technische universität
dortmund

Planning Integrated Approach in River-based Regions towards Low-carbon Development

By

Xiao Li

A dissertation submitted to the Faculty of Spatial Planning of TU Dortmund University in partial fulfillment of the requirements for the degree of Doctor of Engineering (Dr.-Ing.)

Dissertation Committee

Supervisor: Prof. Dipl.-Ing. Christa Reicher, TU Dortmund
Supervisor: Prof. Dr.-Ing. Dietwald Gruehn, TU Dortmund
Examiner: Dr.-Ing. Jan Polívka, TU Dortmund

Date of Defense: August 31th, 2016

Declaration

I hereby declare that all information in this paper has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have already cited and referenced all material and results which are not original to this work.

Xiao Li

September, 2016

Acknowledgements

There is no doubt that this dissertation could not be carried out and completed without the support from many persons and institutions that are needed to particularly acknowledge here.

First of all, I would like to express great appreciation to my supervisors, Prof. Dipl-Ing. Christa Reicher and Prof. Dr-Ing. Dietwald Gruehn, who have offered me valuable suggestions on the one hand, on the other hand supported as well as encouraged me a lot. It is my honor to study here under your guidance. Besides, I would also like to thank Dr-Ing. Jan Polívka who serves as the examiner for his kindness and help.

In addition, I would like to express my appreciation to German Academic Exchange Service (DAAD) for its essential financial support during my study period in Germany. Moreover, I wish to extend thanks to many Chinese colleagues especially represented by China Academy of Urban Planning & Design and Tianjin Planning Bureau for supporting the fieldwork investigation, data collection and questionnaire survey of the main case study. Then, thanks are also given to some German professional stuff who I met in workshops and conferences enlightening me useful information regarding the German case.

Last but not least, my deepest appreciation goes to my family for accompanying and supporting me to spend this impressive experience in Germany.

Xiao Li

September, 2016

Abstract

In response to current globe challenging climate change, intervening city space to guide and restrain human activities to promote a low-carbon development (reducing carbon sources and strengthening carbon sinks) attaches great importance, which is an essential step for supporting final sustainable development. When confronted with environmental problems, river-based regions that own both natural landscape and man-made properties are always treated as typical, preferred planning and action spaces (poineering urbanization areas particularly in China). In a word, river-based regions normally act as intervention instruments to carry intervention actions contributing in solving environmental problems (such as implementing river restoration projects, etc.). Taking appropriate practical intervention actions in river-based regions needs pertinent planning approach that serves as the guiding tool and driver behind to support. In this context, this research focuses on the triangulated relation between "low-carbon development", "river-based regions" and supportive "planning integrated approach", from theory to practice covering strategic level and operational level of the planning.

This research is organized by three parts. In the first part, it starts with explaining the development course and definitions of three key words, and further establishes general theoretical framework regarding low-carbon development in river-based regions in the form of six guiding principles and corresponding guidelines. After that in the coming second part, this research analyses two specific case studies: a main Chinese case (Haihe riverside region in metropolis Tianjin) and a referenced German case (IBA Emscher Park in the Ruhr area). It dissects issues around the mechanism of planning integrated approach guiding practical actions relative to low-carbon development goals, through applying established theoretical framework. Finally in the third conclusion part, this research proposes recommendations to different actor groups regarding future optimization of Tianjin's planning mechanism and depicts future development visions for Haihe riverside region.

This research is intended to discuss the thinking mode, value orientation, theories as well as practicable methods in terms of current traditional urban planning paradigm in China, for promoting a low-carbon transformation in the rapid urbanization region.

【Key words】: Low-carbon development River-based region Planning integrated approach Intervention action

Table of Contents

Part II: Analysis

Part III: Conception

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Background

Climate change issues need taking interventions on urban space

Currently in a globe range, the increase of greenhouse gas emissions (GHG) represented by carbon dioxide emissions has directly been posing continuous threatens, including the variation of temperature and precipitation, sea level rise and draught and so on. This situation has brought great challenges to the ecological security and resource supply as well as living quality of human settlement environment.

It is known that respectively 75% and 80% of the energy consumption and GHG emissions of the global total amount come from cities and urban areas (Tibaijuka, 2007). And more than 90% of the possible causes of current global warming is caused by human forces and man-made activities (IPCC, 2007 a). Precisely, on the one hand the urbanization, urban sprawl and high dependency on private vehicles, etc. have brought about large GHG emissions; on the other hand, the destruction of natural resources such as deforestation triggered by human activities also has aggravated the ecological vulnerability.

Definitely the city space is the source of all problems and meanwhile also the key of solving these problems in the process of climate change. Therefore, taking interventions on urban space to guide human activities to create a climate-friendly spatial environment attaches increasingly importance for achieving climatic mitigation and adaption[1].

River-based regions serve as significant intervention instruments

There is no doubt that the river system is an essential resource, energy and also environmental element of city space, which carries important functions such as water supply and discharge, transport, flood control, ecological and landscape, etc. Thus, the attached river-based region that owns both the natural and man-made properties has always been receiving great attention and preference in terms of taking intervention

---

[1] The term *mitigation* and *adaption* first appeared in the *United Nations Framework Convention on Climate Change* (1992), which were two ways to respond to climate change. IPCC's Report (2007) defined *mitigation* as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases", and *adaption* as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage".

actions especially when dealing environmental problems. Its influences on urban space cannot be ignored, including economic transformation, urban spatial restructuring, recovering eco-environment, rediscovering and meeting human's needs, rebuilding the local identity and etc. (Yang, 2012).

Concept of the research

In current era of climate change, river-based regions are facing both challenges and opportunities. On the one hand, global climate change has brought great crisis to the river system, including the increase of flood disaster risk, decline of water level, river channel shrinkage and salinization, etc. And particularly in China, due to rapid urbanization, consequent problems of abusing urban resources and unreasonably river development are still "popular", such as filling the river, creating superficial river landscape, canalizing river banks, mono-functional riverfront land use (real estate), etc. These activities have resulted in not only the damage to the river resource itself, but also the peripheral urban problems such as uncontrolled land sprawl, increased heat island effect and high ecological footprint and so forth. On the other hand, current low-carbon era also symbolizes a new environmental axiology and development view for the reasonably utilization of urban resources and energy, which thus makes the river-based region that holds valuable resource and energy obtain new development opportunities.

There is a need to consider the appropriate interventions taken on river-based regions from a higher perspective, maximizing their contributions to a low-carbon development. Intervention actions are generally in the form of implementation of projects, for which the driver and behind is the pertinent planning approach that is involved with planning system, planning tools, activities, paradigm, interests of stakeholders, political purposes etc.

For these reasons above, this topic is attempted to reveal the relation between low-carbon development, river-based regions and planning integrated approach, in which the triangulation relationship is: planning integrated approach supports and guides intervention actions (such as implementation of projects), these intervention actions are taken on river-based regions to impact related influencing factors on carbon cycle process so as to achieve the effect of low-carbon development, and in turn, low-carbon development serves as a goal and propose requirements for planning approach. The conceptual framework is shown as following [**Figure1-1**].

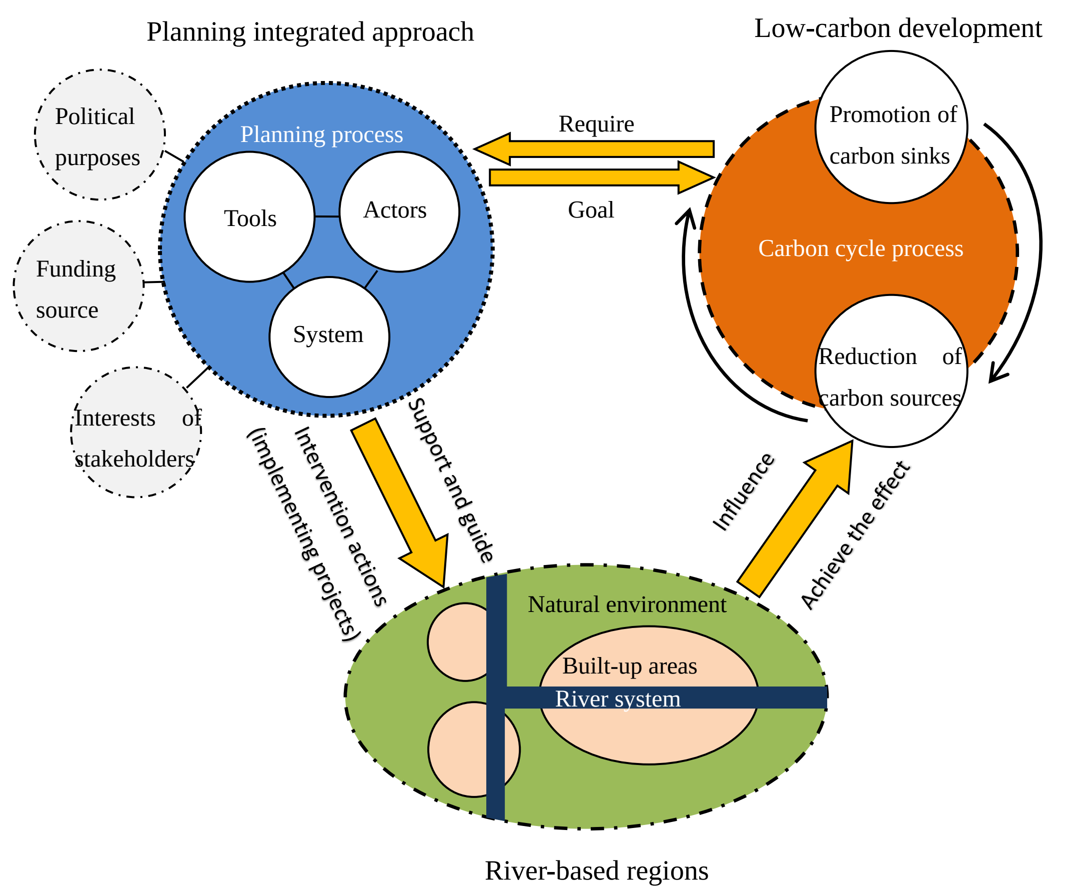


Figure1-1: Conceptual framework

Source: Author' own construct

1.2 Organizational Structure

This dissertation consists of total 8 chapters. This first chapter serves as a preface to introduce the background and motivation of the research as well as corresponding objectives, and indicates its scope and limitation. Then, the thesis is organized by three parts with each respective chapters.

Part I is **"Theory and Methodology"** which includes Chapter 2, Chapter 3 and Chapter 4. Chapter 2 focuses on understanding of the origin, concepts and definitions of the research key words (Low-carbon development, river-based regions and planning integrated approach) derived from related theories. Chapter 3 emphasizes on establishing the linkage between low-carbon development and river-based regions, which analyzes the impact factor system and corresponding intervention mechanism of low-carbon development as well as its application in river-based regions. These two chapters are two main literature review chapters directing to establishing general theoretical framework for this research.

Then, Chapter 4 “Methodology” serves as a transitional “bridge" between “theory and practice” as well as between “general and specific”, which reviews research questions and corresponding objectives, and outlines next research design and case study selection as well as presents research methods to be used.

Part II is **“Analysis”** composed of the next three chapters coming into the specific cases. Chapter 5 is regarding the main empirical case study—Haihe riverside region in Municipality Tianjin (China), which presents its fundamental state, including its context, site situation, intervention actions have been taken related to low-carbon development and planning integrated approach adopted. Chapter 6 further concentrates on the assessment of low-carbon performance after these intervention actions and finds out possible problems and causes behind.

Then, Chapter 7 introduces a German case study as an “episode” aiming at drawing on international transferrable experiences.

Finally, **Part III “Conception”** represented by the last Chapter 8 would propose conclusions to the Chinese case based on all findings obtained in previous chapters, and put forward the issue for further study as the ending.

