities' land, environment, and water resources has increasingly become pronounced, in which land is the core and most prominent problem, and continued growth of land used for construction has further increased the supply–demand contradiction of land use, especially the contradiction between basic farmland protection and cultivated land used for construction brought by land contention. Per capita cultivated land area is 306.9 m^2 in Tianjin, only 118.09 m^2 in Beijing, and 840 m^2 in Hebei, in which land area in Tianjin and Beijing is respectively only 36.5 % and 14.1 % that of Hebei.

2. Environmental carrying capacity

In this regard, Tianjin is superior to that of Beijing and Hebei, and has some development space. The indices of environmental carrying capacities in Tianjin, Beijing, and Hebei are 0.207, 0.674, and 1.559 respectively. The environmental carrying capacity of Tianjin and Beijing is below 1, so the carrying capacity is in good condition; Hebei's index is more than 1, so its carrying capacity is in crisis.

Since 2008, Tianjin drafted action plan for eco-city construction, and has impacted pollution reduction and environmental quality. Tianjin has relatively little environmental pressures. For example, in 2011 Tianjin had the least wastewater emissions. In gross wastewater chemical oxygen demand (COD) emissions, industrial solid waste output and SO2 emissions in the exhaust gas, the least was in Beijing, the most in Hebei, and Tianjin was in the middle. Tianjin has a relatively high supporting capacity. For example, the proportion of investment in industrial pollution treatment in GDP was the highest out of the three areas, at 0.13804 %, which was far higher than 0.00674 % in Beijing and 0.09928 % in Hebei.

3. Carrying capacity on water resources

In this regard, Beijing, Tianjin, and Hebei are in crisis. In 2011, per capita water resources of Tianjin, Beijing, and Hebei were respectively 116 m^3 per person, 134.7 m^3 per person, and 217.7 m^3 per person. The lowest was in Tianjin, but even Hebei only had one-tenth of the 2,100 m^3 national per capita water resources, and the volume of per capita water resources in China was only 28 % of the world's per capita level. The scarcity of water resources needs to be solved.

4. Energy carrying capacity

In this regard, Tianjin is in a relatively good state. In the energy carrying capacity out of the three areas, Tianjin has a comparative advantage, Tianjin's energy carrying capacity scores 0.731, which is higher than 0.668 of Beijing, and lower than 1.33 of Hebei. In 2011 energy consumption of GDP in Tianjin, Beijing, and Hebei was respectively 0.708, 0.43, and 1.3 tons coal equivalent/ten thousand RMB, in which Tianjin was slightly higher than Beijing, and far lower than Hebei, and was in a relatively good state.

5. Infrastructural carrying capacity

In this regard, Tianjin has obvious advantages, and the carrying capacity has enhanced. Indices of infrastructural carrying capacity in Tianjin, Beijing, and Hebei are respectively 0.129, 1.948, and 1.547, in which Tianjin has the absolute advantage in infrastructural carrying capacity. Since 2007, Tianjin has continually increased investment in infrastructure, and has constantly improved the urban carrier functions. In 2011, per capita investment in infrastructure reached RMB 14377.53 in Tianjin, which were 78.7 % higher than that of Beijing, and 46.3 % higher than that of Hebei. In terms of carrying capacity on traffic facilities, Tianjin's advantage is more obvious. In 2011, Tianjin's number of private cars was 1.9102 million, which was half that of Beijing and one-seventh that of Hebei. Tianjin's per capita area of roads increased from 11.94 m^2 in 2007 to 17.05 m^2 in 2011, which had an increase of 42.8 %. In Beijing, road area growth speed was comparative to the growth speed of motor vehicles, and per capita area of roads showed slight decrease rather than increase. The most per capita area of roads was in Hebei, but the highest number of private cars was also in Hebei, which had more relative pressure on traffic capacity. Quantity of transit vehicles per ten thousand persons was least in Hebei, at 10.44 vehicles, which was 11.94 vehicles lower than that of Beijing and 4.75 vehicles lower than that of Tianjin (See Table 10.5).

Table 10.5 Main indicators of infrastructural carrying capacities in Tianjin, Beijing, and Hebei in 2011

Province and city	Quantity of private cars (ten thousand vehicle)	Per capita road area (m^2)	Per capita investment in urban infrastructure (RMB)	Quantity of transit vehicles every ten thousand persons (vehicle)
Tianjin	191.02	17.05	14377.53	15.19
Beijing	473.2	5.26	8043.89	22.38
Hebei	1421.7	17.84	9825.928	10.44

Data sources: China Statistical Yearbook 2012, Statistical Yearbooks of Tianjin, Beijing and Hebei 2012

6. Social carrying capacity

In this regard, Tianjin is better than Beijing and Hebei. Indices of social carrying capacities in Tianjin, Beijing and Hebei are 0.480, 0.502, and 2.214 respectively. The pressure index of Tianjin's social carrying capacity is relatively low. For example, in 2011, Tianjin had the lowest natural population growth rate, which was 2.52 % lower than that of Beijing, and 4 % lower than that of Hebei; Tianjin's social population dependency ratio was in the middle, which was 1.62 % higher than that of Beijing, and 1.62 % lower than that of Hebei. Tianjin's city carrier functions in science, education, culture, and healthcare increased. For example, in 2011, Tianjin's per capita investments in science and education was only inferior to Beijing, and largely greater than that of Hebei, and Tianjin's per capita input in public safety and number of specialized technical personnel per ten thousand persons was the greatest out of these three areas.

10.4 Countermeasures on Improving Tianjin's Integrated Carrying Capacity

10.4.1 Adhering to the Main Theme Is the Inevitable Requirement for Improving Integrated Carrying Capacity

The "Twelfth-Five-Year Plan" proposed to regard scientific development as the main theme, and speeding up the transformation of economic development mode as the main thread. It is a realistic choice to adapt to the new situation and changes in order to solve the deeper contradictions of economy and society in China, and to achieve sustainable development. Improving integrated carrying capacity is to enhance the carrying capacities of resources, energy, environment, and infrastructure to economic and social activities, and is to increase urban development space and flexibility, thus the theme of scientific development and transformation must be practically implemented in all parts of the integrated carrying capacity. The degree of practical implementation of the theme results in the level of integrated carrying capacity. Effective changes should occur in traditional extensive development mode, which attaches importance to input and thinks little of efficiency in land, water, energy, and other resource fields, in order to enhance the intensive economical use of resources and energy and to scientifically develop according to the requirements for building a resource-saving society. The city should increase investment in environmental governance, infrastructure, and social undertakings, reduces environmental load, enhance supporting capacity of facilities and society, and build an environment-friendly society to achieve a economic and social harmonious development.

10.4.2 Playing the Role of Comprehensive Synergy Is an Important Guarantee for Improving the Integrated Carrying Capacity

The integrated carrying capacity is composed of the carrying capacity of land, environment, water resources, energy, infrastructure, and society. It is an entirety organic combination, and also a complex dynamic engineering system. Each carrying capacity has a significant effect on integrated carrying capacity. Improving the integrated carrying capacity focuses on "integrated," and on playing a comprehensive synergy role of various elements. When an element is defective, it difficult for their to be overall advantage, therefore, in terms of improving integrated carrying capacity, improving a single element should be considered, and overall capacity should also be improved through optimizing other system structures.

10.4.3 Strengthening Urban Planning Is the Important Means to Improve Integrated Carrying Capacity

To enhance integrated carrying capacity, there must be full control and a guided role in planning. Urban planning should be based on the level of economic and social development, location characteristics, resource endowment, and environmental characteristics, and reasonably set development objective according to the carrying capacity on resources and environment, formulate suitable measures for local conditions to guide the rational distribution and coordinated development, and plan development according to natural resources and environmental conditions.

10.4.4 Promoting Transformation and Upgrading of Industrial Structure Is the Fundamental Path for Improving Integrated Carrying Capacity

After the founding of new China in promoting catch-up of the economy, the strategy of giving priority to the development of heavy industry was carried out in China. After the reform and opening up for more than 30 years, China's industrialization entered the medium phase, which featured "paying attention to chemical industry;" the industry accounted for a large proportion, and the development of services lagged behind. In 2011, the proportion of the third industry in China was 43 %, which was lower than the average worldwide, and lower than the average in emerging economies. Tianjin continued to make adjustment in its industrial structure in recent years; the proportion of services has increased, the third industry accounted for 46.1 % in 2011, but the industry still occupied a major place in the economy. High input, high consumption, and high emissions caused by the industrial structure of the heavy industry has posed a serious challenge to urban carrying capacity. Improving integrated carrying capacity, speeding up transformation and upgrading of industrial structure from industry to service-oriented development is the fundamental path.

10.4.5 The Strategy of Actively Promoting Urbanization Is an Important Prerequisite for Improving Integrated Carrying Capacity

Adhering to the urbanization development strategy and controlling the population size are the important prerequisites for improving integrated carrying capacity. To avoid overcrowding of the city, Tianjin builds a modern urban system according to five levels: new city, central town, general town, central village, and basal village. In the period of the "Twelfth-Five-Year Plan," Tianjin will plan and build 11 new towns according to the standard of medium cities, and the population on average should reach more than 300,000 people. The population of central towns will on average reach more than 50,000 people, and these towns will build up rural regional economic and cultural center with complete functions, clean and tidy environment and some radiation capacity. The population of general towns will reach 20,000 people, they will be built into a modern, unique, eco-livable small towns. Town planning and layout of scientific and rational, hierarchical structure is propitious to disperse the population of downtown areas, in favor of comprehensive coordination of population, industry, infrastructure, resources, energy, environment, and other elements, so as to help improve integrated carrying capacity.

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Chapter 11
Studies on Hebei's Integrated Carrying Capacity

Gui Zhang and Shuqiang Wang

This paper assesses the development level of carrying capacity on resources and environment in Hebei according to Hebei's features of resource, environmental, economic, and technical development and the "Twelfth-Five-Year Plan," and analyzes the development trend, which provide empirical basis for the governments to formulate sustainable development policies.

11.1 Overall Evaluation of Hebei's Urban Integrated Carrying Capacity

11.1.1 Connotation of Integrated Carrying Capacity and Construction of Indicator System

Regional integrated carrying capacity refers to the maximum safeguard capacity of the regional ecological environment, resource endowments, public services, and infrastructure to their economic, social, and people activities under specific circumstances of technology, economy, society, and laws and regulations, when resources fully play their own functions.

This chapter separates regional integrated carrying capacity into seven big categories, including environmental carrying capacity, land carrying capacity, infrastructural carrying capacity, carrying capacity on water resources, carrying capacity on regional traffic facilities, carrying capacity on urban public traffic, energy carrying capacity and social carrying capacity, and there are in total 41 specific indicators for overall evaluation, and the specific names and categories indicators are as shown in Table 11.1.

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Table 11.1 Evaluating indicator system for integrated carrying capacities in Beijing, Tianjin, and Hebei

Target layer	Indicator layer	
Urban integrated carrying capacity	Environmental carrying capacity	Unit GDP wastewater effluent amount (ten thousand tons/hundred million RMB)
		Industrial smoke & dust discharge amount for unit industrial output value (normal m^3/RMB)
		Per capita domestic refuse discharge amount
		Proportion of number of good days of urban area at level-II air quality above (%)
		Percentage of domestic waste innocent treatment (%)
		Percentage of built-up area green area coverage (%)
		Proportion of environment treatment investment in GDP (%)
	Land carrying capacity	Per capita dwelling space (m^2)
		Land area required per hundred million RMB GDP (km^2/hundred million RMB)
		Proportion of unused land (%)
		Cultivated land area required for unit grain output (ha./ton)
		Per capita cultivated land area (m^2)
		Per capita land area (km^2/person)
		Per capita built-up area (m^2)
	Carrying capacity on water resources	Water consumption per Mu farmland
		Per capita water consumption
		water consumption per GDP
		Per capita water resources
	Carrying capacity on regional traffic facilities	Per capita annual trip times (times)
		Unit GDP annual gross freight amount (ton/ten thousand RMB)
		Per capita total railway mileage (km/ten thousand persons)
		Per capita total road mileage (km/ten thousand persons)
	Carrying capacity on urban public utilities	Quantity of private cars per hundred households
		Gross passenger capacity of transit (ten thousand persons-times)
		Quantity of transit vehicles every ten thousand persons (normal vehicle)
		Quantity of urban transit jobholders
		Per capita road area (m^2)
		Per capita road length (km/ten thousand persons)
		Average road area of each private car (m^2/vehicle)

(continued)

Table 11.1 (continued)

Target layer	Indicator layer	
		Average road length of each private car (km/ten thousand vehicles)
		Quantity of taxies
		Urban drainpipe length (km)
		Urban daily sewage processing capacity (ten thousand m^3)
	Energy carrying capacity	Proportion of self-generating capacity in current drain (%)
		Unit GDP energy consumption (ton coal equivalent/ten thousand RMB)
	Social carrying capacity	Proportion of 0–14-year-old population (%)
		Average teacher-student ratio in all levels of schools (%)
		Quantity of students every hundred thousand persons
		Per capita investment in teaching funds (RMB/person)
		Quantity of hospital sickbeds per mille persons (piece/thousand persons)
		Quantity of qualified doctors and nurses per thousand persons

Scores of integrated carrying capacities in Beijing, Tianjin, and Hebei in all years

11.1.2 *Quantitative Score of Hebei's Integrated Carrying Capacity*

Based on variability, openness, fluidity and unpredictability, and other natures of carrying capacity, this chapter evaluates the integrated carrying capacities of Beijing, Tianjin, and Hebei by rank-sum ratio (RSR) method. If the number of indicators in integrated evaluation system is m, the number of samples (area) is n, ranking samples (R) (in this chapter, optimal rank value is 3, next is 2 and then 1) in accordance with good and bad indicator values, then the sum is divided by the product of the number of indicators m and the number of samples n after finding the sum of the sample ranks, we get the rank-sum ratio, namely score of samples; the higher the score is, the stronger the carrying capacity is. In the average score of

Table 11.2 Total scores of integrated carrying capacities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.6750	0.7250	0.6667	0.6750	0.7000	0.6667	0.6500
Tianjin	0.7083	0.6667	0.7000	0.7000	0.6750	0.7000	0.7333
Hebei	0.6167	0.6083	0.6333	0.6250	0.6250	0.6333	0.6167
Average score of three areas	0.667						

samples, if score of a sample is higher than the average, its carrying capacity is acceptable. Rank-sum ratio formula is as follows:

$$\mathrm{RSR} = \frac{\sum_{i=1}^{m} R_i}{mn}$$

Rank-sum ratio method integrates parametric statistics and non-parametric statistics, and can raise the level of statistical analysis and re-analysis to eliminate the effect of errors in the statistical data to a certain extent are as shown in Table 11.2.

Table 11.2 shows that the scores of Hebei's integrated carrying capacities in 2005–2011 had an upward trend, the integrated carrying capacity gradually increased, but the scores were less than the average of Beijing, Tianjin, and Hebei areas in this period, in which supporting capacity of resources to economic and social development was always insufficient, and policy measures are urgently needed to improve the carrying capacity.

11.2 Basic Characteristics of Urban Integrated Carrying Capacity in Hebei

11.2.1 Basic Characteristics of Land Carrying Capacity in Hebei

The scores of Hebei's land carrying capacity are higher than the average in recent years (See Table 11.3), the land can basically meet demands of economic growth and social development, but in terms of land stock and increment, land carrying capacities of Hebei province had many differences.

1. Analysis of stock land

Land resource is in deficit in Hebei province. Hebei ranks 14th out of 31 -provincial-level administrative regions in terms of area under its jurisdiction. In 2011 per capita land area was 4 Mu, which was far lower than the national level of per capita land area, 10 Mu; per capita cultivated land area was 1.36 Mu, which was

Table 11.3 Scores of land carrying capacities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.667	0.571	0.619	0.619	0.619	0.619	0.619
Tianjin	0.571	0.667	0.667	0.667	0.667	0.667	0.667
Hebei	0.762	0.762	0.714	0.714	0.714	0.714	0.714
Average score of three areas	0.667						

Table 11.4 Land utilization in Hebei province in 2011 Unit: ten thousand hectares

	Land survey area	Agricultural land area	Area of land used for construction	Land used for residential areas and workshop and mining areas	Land used for traffic	Land used for water resource facilities	Undeveloped land
Area	1884.3	1308.2	179.4	154.5	12.0	12.9	396.7
Proportion (%)	100	69.43	9.52	86.10	6.71	7.19	21.05

Data source: China statistical yearbook 2012

lower than the per capita cultivated land area in 2005, 1.43 Mu, and lower than the national level of per capita cultivated land area, 1.38 Mu.

In Table 11.4, it can be seen that the proportion of land area used for agriculture is far more than land used for construction, which indicates low level of urbanization. Undeveloped land area is more than land used for construction, which indicates low land utilization. According to the data in 2005, in land used for residential areas and workshop and mining areas, land used for rural residential areas accounted for 72 %, land used for workshop and mining areas only accounted for 28 %, output value of the second and third industries per unit land used for construction in the whole province reached 500,000 RMB/ha, which was only slightly higher than the national annual average, and overall land intensity was lower (General Planning of Hebei Province on Land Use 2006).

2. Analysis of incremental land

Although Hebei province has lower amounts of available land stock, but as shown in Table 11.4, the proportion of undeveloped land is larger, and usage limit in this part of the land cannot be ignored. Only 162,500 ha of undeveloped land can be developed into cultivated land, and is mainly distribute in mountainous area, contiguity to the sea, and low plain areas of Heilong Harbor and Bashang area, land quality is poor, and it is very difficult to develop, therefore such incremental land is unlikely to be used as cultivated land (Liu Hong 2010).

Land reclamation is another guarantee for land supply; land reclamation rate is relatively low in Hebei province. From 1997 to 2005, supplementary land of 131,900 ha (1.9785 million Mu) was supplied as cultivated land through land-leveling operation and reclamation development in the whole province, which was only 1 % of total agricultural land area (General Planning of Hebei Province on Land Use 2006).

Hebei formulated the rural new residential construction plan in its provincial "Twelfth-Five-Year Plan," the implementation of the plan will largely increase land intensity, and will improve land security capacity.

3. Analysis of land demand

Hebei formulated the development objective that average annual growth rate of GDP in next 5 years would reach 8.5 % in the provincial "Twelfth-Five-Year Plan," which will form the demand for newly increased land, but this growth rate target is far lower than 11.7 % of that during the "Eleventh-Five-Year Plan," therefore the driving force for land demand especially for urban land demand is less than that during the "Eleventh-Five-Year Plan."

Growth and structural changes of population aggregate may also increase demand for land. In 2011, Hebei's natural population growth rate was 0.68 %, in which the rural growth rate was higher than the city so that there was more pressure on the demand for agricultural land.

With the increase in population and urbanization development, the demand for agricultural products quickly increases. Hebei formulated the plan for increase in yield of agricultural products in its provincial "Twelfth-Five-Year Plan," in which the pressure on cultivated land demand has increased. But improvement of farmland output efficiency will offset the cultivated land demand in the future (National Bureau of Statistics of China 2004–2012).

11.2.2 Basic Characteristics of Carrying Capacity on Water Resources in Hebei Province

The scores of carrying capacity on water resources in Hebei province in recent years were equal to the average of Beijing, Tianjin, and Hebei; water resource has been in poor condition, and water crisis has been more severe (See Table 11.5).

In 2011, national annual per capita water resource was 1730.4 m^3, and annual per capita water resource was 217.7 m^3 in Hebei province, which was 13 % less than that of the national level (National Bureau of Statistics of China 2004–2012). According to the standard of the United Nations, annual per capita water consumption less than 500 m^3 belongs to an extreme water-scarcity area. In the first half of 2012, water supply was 11.105 billion m^3 in Hebei, water demand was 15.443 billion m^3, and water supply–demand ratio was only 0.72, in which water deficit reached 4.338 billion m^3 (Liu Qingbo 2012). From 2009 to 2011, average annual

Table 11.5 Scores of carrying capacity on water resources in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.6667	0.6667	0.6667	0.6667	0.6667	0.5833	0.5833
Tianjin	0.6667	0.7500	0.6667	0.6667	0.6667	0.7500	0.7500
Hebei	0.6667	0.5833	0.6667	0.6667	0.6667	0.6667	0.6667
Average score of three areas	0.667						

amount of precipitation was 501.3 mm in Hebei, which was 6 % lower than perennial values. Due to scarcity of water resources, groundwater resources have been in overdraft; from 2000 to 2010, average annual overdraft amounted to 6.6 billion m^3 so that ground-water level continued to drop year after year.

In the face of serious scarcity in water resources, Hebei province has strongly pushed water-saving measures, and citizens' water-saving consciousness has also gradually enhanced, which has caused water utilization rate to improve. In the period of the "Eleventh-Five-Year Plan," water consumption for ten thousand RMB GDP reduced from 214 to 136 m^3 (comparable price in 2005, similarly hereinafter), and water consumption for ten thousand RMB value added reduced from 77 to 34 m^3. However, agricultural water saving had a bad effect; water consumption for agricultural irrigation accounted for 50–70 % of total water consumption, water consumption per Mu farmland did not drop, and was maintained at around 160 m^3 in 2000–2010 ("Twelfth-Five-Year Plan" of Hebei province 2011).

11.2.3 Characteristics of Environmental Carrying Capacity in Hebei Province

In recent years, although the scores of environmental carrying capacities in Hebei showed an upward trend, the score in 2011 was less than the average of these three areas, in which overall environmental quality was worrying (See Table 11.6).

As shown in Fig. 11.1, although the number of good days that on average reached or was better than level-II in Hebei cities continued to increase in recent years, and as shown in Fig. 11.2, in 2011 the concentration of inhalable particles (PM10) in air environment, and the concentrations of sulfur dioxide (SO2) and nitrogen dioxide (NO2) all reached national level-II standard, the frequency of acid rain occurrence was 2.91 % in the whole province, and frequency and intensity of acid rain were minimal in the whole country, but after detailed comparison, it is discovered that the concentrations of three classes of pollutants and the frequency and intensity of acid rain were very close to the control standard, thereby environmental capacity was very limited.

Table 11.6 Scores of environmental carrying capacities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.7619	0.8095	0.6667	0.6667	0.7143	0.6667	0.6667
Tianjin	0.7619	0.6667	0.7143	0.7143	0.6667	0.6667	0.7143
Hebei	0.4762	0.5238	0.6190	0.6190	0.6190	0.6667	0.6190
Average score of three areas	0.667						

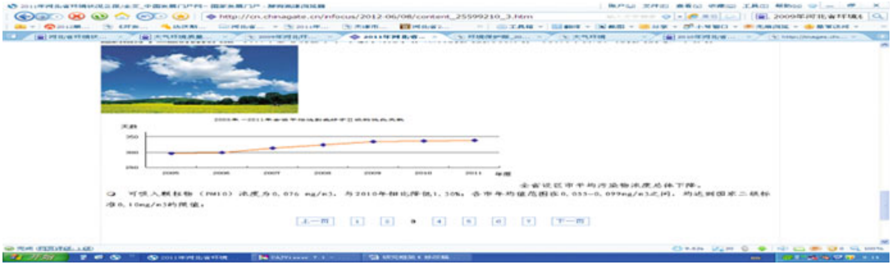

Fig. 11.1 Number of good days at level-II air quality or above in Hebei in 2005–2011 (Data source: Bulletin about Environment Condition of Hebei Province in 2011, Hebei Provincial Department of Environmental Protection http://www.hb12369.net:8000/hjzlzkgb/. day: Number of days; year: Year)

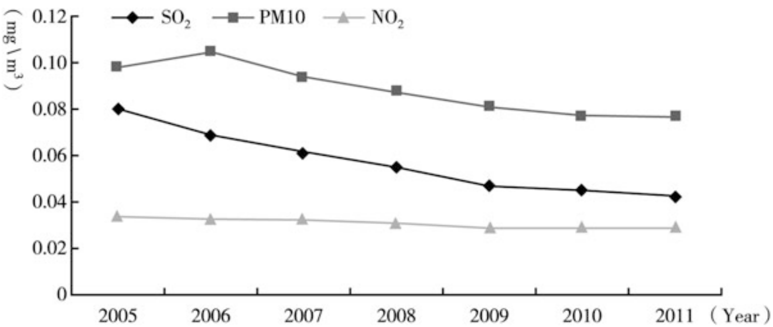

Fig. 11.2 Changes of air pollutant concentration in Hebei province from 2005 to 2011 (Data source: Bulletin about Environment Condition of Hebei Province in 2011, Hebei Provincial Department of Environmental Protection http://www.hb12369.net:8000/hjzlzkgb/)

The target number of good days at level-II air quality or above in Hebei cities at the end of the "Twelfth-Five-Year Plan" was 310 days, as formulated in the "'Twelfth-Five-Year Plan' of Hebei Province on Eco-environmental Protection" (hereinafter referred to as "Plan"), which were far lower than the 339 days in 2011, and indicated a long-term trend of deterioration in air environment in the future. Moreover, the "Plan" explicitly gave the target for reduction of sulfur dioxide and nitrogen oxide emissions, did not formulate the standard of industrial and domestic dust, smoke and dust emission, thereby air content of inhalable particulates will largely increase.

Water quality is also not optimistic, although industrial effluent waste-water amount did not significantly increase in recent years, domestic sewage effluent amount rapidly increased and more than that of the former. In 2010, internal lakes were in moderate eutrophic state, in which class-IV water in Baiyangdian lake accounted for 46.7 %, class-V water 4.8 %, and overall evaluation was class-V, in which pollution was still serious. In 2011, groundwater quality exceeded the standard in four of ten provincial cities.

11.2.4 Analysis of the Carrying Capacity on Traffic Facilities in Hebei Province

In recent years, the carrying capacity on traffic facilities in Hebei province was higher than the average score of the three areas (See Table 11.7), in which infrastructure is more complete.

As shown in Table 11.8, the growth rate of road traffic mileage in Hebei province is higher than the national average, but the growth rate of railway operating mileage is lower than the national average. In transportation capacity, as shown in Table 11.9, growth rate of total traffic volume in Hebei province is as much as the national average, but the passenger traffic is higher than the national average, and the growth rate of freight traffic is as much as the national average; the growth rates of railway and road traffic volume are lower than the national average, the capacity growth of harbor freight traffic and civil aviation passenger traffic are higher than the national average, but because total area of Hebei airport terminals only account for 10 % of total area of Beijing, Tianjin, and Hebei airport terminals, although civil aviation has fast growth, the scale is too small, which makes it difficult to rely heavily on its services. It is observed that harbor freight traffic will be Hebei's direction of logistics development.

In traffic capacity demand, as shown in Table 11.10, unit GDP passenger capacity in Hebei province is higher than the national average, unit GDP freight

Table 11.7 Scores of carrying capacity on traffic facilities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.750	0.750	0.750	0.667	0.667	0.667	0.667
Tianjin	0.583	0.583	0.583	0.583	0.583	0.583	0.583
Hebei	0.667	0.667	0.667	0.750	0.750	0.750	0.750
Average score of three areas	0.667						

Table 11.8 Gross transport mileage and average annual growth rates in 2005–2011
Unit: km

		Road traffic mileage	Expressway	Total railway mileage
Hebei	In 2005	75,894	2,135	4,652
	In 2011	156,965	4,756	5170.5
	Growth rate (%)	15.7	18.9	1.4
Whole country	In 2005	1,930,543	41,005	75437.6
	In 2011	4,106,400	84,900	93,200
	Growth rate (%)	13.40	12.90	3.59

Data sources: China statistical yearbooks in 2006 and 2012

Table 11.9 Growth rates of passenger and freight volume in Hebei province and in the whole country in 2003–2011
Unit: %

	Passenger traffic				Freight traffic				
	Aggregate (%)	Railway (%)	Road (%)	Civil aviation (%)	Aggregate (%)	Railway (%)	Road (%)	Civil aviation (%)	Harbor (%)
Hebei	11.3	6.9	5.3	58.8	11.3	2.6	13.3	3.8	18.7
Whole country	10.5	8.5	10.6	16.3	11.3	7.3	11.7	12.4	15.0

Data sources: China statistical yearbooks in 2004 and 2012

Table 11.10 Transport demands of economic growth in 2011

	Unit GDP railway passenger capacity (person/ten thousand RMB)	Unit GDP Road passenger capacity (person/ten thousand RMB)	Unit GDP civil aviation passenger capacity (person/ten thousand RMB)	Unit GDP railway freight traffic capacity (ton/ten thousand RMB)	Unit GDP road freight traffic capacity (ton/ten thousand RMB)	Unit GDP harbor cargo handling capacity (ton/ten thousand RMB)
Hebei	0.31	3.75	0.02	0.83	6.80	2.89
Whole country	0.39	6.95	0.06	0.83	5.96	1.30

Data source: China statistical yearbook 2012

traffic volume is lower than the national average, the demand for transportation in the economic growth of Hebei province is as much as the national average, but the demand for freight traffic is higher than the demand for passenger traffic, which shows that structural characteristics of traditional industries is still prevalent.

Table 11.11 Scores of energy carrying capacity in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.66667	0.6667	0.6667	0.6667	0.6667	0.6667	0.6667
Tianjin	0.83333	0.6667	0.8333	0.6667	0.8333	0.8333	0.8333
Hebei	0.50000	0.6667	0.5000	0.6667	0.5000	0.5000	0.5000
Average score of three areas	0.667						

Table 11.12 Supply and demand of electric power in Hebei province in recent years

	In 2005	In 2009	In 2010	In 2011	First half year of 2012
Current drain	1501.92	2343.85	2691.52	2984.00	1528.70
Generating capacity	1338.63	1741.90	1992.57	2298.00	1155.83
Electricity import	163.29	601.94	698.95	686.00	372.87

Data sources: (1) Bureau of Economic Operations Adjustment of the National Development and Reform Commission "Electricity operations adjustment work of Hebei province in 2011", http://yxj.ndrc.gov.cn/gjyx/dl/t20120118_457372.htm. (2) "152.87 Billion KWH, Hebei's electricity consumption at top four in the first half of year in the whole country", www.hebei.com.cn, at 16:33, August 17, 2012. (3) China statistical yearbooks in 2011 and 2012

11.2.5 Analysis of Energy Carrying Capacity

Although the scores of energy carrying capacity in Hebei province in recent years was equal to the average of the three areas in 2006 and 2008, it was far less than the average in other years (see Table 11.11), in which the energy carrying capacity is not strong.

As shown in Table 11.12, as the economy continues to grow, generating capacity and electricity consumption in Hebei province are gradually increasing, and electricity consumption is always bigger than generating capacity, electricity import increases year after year so that electric power gets tight, even though the balance is kept in year-round electric power supply and demand, the electrical load varies widely, and power balance is absent in some periods of time. In the first half of 2012, total electricity consumption in Hebei province grew 4.7 %, the growth rate dropped 4.86 %, and power generation growth rate of the province also dropped 5 %.

11.2.6 Analysis of Carrying Capacity on Municipal Facilities

The scores of municipal facilities in Hebei province in recent years did not increase and were less than the average of the three areas, in which service capacity of municipal facilities is very limited (see Table 11.13).

Table 11.13 Scores of carrying capacities on urban municipal facilities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.7778	0.7778	0.7778	0.8333	0.8333	0.8333	0.8333
Tianjin	0.6667	0.6667	0.6667	0.6111	0.6111	0.6111	0.6111
Hebei	0.5556	0.5556	0.5556	0.5556	0.5556	0.5556	0.5556
Average score of three areas	0.667						

Table 11.14 Heating capacity in 2011

	Per capita length of heat supply pipeline (km/ten thousand persons)	Per capita heating area (m^2/ten thousand persons)	Per capita heating aggregate (ten thousand GJ/ten thousand persons)
Hebei	1.40	5.81	3.15
Shanxi	1.56	9.14	3.41
Whole country	1.09	3.52	2.08

Data source: China statistical yearbook 2012

In all classes of municipal facilities, besides the basic telecommunication facilities and environmental protection facilities in Hebei province that are more complete, service capacity of other facilities is obviously inadequate. Table 11.14 shows that the heating capacity of Hebei province is higher than the national level, but lower than Shanxi province in which the climate is similar to Hebei, and annual per capita GDP level is inferior to Hebei province, which Hebei's social carrying capacity is bad; Table 11.15 indicates that per capita GDP in Hebei is equivalent to the whole country, but urban transit carrying capacity does not reach the national average. Table 11.16 means that Hebei's urban public traffic facilities are not complete, and inferior to the national average, thereby its carrying capacity is insufficient. As shown in Table 11.17, natural gas supply capacity of Hebei province also falls short of the national average. Hebei's urban facility scale is less than the national average, and the carrying capacity is insufficient.

11.2.7 Analysis of Social Carrying Capacity

Social carrying capacity mainly includes carrying capacities on education and medical services. As shown in Table 11.18, Hebei's social carrying capacity is still lower than the average of the three areas, and scale and quality of medical and education services cannot meet the demands of social and economic development.

As shown in Table 11.19, through analysis of educational investment, human resource investment in Hebei province is higher than the national average, but

Table 11.15 Analysis of carrying capacity on urban transit

	Per capita GDP (ten thousand RMB/person)	Per capita transit vehicles (vehicle /ten thousand persons)	Per capita traffic line length (km/ten thousand persons)	Per capita quantity of taxies (vehicle/ ten thousand persons)
Hebei	3.39	2.14	2.42	6.55
Whole country	3.51	3.06	3.87	7.44

Data source: China statistical yearbook 2012

Table 11.16 Carrying capacity on urban facilities

	Per capita urban road length (km/ten thousand persons)	Per capita urban road area (sq. m/ten thousand persons)	Per capita quantity of bridges (each/ten thousand persons)
Hebei	1.7	3.86	0.2
Whole country	2.29	4.18	0.4

Data source: China statistical yearbook 2012

Table 11.17 Gas supply capacity

	Per capita natural gas pipeline length (km/ten thousand persons)	Per capita gas supply aggregate (cu. m/person)	Proportion of natural gas consumers (%)
Hebei	1.31	57.77	19
Whole country	2.31	136.91	26

Data source: China statistical yearbook 2012

Table 11.18 Scores of social carrying capacities in Beijing, Tianjin, and Hebei in all years

Area	In 2005	In 2006	In 2007	In 2008	In 2009	In 2010	In 2011
Beijing	0.7778	0.7778	0.7778	0.8333	0.8333	0.8333	0.8333
Tianjin	0.6667	0.6667	0.6667	0.6111	0.6111	0.6111	0.6111
Hebei	0.5556	0.5556	0.5556	0.5556	0.5556	0.5556	0.5556
Average score of three areas	0.667						

educational funds are lower than the national average, thus inadequate overall investment indicates that its quality of education cannot reach the national average. Table 11.20 shows that enrollment ratio in compulsory education in Hebei province is as much as the whole country, but with speeding up of urbanization and the

Table 11.19 Analysis of educational input in 2011

	Average teacher-student ratio in basic education	Teacher-student ratio in vocational school and colleges and universities	Per capita educational fund (RMB)
Hebei	14.76	22.36	900.58
Whole country	16.00	23.50	1224.43

Data source: China statistical yearbook 2012

Table 11.20 Enrollment ratio in compulsory education in 2011

	Enrollment ratio of school-age children in elementary schools (%)	Proportion of primary school students entering schools of a higher grade (%)	Proportion of middle school students entering schools of a higher grade (%)
Hebei	99.8	99.97	86.2
Whole country	99.8	98.3	88.9

Data source: China statistical yearbook 2012

Table 11.21 Analysis of medical and health resources

	Per capita quantity of sickbeds in hospitals and health centers (piece/thousand persons)	Quantity of sickbeds in health centers of villages and towns per farm population (piece/thousand persons)	Per capita quantity of practicing doctors (person/thousand persons)	Per capita quantity of registered nurses (person/thousand persons)
Hebei	3.35	1.18	1.86	1.27
Whole country	3.50	1.16	1.82	1.66

Data source: China statistical yearbook 2012

promulgation of entrance examination policies, compulsory education will face unprecedented pressure so that the carrying capacity will gradually decrease.

As shown in Table 11.21, Hebei's level of medical resources is equivalent to the national average, but Table 11.22 shows that per capita medical expenses in Hebei's financial expenditures are far less than the national average, and insured rates of urban and rural medical insurances are lower than the national average, although its financing of medical insurances reaches the national average, Hebei's medical security capacity is still insufficient; considering the pressures on medical security and Hebei's downtrend of revenue growth after urbanization, Hebei's carrying capacity on medical services will also decrease for a long term.

Table 11.22 Analysis of investment in medical services

	Per capita hospitalization costs (ten thousand RMB/person)	Insured rates of urban & rural medical insurances (%)	Per capita financing amount for new rural cooperative medical system (RMB)	Per capita urban medical benefits fund revenue (RMB)
Hebei	418.11	91	232.1	1,204
Whole country	477.20	97	246.2	1,170

Data source: China statistical yearbook 2012

11.3 Countermeasures and Suggestions on Improving Hebei's Integrated Carrying Capacity

11.3.1 Countermeasures and Suggestions on Improving Hebei's Land Carrying Capacity

1. Protecting high-quality cultivated lands and basic farmlands

Hebei should comprehensively implement the national objective of cultivated land area and basic farmland protection, and rigorously enforce annual plan control, and prequalification of land used for construction projects, planning inspection of land use approval, overall planning adjustment of land use, and full-process supervision of planning implementation.

2. Promoting saving and intensive utilization of the land used for building

Hebei should improve the taxation regulatory mechanism to promote land saving and intensive utilization; improve the land tax system in accordance with the principle of increasing incremental costs and reducing inventory cost, and play the role of land price and tax regulator. Urban land purchases and reserve agencies should be strictly prohibit to drive down purchase price and to raise bid price on the basis of promoting saving and intensive land use as the core and satisfying the management costs as the principle. Hebei should strictly implement the idle land disposal policy, and should levy value-added land tax and unused land tax for idle land particularly for the land used for idle real estate; increase the strength of deep land development tax adjustment, and no longer increase the land-value money of those industrial enterprises which improve the land utilization rate and strength on the premise of no change of use under the plan (General Planning of Hebei Province on Land Use 2006).

3. Implementing urbanization and urban and rural unified planning of land use

On the premise of controlling total urban and rural land used for building, Hebei should implement urban and rural unified planning of land use, explore and implement policies on linking up the increase of land used for city construction while reducing the land used for rural construction, so as to strengthen the level of intensive land use for urban and rural construction, and to promote coordinated development of urban and rural areas.

4. Carrying out differential land use space regulation

According to spatial variation of land resources and economic development, the province is divided into different areas of land use. The different areas respectively determine the direction of areal land use and land-use control measures according to land-use characteristics in order to promote areal coordination and rapid development.

11.3.2 Countermeasures and Suggestions on Improving Hebei's Carrying Capacity on Water Resources

1. Adopting market mechanisms, comprehensively building Hebei's water market system

Departments concerned should attract private capital or foreign investment for water resources management, sharply increase the investments in water engineering and facilities for water delivery and mining and water supply, improve water supply efficiency and water quality, and comprehensively introduce price mechanism in water utilization, strongly advance metered water price, and grade water price in accordance with water quality and usage of water resources, and lead spontaneous grading water utilization of enterprises and residents to consciously install and use water-saving equipment. The Government should withdraw or partially withdraw from water conservancy investment and water affair operation, and collect material and financial resources to strengthen hydraulic engineering quality supervision, water administration verification and law enforcement, water delivery and supply quality monitoring and information issuance, control and management of flood disasters and geological disasters, hearing and regulation of water price, preferential policies on production and using subsidies of water saving equipment and taxation, governance and recovery of water pollution, areal distribution of water sources and regional collaboration and other public affairs.

2. Developing and spreading new technologies on development and utilization of water resources to quickly improve water use efficiency

Emerging industries should strongly focus on technical research and development for the development and utilization of water resources, private investment should be encouraged and led to enter research and development of the field, water quality grade of unconventional water including salt water, reclaimed water, seawater desalination, and rainwater and floodwater resources should be raised, their costs of production, purification, and storage should be quickly reduced, and commercial competitive power of unconventional water should be enhanced through government's deduction and exemption and subsidies in taxation.

3. Actively participating in building a new mechanism for management and coordination of water resources in Beijing, Tianjin, and Hebei

The departments concerned of Beijing, Tianjin, and Hebei should establish a consultation mechanism to equally settle the disputes on water utilization and compensation standard and method, solve distribution method of external water transfer, compensation program for water delivery and cooperative technical research, and development for development and utilization of water resources, and encourage Beijing and Tianjin to compensate Hebei province for water delivery and transfer through technical support of water resource development.

11.3.3 Strongly Promoting Energy Conservation and Emission Reduction, Improving Carrying Capacities on Energy and Environment

1. Accelerating the establishment of pollution discharge trade system, promoting harmonious development of the regional basins

The departments concerned should speed up to establish and to consummate main pollutants discharge trade platform. Firstly, should guarantee the development of those industries which are encouraged in national industrial policies, and which are first fostered in strategic industrial restructuring and development transformation implemented by Hebei province, promote industrial restructuring by market methods, and improve enterprises' performance of emission reduction; encourage interregional implementation of main pollutants discharge trade on the premise of improving the eco-environment quality.

2. Advancing the construction of the automatic monitoring capacity of pollutant sources

The database of dynamic key pollution sources management should be established and consummated to achieve supervision of sewage treatment plants, landfills, coal-fired power plants, steel enterprises, national and provincial key pollution sources, and new major pollution sources.

3. Advancing marketization process to abate pollution

The local governments should widen financing channels, and encourage diversified forms of financing in construction of environmental protection infrastructure to achieve multiple investment subjects, enterprise operation, and marketization management, so as to improve pollutant treatment capacity; further perfect adjustment mechanisms for environmental taxes and charges, and build the market mechanism for enterprises' voluntary emission reduction, spontaneous sewage delivery to wastewater treatment plants, and spontaneous participation in pollution discharge trade.

4. Vigorously promoting research and development of environmental protection technology, establishing long-acting mechanism for eradication of high energy consumption and environmental pollution

The Government formulates preferential policies to encourage environmental protection technological innovation, and to attract venture capital companies, environmental protection enterprises, and scientific research institutes to set up environmental protection technological development alliance so as to strenuously achieve accurate joint production, teaching, and research in environmental protection technological achievements, thereby to improve market conversion efficiency.

5. Increasing support for geological, energy, and technology exploitation, rapidly increasing clean energy output

In "China's 'Twelfth-Five-Year Plan' on Energy," the technological development of coal bed methane and shale gas exploration is listed at the top of key support energy technologies by the central government. Hebei provincial government should seize the opportunity to form more preferential policies on the basis of central financial and tax support, to rapidly enhance shale gas exploration and production technology, thus to occupy the ground of energy technology strategy; simultaneously increase the support strength of development, production, and consumption of non-conventional electric vehicle, so as to rapidly reduce domestic smoke and dust emission in major cities.

11.3.4 Countermeasures and Suggestions on Improving Carrying Capacity on Infrastructure and Municipal Facilities

1. Actively striving for administrative resources support outside the province to accelerate the optimization of all levels of road networks

Hebei province should seize the opportunity of the high-speed rail and road network construction in China to actively strive for listing the road network projects urgently needed in Hebei province's economic and social development in the national plan, and seek more construction fund support from the central departments concerned. Hebei province should deepen cooperation with central railway management departments to innovate construction mode of the inter-city railway, and to consummate the road network structure; actively promote the establishment of mechanisms for communication and collaboration of Beijing, Tianjin, and Hebei's government departments concerned in railway and highway planning, accelerate construction of primary highways, enhance the right to speak in the three areas in their cooperation with central departments concerned, and strive for more national preferential policies; strengthen the integration of construction and operation business of Beijing, Tianjin, and Hebei airports and Tianjin and Hebei ports, avoid repeated construction and low level of vicious competition, and increase regional overall operating income.

2. Eliminating institutional obstacles, widening infrastructural construction's financing channels

Hebei province needs to widen investment and financing channels of infrastructure, to increase construction and maintenance costs and to improve operation benefits. Hebei province also needs to ease access conditions of private capitals in charge of permit infrastructure projects of railway, expressway, sewerage treatment plants, public traffic, water, electricity, heating, fuel gas, and other public facilities, and encourage professional private enterprises with good qualification and credit to fully participate or lead project construction and operation using PPP, BOT, BT, and other project operation modes. In general roads, public utilities, and other indirect charge projects, local government should encourage construction and operation of domestic and foreign capitals in the form of exclusive investment or joint-ventures, invite public bidding, take fuel tax repayment of bank loans and the fuel tax redemption of construction and operation of private and foreign capitals to raise construction funds, and reasonably determine the proportion of investment, loan repayment, and income of owners and investors in construction projects.

11.3.5 Suggestions on Improving Carrying Capacity on Social Services

1. Policy suggestions on improving educational carrying capacity

The authorities should consummate the pre-school education operation system that is government-led, with social participation and simultaneous develop public and private kindergartens, establish pre-school education public service system with reasonable layout covering urban and rural areas, and ensure that school-age children can be accepted into basic and high-quality pre-school education; reasonably deploy compulsory education resources, and speed up the disparity between rural and urban schools; establish and perfect the school running mechanism that is led by the government, guided by the industry, and has the participation of enterprises; consummate the vocational education system so that vocational education running scale and curriculum design can meet economic and social development demands; adhere to quality improvement as the core to enhance the ability of university talent training, scientific research, and social services; further align the modern national education system with education principles and talent growth principles; promote coordinated development of education for academic schooling and education for non-academic schooling, mutual accommodation of vocational and general education, and effective linking of pre- and post-vocational education;

accelerate the development of continuing education, establish a continuing education network with wide coverage, and build a flexible and open system of lifelong education.

The qualities of the faculty should be comprehensively improved. The authorities should strengthen the construction of teachers' morality and conduct, raise the professional level of teachers, encourage talents' life-long teaching, strive to create a professional teacher force with noble-minded ethics and business skills; increase educational fund input so that the proportion of financial education expenditure in gross provincial product can increase significantly; innovate education development mode, improve the system of talent training and education management and school system, and reform teaching contents, teaching methods, quality evaluation, and the examination enrollment system.

2. Policy suggestions on enhancing carrying capacity on medical services and health care

Healthy cities should be created. The authorities should launch the action of "Healthy Hebei, Happy People," carry out "Hebei Provincial Health Regulations," comprehensively launch health education, and activities of comprehensive rectification of environmental sanitation and sanitation reaching the standards; comprehensively launch activities for healthy communities, healthy units, healthy towns, and villages and healthy families so as to improve the overall health of urban and rural residents.

The reform of the medical and health system should be deepened. The authorities should adhere to guarantee basic medical care and healthcare, strengthen grass-root medical care and healthcare, and build a medical and healthcare mechanism to promote reform with five emphases: establish and perfect the basic medical and health system covering urban and rural residents, consummate the basic medical insurance for urban employees and basic medical insurance system for urban residents, and consolidate and consummate the new rural cooperative system; vigorously develop the health industry; formulate health industry development planning, and promote accelerated development of health care rehabilitation and fitness industry; enhance the driving role of health industry brand demonstration, and extend the health industry; set up a scientific fitness concept, launch nationwide body-building activities, and popularize knowledge on "homology of medicine and food."

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Part III
Appendix

Chapter 12
Data Drawing List: Data and Spatial Distribution Graph on Carrying Capacities of Beijing, Tianjin, and Hebei

Qingmiao Li and Mengxin Zhang

This appendix provides partial spatial data on the ecological carrying capacity in Beijing-Tianjin-Hebei region for the book. These data reflect population, economy and industrial structure, and ecological environment, and they are mainly displayed in the form of maps, and the original data can be seen in the date sources found at the bottom of each map (Figs. 12.1 and 12.2).

Interpretation: currently Beijing-Tianjin-Hebei population spatial distribution has the following four characteristics: (1) As a whole, the density in the plain region is higher than the mountainous area and the Bashang plateau. (2) In the plain region, the population is greater in the piedmont of Yanshan and Taihang mountains. With the rivers that come out of the Haihe River system from the mountains, rivers drop lower than the flow rate so that there is a lot of sediment deposition, which comes from the upstream sediment surface soil, the soil is fertile, the terrain remains at a certain slope, irrigation and drainage are in good conditions, therefore it has always been a densely populated area. In the future, this area will continue to be a densely populated area, and thereby there is big pressure on the eco-environment. (3) In plain hinterlands such as Cangzhou and Hengshui, and coastal areas such as Qinhuangdao, Tangshan, and Cangzhou, there are low-lying terrain, small slopes, and higher land salinization, thereby the population in these areas is less than that of the piedmont. (4) The population in urban districts of various cities has high primacy ratio in the urban domain that forms peaks of spatial distribution in the population.