This whole organizational structure is figured in the following [**Figure1-2**]:

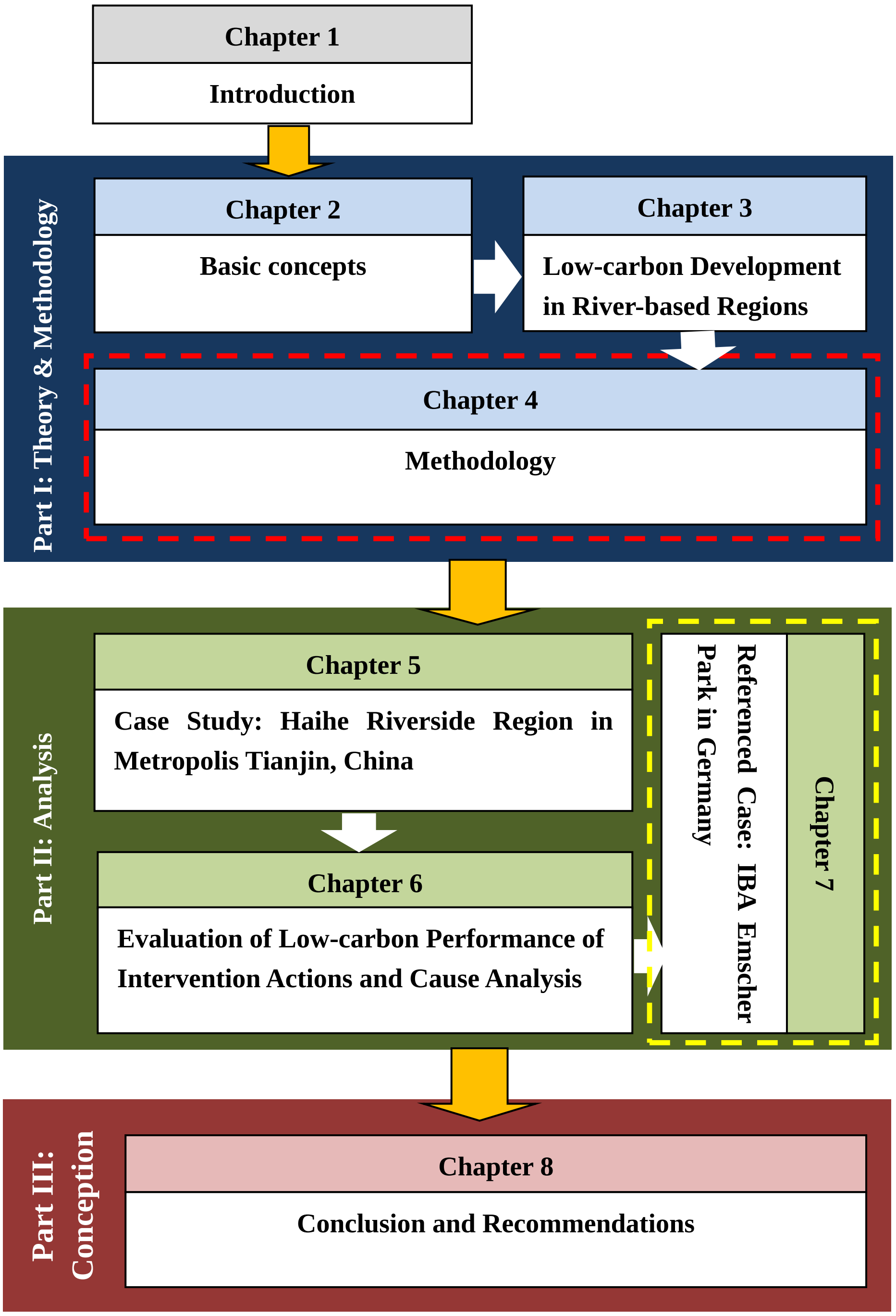


Figure1-2: Organizational structure of thesis

Source: Author' own construct

.

1.3 Research Scope

The theme of this topic is concerning interventions on river-based regions in a low carbon context and pertinent planning approach. As the possible research scope on this theme could be broad and diverse, in order to narrow down and more concentrate on the scope and also in consideration of the author's own professional background and ability, a limit of the scope of this research should be defined in advance.

First, this research is not a study of climate change issue or low-carbon city itself, while regarding them as a macro backdrop, goal orientation as well as starting point of raising and analyzing issues, the actual subject is dealing with the river-based region. Besides, the mechanism of low-carbon-oriented intervention in this topic is to be developed from urban planning perspective, which is mainly involved with the physical environmental dimension, but not the dimension of economics and sociology concerning the low-carbon issue. That is to say, this research is mainly based on the overall physical urban planning, including urban design, while the scope of some other special professional fields (such as hydrology, hydrodynamics or micro architectural technological science, etc.) is not the topic here. Moreover, this research concerns about specific operational planning approach, which mainly stands at the perspective from comprehensive urban planner who is engaged in comprehensive urban planning but not some specialized sectoral planning or architectural design, although they would be inevitably involved, not the focuses. Then, the planning approach at policy making and economic leverage level will also not be the topic here. Last but not least, this research is pertinent a large holistic spatial scale (such as regional and city scale) while not focusing on micro scale such as site or single architectural scale.

Part I: Theory and Methodology

- Chapter2: Basic Concepts
  - Low-carbon, Planning and Practice in River-based Regions in Historical Evolution
  - Defining Low-carbon Development
  - Defining River-based Regions
  - Defining Planning Integrated Approach
- Chapter3: Low-carbon Development in River-based Regions
  - Low-carbon Involved Fields
  - Low-carbon-related Impact Factors
  - Low-carbon-oriented Intervention Mechanism
  - Application in River-based Regions
- Chapter4: Methodology
  - Research Questions and Objectives
  - Research Design
  - Selection of Case Study
  - Methods Used and Data Collection

Chapter 2 Basic Concepts

2.1 Low Carbon, Planning and Practice in River-based Regions in Historical Evolution

The evolution of modern urban planning covers the attitude to environment and resource utilization, in which process some ideas and models that still have lessoning values could be regarded as the "predecessor" of today's "low-carbon concept", and also in which process the intervention actions taken on river-based regions always occupy an important position of focus.

The historical origin of the term "**low carbon**" can be divided into three stages, in which the development course of modern urban planning concepts and corresponding practices on river-based regions could be summarized respectively, along with the transformation of different development views in each stage [**Figure2-1**].

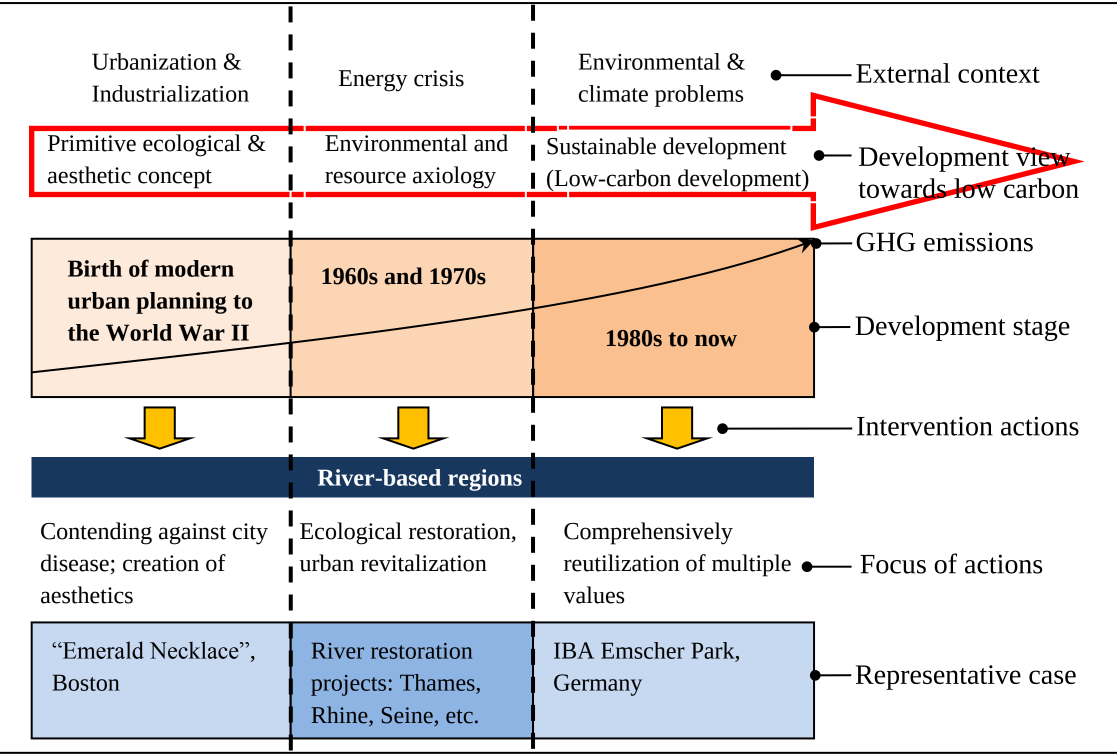


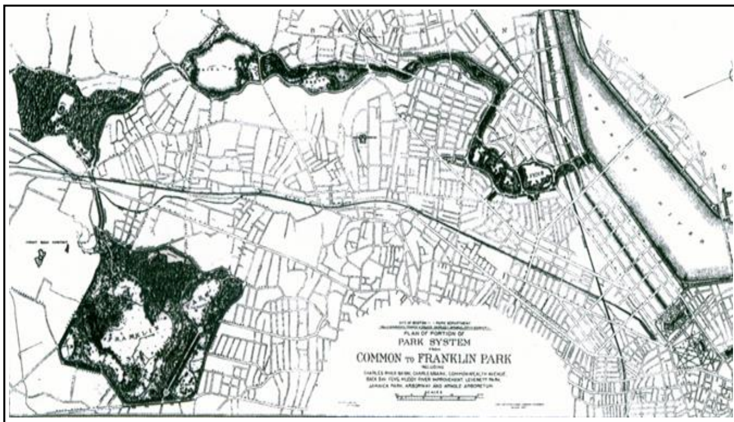
Figure2-1: Low-carbon context, planning and practice in river-based regions in historical evolution process

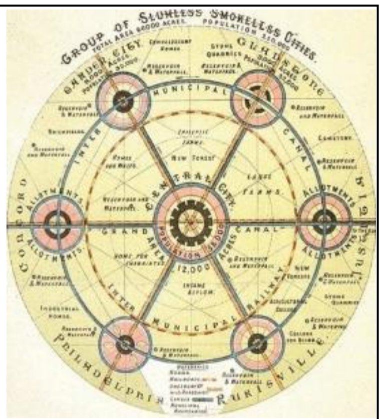
Source: Author' own construct

A From birth of modern urban planning to the Second World War

In 1898 Howard first put forward the concept of “Garden City” in response to the problems like urban expansion and environmental deterioration originated from industrialization. This was an ideal city model that was used to try to lead a healthy urban development, in which several urban groups with respective centers surrounded a single-nuclei big city. From today’s perspective, some of its ideas are relevant to low-carbon issue, such as restricting population size, minimizing commuting distance, digesting waste in the farmland nearby, embracing the city with nature and so on (Zhang, 2011). Then, in 1911 Garnier proposed the “Industrial City” model in which low-carbon-related ideas included: emphasizing urban functional division, placing large green spaces in industrial areas, mixing service facilities with residential buildings, leaving half lands for green land uses, etc. After that in 1923 Corbusier’s “Radiant City” model placed a large number of high-rise buildings to accommodate larger population and offer more sunlight and open spaces. This innovative plan also has its advantages in terms of current low-carbon context: high-density development, public and pedestrian-oriented traffic mode on the ground. And in 1934, Wright advised decentralized, low-density development and connected highways between residential units in his “Broadacre City” plan. However, this pattern was inclined to rely more on private cars and consume more land resources and energy (Zhang, 2005). By 1943, the “Organic Decentralization” concept from Saarinen advocated to replace urban centralized pattern by dispersed but linked clusters, with green belts that contained traffic arteries between them to connect towns and separate industry. In this urban form, the areas named “daily activities” were centralized in a certain range as much as possible to minimize the traffic demand, while those areas for the "occasional activities” were arranged dispersedly (Zhang, 2005).