From the development in the past 5 years, it is observed that various areas had different population growth rates, its features are: (1) Areas of fast population growth are divided into the following three classes: class-I is the areas around the megalopolis, for example, main function areas of Beijing have been positioned as expansion areas of urban functions and new areas of city development; class-II is north Hebei and urban districts of cities in the east, namely urban districts of

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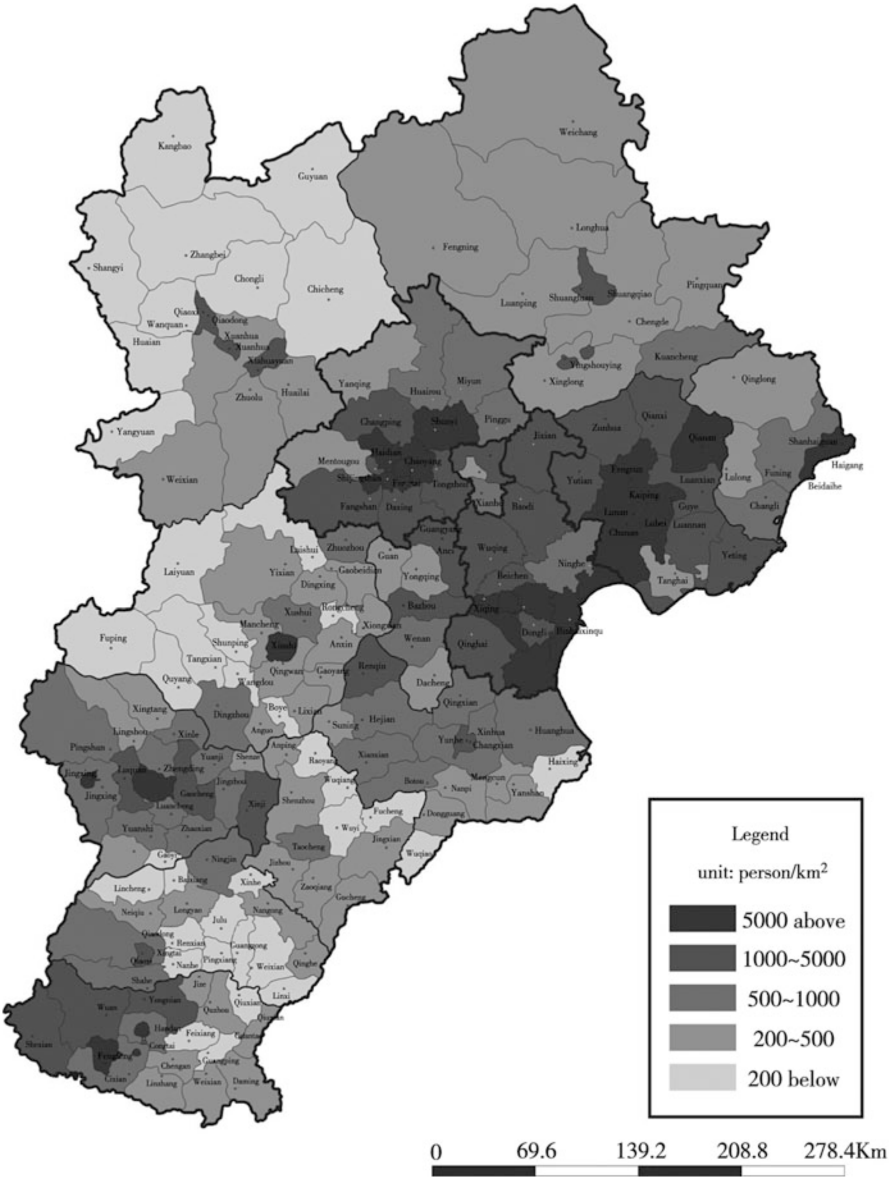

Fig. 12.1 Population density distribution in Beijing, Tianjin, and Hebei (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

Zhangjiakou, Chengde, Tangshan, and Qinhuangdao; class-III is the area east of the Beijing-Guangzhou line in Xingtai and Handan. (2) Areas of slow population growth and even reduction include: class-I is north Hebei, and adjacent counties around cities in the east, particularly around Zhangjiakou, Chengde and

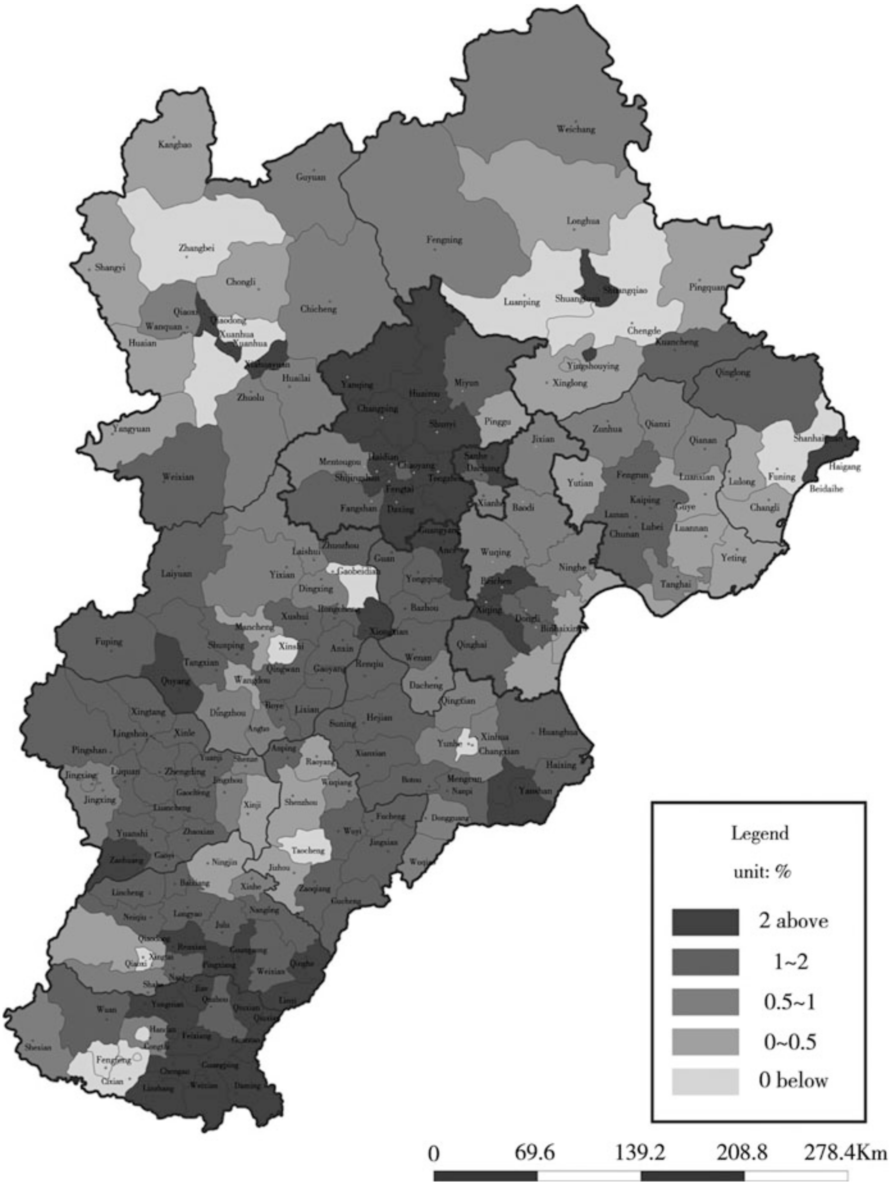

Fig. 12.2 Distribution of Beijing-Tianjin-Hebei population growth rate (2005–2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

Qinhuangdao; class-II is urban districts of cities in south Hebei, urban districts of Baoding, Hengshui, Cangzhou, Xingtai, and Handan, which have all showed a pattern of population reduction (Figs. 12.3, 12.4, 12.5 and 12.6).

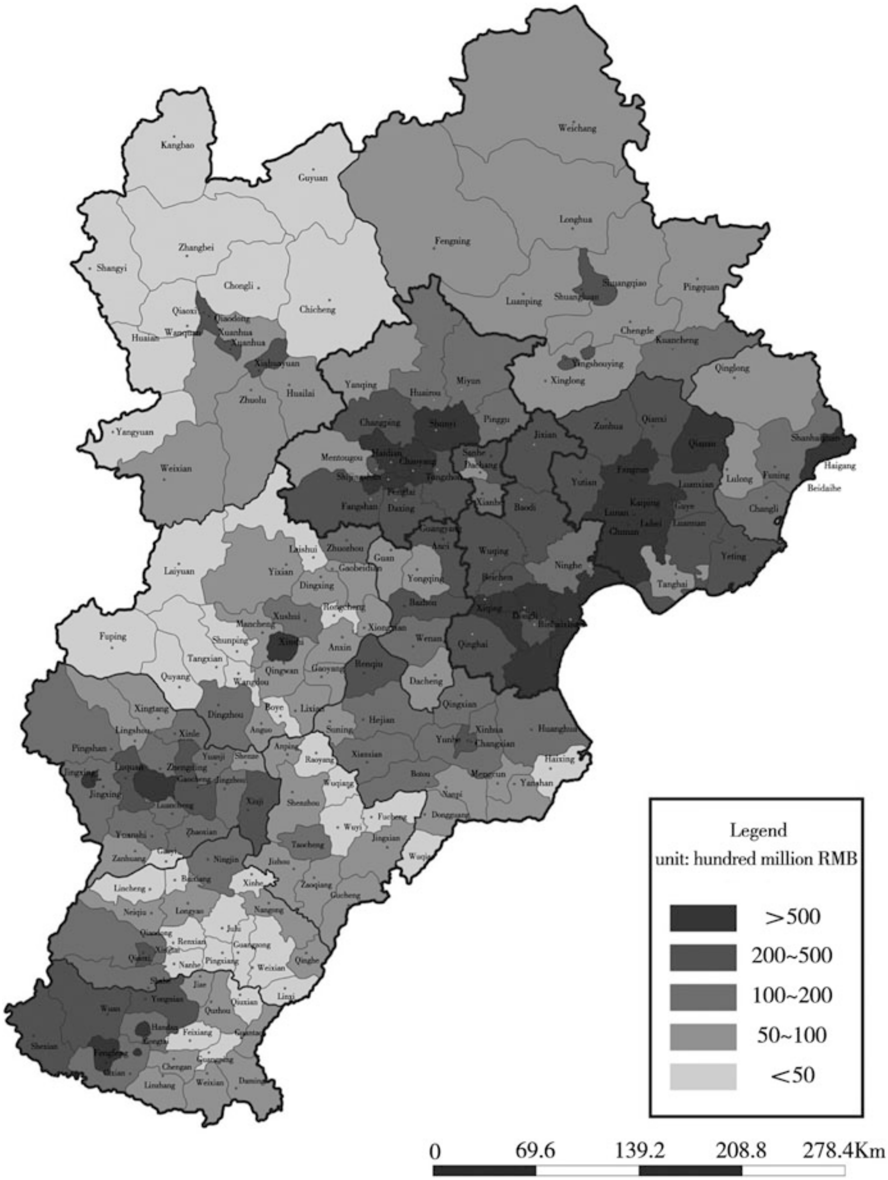

Fig. 12.3 Distribution of Beijing-Tianjin-Hebei GDP (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

Interpretation: in conditions of extensive development, the eco-environment is often sacrificed for economic development, thereby there is relatively larger pressures on the eco-environment in developed areas. In conditions of intensive development, economic development and eco-environment are expected to exist in

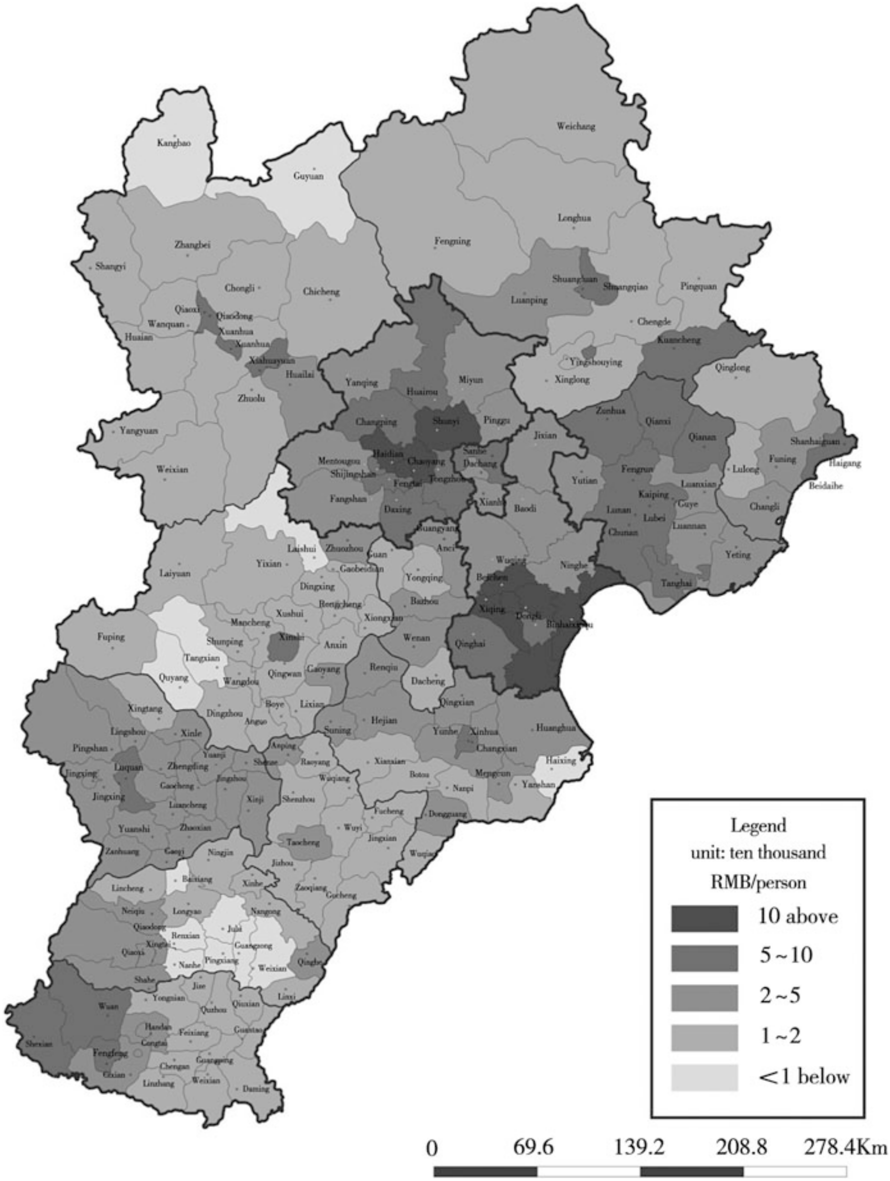

Fig. 12.4 Distribution of Beijing-Tianjin-Hebei per capita GDP (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

perfect harmony, thereby correlation between economic development and ecological pressures weakens. Sometimes, in developed areas, more attention is placed on ecological civilization construction, and thus instead they show negative correlation

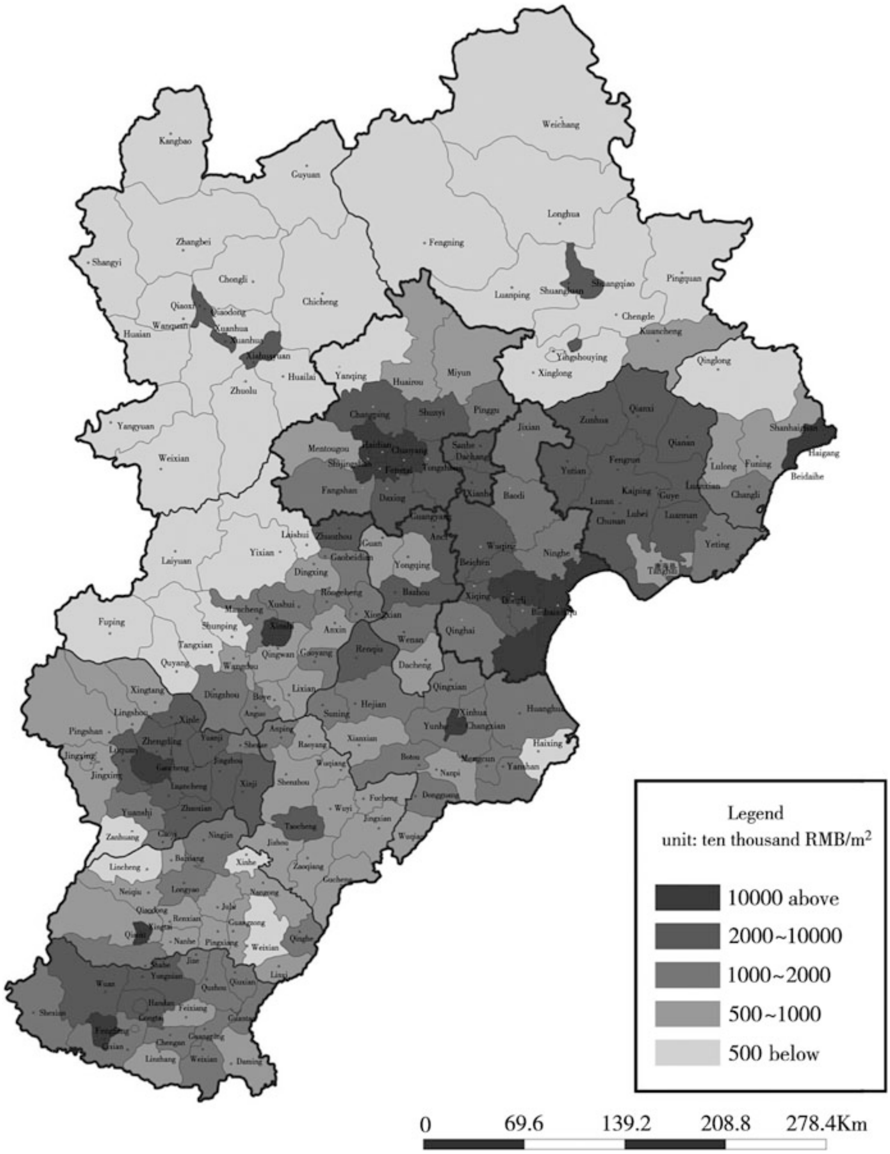

Fig. 12.5 Distribution of Beijing, Tianjin, and Hebei per land GDP (2010) (Data source: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

to a certain extent. Beijing-Tianjin-Hebei region is currently in a critical period of transformation from extensive production to intensive production, some developed areas have completed such a transformation, and this transformation in many underdeveloped areas is not yet completed, therefore, suitable measures should be

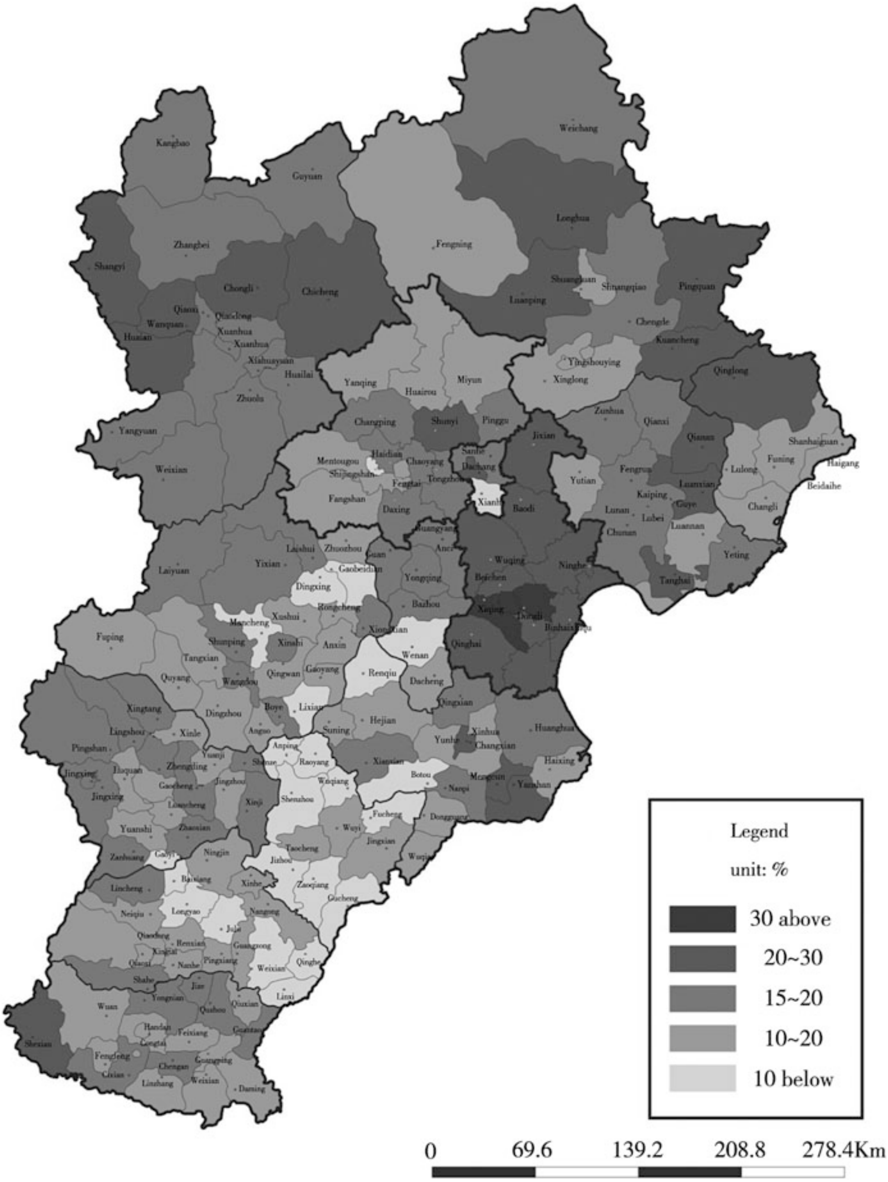

Fig. 12.6 Beijing-Tianjin-Hebei average annual GDP growth rate (2005–2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

taken according to local conditions. Here we make a brief introduction to the spatial differences of the Beijing-Tianjin-Hebei regional economic development to mainly provide a data base support for specific discussion on relevant chapters of the book.

According to the data of 2010, those areas of higher GDP were mainly the districts and counties of the Beijing plain, Tianjin's central urban area and the new area of Binhai, Tangshan urban area, districts and counties in the east side of the Beijing-Guangzhou Railway in Shijiazhuang, districts and counties in the west side of the Beijing-Guangzhou Railway in Handan. Those areas of lower economic development level have two classes; class-I was districts and counties in mountainous areas, they were mainly located in north Qinhuangdao, Chengde, Zhangjiakou, and west Baoding; class-II was plain hinterlands, they were mainly located in Hengshui and east Xingtai. More population were in developed areas, but low administrative area, therefore in the per capita GDP distribution map, spatial disparity was reduced, and in the GDP distribution map, the disparity was further enlarged.

From 2005 to 2010, faster economic growth speed was in northern mountainous area and Tianjin, because the former's base number was too low, average annual economic growth rate at below 10 % was mainly distributed in the mid-plain area because the industrial structure in those areas depended on agriculture for a long time.

In Chapter V "Beijing-Tianjin-Hebei Regional Spatial Development" of the "*Beijing-Tianjin-Hebei Regional Development Report 2012,*" the authors analyzed the regional differences of economic development using the Theil Index. Through this analysis, following conclusions can be reached:

1. As for Beijing-Tianjin-Hebei region as a whole, Theil Index in 2010 slightly rose over that in 2005, but the increase was moderate, which indicated the regional differences were still slightly extending in recent years.
2. In provincial variation, the highest Theil Index was in Tianjin, which indicated local differences were the most prominent, the lowest was in Beijing, and Hebei was close to Beijing; from 2005 to 2010, Theil Index of Beijing and Hebei slightly rose, and Tianjin greatly dropped, in which inter-provincial disparity increased over the 5 years. By 2010 the regional differences were mainly at the provincial level.
3. In Hebei province, as for the variation of prefecture-level cities, the bigger Theil Index was in Shijiazhuang, Tangshan, and Zhangjiakou, which indicated balanced economic development in these cities was particularly evident. But provincial differences were mainly reflected in the differences among these cities, and they contributed to more than one-third.
4. As for landforms, internal differences in the plain areas form mainly regional differences, but the differences between the plain and mountainous area and internal differences of mountainous area do not have an effect because most districts and counties in mountainous area have a relatively underdeveloped economy, and the plain hinterlands re far behind that of the piedmont according to the previous statement.
5. In traffic location, although there are big internal differences in those counties with good location, in comparison with the contribution of internal differences in the plains, they have relatively small contribution to overall regional differences, which indicates that improving regional location conditions is generally helpful to narrow regional differences (Figs. 12.7, 12.8, 12.9, 12.10, 12.11 and 12.12).

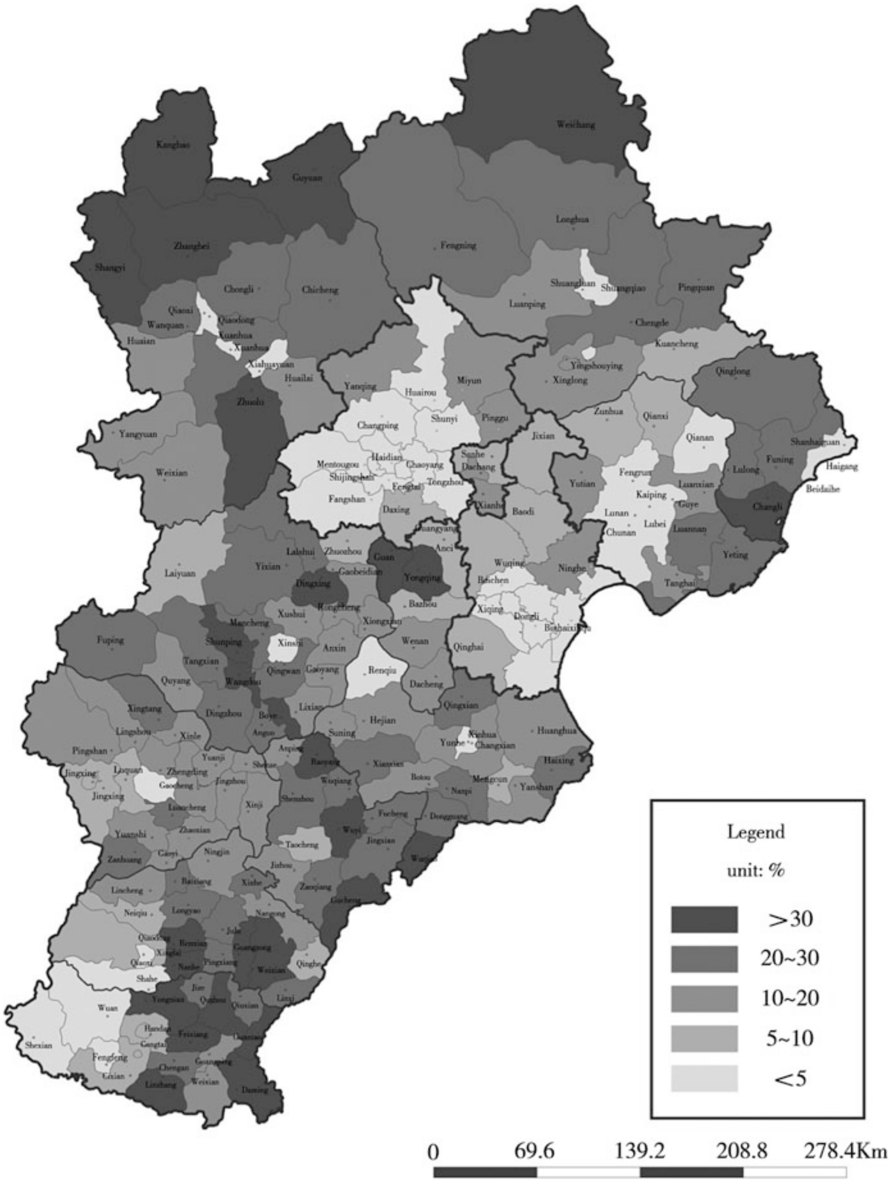

Fig. 12.7 Proportion of the first industry in districts and counties of Beijing, Tianjin, and Hebei (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

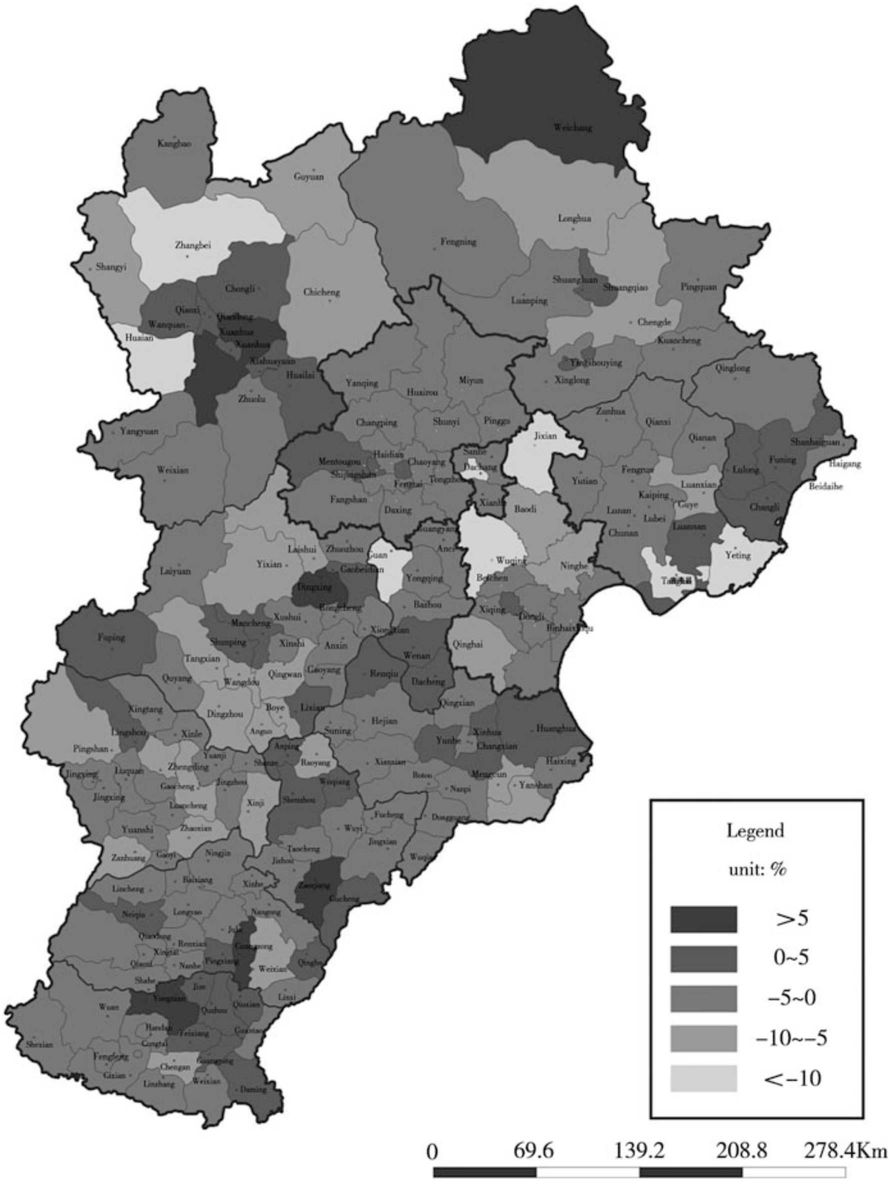

Fig. 12.8 Increases in the proportion of the first industry in districts and counties of Beijing, Tianjin, and Hebei (2005–2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

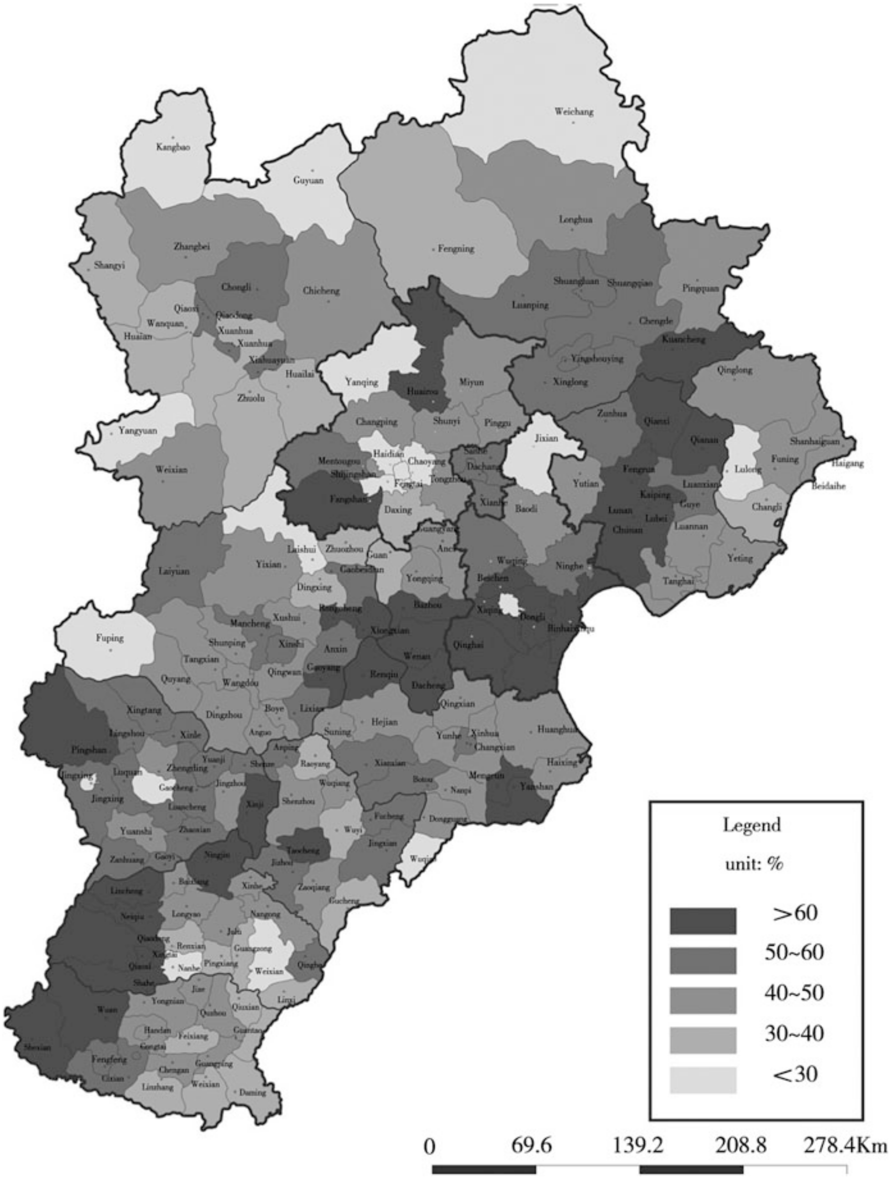

Fig. 12.9 Proportion of the second industry in districts and counties of Beijing, Tianjin, and Hebei (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

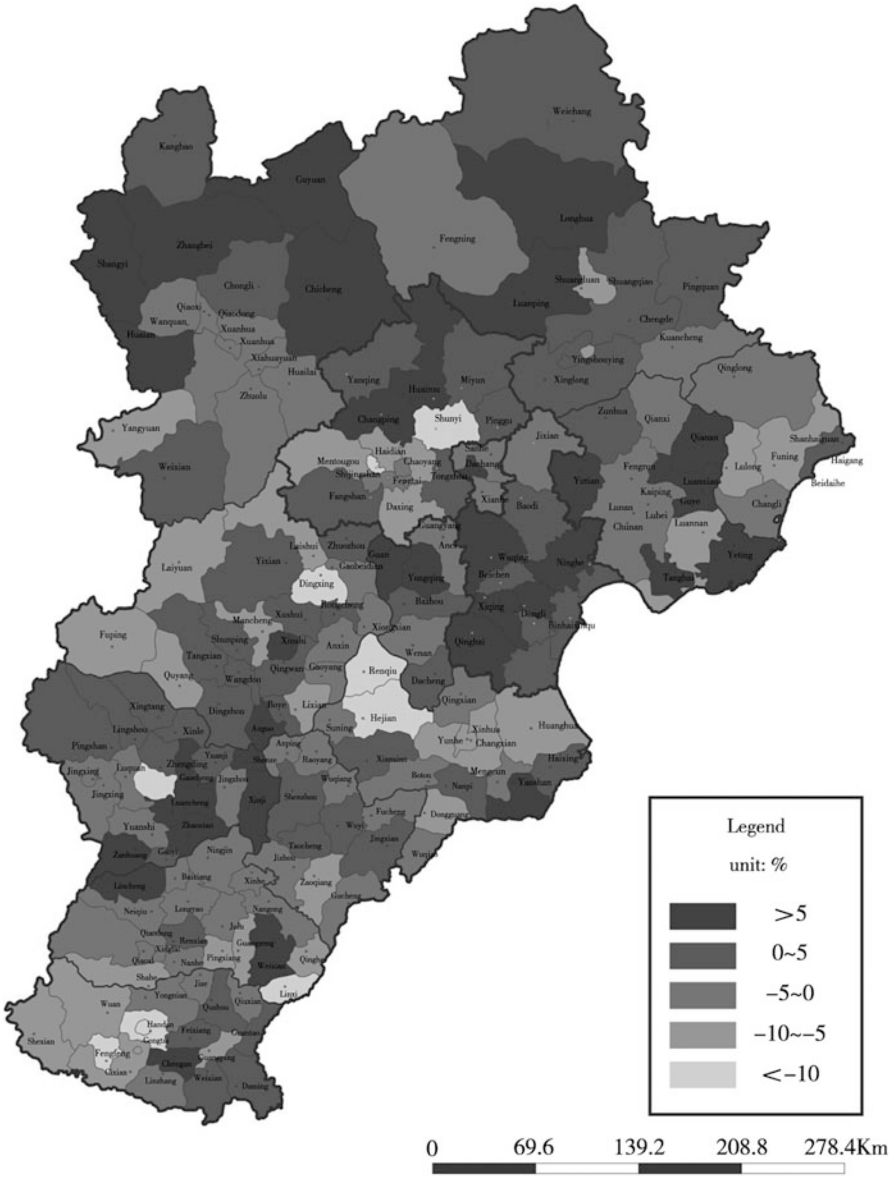

Fig. 12.10 Increases in the proportion of the second industry in districts and counties of Beijing, Tianjin, and Hebei (2005–2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

Interpretation: why is it that the more developed the economy in some places are, the bigger the pressure on eco-environment is? On the contrary in some place, why is it that the more developed economy the some places are, the smaller the pressure

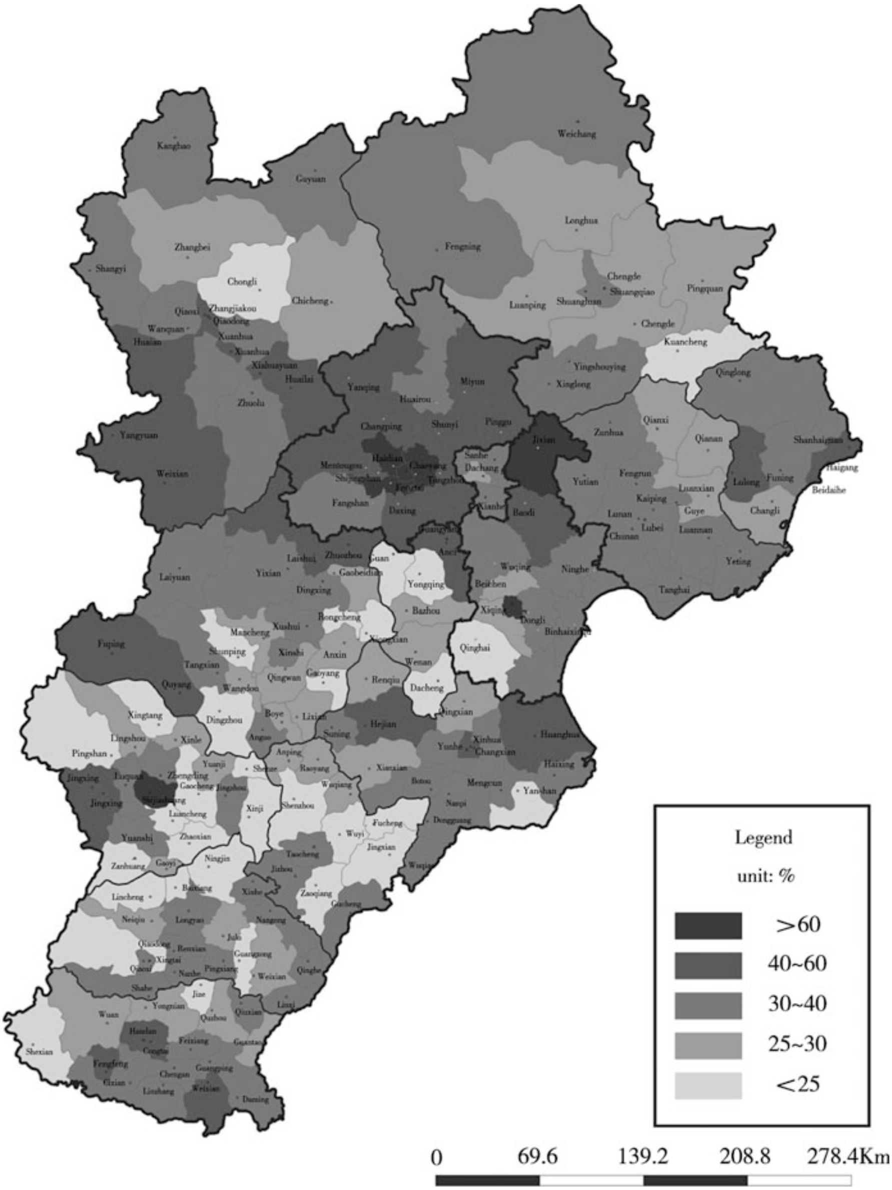

Fig. 12.11 Proportion of the third industry in districts and counties of Beijing, Tianjin, and Hebei (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

on eco-environment is? This is mainly because the different areas have different economic structures. In this way, we emphatically analyze the spatial differences of Beijing-Tianjin-Hebei economic structure.

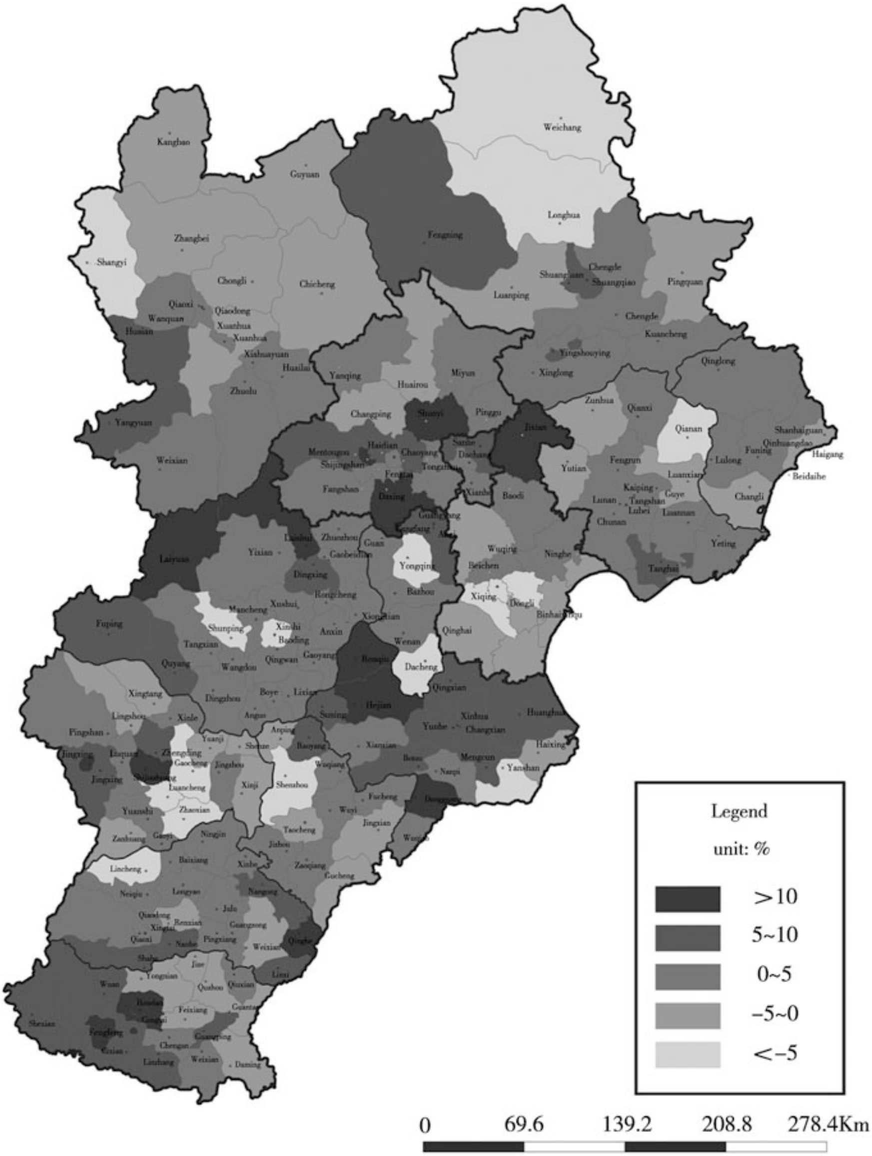

Fig. 12.12 Increases in the proportion of the third industry in districts and counties of Beijing, Tianjin, and Hebei (2005–2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011, the Beijing Statistical Yearbook 2006, the Tianjin Statistical Yearbook 2006, the Hebei Economic Yearbook 2006)

As of 2010, the differences in the spatial distribution of the third industrial structure of the Beijing-Tianjin-Hebei region were still very evident, in which various areas showed different functional characteristics. Higher proportion of the first industry mainly concentrated in mountainous area and in most of the coastal counties (excluding districts) including the overwhelming majority of counties in Qinhuangdao, Chengde, Zhangjiakou, Baoding, and Hengshui except for urban areas, and proportions of the first industry were higher than 20 %, even 30 % in counties of Xingtai and Handan in the plain hinterlands in the east side of the Beijing-Guangzhou Railway line. In changes from 2005 to 2010, the proportions of the first industry in most districts and counties dropped year each year, at about 0–5 % in 5 years. In some districts and counties, the drop was by more than 5 %, and the proportions of the first industry instead rose in fewer districts and counties because districts and counties made industrial restructuring after implementation of main functional divisions since the "Eleventh-Five-Year Plan," the third industry did not immediately fill the gap left after the "withdrawal" of the second industry in some districts and counties after the proportion of the second industry dropped so that the proportion of the third industry rose instead.

Strong industrial districts and counties are mainly concentrated in south Tianjin, north Tangshan, south Langfang, most cities and counties of Shijiazhuang, and counties and cities of Xingtai and Handan in the west side of the Beijing-Guangzhou Railway; in data on water and air quality of the basins in the following text, those districts and counties that have high proportion of the second industry have bigger pressure on the eco-environment. Except for some counties that have a bigger proportion of the first industry, proportion of the second industry in core areas of major cities is not big because these areas have largely completed the process of "withdrawal of the second industry, and promotion of the third industry." In the 5 years of the "Eleventh-Five-Year Plan," larger increases in the second industry were in Zhangjiakou, cities and counties in north Chengde, coastal counties of Tangshan, some districts and counties of Tianjin, cities and counties in east Shijiazhuang, larger decreases were in cities and counties in north Cangzhou, mountainous counties in west Baoding, and cities and counties in west Handan, and in these counties and cities, most of the second industry were replaced by the third industry.

Those districts and counties that have higher proportion of the third industry are divided into two classes; class-I is those areas that have entered or are entering the post-industrial stage after experiencing the industrialization stage, including Beijing, Tianjin, and even core areas of some important cities in Hebei; class-II is some counties in which the second industry is relatively weak, and they mainly depend on agriculture and services (particularly tourism). Promotions of the third industry in urban core areas of Qinhuangdao, Shijiazhuang, and Handan increased 10 % from 2005 to 2010, which indicated these 5 years were the transformation period of core areas of these cities from industry to services, and the transformation in urban core areas of Beijing and Tianjin was completed in the period of the "Tenth-Five-Year

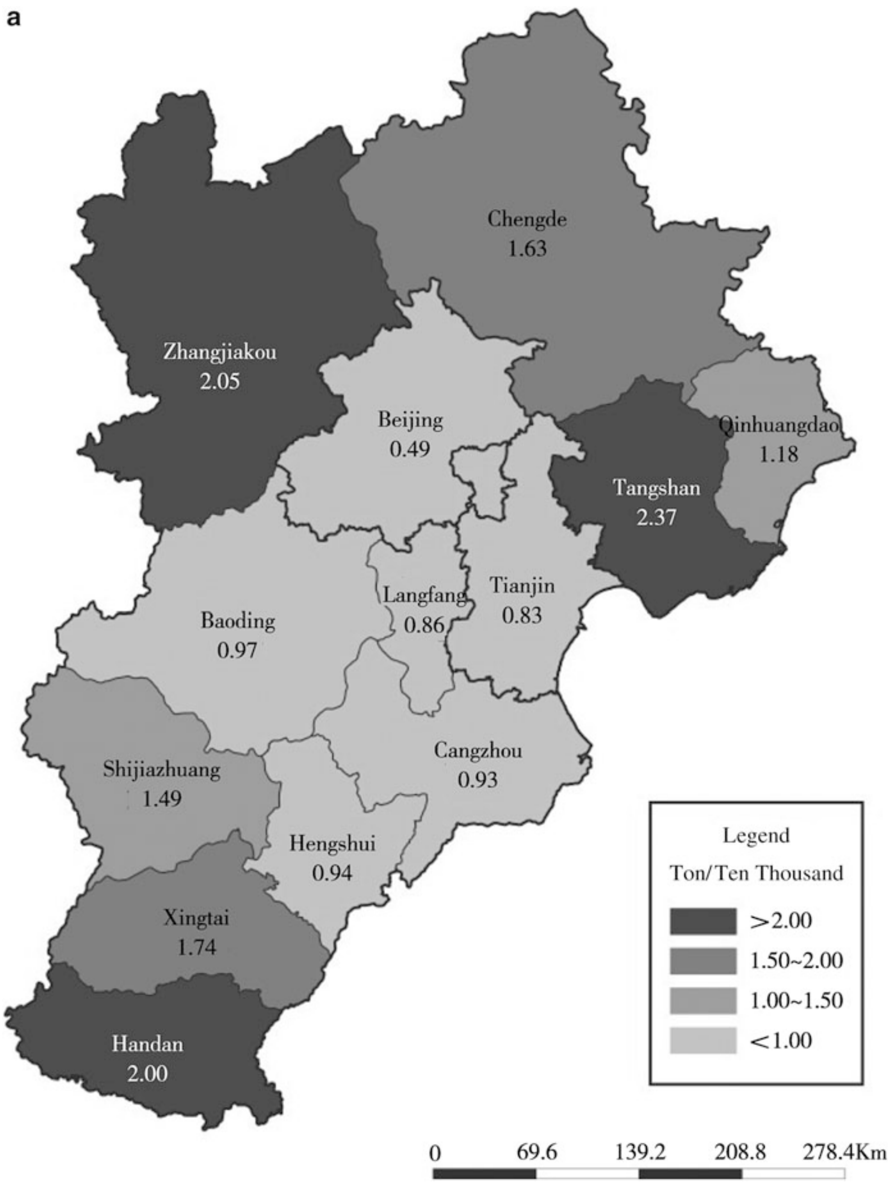

Fig. 12.13 (**a**) Energy consumption per unit GDP in cities of Beijing, Tianjin, and Hebei (2010). (**b**) Current drain per unit GDP in cities of Beijing, Tianjin, and Hebei (2010)

Plan." In addition, promotions of the third industry in some mountainous counties also increased more than 5–10 % in the past 5 years because some industrial sectors were limited to develop in the positioning of main functions in these counties (Figs. 12.13 and 12.14).