During this period, the locational and spatial values of riverside areas were also realized in terms of utilizing them to solve part of emerging “city disease”. The river-based region was viewed as an essential carrier of open spaces and urban-rural buffer zone as well as the chance of returning to nature, which represented the origin of ideology and practices of today’s low-carbon issue. Precisely, during 1878-1895 Olmsted planned the “Emerald Necklace” based on existing river system in Boston, in which the river’s natural status and associated flood plain was retained and space in 61-457 meters width was controlled as the boundary land on both sides of the river. Ultimately this river-oriented open system stretched 16 kilometers connecting 9 separate parks and other swales, wetlands and protected lands together. It largely functioned in providing improved water-recycling system, scenic amenity and recreation and wildlife habitat as well. After that in 1899, Eliot expanded this “Emerald Necklace” plan by integrating them into a larger open space scale, which connected three rivers and six large suburb areas forming a more comprehensive regional open space system (Boston Landmarks Commission Study Report, 1989; Watson & Bentley, 2007) [**Figure2-2**]. And also in Howard’s “Garden City” plan in 1898, the canals and waterways with green belt served as the protected buffer zone surrounding the urban core area, connecting street blocks with peripheral natural rural landscape [**Figure2-3**]. The idea of restricting urban sprawl via utilizing river courses could be seen from this plan (Wang, 2004). Moreover, in 1938 Seifert set forth the river-focused concept named “Near-natural Control (*Naturnaherer Wasserbau*)”, which proposed that river engineering facilities were supposed to assert functions originated from natural river system such as flood prevention, water supply and conservation, etc. on the one hand, and on the other hand also keep aesthetics close to nature (Zhu, Wang & Wang et al, 2006).





Left—Figure2-2: Boston’s “Emerald Necklace” plan；Right—Figure2-3: “Garden City” plan
Source: (Wang, 2004)

B In the 1960s to 1970s

The outbreak of two-time oil crisis in 1970s caused the transformation of environmental view and values, and enabled people to deeply realize the importance of preserving energy, natural resources and ecological environment. Studies from western countries began to incorporate issues like usage of energy flow and resources into urban planning issue, in which representative included Kevin Lynch’s *Site Planning* (1971), Ralph Knowles’s *Energy and Form* (1973), Schumacher’s *Small is Beautiful* and so on (Zhang, 2005).

In this trend, people set about the exploration of restoring the river system as an indispensable resource and energy source in order to achieve the coordinated development between "human, city and nature". In 1969 McHarg in his book *Design with Nature* (1971) presented some measures regarding the preservation of river valley areas, including: retain the original topographic feature, native flora and fauna on both sides of the river valley; keep the land-water border as the natural gateway, and carry out soil and water conservation and vegetation; extend the stream tributaries and their associated green areas to every urban neighborhood; develop available green spaces and squares beyond the flood hydrograph, and so on. As to the practices, during this period many European countries started the comprehensive river remediation and regulation projects, including the river Thames, Rhine, Seine, Danube, etc., which strived to let the river return to the natural status by using near-natural control means. For one example, the nine countries where Rhine river passed through founded "International Commission for the Protection of the Rhine (ICPR)" to seek solutions and implement a series of concrete actions together by cross-regional collaboration (Yuan & Zhang, 2013). After 1970s, the concept of "Greenway" increasingly arisen, for which dealing with the blue-green river corridor was the key point of planning and practice. For instance, Simonds in his book *Earthscape: A Manual of Environmental Planning and Design* (1978) presented some greenway approaches based on the riverfront in Toledo city, including: remove the harmful weeds along the water; cut some of the waterside thick woods to increase ventilation; reshape the water edge to gain more solar penetration; grow more aquatic flora to purify the air to promote the photosynthesis, and etc.

C **1980s to nowadays**

With the emergence of "Sustainable Development" concept in 1989, issues regarding the relationship between resource protection, ecological environment and urban development reached the peak. Precisely, based on the "Green paper on the Urban Environment" of Commission of the European Communities (CEC), Breheny in 1992 first explained the term "Compact City", which advocated mixed land use, pedestrian and public transport priority and respecting natural resources（Li，2008）. Also in the 1990s, the concepts of "Smart growth" and "New Urbanism" had some similar ideas. Furthermore especially during this period, the climatic change issue received more attention, which gradually developed into current low-carbon concept. For example, Jon Lang (1994) thought that urban planning is supposed to respond to the problems of globe warming and sea level rise. And Carmona, Heath & Oc et al. in the book *The Dimension of Urban Design* (2003) pointed out that when confronted with the coming global climate change and environmental deterioration and resource exhaustion as well, urban designers should take more environmental responsibilities. Finally, along with the establishment of the IPCC In 1988 and the target of GHG reduction present in *Kyoto Protocol* in 1997, the term “low carbon” firstly appeared in the British White Paper—*Our energy future - creating a low carbon economy* in 2003 (Zhang, 2011).

The external context mentioned above also influenced the development view on river-based regions—to promote sustainable urban development by taking interventions on them as instruments based on their multiple values and functions. A vast of practices were widely developed, such as the “Project for Creation of Rich in Nature” operated in 1991 in Japan, which covered more than 600 rivers for pilot projects; and the German IBA Emscher Park Initiative launched in 1989 was also an exemplary case that promoted the regional renaissance depending largely on dealing with its river system; other cases at the same time included the German Watercity Project of Spandau, American Anacostia River Rehabilitation, London’s Blue Ribbon Network and so on. In terms of policy making field, the Japanese government amended its *Rivers and Harbors Act* in 1997, which treated the river body and surrounding landscape space and urban communities as an integral whole and added a new target for watershed management (Zhu, Wang & Wang et al, 2006). Moreover, the European Union issued the *Water Framework Directive* in 2000，which raised legislative approach to managing and protecting waters including rivers, lakes, groundwater, etc., based not on national boundaries but on natural geographical formations—river basin unit. This document led to cross-boundary and large-scale river basin management (Yuan & Zhang, 2013). And in 2009 one of the *European Environment Agency Report* pointed out that as a most vital resource, water is particularly affected by climate change, the risks include flooding, drought, access to sustainable and sufficient supplies. It is necessary to move towards integrated planning for land and water through river management approach with spatial planning to respond to climate change (EEA, 2009a).

It can be seen from above that during the transformation process of previous industrial civilization to present ecological civilization, the term “**low carbon**” emerges along with globe environmental issues, as both the time and context require. In this contextual process, the changing urban planning concepts and development views always lead the new identification and trigger interventions on the river-based regions, since they are involved with vital urban resources and energy. This is the external backdrop that need to be first understood.

2.2 Defining Low-carbon Development

Understanding of the essence and connotation of "low-carbon development" could be derived from two theories: urban metabolism and urban carbon cycle.

2.2.1 Urban Metabolism Theory

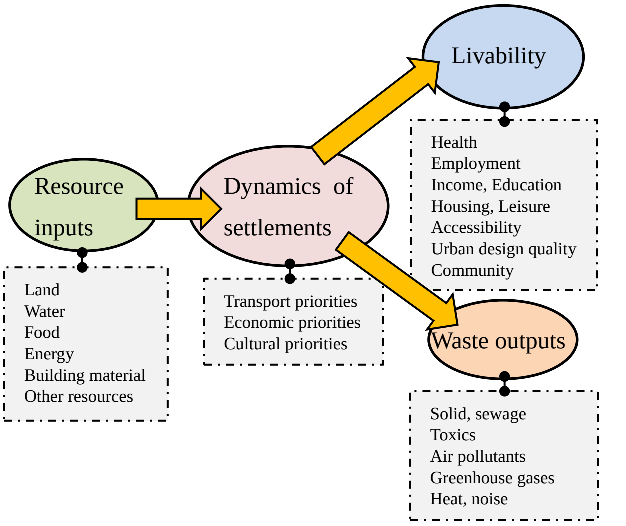
The term "Metabolism" is originated from biology, which is defined as "the chemical processes in living things that change food, etc. into energy and materials for growth"[1]. Generally speaking, the metabolism process includes two stages: catabolism (the breaking down and discharge of organic compounds and release of energy) and anabolism (the opposite of catabolism, which means the construction of organic compounds via deriving the energy from external environment).

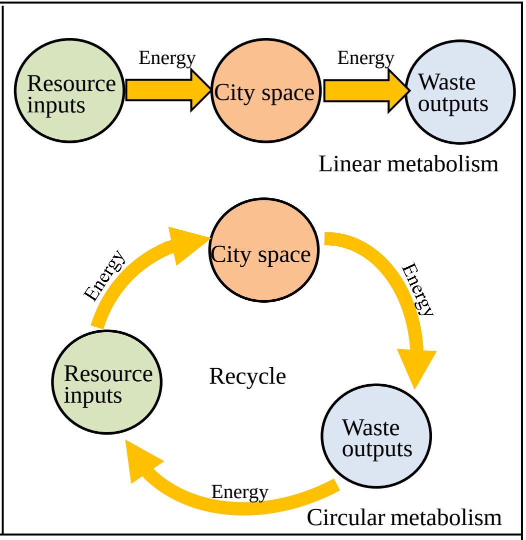
From an urban running perspective, the city has its own metabolism process. Unlike the original natural world, the modern cities are systems of production and consumption whose lands and supply of resources are directly influenced by human forces (Turner, 1989; Alberti, 2008). Newman (1999) defined urban metabolism model as "a biological systems way of looking at the resource inputs and waste outputs of settlements" [**Figure2-4**], and Kennedy et al. (2007) defined it as "a technical and socio-economic processes that occur in cities producing growth, production of energy, and elimination of waste". According to Newman's (1999) points, urban metabolism is originated from numerous resource inputs (land, water, raw materials, etc.). Then, through the dynamics of human settlements (transportation, economic activities, etc.) on the one hand these resources are transferred into something useful for sustaining urban livability by the action of energy, on the other hand discharge the rest in form of waste outputs (sewage, GHG emissions, solid wastes, etc.). This urban metabolism process unfortunately often performs in a linear and incomplete way, in which the generated waste outputs always ruin the environment and therefore cannot satisfy the needs for sustainability and low carbon cities (Karakiewicz, 2011). Furthermore, it is known that the city is an open system that allows exchange of materials and energy conversion with surroundings in

[1] Oxford Advanced Learner's Dictionary: Metabolism.

its metabolism process. Based on the second law of thermodynamics the physicist Erwin Schrödinger (1967) explained that every conversion of energy brings about the increase of entropy which further means disorder and chaos of the system. And life feeds on negative entropy that is inversely proportional to the consumption and dispersion of energy represents the order. This rationale implies the city needs to reduce consumption of energy to increase the negative entropy.

Therefore, under the context of climate change there is a need to optimize the urban metabolism into a circular process in which waster outputs can be recycled as a resource inputs [**Figure2-5**]. Besides, in this process urban systems are also required to maximize the storage and reuse of energy and resources in order to maintain the order.





Left—Figure2-4: Urban metabolism model; Right—Figure2-5: Two patterns of urban metabolism

Source: Left—Construct based on (Newman, 1999);

Right—Construct based on (Karakiewicz, 2011)

2.2.2 Urban Carbon Cycle Theory

IPCC's two-time reports (2007 b; 2013) indicated that the carbon dioxide is the most important anthropogenic GHG and the largest single contributor which has resulted in radiative forcing. From the perspective of environmental studies, the generating of carbon dioxide in atmosphere is originated from natural processes (evolution of vegetation) and human activities (combustion of fossil fuel in transport, deforestation, industrialization, etc.) [**Figure2-6**], and the latter is the most major cause that results in global climate change (Zhou, 2003; IPCC, 2007 a), as mentioned also in Section 1.1.