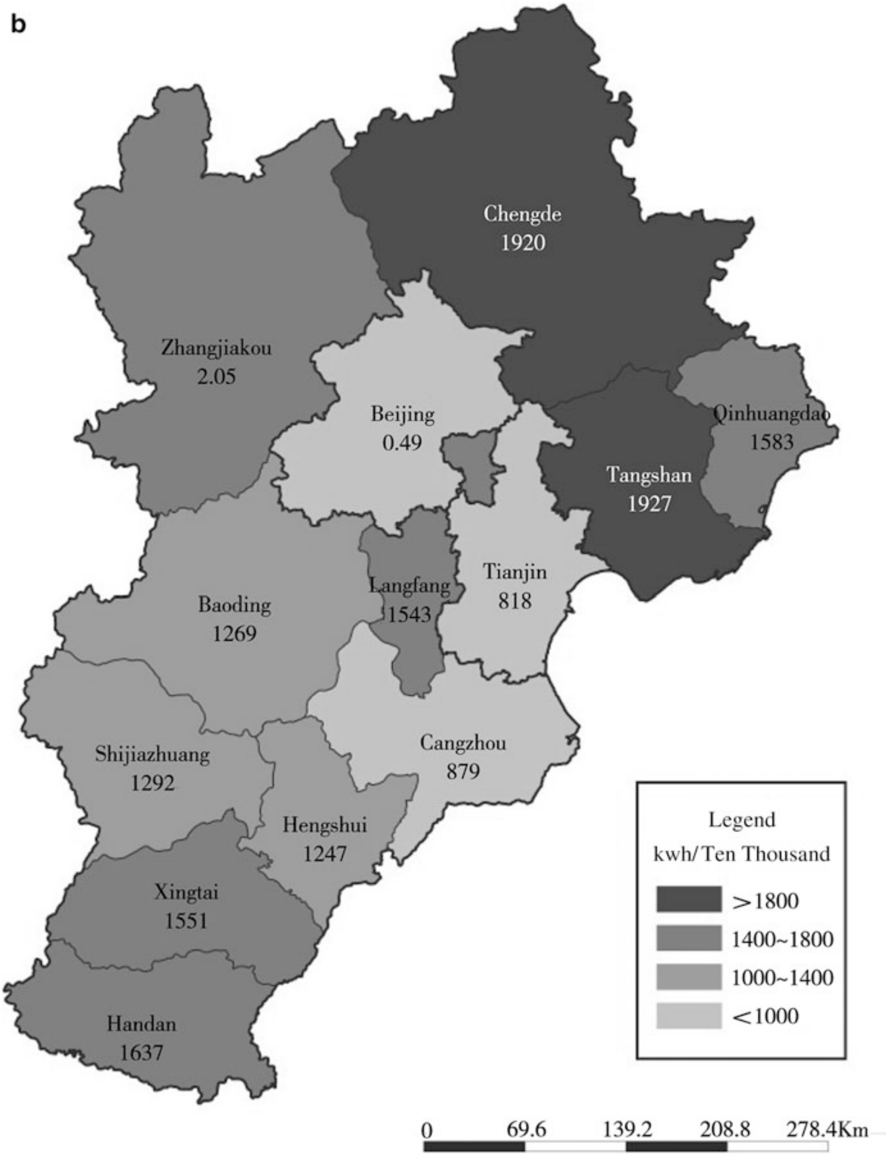

Fig. 12.13 (continued)

Interpretation: the above data reflects economic aggregate and types of industrial structure various areas. If energy consumption or water consumption per unit industrial value added are the same, districts and counties that have large proportion of the second industry naturally have large pressures on the eco-environment. But if the internal structure of the second industry is different in various areas, even if in the same categories of industry, production technique is also different, in which

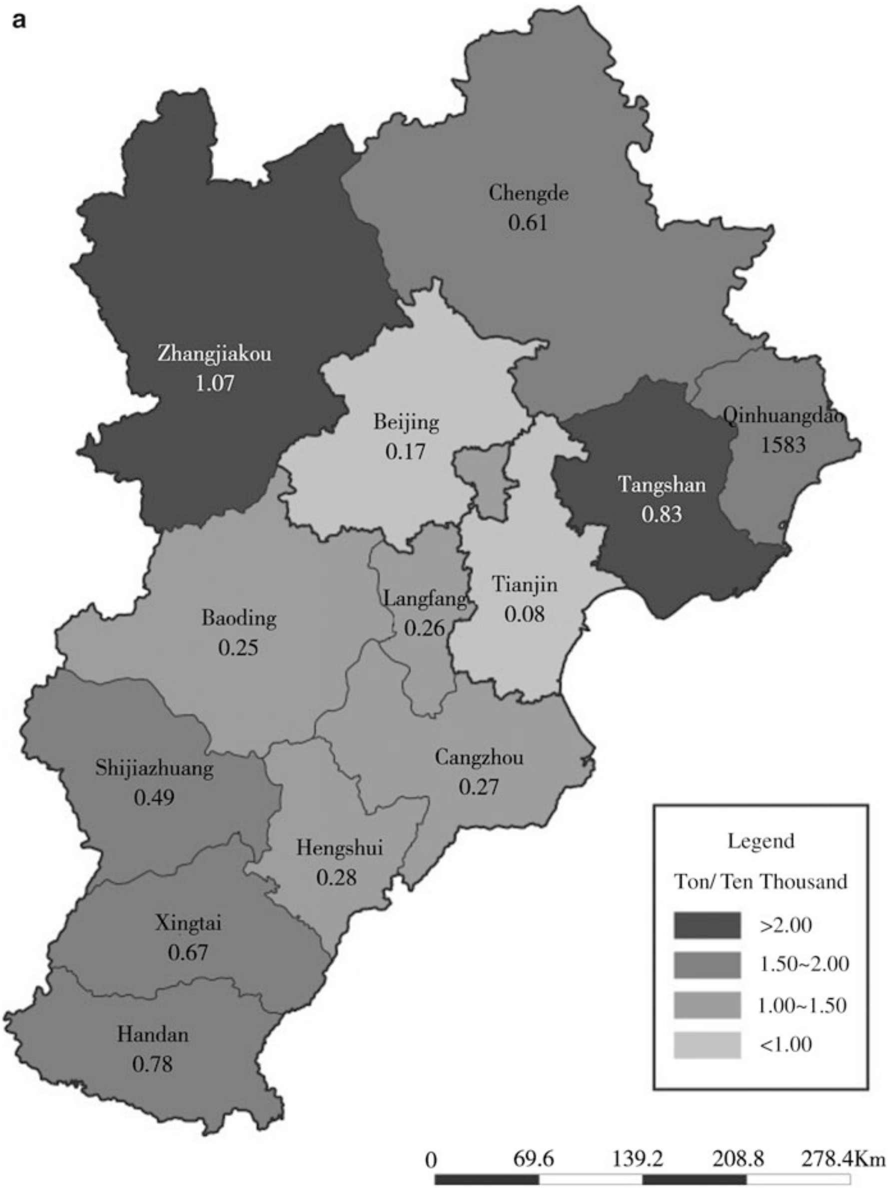

Fig. 12.14 (**a**) Energy consumption per unit value added of large-scale industries in various cities (2010). (**b**) Water consumption per unit value added of large-scale industries in various cities (2010) (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

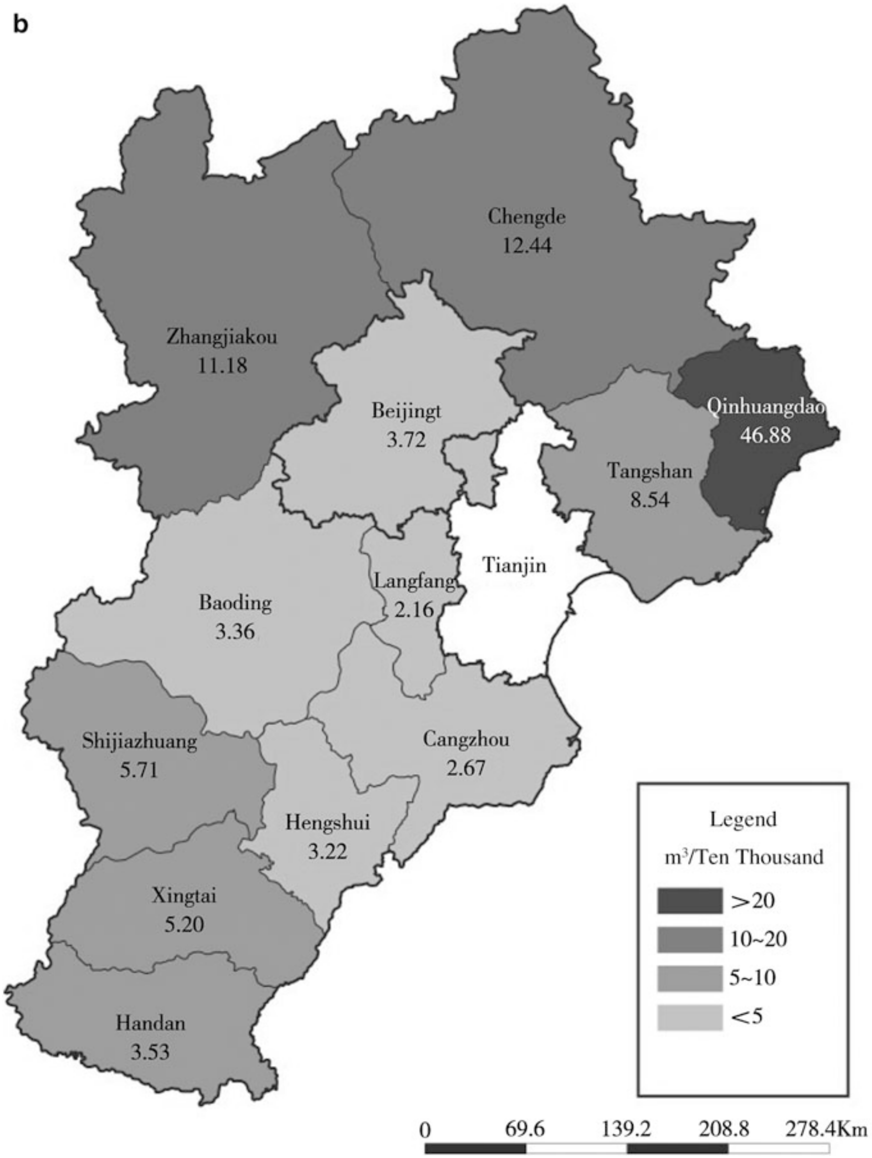

Fig. 12.14 (continued)

space comparison work of energy and water consumption for per unit value added or industrial value added is more significant.

In the Yearbooks that we have, there are four sets of city-level detailed data, namely, energy consumption per unit GDP, current drain per unit GDP, energy consumption per unit value added of large-scale industries, and water consumption per unit value added of large-scale industries, in which the last set of data on Tianjin is missing. In energy consumption and current drain per unit GDP, it is observed that, Zhangjiakou and Chengde in the north side of Beijing and Tianjin, Tangshan and Qinhuangdao in the east side, and Xingtai and Handan in the southernmost of Hebei, including the provincial capital city Shijiazhuang, all have more consumption, and Beijing and Tianjin has maintained low consumption. In energy consumption and water consumption per unit value added of large-scale industries, there is a similar situation, which indicates that economic development in Beijing and Tianjin is more intensive and efficient and environmental protection as cities of leading technical level and management level in the region, of course, higher score of Zhangjiakou and Chengde is due to their low value added.

Through further analysis, does the unit energy consumption and current drain have something to do with functional structure? We elaborate on this issue with location entropy. Due to the lack of detailed data of jobholders in urban industrial sectors in 2010, economic census data in 2008 are used tentatively as comparative data, after deducting the number of unit jobholders in farming, forestry, animal husbandry, and fishery, location entropy of industrial sectors in various areas is shown in Table 12.1.

As shown in Table 12.1, in those areas with high energy consumption and current drain, such as Tangshan, Handan, Qinhuangdao, Chengde, Zhangjiakou, and Xingtai, they have high entropy values in mining industry, production and supply of electricity, gas and water, namely energy production is dominant, and high consumption almost has nothing to do with entropy values of manufacturing sectors. Simultaneously, these areas and cities have universally lower entropy values, except for public administration and social organizations, higher entropy values indicate jobholders are more likely to concentrate in those sectors relying on public fiscal expenditures in these areas and cities in Beijing-Tianjin-Hebei region (Fig. 12.15).

Interpretation: in total agricultural output value, Shijiazhuang, Tangshan, Handan, and Cangzhou are big agricultural cities, but in value added, Beijing and Tianjin have larger proportion of intermediate consumption, at more than 50 %. In total agricultural output value in these cities of Hebei, the proportion of intermediate consumption is almost equivalent, at 40–50 %, and is less than 40 % only in Tangshan.

In cultivated land area, Baoding, Cangzhou, Handan, Shijiazhuang, and Xingtai have more than one million hectares of crop area, and they are mostly located in the piedmont around Taihang mountain; Beijing, Qinhuangdao, Chengde, Tianjin, and Langfang have less than 500,000 ha of crop area, in which Beijing has only 30,000 ha of crop area.

In crops types sown, except for Beijing, Tianjin, and cities of Hebei, grain crops dominate, crop area accounts for more than 60 % of total cultivated land area. There is a higher proportion of cotton acreage in Xingtai, Hengshui, Tianjin, Handan, and Cangzhou, at more than 10 %, and there is a higher proportion of vegetable oils acreage in Beijing, Qinhuangdao, Tangshan, and Zhangjiakou, at about 10 %.

Interpretation: Fig. 12.16 is about the proportion of the number of days of air quality from good to heavy air pollution in Beijing-Tianjin-Hebei major cities in

Table 12.1 Location entropy of industrial sectors in various areas

Industrial sectors	Beijing	Tianjin	Shijiazhuang	Tangshan	Qinhuangdao	Handan	Xingtai	Baoding	Zhangjiakou	Chengde	Cangzhou	Langfang	Hengshui
Mining industry	0.211	0.613	0.386	3.987	1.135	2.477	1.791	0.446	3.665	4.864	0.813	0.071	0.002
Manufacturing	0.529	1.283	1.391	1.228	1.005	1.050	1.372	1.251	0.785	0.659	1.420	1.425	1.431
Production and supply of electricity, gas and water	0.636	0.930	1.046	1.426	1.595	1.458	1.654	1.291	1.513	1.067	0.986	0.955	1.481
Construction industry	0.690	1.062	0.969	1.135	0.989	1.498	0.855	1.612	1.114	1.635	1.014	1.223	0.994
Traffic, transport, storage and post	1.380	0.981	0.819	0.587	1.546	1.098	0.486	0.498	0.644	0.688	0.960	0.464	0.334
Information transmission, computer services and software industry	2.352	0.355	0.388	0.296	0.420	0.198	0.213	0.195	0.273	0.362	0.274	0.333	0.244
Wholesale and retail business	1.325	1.188	0.721	0.795	0.781	0.831	0.634	0.576	0.864	0.634	0.633	0.443	0.571
Lodging and catering services	1.776	0.868	0.606	0.461	0.863	0.479	0.379	0.474	0.702	0.583	0.264	0.445	0.314
Banking	1.212	0.688	1.304	0.848	1.385	0.627	0.999	0.942	0.998	1.392	0.805	0.596	1.094
Realty business	1.768	0.761	0.640	0.404	0.697	0.231	0.302	0.305	0.761	0.385	1.330	0.832	0.225
Leasing and commercial services	2.183	0.665	0.375	0.294	0.543	0.194	0.116	0.160	0.295	0.553	0.147	0.515	0.129
Scientific research, technical services and geologic prospecting	1.928	0.782	0.536	0.223	0.440	0.227	0.232	0.817	0.295	0.363	0.142	1.020	0.125

(continued)

Table 12.1 (continued)

Industrial sectors	Beijing	Tianjin	Shijiazhuang	Tangshan	Qinhuangdao	Handan	Xingtai	Baoding	Zhangjiakou	Chengde	Cangzhou	Langfang	Hengshui
Management of water conservancy, environment and public establishment	1.233	1.141	0.845	1.102	1.394	0.488	0.644	0.489	1.312	1.181	0.456	0.560	0.488
Resident services and other services	1.290	2.277	0.251	0.284	0.439	0.415	0.284	0.260	0.346	0.293	0.173	0.265	0.091
Education	0.846	0.706	1.177	0.873	1.299	1.181	1.415	1.395	1.372	1.321	1.203	1.235	1.611
Sanitation, social security and social welfare	0.991	0.841	1.049	0.966	1.338	0.857	1.099	1.167	1.167	1.522	0.970	0.990	1.144
Culture, sports and entertainment	1.979	0.551	0.753	0.305	0.968	0.369	0.334	0.415	0.404	0.594	0.413	0.298	0.546
Public administration and social organizations	0.618	0.619	1.176	1.031	1.328	1.649	1.615	1.470	2.085	1.481	1.425	1.363	2.001

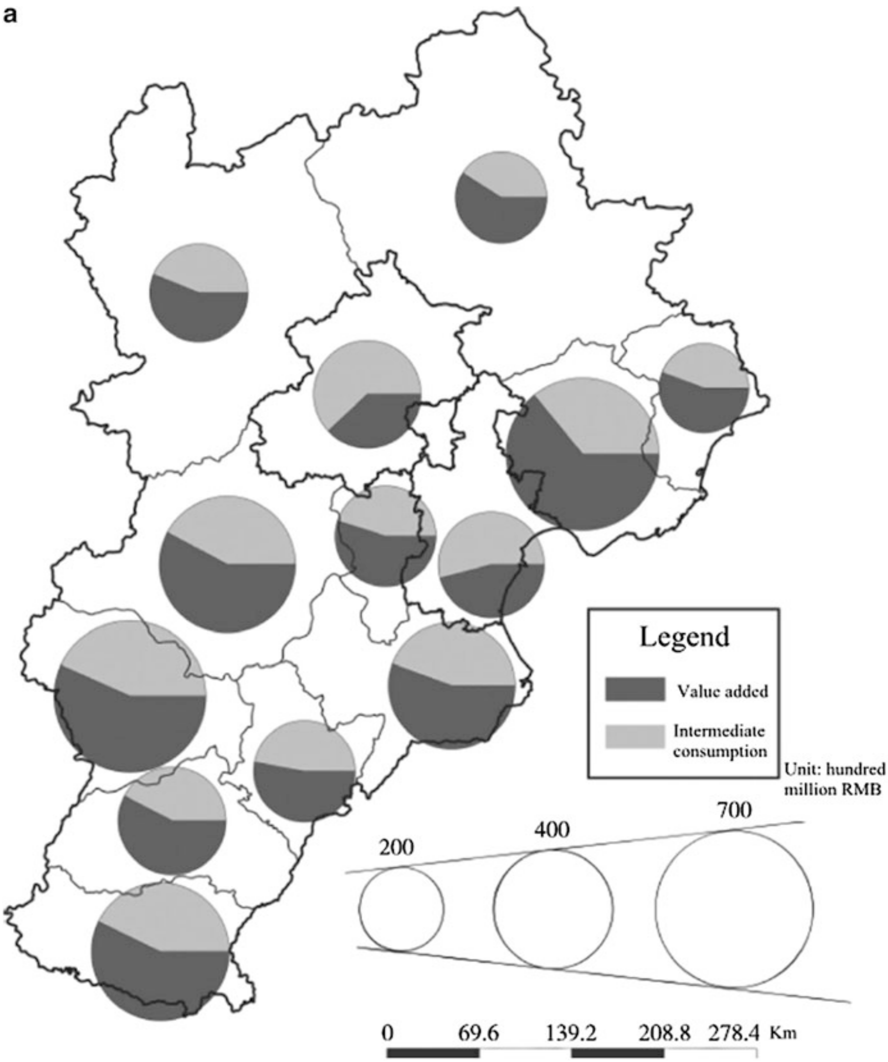

Fig. 12.15 (**a**) Proportion of total agricultural output value, intermediate consumption and value added. (**b**) Proportion of cultivated land area and planted area of grain crops, cotton and vegetable oils (Data sources: the Beijing Statistical Yearbook 2011, the Tianjin Statistical Yearbook 2011, the Hebei Economic Yearbook 2011)

2010. The highest number of days of good air quality is in Chengde, just more than half of the year, at 185 days, and 158 days in Zhangjiakou. There were more than 90 days in Baoding, Qinhuangdao, Langfang, and Cangzhou, 53 days in Beijing, at the least amount of days in Shijiazhuang, only 34 days, and 38 days in Tianjin, next to the last. In sum of the good and excellent days, Qinhuangdao is number one, at 354 days, only 11 days are slight pollution in all the year, Chengde is top two at 351 days, Cangzhou, Langfang, and Hengshui are top three at 344 days, only Beijing has less than 300 days, at 286 days. In Beijing, 56 days are slight pollution,

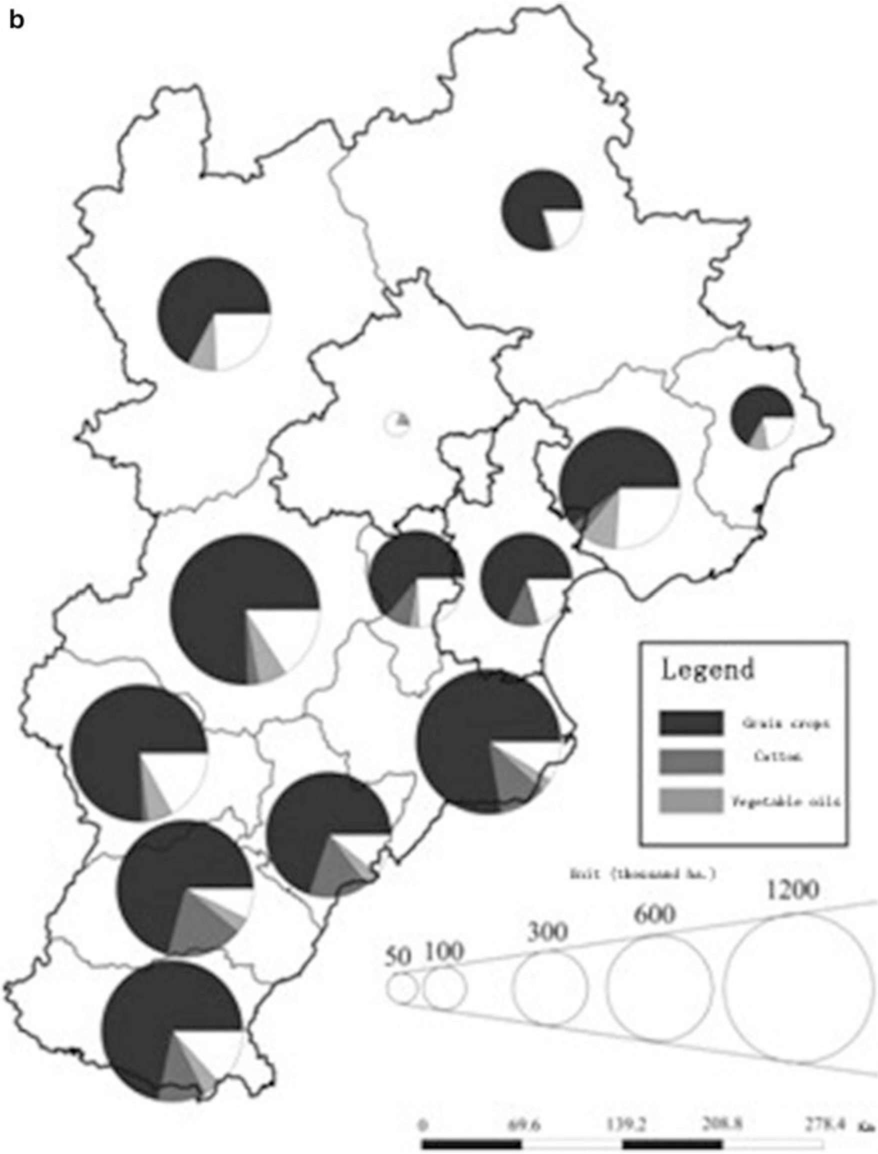

Fig. 12.15 (continued)

17 days light pollution, 4 days moderate pollution, 2 days heavy pollution, after the Olympic Games, Beijing still has big pressure on air quality. In addition, Baoding and Zhangjiakou have 1 day of moderate pollution in the year, 1 day heavy pollution, Shijiazhuang has 2 days of heavy pollution, and Handan has 1 day of moderate heavy pollution (Figs. 12.17, 12.18, 12.19, 12.20, 12.21, 12.22, 12.23, 12.24, 12.25 and 12.26).

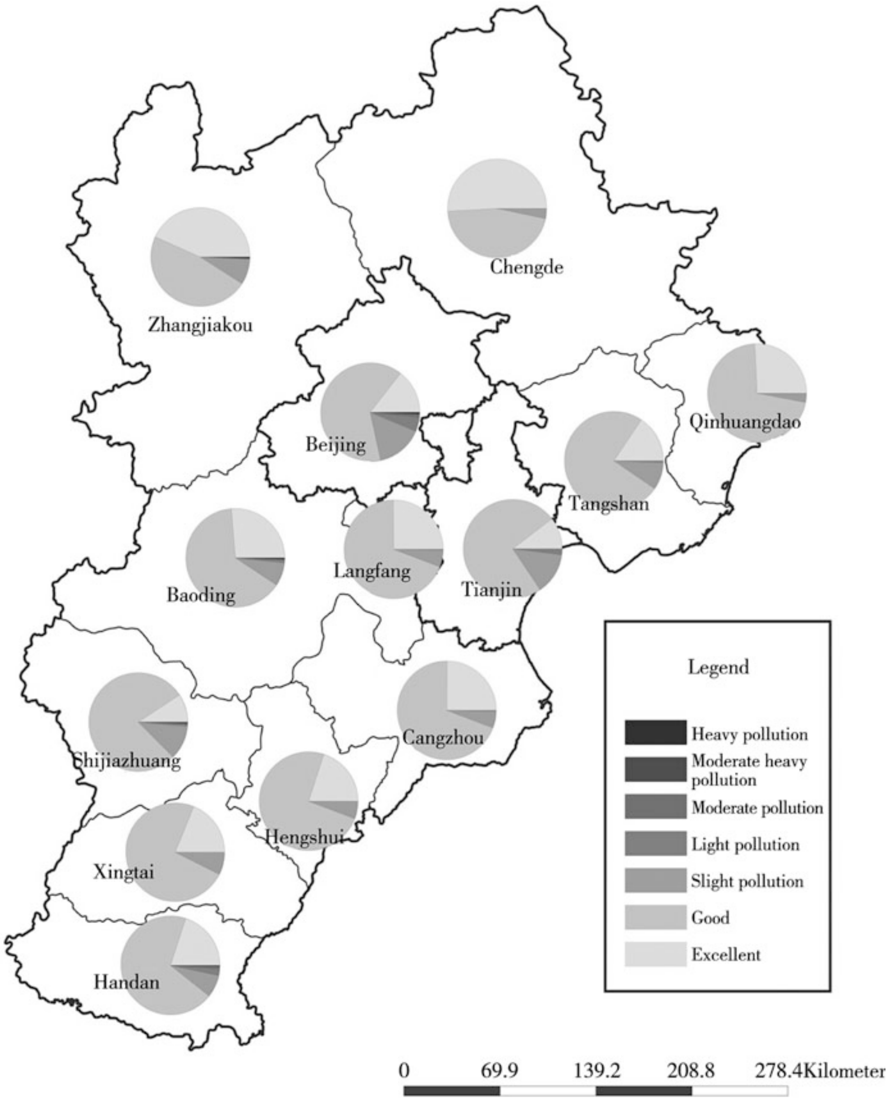

Fig. 12.16 Proportion of air quality in major cities of Beijing, Tianjin, and Hebei (2010) (Data sources: the China Environment Yearbook 2011)

Interpretation: through monitoring of the water quality section, water quality in Beijing-Tianjin-Hebei region is worrying. The reach of the best water quality is the upper reach of the Yuecheng Reservoir on Zhang River, but the upstream of this reach is the common boundary of Hebei and Henan provinces, and its upstream is Shanxi province, and has nothing to do with Hebei. Slightly better water quality is in the upper reach of Luanhe River in Qianxi County, it mainly flows through counties in Chengde,

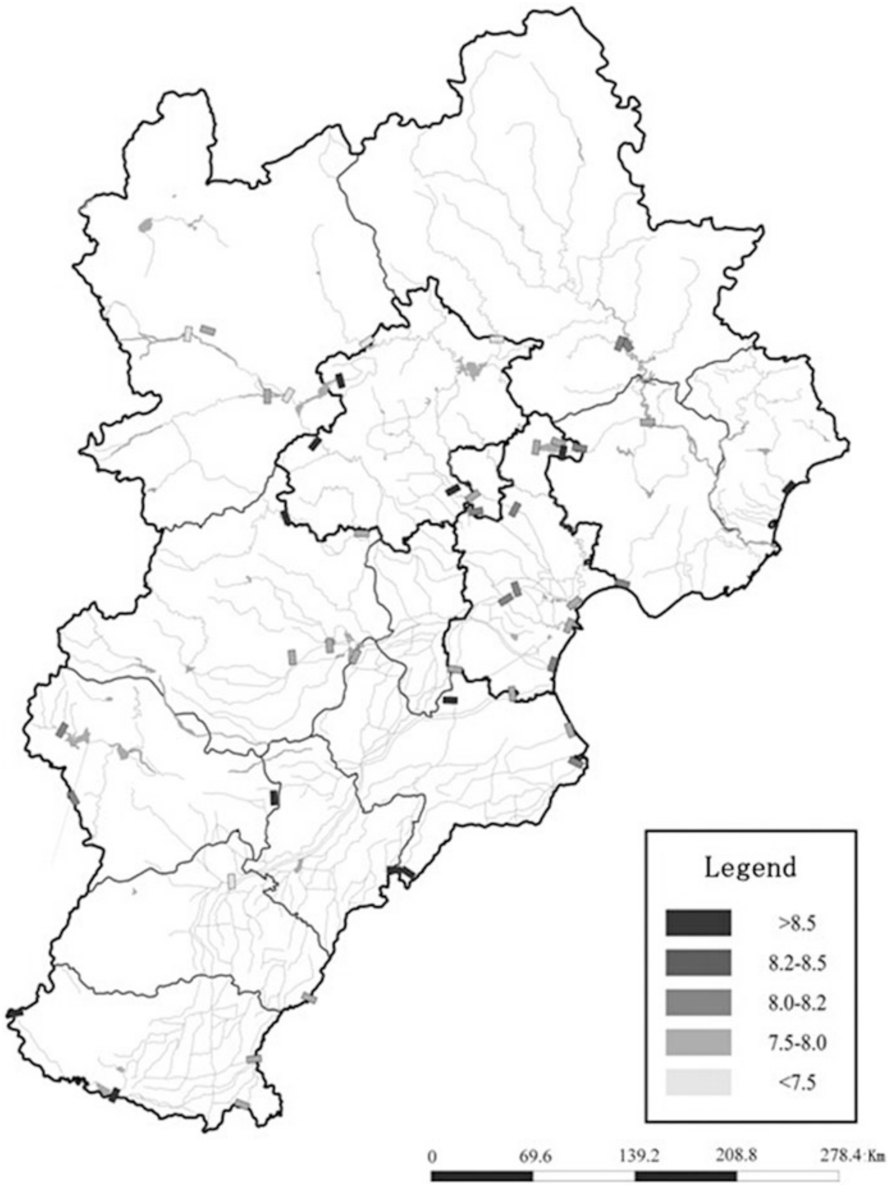

Fig. 12.17 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – PH value (2010) (Data source: the China Environment Yearbook 2011)

water quality remains in grade-II at the Daheiting Reservoir of Qianxi County, and water quality is grade-I at the branch where Liuhe River flows into Luanhe River. Superior water quality of Luanhe River also affects relevant rivers in Luan River diversion to Tianjin, such as Lin River, Li River, and Sha River, their water quality are

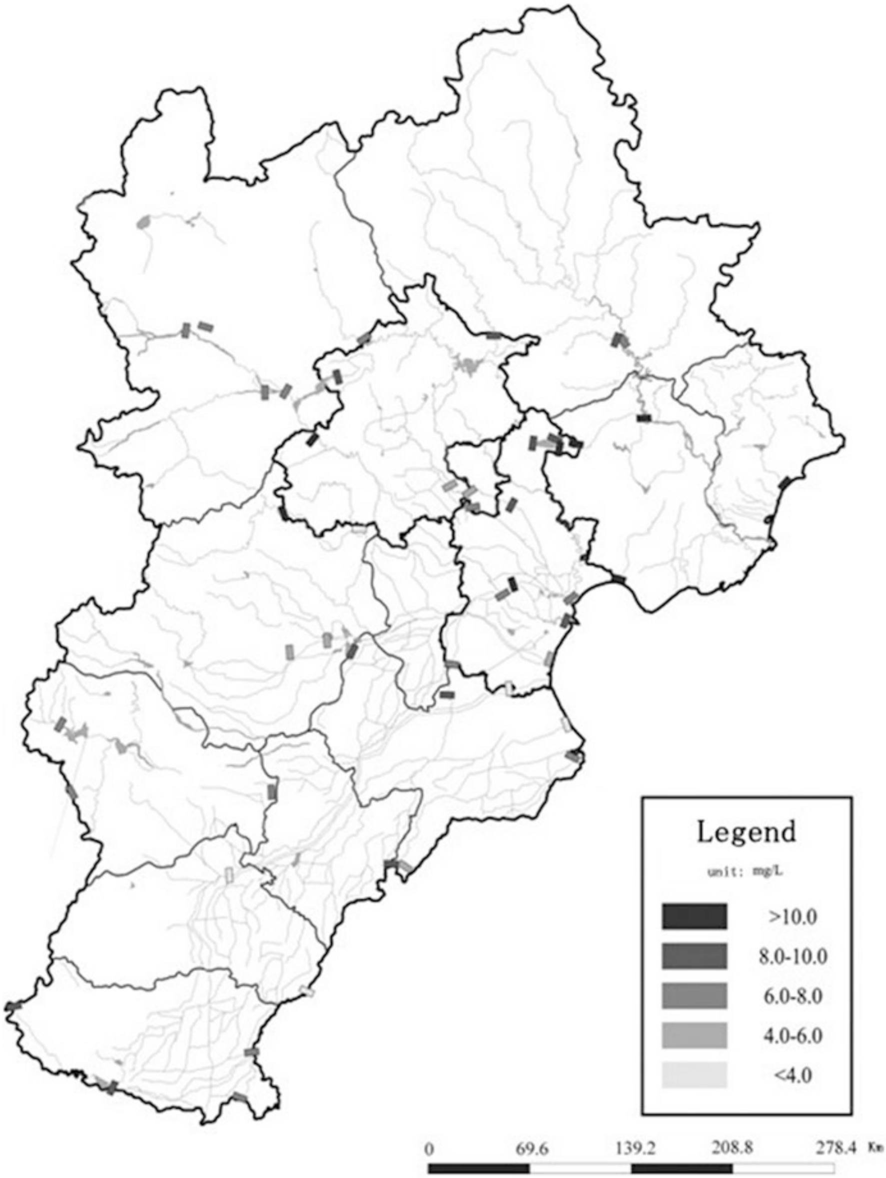

Fig. 12.18 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – dissolved oxygen (2010) (Data source: the China Environment Yearbook 2011)

good, and water quality is grade-II before entering Yuqiao Reservoir. In addition, due to Hebei province guarantees the requirements of water quality for Beijing, water quality of river sections is relatively good when the Yongding River, Chao River, Bai River, and Juma River enter Beijing, besides that water quality is grade-III when the Bai River enters Beijing, the rest is kept at grade-II.

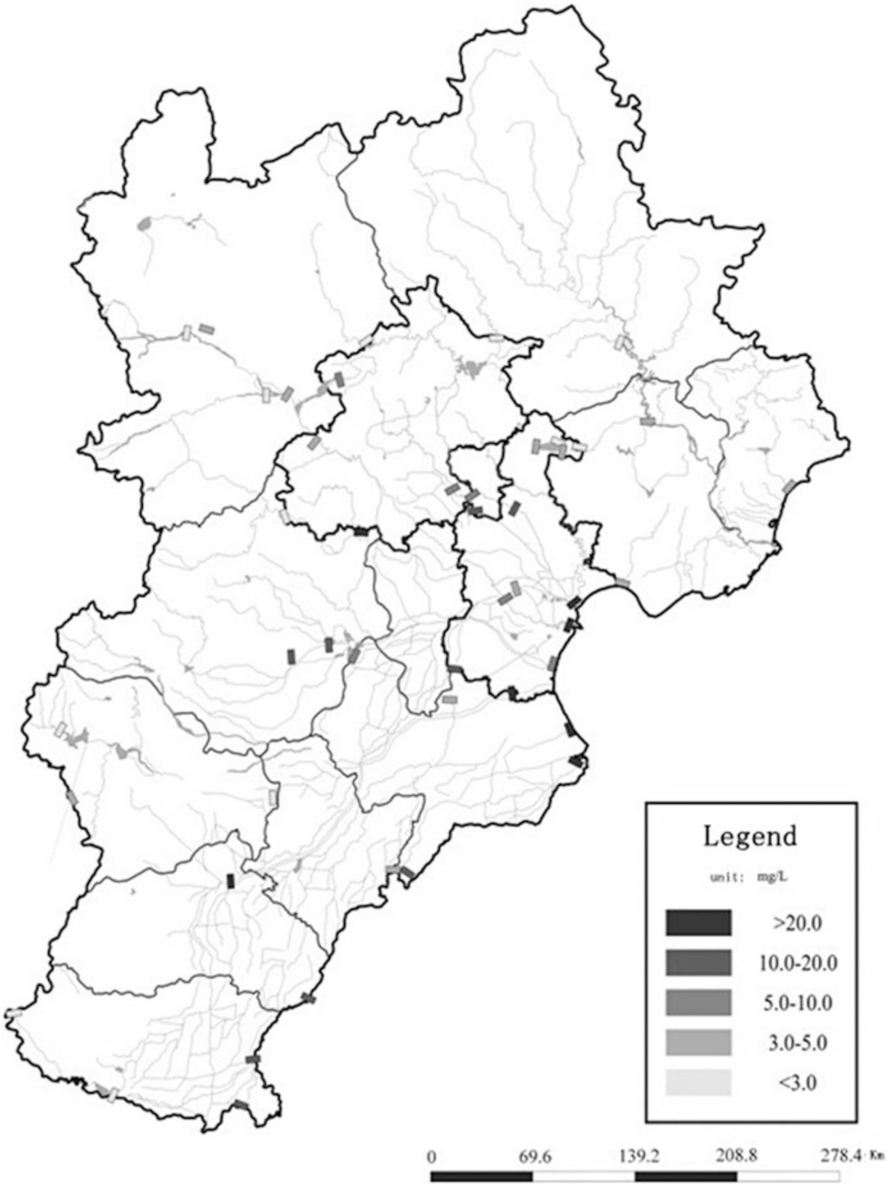

Fig. 12.19 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – permanganate index (2010) (Data source: the China Environment Yearbook 2011)

Except for Yang River in Zhangjiakou, most rivers are at moderate water quality, at grade-III, which is slightly worse than the Luanhe River water system on the side of Chengde, and water quality of the Yang River is grade-IV at the Zuowei bridge section in South Wanquan County. Water quality of Dou River and

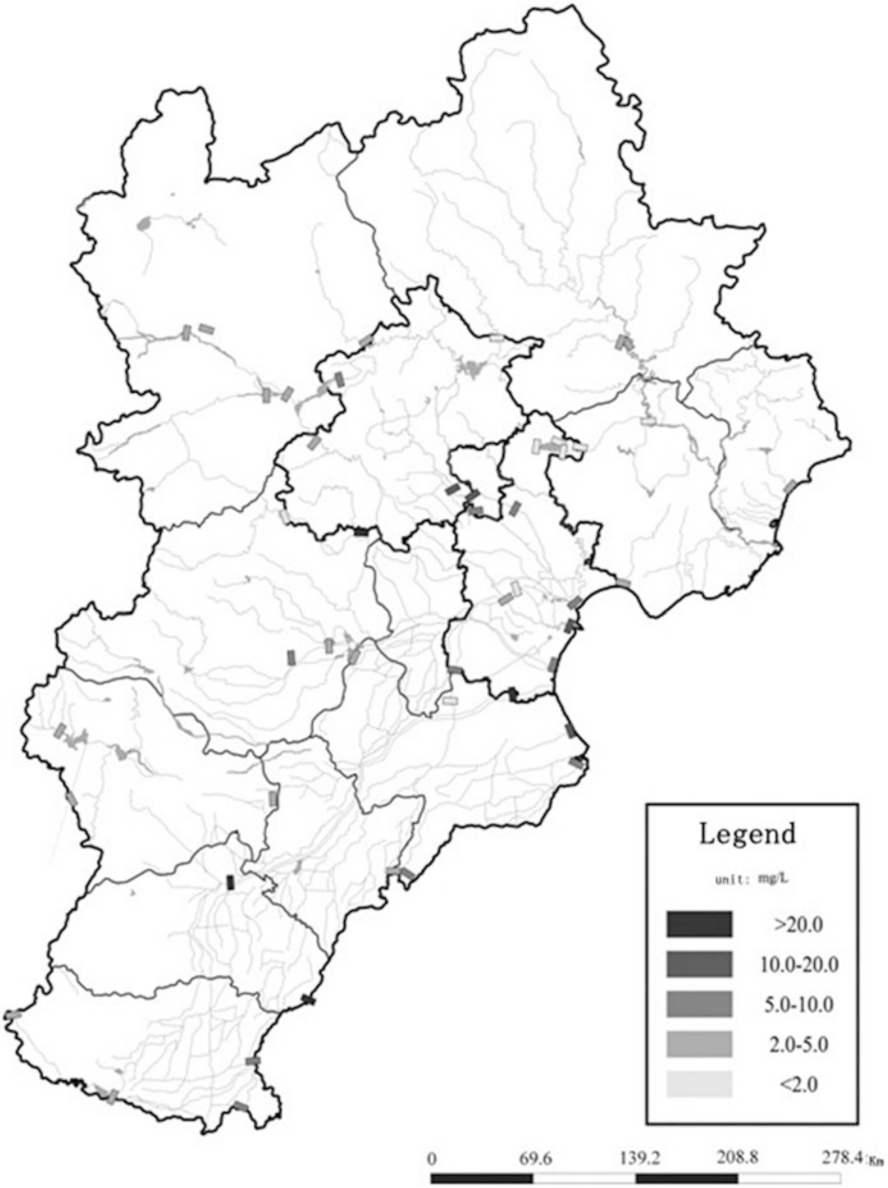

Fig. 12.20 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – BOD of 5 days (2010) (Data source: the China Environment Yearbook 2011)

other rivers in Tangshan and Qinhuangdao that directly enter the sea is also grade-III at the estuary. In Baiyangdian in Baoding, at the Haihe divergence of Tianjin and other famous scenic areas, water quality is kept at grade-IV.

Water quality of the Haihe River is not good in Tianjin, before passing through the new are of Binhai, including Heilonggang River, Duliujian River, Chaobai new river,

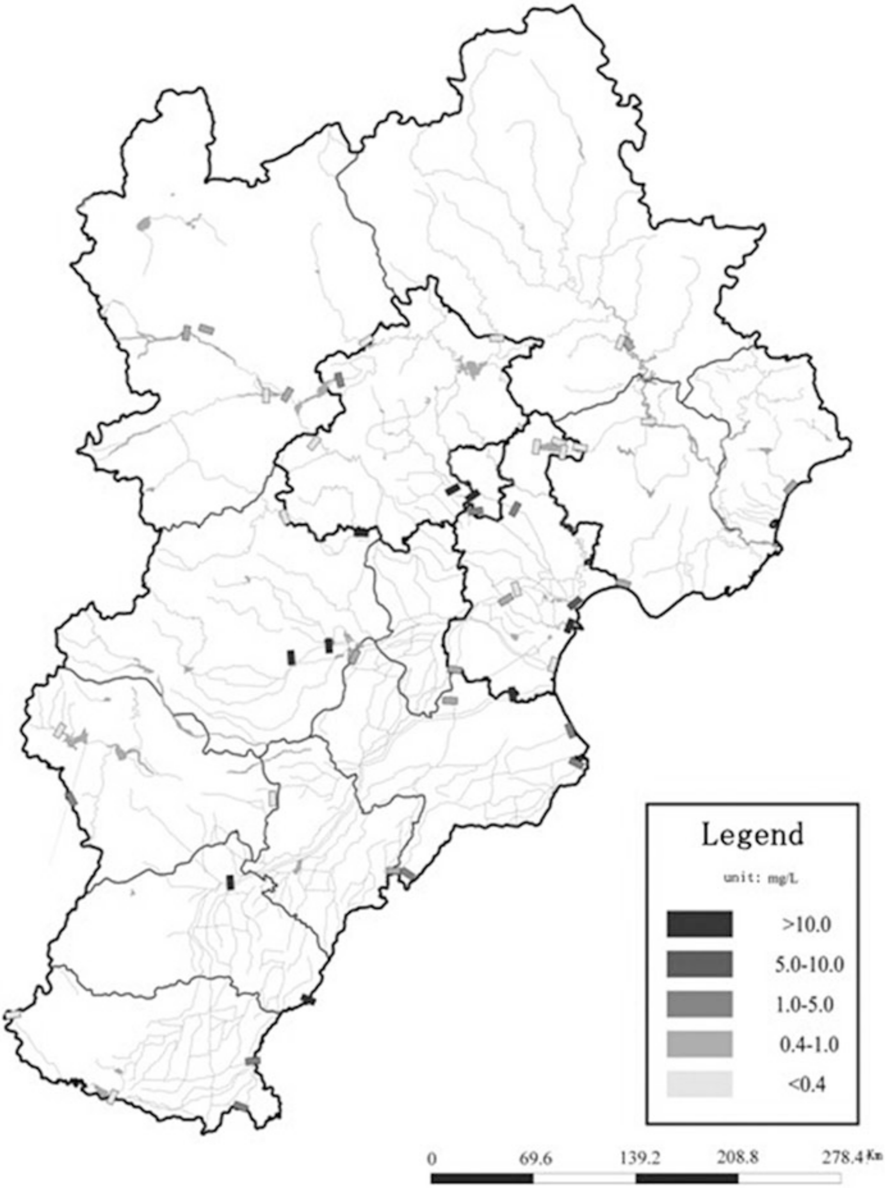

Fig. 12.21 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – ammonia nitrogen (2010) (Data source: the China Environment Yearbook 2011)

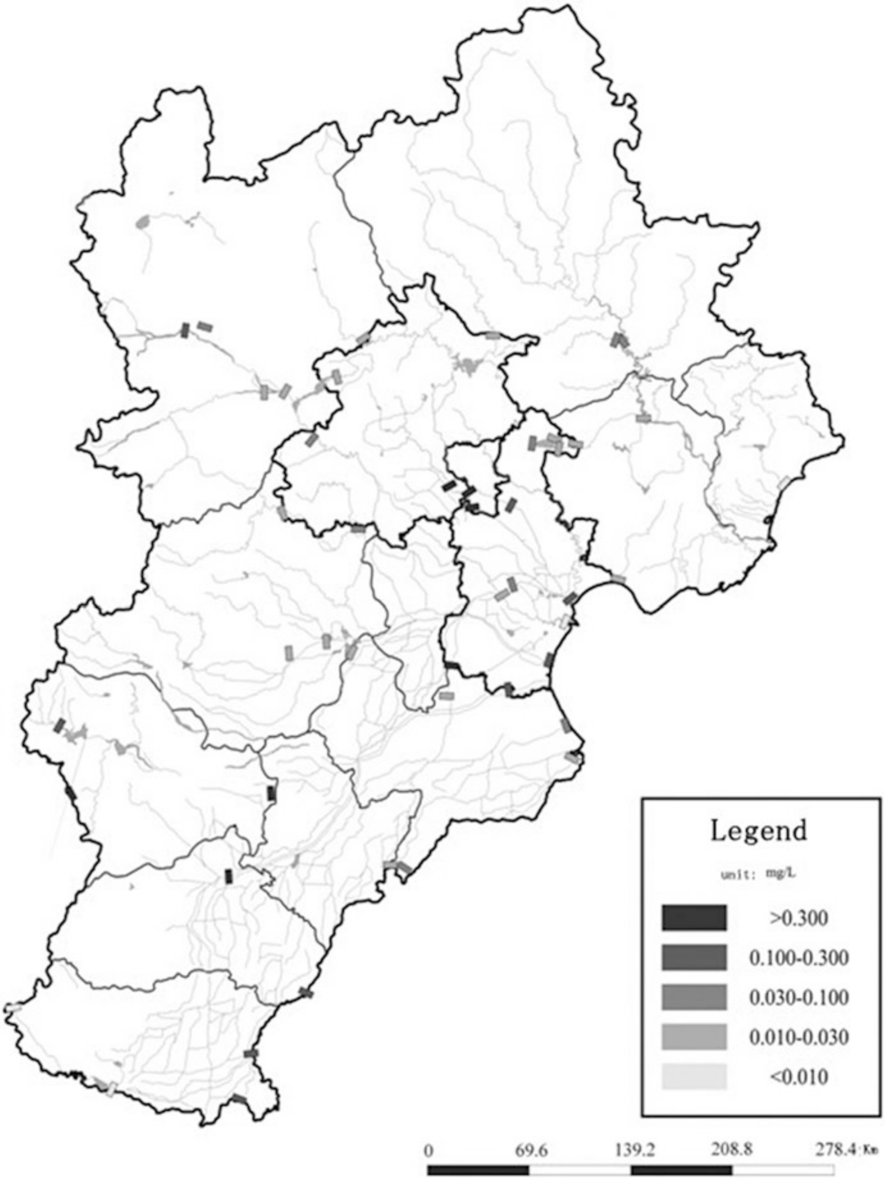

Fig. 12.22 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – oil class (2010) (Data source: the China Environment Yearbook 2011)

North Canal and other sections in Tianjin, their water quality is grade-V, and water quality of the Gui River in Yanqing is grade-V before entering the Guanting Reservoir.