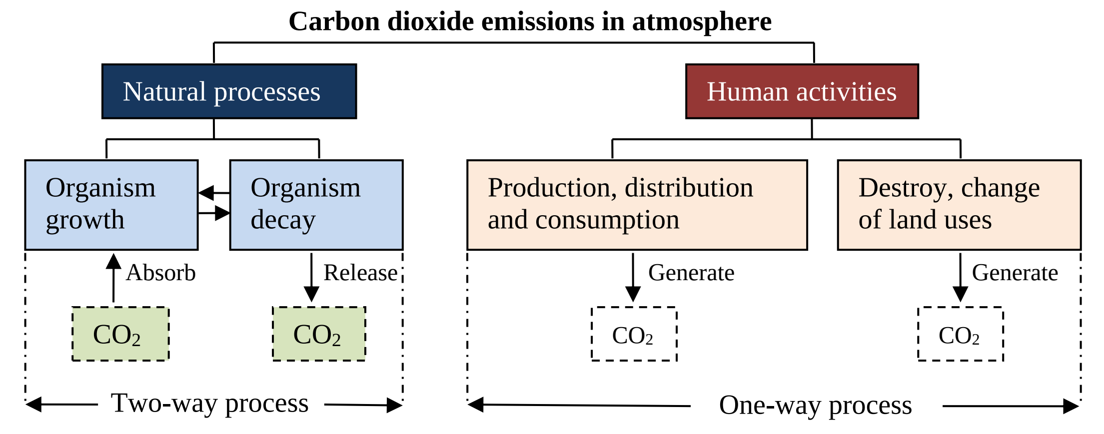


Figure2-6: Rationale of generating of carbon dioxide emission

Source: Construct based on (Zhou, 2003)

On the basis of understanding the generating rationale of carbon dioxide, the term "carbon cycle" describes the biogeochemical movement that allows carbon to exchange among lands, atmosphere and waters, which process is closely linked to hydrological cycle and vitally important to life (Sulzman, 2000). Furthermore, this mechanism of carbon cycle in city space is involved with three aspects [**Figure2-7**]:

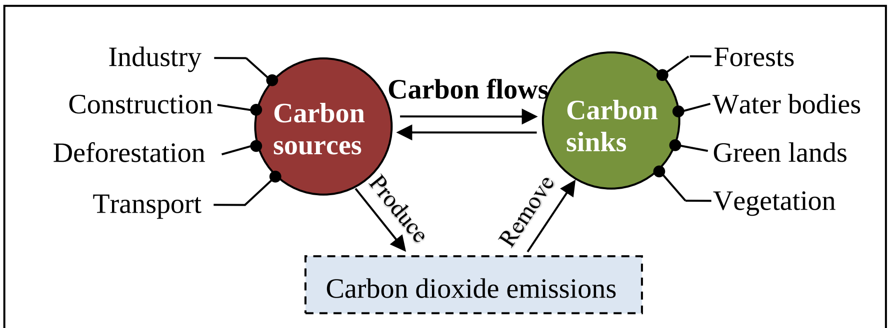


Figure2-7: Mechanism of urban carbon cycle

Source: Construct based on (Zhou, 2003)

1).the carbon source, which means any process or activity that releases GHG emissions, an aerosol or precursor of greenhouse gases into the atmosphere (UNFCCC, 2006). Carbon sources in urban systems involve all human activities that consume fossil energy or destroy carbon pool, as mentioned above. 2).the carbon sink, which refers to any process, activity or mechanism which removes greenhouse gases, an aerosol or a precursor of greenhouse gases from the atmosphere (UNFCCC, 2006). Nature carbon sinks in urban systems cover forests, water bodies, soil and vegetation, etc. in which the green carbon sink and blue carbon sink (water) occupy the main part. They work in removing the carbon dioxide through photosynthesis and gas exchange and then deposit it. 3). the carbon flow, which could be deduced based on above two definitions, representing a process or activity that processes and transits carbonaceous substances between carbon sources and carbon sinks. Carbon flows in city space mainly involve the movement process of water flow, traffic flow and material flow as well as gas flow, etc.

As explained above, the urban carbon cycle process mainly influenced by resource consumption from human activities is also a form of urban metabolism, which is closely involved in exchanges of materials and energy flow and supposed to be optimized in a circular way but not linear.

2.2.3 Definition

By referencing existing definitions, the term “low carbon” is officially originated from the description of “low carbon economy” in British *Energy White Paper—Our Energy Future: Creating a Low Carbon Economy* in 2003. It represents a development path to keep stable economic growth while with fewer consumption of natural resources and less pollution, which will contribute to higher living standards and a better quality of life. In addition, “Low carbon” refers to promoting high efficiency of resource and energy use, reducing environmental contamination and GHG emissions, maintaining the ecological balance and cleaner production (Feng & Zhou, 2010). And Low-carbon development also emphasizes the transformation of traditional industry and healthy living style, reducing the carbon footprint and energy consumption caused by human activities and leading a simple but high-quality life (Zhou, Zhang & Cui et al, 2010).

Based on all above, “**low-carbon development**” in this thesis means a resource-based and goal-oriented development model with following characteristics:

- It points to the reduction of carbon sources (emissions) and strengthening of carbon sinks (removal capacities) via influencing both human activities and natural processes within city space;
- It follows and optimizes the rationale of urban metabolism and urban carbon cycle process;
- It advocates to efficiently arrange and utilize urban resources in a recycled way;

- It reflects an environment attitude and a living philosophy which describe a direction for promoting living quality.

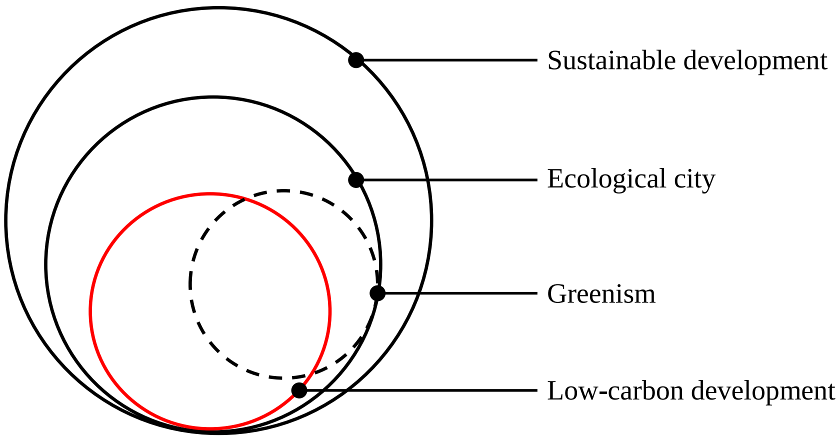


Figure2-8: Relationship between different terms

Source: Author's own construct

When comparing "low-carbon development" with other similar terms, such as "sustainable development", "ecological city", "greenism" [**Figure2-8**], their views of environment and key value orientation as well as ideology are almost the same—all are calling for promoting harmonious effects between natural setting and man-made environment. However, there are still some differences in terms of specialized concerns [**Table2-1**]. Take "sustainable development" as an example, which is a more comprehensive, much higher and long-term goal orientation covering social, economic and environmental dimension. Responding to climate change and reducing GHG emissions is one of the goals of sustainable development but not the all. That is to say, "sustainable development" is in a much broader sense than "low-carbon development", the latter takes reduction of carbon emissions and enhancement of carbon removal as the emphasize, which is more direct and specific and pertinent as well. In a word, "low-carbon" development serves as a branch, one of the concrete "handtools" and a medium-term step for achieving long-term sustainable development. As a study indicates, cities that embark on a low-carbon development will become more livable, efficient, and ultimately sustainable (World Bank, 2012).

Table2-1: Comparison between different terms

Term	Context of emergence	Goal orientation	Level &Scope
Sustainable development	Rethinking of industrial civilization	Equilibrium between social, economic and environmental development	Comprehensive & Broad
Ecological	Energy and resource	Harmonious symbiosis of	Comprehensive &

city	crisis	nature-human complex ecosystem	Broad/specific
Low-carbon development	Climate change	Reducing GHG emissions and strengthening carbon removal capacities	Strategic & Specific/technical
Greenism	Environmental and technological pollution	Resource saving and low energy consumption	Strategic & Specific/technical

Source: Construct based on (Zhou, Zhang & Cui et al, 2010); (Qiu, 2011)

2.3 Defining River-based Regions

Understanding river-based regions also need to first start with two theories regarding the river system that serves to blue-green corridor: urbanology and landscape ecology.

2.3.1 Urbanology Theory

From the perspective of the relationship between city and river based on urbanology, the river system is a kind of essential urban resource, environmental element and also energy that closely linked to the running of city.

Historically, most of the city starts from the settlement on the riverside, and the river served as the heart of the location of human settlements due to its water supply, transport function and suitable climate as well as fertile soil (Shaziman, Usman & Tahir, 2010). A large number of resources provided by the water, such as waste disposal, energy and goods, have promoted this distinctive spatial interface throughout the globe urban landscapes designed to utilize it (Davidson, 2009). In addition, due to the physical and ecological characters, the urban metabolism and carbon cycle process mentioned above (see Section 2.2.1&2.2.2) also apply to the river-based area [**Figure2-9**]. Specifically, the metabolism between city and river refers to exchanges from raw materials to waste matter and from water supply to sewage drainage, in which this process the rivers in particular serve as natural liquid receptacles (Barles, 2007). What is more, as another research explained (Rodriguez-Iturbe, Caylor & Rinaldo, 2011), this river-based metabolism (green and blue) is the set of processes that allows the river basin to responds to its environment through the physical processing of evaporation, condensation, precipitation and run off. Green metabolism is measured via transpiration and blue metabolism through runoff. Green metabolism refers to the transformation undergone by precipitation, in which process the carbon fixation is absorbed by the basin vegetation via photosynthesis, while blue metabolism means the process involved in the transport of runoff from every site to the outlet. Along with the green and blue metabolism mentioned above, the carbon dioxide will be partly sequestrated in the water body (as also mentioned in Section 2.2.2) in the carbon cycle process.

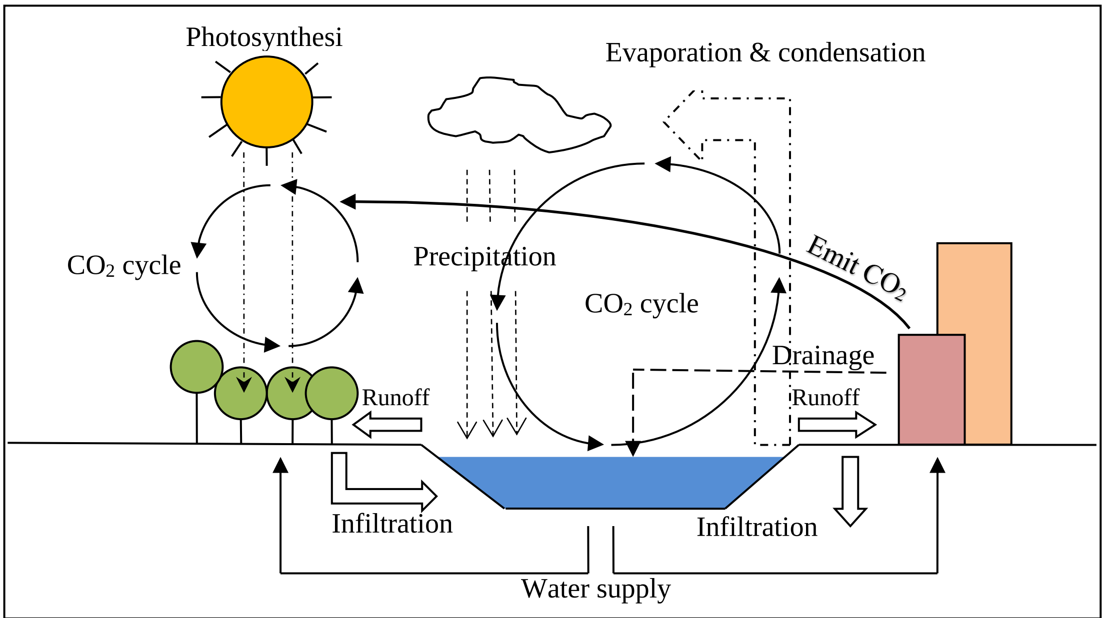


Figure2-9: River-based metabolism and carbon cycle
Source: Author's own construct

In a word, from a view of urbanology the river system acts as integrator and center of organization within the city system, touching nearly all aspects of the natural environment and human culture (Naiman & Turner, 2000). As a consequence, the river-based region always serves as an intervention instrument receiving various human actions along with the developing environmental values, as presented in Section 2.1.

2.3.2 Landscape Ecology Theory

Two aspects of points from landscape ecology could serve to important theoretic foundation and guidelines for understanding the river system which is the "protagonist" of a river-based region.

First aspect is the role and form of river system. It is known that any landscape is determined by the flow of materials, species, energy and water through three basic forms: patch, corridor and matrix, in which the river is mostly involved with *corridor* and *patch*. As one of these three types of corridors defined by Forman & Godron (1986), the *river corridor* (the other two are linear and strip corridor) typically refers to the water body and adjacent riverfront landscape areas (or called buffer strip) that differ from surrounding matrix. By referencing other definitions, a *river corridor* includes lands adjacent to and including the course of a river, which is intended to provide land use planners and river managers with a width of a balanced channel, offering the dissipation of the energy of moving water and the transportation of sediment (VRMP, 2005). The *stream corridors* serve as complex ecosystems that include the land, species, and network of rivers within them. They perform a number of ecological functions such as removing harmful materials from water, and providing habitat for aquatic and terrestrial species (FISRWG, 2001). In addition, *Riparian zone* along rivers influence transport of nutrients and sediments from upland urban areas to aquatic ecosystems, and can take up large amounts of water, sediment, and nutrients, often substantially reducing the discharge of nutrients to aquatic ecosystems. A common theme of land-water interactions is the land use along rivers and the spatial arrangement of these land uses (Turner, Gardner & O'Neill, 2001). It can be seen from above that the *river corridor* is an active system which influences the exchange and transfer of material and energy in a land-water interaction process, carrying important ecological functions. However, there is no unified conclusion regarding the effective width of a river corridor, as different landscape position of rivers is in correspondence with different environmental status and ecological functions. Forman (1983) suggested that the width of river corridor should cover the riverbed edge, flood plain and a certain interior upland that exceeds the edge effect. In general speaking, the wider corridor brings about more environmental heterogeneity and enhancement of species diversity and better control of dissolved substances (nitrogen, phosphorus, carbon) which are the pollution sources for water quality (Zhu, Yu & Li, 2005). As to the *patch*, the usual forms involved with river systems include the natural water conservancy area (reservoirs, wetlands, water-source protection areas) and also man-made water landscape. The patch characters (size, shape, location, and orientation) play an important ecological role, which can affect species habitat, resource availability, etc. A combined patch—corridor—matrix networked pattern can be contributed to the self-circularity and stability of the whole ecosystem. In particular, a more complex network pattern of patches and corridors provides higher effectiveness for individuals' survival and movements, and a small patch or node along the network is more likely to have better habitat conditions and higher diversity when compared to other parts of corridors (Dramstad, Olson & Forman, 1996).

Second aspect covers some basic principles that can apply to the river system. 1) *Holism* and *spatial heterogeneity*. *Holism* is a philosophy attitude that emphasizes on the importance of a whole system as against that of its individual parts. Any system is not only a simple aggregation of each separate element, which owns characteristics that each element does not have, as Golley (1998) stated, the "properties of a whole cannot be predicted from the knowledge of the parts", so do the river system. The second principle is the *Spatial heterogeneity* or called *diversity*, which means a status of consisting of dissimilar elements, with mixed cover types. Simply speaking, spatial heterogeneity offers diverse resources influencing the symbiosis of species and the abiotic functioning of the landscape, which also tends to stabilize the landscape process (Wu, 2000). 2) *Connectivity* and *stability*. *Connectivity* usually involves corridors and networks, and describes how patches are connected in which the movement can occur among them. High connectivity implies more interactions between the movement of animals, plants, heat energy, water, and materials among elements (Forman & Godron, 1986). A continuous river corridor without major gaps is essential to maintain cool water temperature and high oxygen content (Dramstad, Olson & Forman, 1996). The last principle *Stability* is contributed to maintaining functional ecological processes and promoting their healthy development (Yu & Li, 2003). Forman (1995) identified five negative landscape changes (perforation, dissection, fragmentation, shrinkage, attrition) that will brings about the instability and isolatism of a landscape.

2.3.3 Definition

It can be seen from all contextual histories and theories mentioned above that the river system plays a role as a kind of unique urban resource, compound landscape ecological element and renewable energy. The term "**river-based region**" in this thesis refers to the part of city space where the river system meets surrounding urbanized and natural land. Its spatial range covers the river bodies and their adjacent closely-associated terrestrial units as well as peripheral influencing area. In terms of the spatial form, the across-river form (a mainstream passing through with its tributaries) is the main object of discussion in this paper, while some other forms (water-networked, lakefront or seafront) are not. In a word, the "river-based region" is a whole region with following characteristics [**Figure2-10**]:

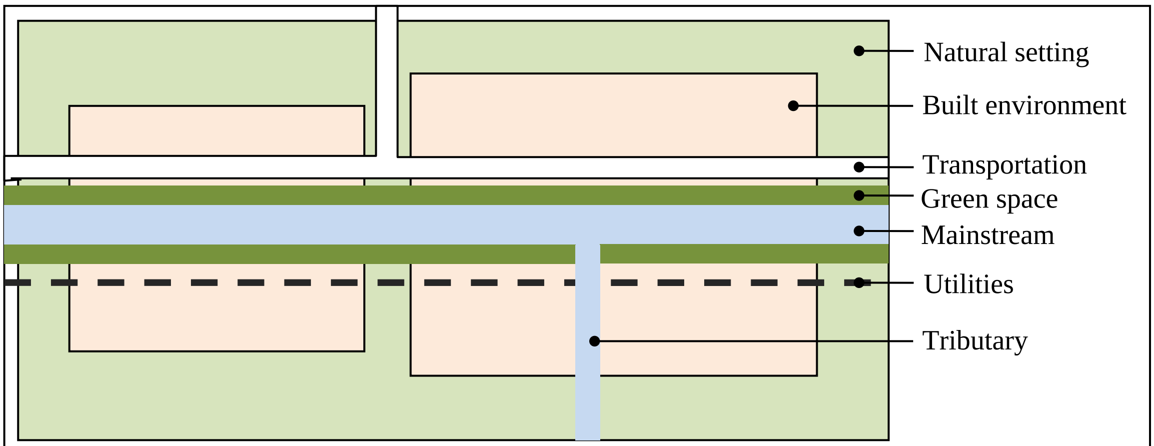


Figure2-10: Illustration of river-based region

Source: Author's own construct

- It owns both natural & man-made properties and thus is a combined system covering natural processes and human activities including land use, transport, landscaping, infrastructure, etc.
- It is involved in urban metabolism and carbon cycle process with its own features;
- It carries indispensable ecological functions attributed to the river system that is supposed to follow the principle of integrity, heterogeneity, connectivity and stability.
- It serves as an instrument to carry intervention actions especially when confronted with environmental problems;
- It is always treated as a typical, preferred planning space (*Planungsgebiet/Planungsraum*) and action space (*Handlungsraum/Actionsraum*) of highly concern, particularly a kind of poineering urbanization area in China.

2.4 Defining Planning Integrated Approach

2.4.1 Planning Instruments

As defined by Cullingworth & Nadin (2006), spatial planning instruments are the methods concerning the problem of coordination or integration of diverse sectors through a territorially-based strategy, influencing the arrangement of activities. Planning tools can be classified according to different criteria. Precisely, they can be divided into formal tools which are regulated by legislative power and informal tools which do not own statutory binding forces; besides, they can be divided into overall planning which deals with comprehensive issues and sectoral planning that focuses on specialized fields (landscape, transportation, infrastructure, etc.); moreover they can also be divided into different levels in terms of administrative boundaries, such as national level, province (or state) level, regional level and local city level, community level.

It should be realized that there are no universal structure, forms and contents of spatial planning tools due to differentiated country-to-country context and political system, so they have to be analyzed in terms of indigenous specific context. Anyhow, planning tools deal with area-based elements (land use, water, open space, transport, etc.) and thus influence the human interventions on urban systems for achieving some goals (such as sustainable development). It can be said that planning tools serve as guidance, driving and supportive forces of actual interventions (taking actions, implementing projects, making policies, etc.) and also serve as the basis for decision making to some extent. The motivation of adopting planning tools are normally influenced by political purposes, source of funding as well as interests and appeals of various actors and stakeholders.

2.4.2 Definition

The *Machu Picchu Charter* (1977) indicated that planning, architecture, and design today should not treat the city as a series of separated parts, but must strive to create an integrated multifunctional environment (qtd in Zhang, 2005). Based on this understanding of systematic entirety, “integrated approach” represents a mechanism of organizing isolated factors to let them have cohesions and promoting them to develop in cooperation.

Therefore, “**planning integrated approach**” refers to a way and process of using, organizing separate planning tools and activities in order to work together, in which process the planning tools and actors based on a specific planning system are the key objects. The characteristics of planning integrated approach are:

- It follows the philosophy of systematic entirety and synergetics;
- It is supposed to be a dynamic process in which different planning tools and actors are organized on the basis of a specific planning system;
- It is supposed to be a comprehensive framework that integrates various planning elements;

- It supports and leads the direction of associated intervention actions taking the form of implementation of projects. On the contrary, intervention actions are its consequences;
- It is supposed to balance interests of stakeholders behind and mitigate conflicts emerged.

2.5 Summary

This chapter first teases out the evolution process of low-carbon context with urban planning concepts therein as well as the representative intervention practices in river-based regions. It can been seen that dealing with river-based regions has always been the concern of planning and action along with the developing external environmental context and development values and views as well in each historic stage of modern urban planning.

Then, this chapter explains the definitions of low-carbon development and river-based regions as well as planning integrated approach by referencing respect related fundamental theories and combining with the author's own understanding. As also can be seen in the conceptual framework in Section 1.1, "low-carbon development" refers to a resource-based and goal-oriented development model that need to intervene in urban space, "river-based regions" represents a typical planning and action space that carries preferred interventions, while "planning integrated approach" implies the process of organizing planning tools based on planning system to guide intervention actions.

Chapter 3 Low-carbon Development in River-based Regions

3.1 Low-carbon Involved Fields

As explained previously (see Section 2.2.2), urban carbon cycle process consists of carbon sources and carbon sinks as well as the flows between them. Based on this rationale here references an existing research's classification method of low-carbon elements (Qiu, 2011), and further transfers into classified four involved fields to be intervened in for low-carbon development in urban space [**Figure3-1**], which would serve as important theoretical basis for next sections:

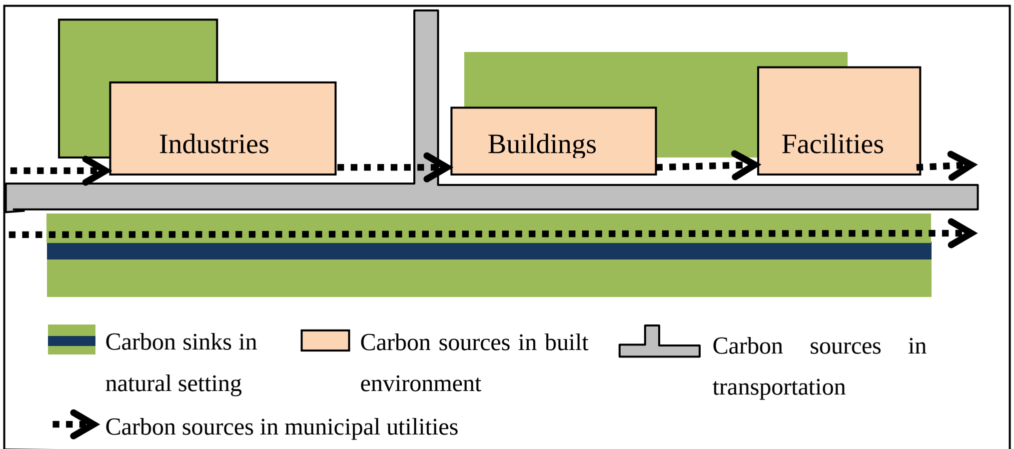


Figure3-1: Involved fields of Low-carbon development
Source: Author's construct based on (Qiu, 2011)

Carbon sinks in natural setting

Carbon sinks that cover green resources in natural setting serve to carbon removal including absorption and sequestration. Their types include forests, waters, grasslands, etc., with different carbon removal capacities [**Table3-1**]. From a landscape ecological perspective, carbon sinks could be divided into point sinks, area sinks and ribbon sinks in terms of their patterns. It should be recognized that strengthening the ecosystem functions could be contributed to reducing the natural vulnerability and enhancing carbon removal capacities (see next Section 3.2.1).