River sections in which water quality is inferior grade-V are mainly found in Beijing, Tianjin, Baoding, Cangzhou, Xingtai, and Handan. For example, in Yulin village section of the North Canal in Beijing and Wangjiabai section of downstream

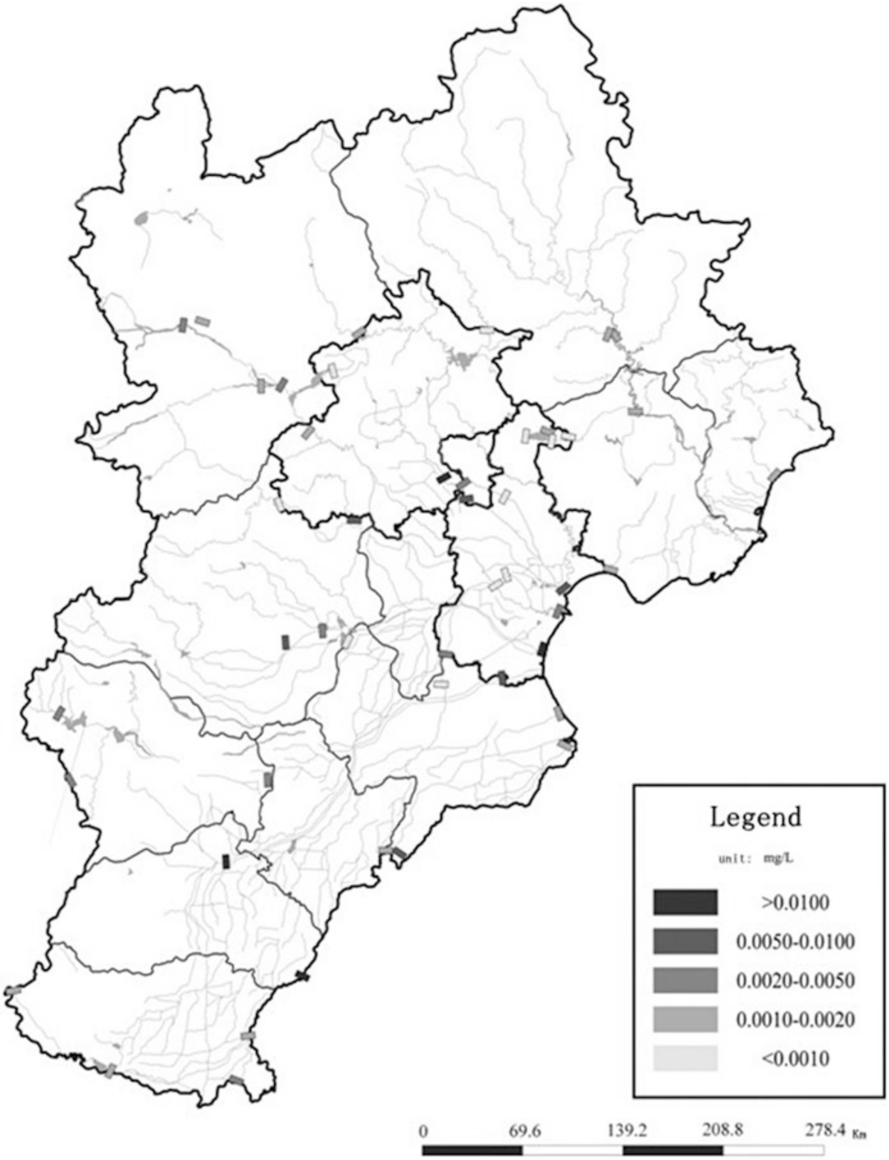

Fig. 12.23 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – volatile phenol (2010) (Data source: the China Environment Yearbook 2011)

Langfang, water quality is inferior grade-V. Water quality at the estuaries of Yongding New River and Haihe River in Tianjin is inferior grade-V. In two sections of Fu River that flow through Baoding City, water quality is inferior grade-V. Water quality of most of the rivers in Cangzhou is inferior grade-V when entering the sea or departing towards Tianjin, such as Nanpai River, Ziya

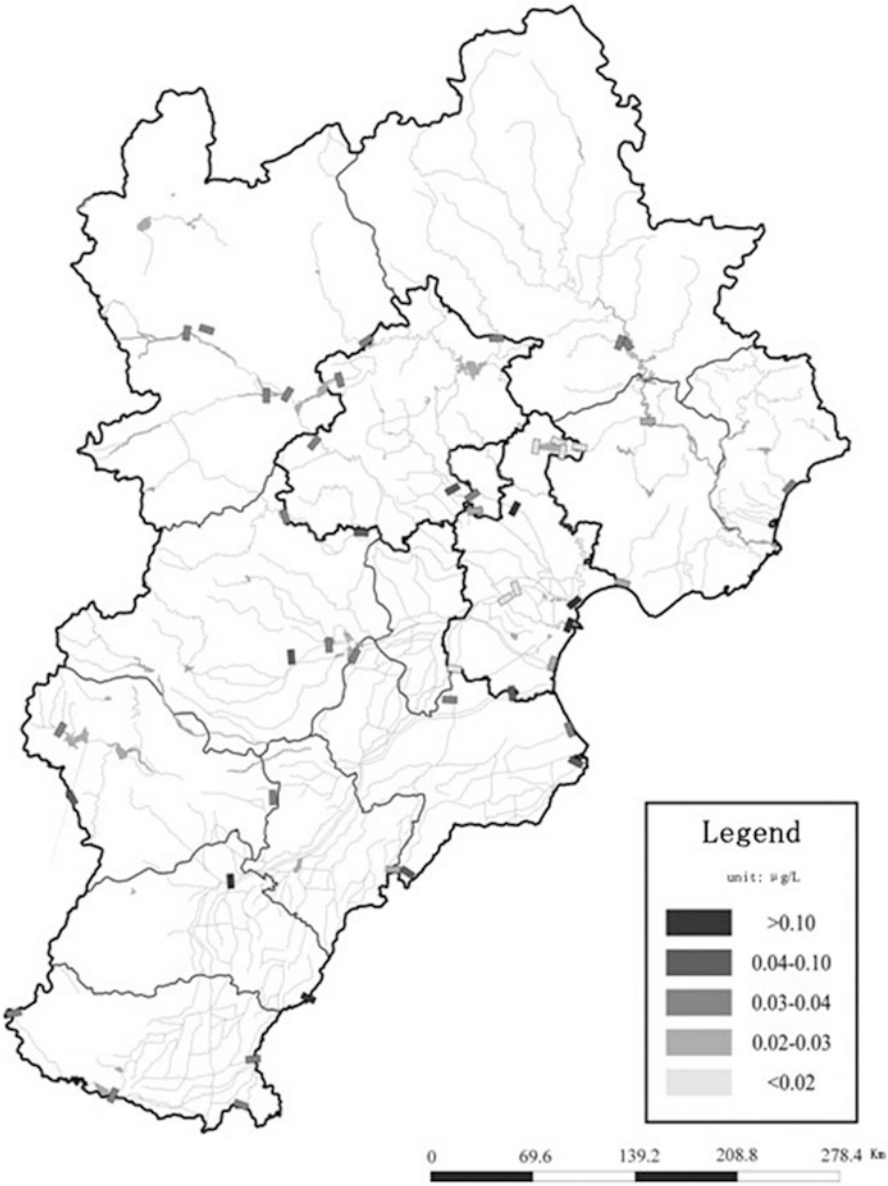

Fig. 12.24 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – mercury (2010) (Data source: the China Environment Yearbook 2011)

New River, and Xuanhui River; water quality in Dongsongmen section of the Cha River is inferior grade-V, but it is from Shandong province. In sections of Fuyang River and Weiyun River in Xingtai, water quality is inferior grade-V. Water quality of two sections of Wei River in Handan is inferior grade-V, but Dragon King Temple section is from Henan province (Figs. 12.27 and 12.28).

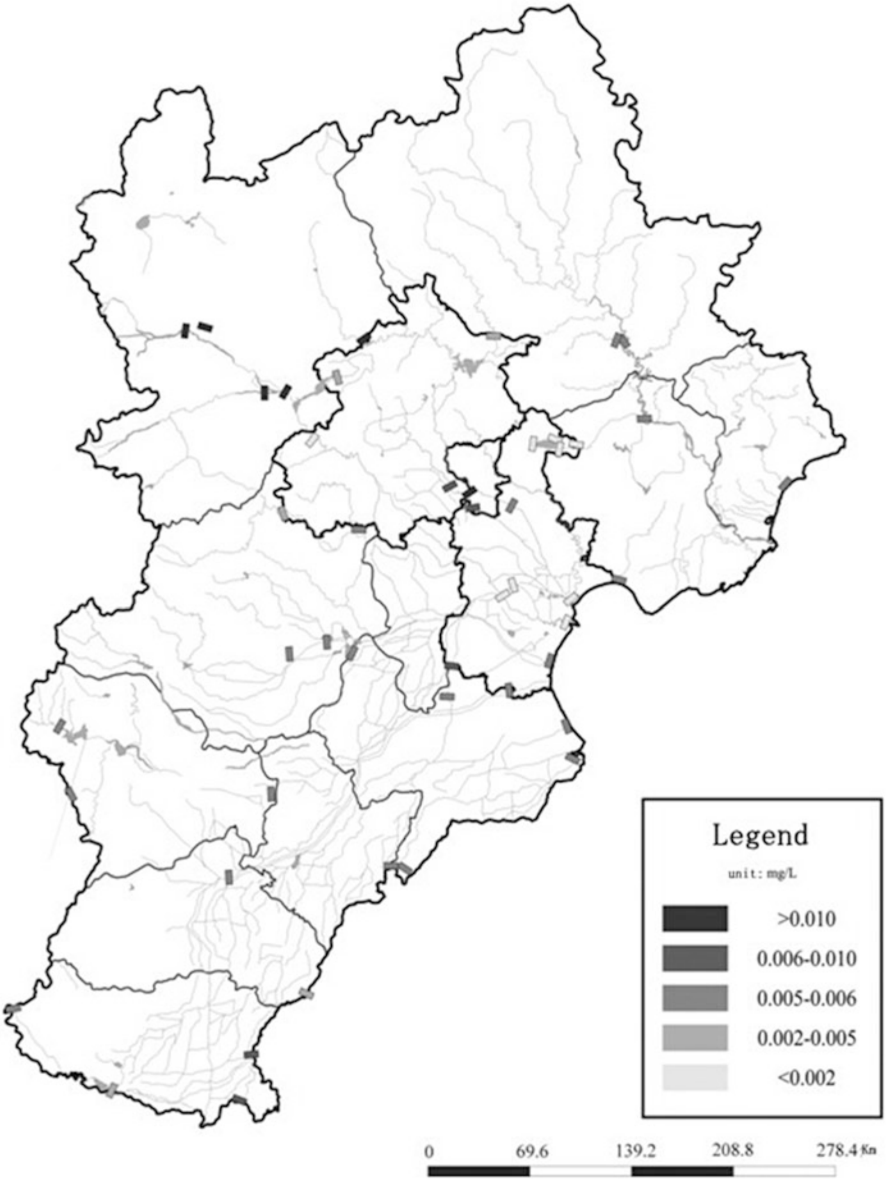

Fig. 12.25 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – lead (2010) (Data source: the China Environment Yearbook 2011)

Interpretation: at present, there are 18 state-level nature reserves in the Beijing-Tianjin-Hebei region, in which 2 nature reserves are in Beijing, 3 in Tianjin, and 13 in Hebei; there are 42 provincial or municipal-level nature reserves, in which 18 are in Beijing, 4 in Tianjin, and 20 in Hebei. Nature reserves

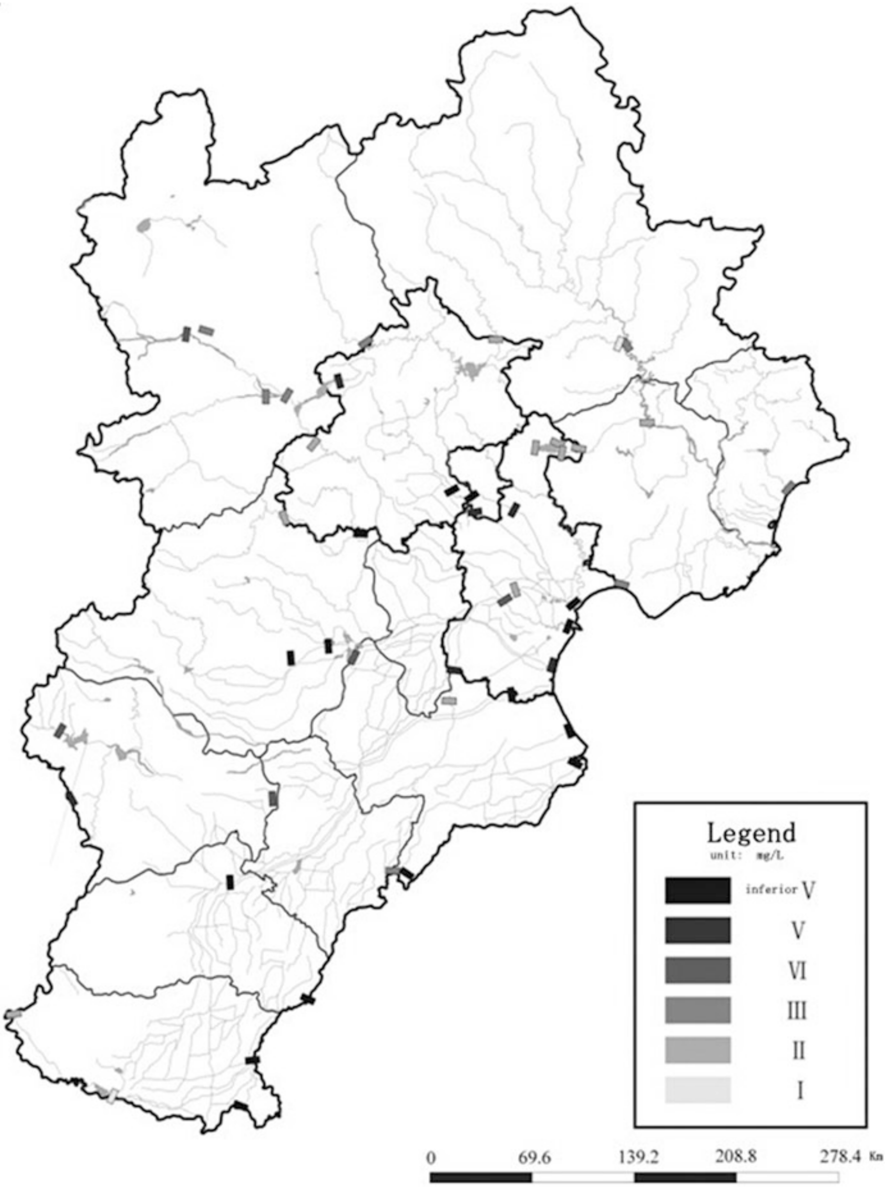

Fig. 12.26 Main monitoring indicator of state-controlled sections of the Beijing-Tianjin-Hebei rivers – water quality (2010) (Data source: the China Environment Yearbook 2011)

are mostly located in mountainous areas, and wetlands and lakes are mainly form in plain areas, and most are located in mountainous areas of the Yanshan mountain, and a few are located in the Taihang mountain and the Bashang plateau. Besides Langfang, Zhangjiakou, Hengshui, and Handan in Hebei

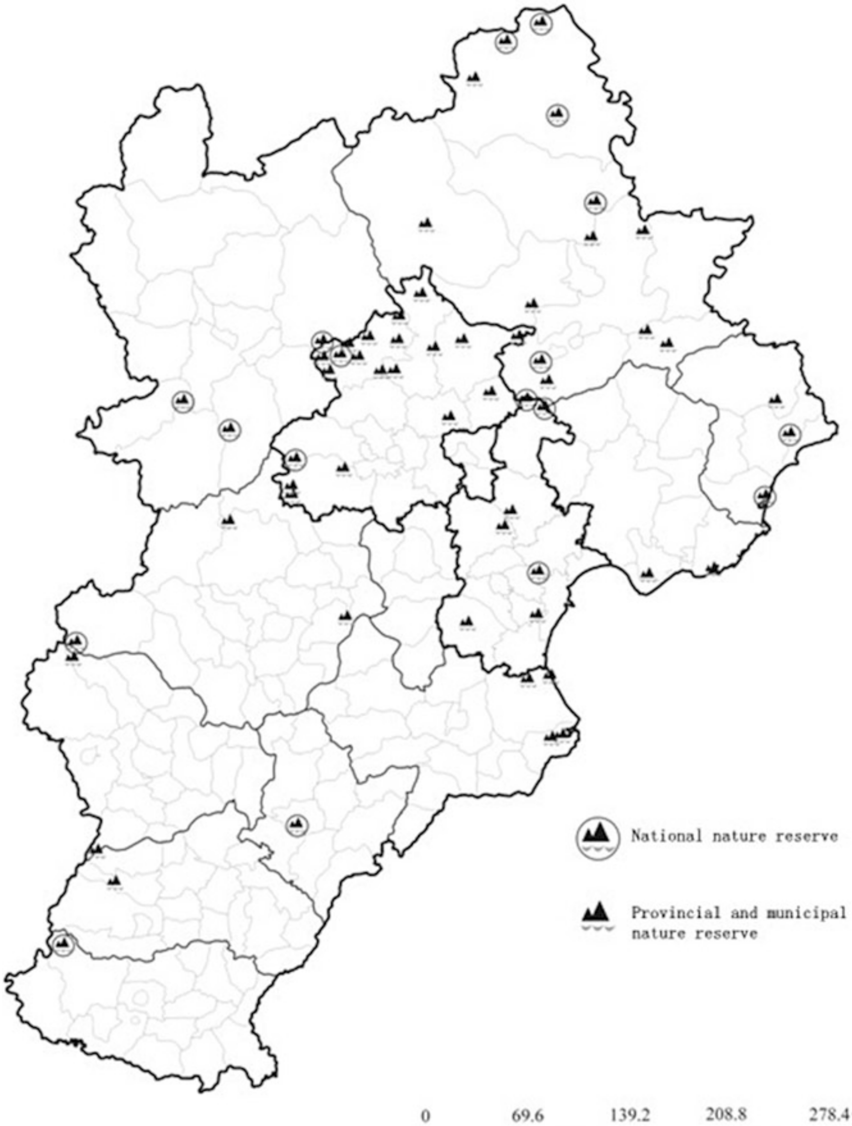

Fig. 12.27 Nature reserves in the Beijing-Tianjin-Hebei region

province, there are nature reserves in other areas and cities. As for Beijing, Tianjin, and other cities, nature reserves are basically distributed within a 2-h traffic radius around the urban core area.

There are 41 national forest parks in the Beijing-Tianjin-Hebei region, all are located in mountainous areas, in which there are slightly more in the Taihang

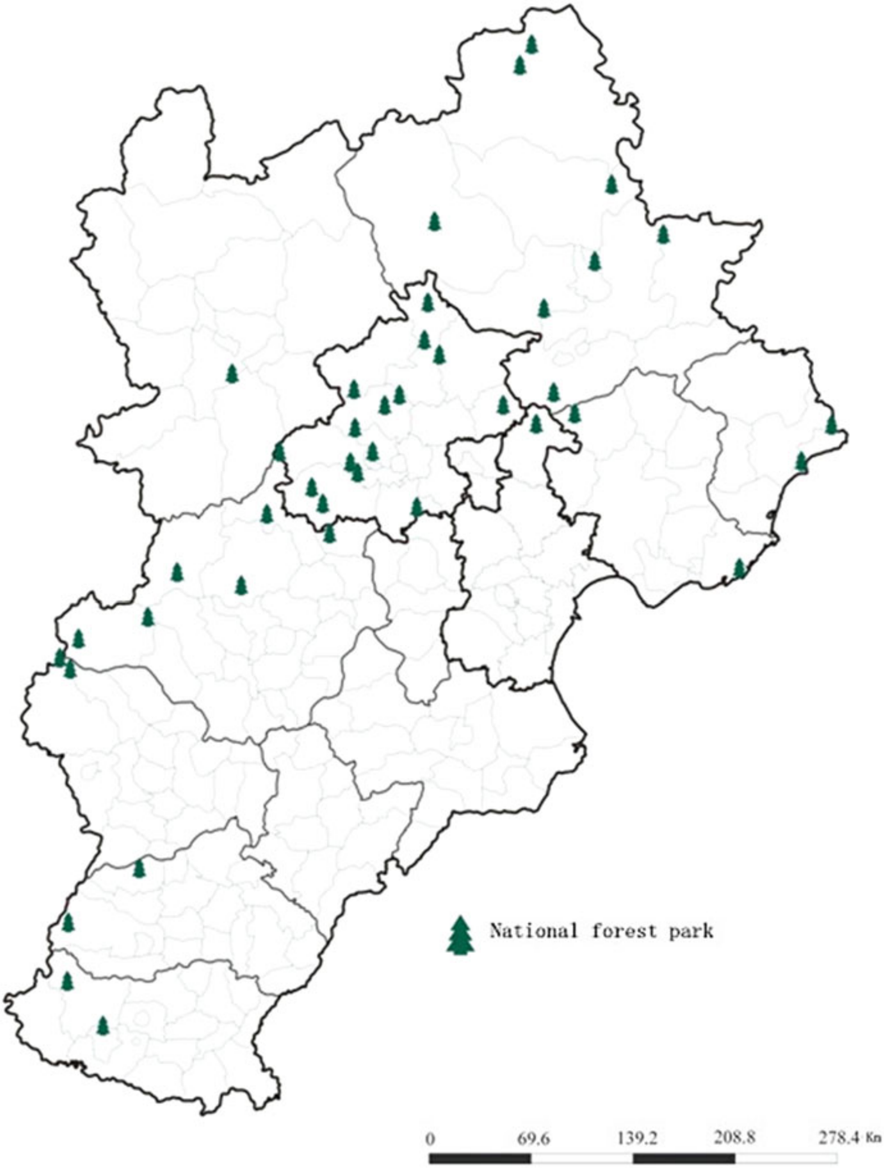

Fig. 12.28 National forest parks in the Beijing-Tianjin-Hebei region

mountainous area than in the Yanshan mountainous area, and some are located in the Bashang plateau. In the 41 national forest parks, 15 are in Beijing, 1 in Tianjin, and 25 in Hebei province, and none are in Langfang, Cangzhou, and Hengshui where the terrain is basically plains.

Chapter 13
International Experiences and Revelations on the Approach to Upgrading Carrying Capacity

Lichao Niu

Carrying capacity is the eternal proposition of regional economic and social development. Regional and urban carrying capacity not only concerns the future fate of the city, but also whether its peripheral areas can smoothly achieve the objectives of sustainable development and scientific development.

13.1 Regional and Urban Experiences and Acts of Upgrading Carrying Capacity Domestically and Abroad

13.1.1 Perfecting the Legal System, Guaranteeing Effective Execution of Measures

The system is a configuration system of urban resources and elements; the city governments change the cost of hardware elements use directly by price or other means through price law, energy law, environmental law, limited plastic order, and other policy systems, which can improve carrying capacity of unit hardware elements, and then improve urban carrying capacity.

In Japan, as an integrated fundamental law on environmental protection, legislation of Japan environmental law experienced the process from "Basic Law on Environmental Pollution Control" in 1967 to "Natural Environment Preservation Law" in 1972, then to "Environmental Basic Law" in 1993, and the legislative purpose developed from pollution control to protection of the environment as a whole, and the legislative purpose was continually deepened. Since 1993, Japan

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also enacted "The Container and Packaging Recycling Law," "Environmental Impact Assessment Law," "Home Appliances Recycling Law," "Promotion of Circular Society Fundamental Law," "Promotion Law on Effective Utilization of Resources," "Green Product Purchase Law," "Construction Waste Recycling Law," "Container Recycling Law," "Food Recycling Law," "Automobile Recycling Law," "Chemical Substances Control Act," and "Law for Recycling of Specified Kinds of Home Appliances," in which "Promotion of Circular Society Fundamental Law" posed suggestions in "promoting the circulation of materials, and reducing environmental loads, thereby seeking to achieve sound economic development, to construct a sustainable society." Japan established a unified integrated environmental fundamental law mode under the guidance of the viewpoint of the environment as a whole, and formed a healthy environment legal system through rational design of a progressive legal system.

In terms of the experiences of the European and American on governing PM2.5, European Union successively promulgated about 20 regulations and orders such as "Environmental Action Plan of the European Union" and "European Clean Air Plan," and formulated air quality standards, emission standards for motor vehicles and other pollution sources, the regional air quality monitoring and evaluation system and the national emission limit and verification system, which have formed a complete set of perfect regulation system for controlling PM2.5 pollution. In the United States, besides the regulations and standards that are applicable to all of America, there are local regulations as supplements. New York City released a series of local regulations such as Anti-idling Act according to local conditions, strictly stipulated that the engine idle running time cannot exceed 3 min after a vehicle stops. Close integration of local and national regulations has strongly promoted the governing work.

13.1.2 Good Planning, Focusing on Harmonious Development

In a sense, planning is the soul of urban and regional development. When doing urban planning, the departments concerned should reasonably determine areal and urban development scale, development goals, and development possibility on the basis of carrying capacities on resources and eco-environment of the city, and according to a city's economic and social development level, location characteristics, resource endowment and environmental basis, and other objective conditions. With overall and long-term interests in mind, a city should be reasonably and orderly planned and space resources should be configured in order to have efficient urban agglomeration and radiation to enhance the city's radiation and driving force.