Table3-1: Carbon absorption and emission intensity of different sink types

Land use pattern	Farmlands	Forest lands	Grasslands	Wetlands and waters	Unused lands
Carbon absorption intensity (tC/ha)	0.13	0.52	0.05	0.045	0.005
Carbon emission intensity (tC/ha)	0.502	0.033	0.241	0	0

Source: (Dong, 2010)

Carbon sources in built environment, transportation and municipal utilities

Here further divides the carbon source into three types based on its generating field: carbon sources in built environment, transportation and municipal utilities, with all their impacts respectively (see next Section 3.2.2).

Specifically, the *carbon sources in built environment* refers to the energy consumption and GHG emissions derived from built-up entities caused by human construction behavior during the process of living, working, trading, industrial production and recreation and landscape maintenance as well, which is like the point pollution source. In addition, the *carbon sources in transportation* means the energy consumption and GHG emissions originated from the fossil fuel burning of transportation and commuting process, including road-based sources (private vehicles, trucks) which occupy the main portion in urban space and also non-on-road sources (airplanes, ships). Last but not least, the *carbon sources in municipal utilities* implies the energy consumption and GHG emissions generated in the facility-based operation process (supply, treating and discharge) of materials such as foods, electricity, water and wastes and other substances as well indispensable in human daily lives and production process. The latter two kinds of sources are like non-point pollution sources.

3.2 Low-carbon-related Impact Factors

3.2.1 Impact Factors of Carbon Sinks

Many studies have shown that urban green spaces (forestry, agriculture, water, natural conservation, etc.) can serve as climate-sensitive factors and play big a role in carbon sinks to remove GHG emissions in the atmosphere (Paoletti, Bardelli & Giovannini et al, 2011; Davies, Edmondson & Heinemeyer et al, 2011; Strohbach, Arnold & Haase, 2012). Generally there are two approaches of their carbon removal effects: active and passive. Active approach refers to the natural ecological photosynthesis function, in which process carbon dioxide is absorbed by vegetation (see Section 2.2.2). While passive approach first involves that the natural landscape including blue and green spaces could alleviate urban "heat island effect", cool the temperature and adjust urban microclimate (Bowler, Buyung-Ali & Knight et al, 2010; Oliveira, Andrade & Vaz, 2011; Völker, Baumeister & Classen et al, 2013). In this process the energy demands for artificial active adjustments for environmental amenity might also be mitigated by them due to environmental amenity (such as offering shade, cooling and ventilation), thus to reduce the GHG indirectly. Besides, a well-organized and well-designed green system plays a role in encouraging non-motorized travel activities, promoting green food production and recycling use of waste waters as well as increase of rainwater retention for nearby inhabitants, which could therefor save energy consumption in the long-distance delivery process (Groth, Miller & Nadkarni, 2008; Zhao & Liu, 2010).

Based on literature review regarding green spaces working as carbon sinks to remove carbon emissions, the impact factors are classified below [**Table3-2**]:

Table3-2: Argument box of impact factors of carbon sinks

Impact factors	Main arguments
Ecological processes	Much uncertainty is linked to tree growth and tree mortality. Increasing annual tree mortality from 0.5 to 4% reduces carbon sequestration by over 70% (Strohbach, Arnold & Haase, 2012). Vegetation in the growth period have a stronger capacity of carbon removal, and stronger in daylight/summer than in the evening/winter, which are also in relation to effect sunshine area/temperature and humidity/water and nutrition. (Zhao & Liu, 2010)
Functions of green resources	Urban green space can act as a carbon sink and the design and maintenance have a strong influence on the carbon footprint (Strohbach, Arnold & Haase, 2012). The Carbon storage by urban green spaces was estimated at about 139 kt equal to 56.5% of the emissions from fossil fuel use (Jo, 2002). Green parks are cooler than the surrounding, with an average temperature reduction of 0.94 degrees C during the day, based on 26 effect sizes from 16 studies, at night the temperature difference was 1.15 degrees C (Bowler, Buyung-Ali & Knight et al, 2010).
Types of green resources	An average cooling of 2.5 K can be attributed to urban blue spaces (river, stream, lake, pond, etc.) compared to urban reference sites. The temperature-mitigating capacity of urban blue can reduce heat stress in urban areas (Völker, Baumeister & Classen et al. 2013). An estimated 231 521 tonnes of carbon is stored within the green spaces of Leicester, largely in trees rather than herbaceous and woody vegetation (Davies, Edmondson & Heinemeyer et al. 2011). The reduction in the number of large trees implied a 43% decrease in the carbon storing in Florence in 2004 compared to 1985 (Paoletti, Bardelli & Giovannini et al. 2011). One hectare of forests absorb 67—69kg carbon dioxide and release 29-69kg oxygen per day; well grass per square meter absorbs 36g carbon dioxide per day, less than trees; the storage volume in mixed-planting soil is 5-6 times as much as mono-planting soli (Wang & Gong, 2002);
Spatial configuration of green resources	Planting an average of four shade trees per house would lead to an annual reduction in carbon emissions from power plants of 16,000, 41,000, and 9000 t, respectively (the per-tree reduction in carbon emissions is about 10-11 kg per year). Once the impact of the community cooling is included, these savings are increased by at least 25% (Akbari, 2002). The ability of carbon sequestration in a densely timbered community can be reached 17t

	per hector while less that 1t per hector in sparsely timbered community (Konijnendijk, Nilsson & Randrup et al. 2005)
Land use change	Timber harvest and site preparation largely changed the C and N distribution in the soil. The C/N ratio applies to be environmentally controlled based on variation of site management after timber harvest activities (Black & Harden, 1995). Forest soil carbon storage is a significant element of the global C cycle. The impact of harvesting changes on soil C storage in forest floors is represented by the variation of species composition, soil taxonomic order, and time after harvest (Nave, Vance & Swanston et al. 2010).

Source: Author's own collection

3.2.2 Impact Factors of Carbon Sources

A Factors influencing carbon sources in built environment

Definitely urban industrial structure in the form of land use highly influences energy demands and GHG emissions, especially in those developing industrializing countries (Zhong, Ge & Zhang et al, 2010; Yu, Zheng & Zhang, 2011; Wu, Xie & Wang, 2012). Apart from the micro level of building technology, many studies have already shown that urban morphology features (urban scale, spatial structure and form, density and land intensity) at the city level play a more dominant role in energy consumption (Owens, 1986; Newman & Kenworthy, 1989; Vettorato, 2011, UN-Habitat, 2011). In addition, these morphology features are also in key relevance to users' behavior (individual, social, organizational), including the time, frequency, intensity and mood of using energy source like heating and cooling, etc. (Schipper & Meyers, 1993; EEA, 2013). That is to say, the urban built environment has big physical impacts on human bodies and feelings of environment (temperature and humidity, air radiation), which may further make people to coordinate comfort by active measures (artificial lighting, cooling and warming). Therefore, how to change the behavior features of users is also of importance to both acquire environmental amenity and thus get more opportunities of passive energy gain so as to reduce active energy demands.

The impact factors of this kind of carbon sources are described in the following by referencing relevant studies [**Table3-3**]:

Table3-3: Argument box of impact factors of carbon sources in built environment

Impact factors	Main arguments
Industrial structure	The ratio of second industry is in direct proportion to carbon dioxide intensity, the higher ratio, the more emissions (Yu, Zheng & Zhang, 2011) When the high carbon industry(traditional secondary sector) decreases by 1%, the carbon emission per capita reduces by 0.3217%; developing the tertiary industry is a good way for low carbon (Wu, Xie & Wang, 2012) The ratio of tertiary industry that serves as low energy consumption will directly determine the intensity of carbon emissions (Zhong, Ge & Zhang et al, 2010)
	Urban scale (concentration of people, industries, resources) and thermal environment

Urban scale and settlement structure	(increase heat waves, carbon emissions, etc.) are closely interconnected, the mitigation and adaptation of climate change needs to be connected for urban planning to limit urban scale and optimize infrastructure system (Zhong, Ge & Zhang et al, 2010; Dhakal, 2010). Medium-density, mixed-use polycentric settlement structures may be better to have an important enabling function for sustainability drivers (such as air ventilation, access to open space, etc.) and mobility patterns than concentrated spatial structures. (Wegener, 2013)
Spatial form	Spatially compact form (high density, mixture of land use) of settlements around employment centers is contributed to minimizing heat transfer and reducing carbon emissions (Owens, 1986, Vettorato, 2011; UN-Habitat, 2011)；
Development intensity and density	Urban heat island effect is connected with land use intensity, the higher development intensity the more obvious heat island effect, since the rise of surface increases the energy from refection of buildings (van Hove, Steeneveld & Jacobs et al, 2011; EPA, 2008) High-density model of residential settlements could reduce heat loss when compared to independent low-density housing, and in the mean time causes compacticity (Newman & Kenworthy, 1989; Lu & Sun, 2013)
Block layout and building density	Orientation and layout of architectural complex impact urban thermal performance, demands for lighting and ventilation of buildings (Yao, Steemers & Li, 2006). Low-pilot-ratio but high-building-density urban block in which the space between buildings is narrow usually implies strong heat island area. Restraining building density (under 60%) is in favor of resisting heat island effect (Peng, Shi & Wang et al. 2013).
Human behavior and life style	People make the decisions that affect energy use. Insight into the human dimension of energy use is key to better understanding future energy trends and how to act effectively to manage them (Schipper & Meyers, 1993). Energy infrastructure plays an important role in determining consumer behavior vis-à-vis energy consumption, and such interaction needs to be considered (EEA, 2013). The age /family structure /education degree/incomes are key factors influencing energy consumption behavior in daily household life (Sun & Jiang, 2013).

Source: Author’s own collection

B **Factors influencing carbon Sources in transportation**

Normally the factors impacting energy consumption in transport depend on two aspects: one is the performance of traffic tools at the technological level; the other involves travel behavior characteristics of commuting and freightage, including choice of traffic mode (private cars, buses, bicycles or pedestrians), travel distance and frequency, etc. This point can be proved via two well-known formulas shown below (Darido, Montoya & Mehndiratta, 2009), in which (E) means urban transportation energy consumption, (i) represents traffic means. The first formula is defined by the parameters of number of vehicles, vehicle-miles of travel (VKT) as well as energy and fuel consumption of vehicles (E/VKT). The second formula is defined by the parameters of travel times, travel distance, passenger capacity per vehicle and also the (E/VKT).

$$\sum \mathrm{E(i)} = (\text{the number of vehicles })\mathrm{i} * (\mathrm{VKT/year})\mathrm{i} * (\mathrm{E/VKT})\mathrm{i}$$

$$\sum E(i) = (\text{travel times})i * (\text{travel distance})i * (\text{passenger capacity per vehicle})i * (E/VKT)i$$

What is more, many empirical studies have proved that only relying on technological innovation of vehicles is not enough for improving urban energy efficiency. That is to say, guiding traffic behavior characteristics called “behavioural determents of mobility” plays a more important role in addressing GHG emissions (Schäfer, 2012, Waisman, Guivarch & Lecocq, 2013). Furthermore, improving the combined cooperative relationship between land use, urban form and organization of traffic modes will also affect the spatial distribution of origins and destinations and derived traffic behavior as well, thus to further affect energy consumption (Stead & Marshall, 2001; Glaeser & Kahn, 2003; Grazi, Bergh & Ommeren, 2008). Last but not least, the physical environment is also contributed to impacting individual choices of traffic modes.