We take land planning of Singapore as an example. Singapore had a two-stage system of development planning: strategic concept planning and enforceable development guide plan concept. Land and traffic planning blueprints were mainly drafted. Based on this general principle, overall planning blueprint and statutory documents of controllable detailed planning are formulated. In this blueprint, public supporting facilities for population intensive and non-intensive areas, traffic network, and industrial layout were clearly marked and had a detailed budget. Vertically, the blueprint considered to what degree each area would develop each year, and in each small block, even the floor area ratio was detailedly stipulated. Concept plan is the long-term comprehensive development plan of Singapore. It was formulated according to Singapore's long-term development strategies, which has overcome the characteristics of static blueprint for overall planning, which has provided the basis for periodic revision of overall planning.

As another example, Kitakyushu, Japan began construction of its eco-city from 1980s. Its specific planning included construction of the environment industry (the construction included integrated environment industry zone for recycling and reutilization of home appliances, waste glass, and waste plastic), development of new environmental technology (the construction of research center based on development of new environmental technology and practice research on technology developed), social comprehensive development (construction of basic research and education base based on training talents in terms of environment policy and environment technology).

13.1.3 Strengthening the Management System, Rationally Dividing Responsibilities and Rights

Management system refers to management strategies, management policies, management systems, management levels, and management efficiency of the urban subjects, such as energy, water sources, infrastructure, environmental protection, and other management means, methods, and measures; it affects and restrains use and utilization efficiency of urban hardware elements, thus affects changes of its carrying capacity. By perfecting the management system, the urban carrying capacity can be increased so that the city can maintain sustainable and healthy development.

As an important safeguard of urban construction, foreign cities also gained extensive experiences on the management system. For example, Australia's famous eco-city, Halifax, in recent years integrated organizations of political circles, construction, forestry, mining and energy, nature protection organizations, and enterprises, such as South Australia gas company, heritage preservation committees, and other forces into its eco-city construction activities to guarantee the favorable development of eco-city planning and construction project that was well under way.

Utilization of urban rainwater resources falls within the scope of development and management of water resources, and specific implementation needs the cooperation of many sectors such as that of urban construction, municipal administration, architectural design, and the environment. Experiences and practices of Germany are that, water affair department makes unified management for all matters regarding rain water, formulates corresponding policies and specifications on rain resource using engineering construction and operation, and makes unified coordination and management from the two levels of functional department management and project management of city rain resource use; formulates rain use development planning, and has effective management and supervision of rain projects, demonstration, program review, design approval, and construction supervision; makes program evaluation, design prescription, construction and verification, operation and maintenance to rain resource use projects, and operates by the market economy mode, and is subject to social supervision.

Singapore's city management system emphasizes the idea of people-oriented, service first and guaranteed by law. Singapore's good urban governance effect profited from its sound legal system and strict enforcement environment to a large extent, and established a complete set of a strict, specific, careful, realistic, and operable legal system for urban management. Singapore made specific provisions on the urban building billboard, landscaping, and flue gas emission, and supervisory contents and approaches, as well as punishments, were regulated. Based on a sound legal system, Singapore formulated the penalty system covering all aspects of urban management, with numerous items that can be penalized, with a large penalty, and strict enforcement.

13.1.4 Promoting the Transformation of the Economic Pattern by Economic Means

Advanced cities and regions change the development mode of traditional capital-led, consumption of resources, extensive management by economic means, and achieve an upgrade of regional carrying capacity through developing the circular economy and optimizing the industrial structure.

For example, Tokyo moved manufacturing enterprises to the Yokohama area and even abroad, and focused on trial research and development of new products, made great efforts developing knowledge-intensive "new and high-tech" industries, and transformed "volume production factories" into "factories for research and development of new products" to gradually occupy the high-end industry chain value, which not only maintained Tokyo's fast economic growth for 30 years, but has also largely improved air and environment quality in the Tokyo area. In addition, various types of air pollutants such as PM2.5 are mainly from primary and secondary products of coal, oil, and other fossil fuel combustion and emissions. To reduce the emission of pollutants, various countries make great efforts to change the structure of energy consumption, and to increase use of clean energy. In 2009, Japan formally listed the development of solar energy in Japan's economic stimulus plan for the first time. London adjusted energy supply and distribution layouts, promoted distributed energy supply mode, and replaced a part of state grid-supplied electricity by the combined heat and power system in London and small renewable energy installations (wind and solar energy).

13.1.5 Strengthening Infrastructural Construction, and Increasing the Supply Capacity of Public Products and Services

Urban carrying capacity and sustainable development capacity are dependent on supply capacity of public goods and services to a large extent. Improving traffic facilities, social housing, hospitals, and other infrastructures play a huge role in accelerating social and economic activities, promoting spatial distribution evolution, and enhancing urban integrated carrying capacity. The municipal authorities should establish perfect infrastructures, particularly putting emphasis on the construction of public transportation, enhance traffic efficiency, strengthen the underground pipeline network facilities and the development and utilization of underground space, increase marketization reform strength of municipal utilities, and fully play the basic role of market allocation resources, thereby to increase the supply capacity of public products and services.

Guiding urban development mode by construction of public traffic infrastructure is considered to be successful urban development mode, namely the public traffic system is regarded as the skeleton of urban development to lead orderly expansion of a city along the public transportation routes, and to avoid the disorderly spread of urban space. At the same time, public transportation development mode is conducive to meet the trip demands under high-density land development, can enhance community vitality, effectively control and guide the development of automobiles, and improve the urban environment. As Copenhagen of Denmark has successfully constructed a city of radial development using mass transit system under the guidance of overall urban planning, it has more than 300-km-long bicycle reserved lane which is as wide as the road for motor vehicles, there are many “car parks” in the city, more than 2,000 free bicycles park in each “car park” for pedestrians, and one-third of citizen in the city choose to ride a bike to work.

Curitiba of Brazil is a recognized model city of public transportation, the city carried out high-density linear development along five major traffic axis, and transformed the inner city following the principle of priority development of public transportation and pedestrian traffic. Currently, 75 % of the population trip by bus in the city, and the city saves seven million gallons of fuel every year.

13.1.6 Optimizing Spatial Layout, and Increasing Land Use Efficiency

Scarcity and limitation of urban land utilization can promote or restrict urban development. Urban land carrying capacity can directly decide whether urban economy and society can have sustainable development. City builders domestically and abroad have recognized the hazard brought about by urban willful spread and loose spatial organizational structure, thus they advocate for a "compact, high-density, cluster form" urban development mode. The general choice of city managers to achieve sustainable development of a city is to pay attention to optimization and integration of urban agglomeration, comprehensively promote harmonious development of large, medium, and small cities and small towns, simultaneously handle well the relationship between urban and rural unified development.

Foreign proposed urban–rural mode is a typical mode of a compact city. Urban–rural mode is a compact neighborhood mode with mixed functions in favor of walking, and is a community mode of rural small town with multi-culture and natural characteristics. In small rural towns, walking and cycling can meet all demands, compact mode is an ideal urban development mode in view of suburbanization urban development mode of infinite expansion and spread. For example, Chiba of Japan highly respected original natural landforms in their planning, and carefully planned lakes, rivers, and mountain forests in urban areas; these elements were closely integrated into the public facilities for exchange activities, and were accompanied by the appropriate landscape design to form dozens of open parks of different sizes and various landscape features evenly distributed in the urban area.

13.1.7 Avoiding the Short Board Effect, Playing Urban Integrated Carrying Capacity

Integrated carrying capacity can be divided into actual urban integrated carrying capacity and potential urban integrated carrying capacity. Actual urban integrated carrying capacity can be determined based on the "Barrel Theory," namely actual urban integrated carrying capacity should be determined according to actual carrying capacity of the minimum term in single resource and development conditions of the city. Potential urban integrated carrying capacity should be determined on the basis of measurement and calculation of the carrying capacities on single resource and development conditions, taking measures, and improving the carrying capacities of one or several urban resources and development conditions with small carrying capacity during a period of time, namely increasing the length of some short boards. In this case, the urban integrated carrying capacity in future period of time is determined according to corresponding demand standards.

For example, water resource has become the development short board of many cities in the world, therefore, how to improve the utilization ratio of water resources and avoid the short board effect have become very important subjects. In Germany and Japan, they respectively encourage citizens to use rainwater utilization technology through levy of rainwater drainage charges, subsidy system, and other economic means. Cities in Germany formulated standards for rainwater drainage charges (also called as pipeline fees) according to the provisions in the ecological law, the water law, and the local administrative costs management regulations, and calculated receivable rainwater drainage charges based on annual rainfall and impervious surface area owned by owners. If citizens implement rainwater utilization technology, the government will no longer levy drainage charges on the owners. Japan carries out subsidy system for rainwater utilization. For example, Sumida-ku of Tokyo began to establish Sumida-ku subsidy system for promotion of rainwater utilization in 1996 to give some subsidies to underground rain storage devices, medium and small rain storage devices.

13.1.8 Strengthening Technical Support, Upgrading Use Efficiency of Resource Environment

Technology is the reactor for urban resources and elements to have multiple effects, urban technology can produce a multiple carrying capacity while fusing in other urban hardware, is the decisive impetus of urban carrying capacity, such as water purification and water-saving technology, development and utilization of nuclear energy, land development and utilization, and planning and adjustment of infrastructure, which all have directly affected and changed urban integrated carrying capacity. Foreign countries always place technical development and research on strengthening ecological environment in an important position in urban construction, choose the key breakthrough domains required to brainstorm for scientific research, and industrialize them as soon as possible. For example, in the eco-city construction, Kalundborg of Denmark regarded eco-industrial park construction as the breakthrough point to strenuously develop resource alternative technology, resource recovery technology, resource consumption reduction technology, harmless treatment technology, and waste recycling technology, and supported related industries to construct industrial chain of circular economy to form an industrial symbiosis system, which has laid the important industrial bases for eco-city construction.

In the 1990s, Kyushu of Japan began eco-city construction to reduce waste and to achieve a circular society, and emphatically proposed the assumption of "areal waste zero emission." To this end, in 1997, Kyushu city set up a special center for waste recovery processing and recycling technology research, and sped up its industrialization process through more policies that encourage and support its cause.

Germany's technology of urban rainwater utilization has gone through three major changes from the 1980s to the present, the release of standards for rainwater utilization facilities in 1989 marked the matureness of "first generation" of rainwater utilization technology, and currently rainwater utilization technology is at the stage of development of "third-generation" equipment integration after the automatic control technology was upgraded in 1992. After development for many years, the rainwater utilization technology has entered the stage of standardization and industrialization. United States emphasizes development and application of non-engineering ecological technology in urban rainwater utilization processing technology, and even more so emphasizes the ecological design integrated into the plant, greenbelt, water, and other natural conditions and landscape in the second generation "Best Management Practice" (BMP) for urban rainwater resource management and rainwater runoff pollution control, such as vegetation buffer zone, shallow trenches for plants, and wetlands, to obtain multiple benefits in environment, ecology, and landscape. The surface water infusion system composed of roof water storage and infiltration pond, well, grassplot, and permeable ground has been largely applied.

13.1.9 Paying Attention to Disaster Mitigation and Prevention, Improving the Ability to Withstand Risks

Human factors such as environmental pollution and industrial accident, and natural disasters, such as earthquakes, can affect urban safety and normal operation of the city. Improving the management quality of urban public crisis decision-making ability, preparing for disaster mitigation, and implementing rescue relief, establishing and perfecting early-warning and forecasting mechanisms, and improving the capacity to respond to emergencies and to withstand the risks can also maintain sustainable carrying capacity of the city.

In terms of shock resistant, big cities of some developed countries (such as San Francisco and Los Angeles of the United States on the San Andreas fault in California, and Japan Tokyo earthquake circle, and the Osaka-Kobe seismic belt) have formed collaboration between shock resistant and disaster prevention personnel and city planning personnel, and jointly takes measures to reduce casualties, property loss, and the impact on society and economy caused by future earthquakes under the guidance of government, which has had actual effects. It was estimated that disaster loss reduced by 50 % in the 7.1-magnitude Los Angeles earthquake on January 17, 1994. While implementation of measures on disaster reduction, the city needs to keep social and economic sustainable development, in which the practices of various countries are different. For example, Japan enhances building aseismatic capability, quake resistant exercises, and fast communications and transportation, and effectively uses underground space; Mexico reserves city communications system, and uses underground space; the United States rectifies the urban environment (land use, and active fault survey), improves mode of construction, enhances aseismatic effect, strengthens the earthquake early test system, quickly responds for rescue relief, and guarantees the transportation system.

Under promotion by the United Nations, various countries have gradually brought the task of disaster prevention and mitigation into the strategy target system for urban development to carry out relevant legislation and organization building, and establish the disaster prevention and mitigation system including mechanism design, fund safeguard, technology support, and other contents. In Australia, the Federal Government cooperates with government agencies at all levels to implement all kinds of projects regarding prevention and control of natural disaster risks. It is observed that, in the design of the entire mechanism, the importance of implementation of measures on disaster prevention and mitigation in advance is progressively evident, and ensuring the validity of disaster prevention and mitigation activities by economic methods has also become a necessary link.

13.1.10 Advocating Voluntary Actions and the Whole Population's Participation in Environmental Governance

Urban residents' social consciousness, ethics, culture, habits, and customs may directly affect the use of urban hardware elements of the carrying capacity, thus changing the urban carrying capacity. The consciousnesses of order, saving, and morality in the urban environmental system, urban traffic system, common service facilities, energy and water source system are different, which directly affect the service life, capacity, and efficiency of these urban infrastructures, thereby constraining their carrying capacity.

In the process of foreign urban construction, the governments encouraged broad public participation as much as possible, whether in formulating the planning program, implementing the construction projects, or subsequent supervision and monitoring, all had specific measures to ensure broad public participation. Enhancement of the carrying capacity of a city is on the basis of the public environmental education and the cultivation of social and environmental sense of responsibility. One experience on eco-city construction in Kitakyushu of Japan was to carry out publicity activities at various levels to enhance the public's consciousness of environmental protection. Montreal of Canada called on people to participate in waste recycling activities using advertising shirts, calendar cards, notebooks, and bus and other carriers. The successful bidder of Whyalla eco-city advisory project in Australia gave publicity to Whyalla eco-city project on various occasions, frequently disseminated contents and significance of Whyalla eco-city project in elementary and high schools. Implementation of these projects has laid a foundation for the upgrade of urban carrying capacity.

13.2 Building the Path System for Upgrading Regional and Urban Carrying Capacity

Regional and urban integrated carrying capacities are complex issues that may change over time and as space conditions change. This has two meanings: on one hand, as for carriers, urban carrying capacity should not be limited to hardware only, but should also contain generalized carrying capacity on culture, policy, system, spirit, and learning; on the other hand, due to the problem that carrying capacity is caused by human social and economic activities, the target of urban development is the harmony between human social and economic activities and the corresponding environment, and is protection and improvement to the resources for human survival development, therefore the carrying object should be various human social and economic activities. Therefore, the path of upgrading regional and urban carrying capacity is not singular or static, but there includes many angles, is multi-level and dynamic. Through domestic and overseas experiences on upgrading regional and urban integrated carrying capacities, this paper establishes the path system for upgrading regional and urban carrying capacities, as shown in Fig. 13.1.

To upgrade regional and urban integrated carrying capacities governments, enterprises, social organizations, and residents need to participate. In particular, social organizations, social enterprises, and individual should be encouraged towards innovation behaviors and important practices in terms of upgrading urban carrying capacity; social organizations, business organization, and government organizations should be encouraged towards active cooperation in public services and urban governance, and social organizations and social enterprises should be encouraged to apply emerging science and technology to provide public services for urban residents.

Path measures on upgrading regional and urban integrated carrying capacities mainly include perfecting the legal system, guaranteeing effective implementation of measures; planning well, paying attention to harmonious development; optimizing spatial layout, enhancing land use efficiency; avoiding short-board effect, playing integrated carrying capacity; strengthening technological support, upgrading utilization efficiency of resource environment; paying attention to disaster mitigation and prevention, enhancing risk resistance capacity; advocating voluntary action, and the whole population's participation in environmental governance;

Path measures on upgrading regional and urban integrated carrying capacities mainly affect the integrated carrying capacity through software and hardware. The software carrying capacity includes cultural carrying capacity, system carrying capacity, management carrying capacity, and carrying capacity on science and technology. The hardware carrying capacity includes environmental carrying capacity, land carrying capacity, carrying capacity on water resources, infrastructural carrying capacity, and energy carrying capacity. Upgrading of carrying capacities on software and hardware can necessarily promote the upgrade of regional and

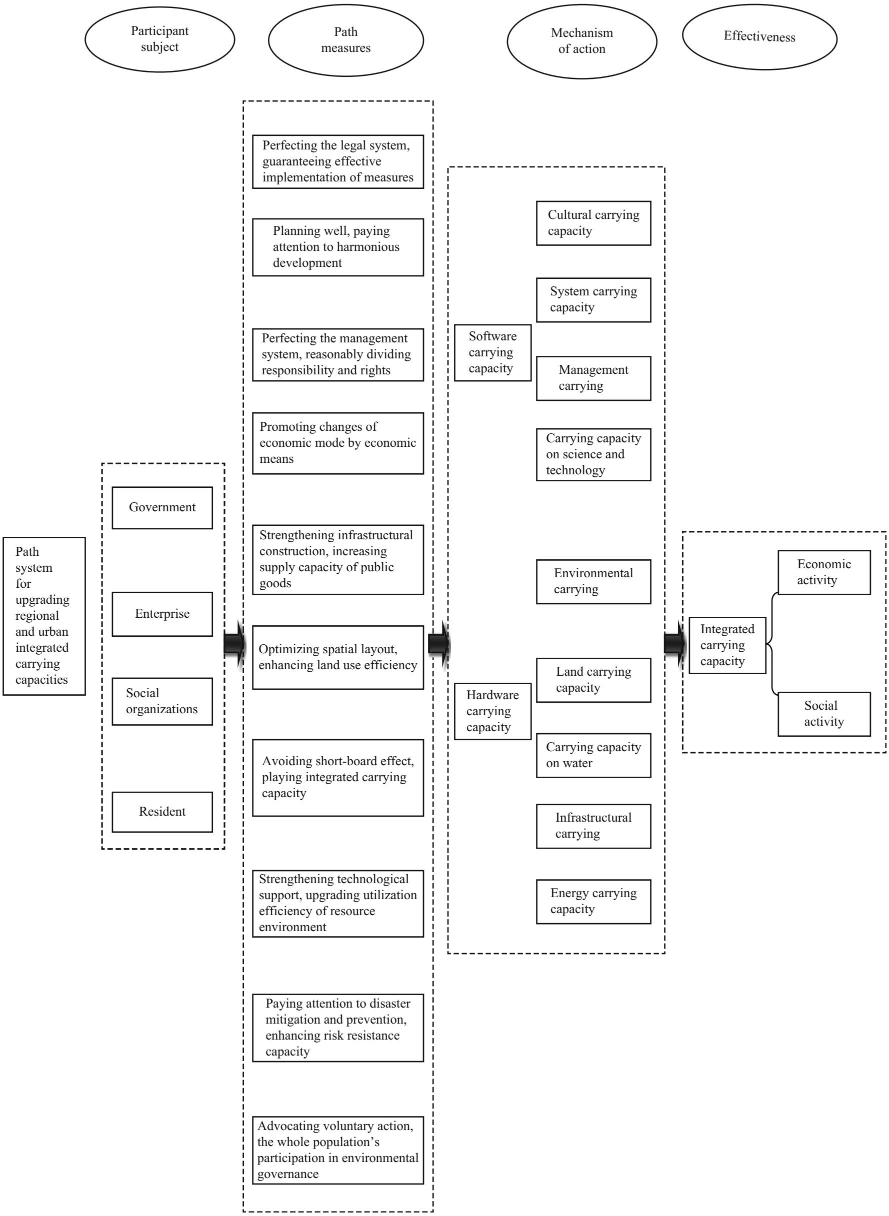

Fig. 13.1 Path system for upgrading regional and urban integrated carrying capacities

urban integrated carrying capacities, so as to improve the quality of human economic and social activities, and to enhance core competitive power of regions and cities.

13.3 Revelations on Upgrading Regional and Urban Carrying Capacities

At present, China's urban carrying capacity is tight, and the potential space of carrying capacity on various urban elements is small; if China continues in its original extensive development mode, it will be difficult to maintain sustainable development of the country. Through summary of path and practices of developed countries and cities to cope with the difficult position of integrated carrying capacity, we have the following revelations.

13.3.1 Reducing the Load of Carrying Capacity by Optimizing Structure and Changing Mode of Growth

High power-wasting industries should be encouraged to upgrade and change generation into low power-wasting industries so as to gradually reduce the energy and water consumption per unit output value. Resource consumption and waste emissions per unit economic output should be strongly reduced so that the consumption of land, energy, water, and other mineral resources per unit economic output can be reduced.

The principles of industrial agglomeration, layout concentration, and intensive land use should be adhered to in order to reasonably and frugally utilize the land, to optimize urban spatial layout, to tap into the latent power of the land used for the old city, and to promote the revitalization of old city zones relying on location, social conditions, and other factors of the old city zones, so as to enhance the vitality and attraction of the old city, and to strengthen the land carrying capacity in the old city.

According to regional differences of land development intensity, the authorities should guide the rational distribution of the population, reform the household registration system and the land system, establish the social security system for peasants working in the city, rightly guide the urbanization of rural populations, mitigate excessive concentration of population in big cities, and promote intensive and compact development of urban and rural land use.

The authorities should impel to develop a circular economy, actively promote the reduction and industrialization of sewage and waste, effectively reduce the discharge of sewage and pollutants, and utilize existing waste and waste as the resource; adopt clean production techniques to enhance use efficiency of raw materials, energy, and other resources at the root, and reduce waste emissions.

The authorities should optimize the structure of the traffic network, and build an efficient traffic network; increase the density of urban road network, and gradually establish a reasonable road network structure, and increase the area rate of urban roads; actively encourage the use of public service vehicles; and reserve appropriate routes for walking and bicycle traffic to fully respect the traffic space of bicycle and pedestrian.

13.3.2 Tapping into the Latent Power of Carrying Capacity, Expanding the Supporting Capacity on Various Elements

The departments concerned should actively develop economical and recycling technology and methods of urban water resources to enhance utilization efficiency of water resources; make unified planning of urban water supply, water use, water conservation, sewage disposal and recycle water based on the social cycle to achieve sound development of social cycle of water resources.

The departments concerned should enhance output benefit of the urban unit land, land and formulate strict qualification system for the economic density of land for different cities; tap into the latent power of land, actively promote the intensive utilization of land, and encourage more quasi-urbanization population to settle in small cities and towns so as to improve land carrying capacity.

The departments concerned should accelerate the construction of urban sewage and garbage treatment facilities, strengthen urban afforestation, and improve the urban environment; actively promote the concession system for urban environmental infrastructure, and enhance the operational effectiveness of environmental infrastructure.

They should also enhance the level of traffic management, improve urban traffic software environment, reasonably separate and dredge the urban traffic, and increase service efficiency of existing road traffic facilities.

13.3.3 Fully Mobilizing the Enthusiasm of Participants

Government, enterprise, social organizations, and the public are the subjects to promote upgrading of regional and urban carrying capacities. Just any one party's efforts is not enough, and the four parties' roles must be fully played in upgrading the carrying capacities on software and hardware to achieve good interaction of social and economic development.

As the leader, the government should enhance disposal capacity and efficiency to urban carrying capacity through policy regulations; as strong supporters that advance industrial restructuring and save urban resources of carrying capacity, enterprises need to strengthen the understanding on the importance of urban sustainable development, and to cultivate the consciousness of social responsibility; social organizations should fully play the role of social intermediary, contact other subjects through varying methods, thus to have a great impact on upgrading urban carrying capacity; the public should further upgrade personal quality, actively participate in the upgrading of urban carrying capacity and in the process of sustainable development. If the four subjects continuously work together, the upgrading of urban carrying capacity will not simply be "on paper," but can really be put into practice to benefit from the public and enterprises and from the society and the country.

13.3.4 Establishing and Perfecting the Crisis Management System and Early-Warning Mechanism for Emergency

The authorities should establish an environmental crisis mechanism; build an intercity joint early warning and forecast system to circulate the information of major regional pollution sources; provide the scientific basis for the formulation of regional risk management strategy, and provide full environmental risk information for decision-making of production and living in the region through the environmental risk division; fully implement the principle of pollutant emission aggregate control; strengthen environmental supervision, and prevent pollution accidents and environmental safety accidents.

The authorities should establish the land crisis mechanism; strengthen land legislation, combine administration with legal constraints, and strengthen land management means; perfect the system for paid use of land, effectively play the basic role of the market mechanism for land resource allocation, promote the change from extensive to intensive utilization of land resources; strengthen land management and conservation, and control the pollution and ecological damage of the land and the environment around the land.

The authorities should establish a water crisis mechanism; fully implement water source security safeguard system to reduce the pollution of point and surface sources of urban water sources, and to reduce internal source pollution; implement water supply security safeguard system based on pipeline network security operation and improving water supply safeguard capacity.

The authorities should establish earthquake, fire, and other crisis mechanisms; establish incident management system, take effective event management measures, reduce the time required for discovery, response, and relief of disasters, improve the efficiency of settling emergencies, and reduce the occurrence of secondary disasters, and restore urban functions within the shortest possible time.

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