The impact factors of carbon sources in transportation are shown below by reviewing related empirical studies [**Table3-4**]:

Table3-4: Argument box of impact factors of carbon sources in transportation

Impact factors	Main arguments
Spatial form and settlement structure	Spatial sprawl will increase traffic energy consumption while sprawl reduction and compact growth play an important role in addressing climate change (Glaeser & Kahn, 2003; Marshall，2008, Grazi, Bergh & Ommeren, 2008). Polycentric urban structure (in which centers and settlement clusters concentrate around traffic nodes and are networked by traffic corridors between them) may potentially reduce traffic volume and commuting time (Thorne, Sankey & Alexander, 2003; Lin, Allan & Cui, 2013).
Population density	Population and housing density of settlements is correlated with carbon emissions, the rising of density will cause reduction of transport energy consumption; decentralized concentration is an effective way (Newman & Kenworthy, 1989; Glaeser & Kahn, 2010, Waisman, Guivarch & Lecocq, 2013).
Land use pattern	Mixture of land use (integrated home, work and service) and facility supply will reduce driving demands and change traffic modes, thus to reduce energy consumption (Cervero, 1989; Stead & Marshall, 2001). Compact and high diversity of land use as well as walking-friendly design of built environment can reduce vehicle-miles of travel per capital and encourage more non-motorized activities (Cervero & Kockelman, 1997).
Traffic modes & environment	In terms of energy consumption per capita evert hundred kilometers, when private cars represent 1, buses and metro stand for 8.4%, 5% respectively (ITRCC, 2009). Improvement of pedestrian and bicycle environment will attract non-motor vehicle travel choices and thus reduce motorized vehicle travel. The more accessible/comfortable/safe/well-lighting/well-equipped non-motor traffic mode in neigouhoods, the greater contribution to conserving energy consumption (Thorne, Sankey & Alexander, 2003; Beatley, 2000).

Source: Author’s own collection

C Factors influencing carbon sources in municipal utilities

Generally the energy consumption and carbon dioxide emissions derived from the running of urban infrastructure is involved with the supply (collection), distribution and treatment process of electricity, gas and heat and water as well as wastes. Take China as an example, the cost of energy consumption occupied 50-70 percent of the operating cost of urban water supply system (Zhou, Zhang & Cui et al, 2010).

As the metabolism process of resources mentioned in Section 2.2.1, studies have also shown that the traditional linear distribution and discharge process of water, wastes, etc. not only brings about massive energy consumption and emissions but also aggravates the situation of resource and environmental crisis, such as water shortage, water pollution, etc. (Zhang, 2011; Beatley, 2000). That is so say, besides the improvement of energy treatment at the technological level, it is also necessary to optimize the arrangement of energy systems combining with appropriate land use and urban form by spatial interventions at urban built-up level in order to facilitate resources and energy to recycled use as far as possible.

The impact factors of carbon sources in the municipal utilities are summarized below by literature review [**Table3-5**]:

Table3-5: Argument box of impact factors of carbon sources in municipal utilities

Impact factors	Main arguments
Spatial types	Different spatial types (city center/edge/inner districts/industrial areas/suburban hinterlands/urban extensions) should have corresponding sectoral energy planning and technologies (TCPA & CHPA 2008).
Scale and form	When reducing reliance on fossil fuels, improving the sustainability of large-scale power stations and focusing on small-scale decentralized energy generation can be adopted (TCPA & CHPA 2008).
Land use pattern	Purely mono function of land use division may cause the urban peak power demands; while mixed land use is contributed to decentralized energy distribution and local CHP projects (Beatley, 2000).
Development density and block layout	Developing small communities can benefit from microclimatic conditions. Increasing development density in a compact way can help balance urban growth and optimize energy and environmental impacts (Bhiwapurkar, 2013). At the street level both the density and layout of properties has a significant impact on the district heating. Higher density, compact urban development has the potential to reduce pipe lengths (TCPA & CHPA 2008).
Energy supply structure	Innovation of traditional energy supply systems (such as widening energy channels; developing clean and renewable non-fossil energy, including wind, solar, water and industrial

	biogas; raising the supply proportion of primary energy for reducing the consumption in this process (Lei, Zhuang & Zhang, 2011)

Source: Author's own collection

3.2.3 Comprehensive Correlation Model

On the basis of analysis above, a comprehensive correlation model among low-carbon involved fields, impact factors and their summarized attributive urban systems to be intervened in could be established [**Figure3-2**]. This correlation model will lay a foundation and serve as the guidance for the next possible intervention mechanism.

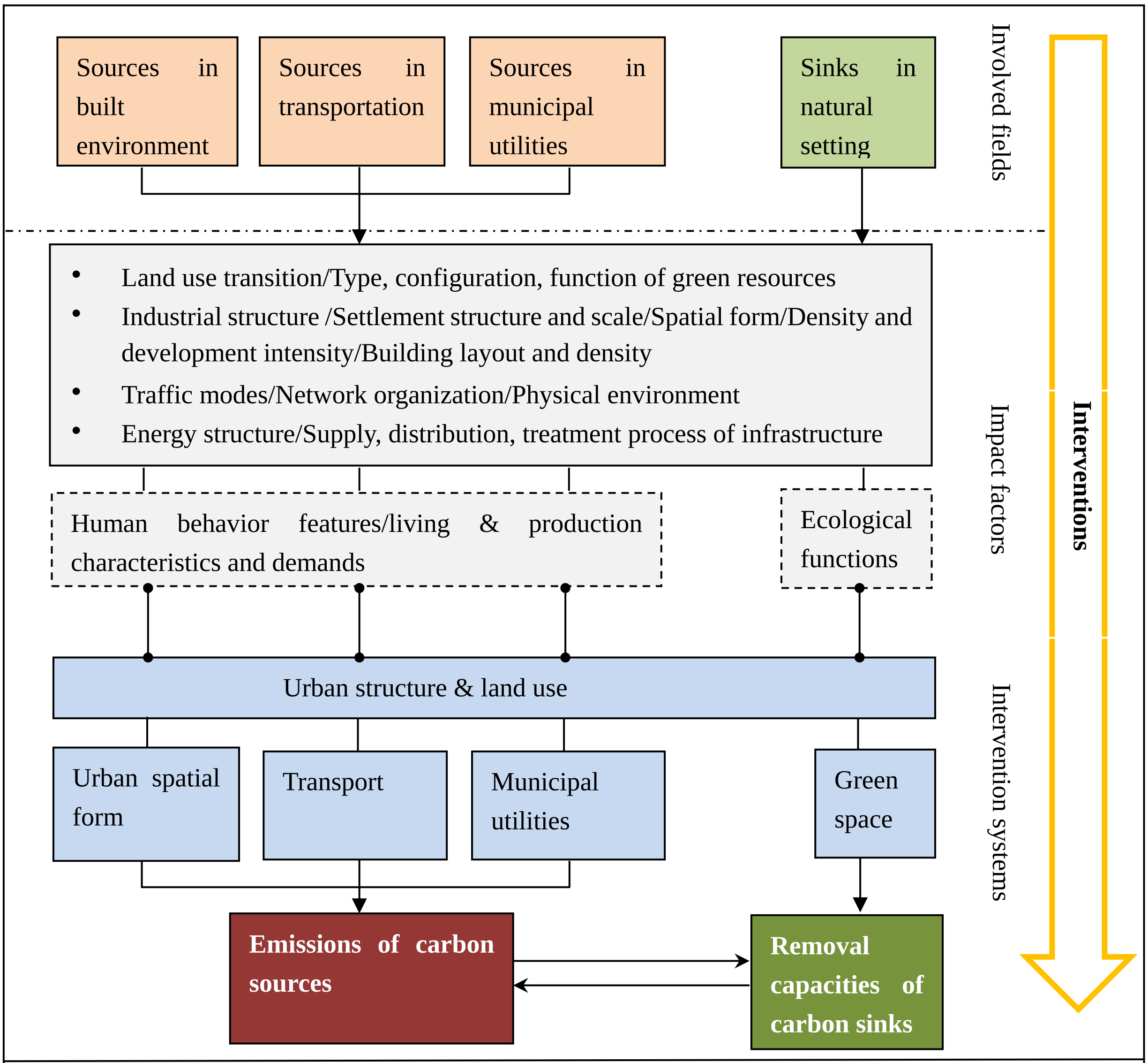


Figure3-2: Comprehensive correlation model regarding low-carbon-related impact factor system

Source: Author' construct based on (Qiu, 2011)

3.3 Low-carbon-oriented Intervention Mechanism

3.3.1 Overall Rationale

By reviewing previous theoretical explanation, it is acknowledged that the essence of carbon cycle belongs to a kind of urban mechanism (see Section 2.2.1), for whose optimization it is supposed to facilitate a way of close-looped and circular flow of energy and resources. Therefore, the overall rationale for promoting low-carbon development is to reduce carbon sources as emissions and strengthen carbon sinks' removal abilities as well as optimize the way of carbon flow between them.

Moreover, based on the analysis of carbon cycle process (see Section 2.2.2), it is known that physical components regarding carbon cycle consist of carbon sinks and carbon sources, which can be further classified into four specific intervention fields (see Section 3.1). Thus, by continuing this classification concept, the overall rationale mentioned above could be dissected into respect four sub-principles as the goals and strategy orientations: strengthening carbon sinks (removal capacities), reducing carbon sources (emissions) in the built environment, transportation and municipal utilities respectively.

By referring to existing literature review, the following will briefly summarize and structure key points regarding general low-carbon-oriented intervention strategies under each goal based on comprehensive low-carbon-related impact factor model (see Section 3.2.3), from spatial planning and urban design perspective. The strategies as findings here will serve as the basis for further deducing their applications in river-based regions.

3.3.2 Strengthening Carbon Sinks

According to the mechanism of carbon sinks functioning in active and passive approach for carbon removal (see Section 3.2.1), the essence of interventions on strengthening carbon sinks is therefore to improve the quantity and quality of green space system so as to maximize its eco-functions for absorbing and sequestrating GHG emissions. Relevant strategies include three aspects [**Figure3-3**]:

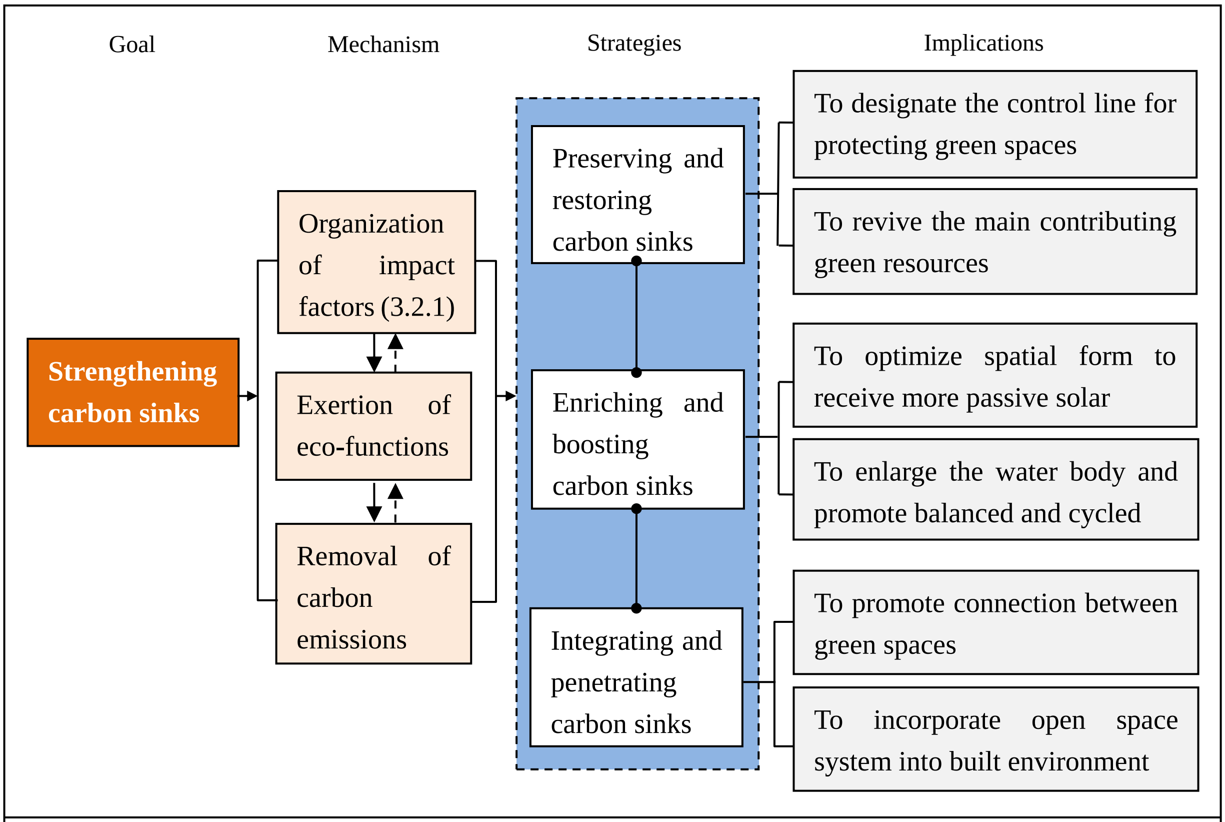


Figure3-3: Intervention strategy framework of strengthening carbon sinks

Source: Author' own construct

A Preserving and restoring carbon sinks

As mentioned in Section 3.2.1, the change of land use pattern serves as a main influencing factor on the exertion of functions of carbon sinks. Therefore at first there is a need to designate the protection boundary of different types of green areas as sinks via spatial planning tool, including natural conservation areas, water source zones, biosphere reserves, prime farmlands and forests and so forth, so as to identify the volumes of all carbon sinks. For this, the required total area of green areas that serve as the basis for designating different ecological boundaries could be calculated by referencing a method named "carbon-oxygen balance" (Wang & Gong, 2002). Secondly, it is also needed to designate their surrounding appropriate land uses in planning in order to prevent from being contaminated and destructed. Moreover, those main contributing carbon sink types (as listed in Table3-5) particularly need to be pertinently revived and endowed priority of active improving by various ecological restoration methods, such as the near-natural control measures adopted in the river-based projects mentioned in Section 2.1 B.

B **Enriching and boosting carbon sinks**

After preserving the primary carbon sinks, furthermore is to enrich and boost them. Actually the capacities of green resources in carbon removal depend on their eco-processes including bioprocesses (organisms' growth and succession) and also non-bio processes (water and material cycle, energy flow) (see previous theories in Section 2.2.2 and 2.3.1). This means that interventions need to intensify the emphasis on maximizing natural eco-processes of carbon sinks. For this, it is known that the solar radiation, water and soil are the major determinants of photosynthesis and growth power of vegetation which further impacts the ability of oxygen release and carbon absorption. Therefore, first the opportunity of passive solar gain for green spaces (receive sunshine) through spatial form design could be considered as far as possible. In addition, creating more water resources and promoting them in a balanced and cycled status also attach importance, since in water cycle process the canopy interception of water volume of vegetation influences its photosynthesis rate (Zuo & Wang, 2006). Specific measures regarding water improvement include: excavate the watercourse based on small ponds or low-lying terrain; expand the width of the river; daylight the buried watercourses; promote rainwater infiltration, etc.

C **Integrating and penetrating carbon sinks**

On the basis above, actually the ecological effects of quantitative but isolated green spaces are still not enough, a well-connected green system with high quality is more essential, as the rationale and principles explained from the perspective of landscape ecology (see Section 2.3.2). Therefore, there is still a need to integrate the green system. First is the integration of carbon sinks themselves. From a landscape ecological perspective, small patches (single trees, ponds, parks, farm dams, etc.) should be acted as "stepping stones", between them are the linear corridors to enhance the habitat connectivity. These corridors cover traffic corridors (slow-traffic system that carries pedestrian and bicycle activities) and natural green & blue corridors. Generally irregular edge and differentiated width in the same corridor could increase ecological interface with built environment (Zhu, Yu & Li, 2005). In a word, a coherent patch-corridor sink network is expected to be developed as a low-carbon open space network, which have the potential to reduce the carbon emissions and air pollution and so on (Fathejalali & Masoudi, 2011). Furthermore is to better penetrate this sink network system into urban built-up areas, linking other kinds of open spaces (such as city-around greenbelt, protective space along the high voltage cables, etc.) and making networked, like the historical Bonston's open space system mentioned in Section 2.1 A.

3.3.3 Reducing Carbon Sources

A Reducing carbon sources in built environment

It can be deduced from the impact factors and rationale (see Section 3.2.2 A) that the essence of interventions on reducing carbon sources in built-up areas involves two aspects: one is to adjust urban and industrial structure so as to improve thermal source environment; the other is to optimize urban morphological layout so as to receive more passive energy, as the following framework shown [**Figure3-4**].

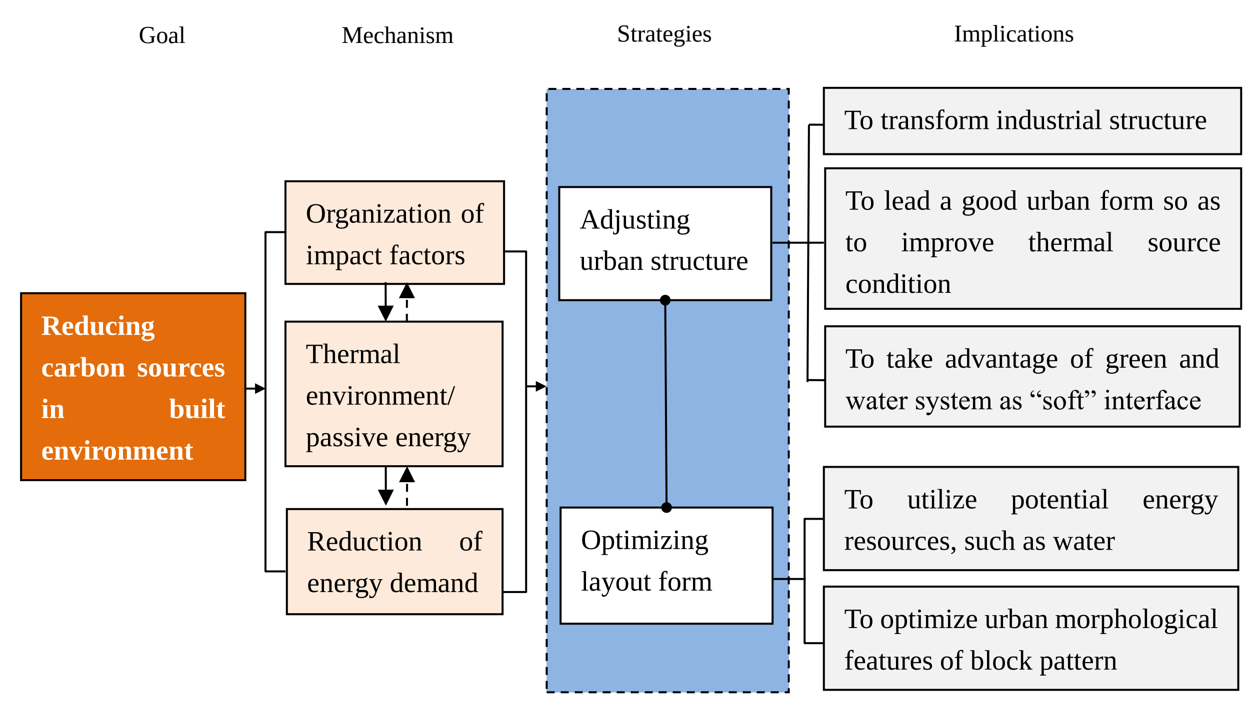


Figure3-4: Intervention strategy framework of reducing carbon sources in built environment

Source: Author' own construct

Adjusting urban spatial structure

First of all, there is no doubt that transforming those traditional energy-intensive industries that represent energy structure into a low energy-consuming industrial structure is an effective way to reduce emissions in built-up areas, however, this point should be positioned in consideration of local economic development stage. Besides, it should be understood that the change of urban thermal sources results in the deterioration of urban climatic environment and increase of energy consumption and GHG as well, in which the thermal pollution "heat island effect" is a typical representative. Therefore, optimizing urban thermal environment should be realized through well improving thermal source conditions (like facilitating cooling, raising relative ventilation and humidity). From a macro level, measures for optimizing urban spatial structure should be encouraged, including limiting urban sprawl and development scale into a compact pattern, leading development intensity by an infill development model (Friesecke, Schetke & Kötter, 2012); adopting a decentralized group-typed urban structure separated by green spaces (avoid large-scale city body); extending green corridors, etc., as their contributions explained in Section 3.2.2. In addition, in reality many urban underlying surfaces still adopt impermeable "hard" paving materials which store and thereby reflect heat owing to their high reflectance. In this regard, there is also a need to make good use of green and water space as "soft" interface in internal built environment, one of the effects is to evaporate the water and transmit into atmosphere to lower the heat island effect (Tong, Liu & Li et al, 2005).

Optimizing layout form

In terms of the meso and micro street level in the urban built environment, as mentioned in Section 3.2.2 A, it is also important to optimize the layout pattern of building block in order to facilitate widely use of passive energy reception to adjust microclimate conditions. Although utilizing potential energy sources by planning and design measures and receiving a passive energy gain cannot completely replace the active cooling and heating system of architecture, they may improve the comport sense or at least extend the time without the running of active energy wasting equipment, which is also a kind of energy reduction (Yao, Steemers & Li, 2006).

Hence, diverse potential climatic resources are supposed to be viewed as urban positive energy resources and to be taken advantage, in which the utilization of wind and solar have been relatively widely considered according to the relationship between building form and climatic direction through urban and architectural design instrument. Moreover, greening resources and water also have unique climatic effects (as listed in Section 3.2.1). In this regard, the river corridor could be utilized as a kind of blue (water) energy, besides its supply and discharge function, its incorporation with open spaces also can form ventilation corridors initiating the occurrence of wind energy.

B Reducing carbon Sources in transportation

The previous contents (see Section 3.2.2 B) has already analyzed the factors influencing carbon emissions in the traffic field, so pertinent interventions should be taken to impact human behavioral characteristics and psychological commuting choices through coordinating the relationship between urban functions and traffic conditions as well as improving travel environmental quality.

Shortening travel distance

Reducing unnecessary travel activities could be contributed to a reduction of total energy consumption and GHG emissions, since the overall travel distance is linked with single travel distance of motorized users and their travel time as well as frequency. In this regard, low-carbon-oriented interventions may aim at creating mixture of land use in order to shorten commuting distance, and in the meanwhile optimizing an effective open road network structure. As listed in Section 3.2.2 B, a mass of empirical studies have already shown that measures like adopting a polycentric urban structure and appropriate mixed land use as well as increasing population (or economic activity) density in combination with improvement of public transport corridor can promote the balance among home, study and job, thus to achieve the effect of reducing unnecessary travel activities and carbon emissions thereby. Moreover, especially for Chinese cities there are still huge demands for improving current road network structure: 1) as a whole, avoid the structure of "external wide road and internal gated community" but adopt a passing-through chessboard-pattern networked road structure. 2) for the major road system, establish the direct and convenient connection between urban center, important nodes and industrial areas, to reduce travel distance of motor vehicles; 2) for the lower-tier road system, adopt a relative "small-scale and high-density" form to supplement the connectivity and diversity of travel choices.

Optimizing traffic modes and travel environment

Raising opportunities of other non-motorized traffic modes is a powerful way to mitigate carbon emissions in transport field, so the strategy here mainly refers to making the public transport system diversified. In this regard, a study concludes that for Chinese cities the priority order of public transport in planning should be "POD over BOD over TOD"[1] (Pan, Tang & Wu et al, 2008). Especially the slow-travel system

[1] P=Pedestrian; B=Bicycle; T=Transit; OD=oriented development

(pedestrian and cycling trip) is supposed to be improved, which is intended to encourage people to give up selecting private cars at a relative short commuting distance. Generally the design of slow-travel system is needed to meet the demands of safe, convenience and amenity, as the arguments listed in Section 3.2.2 B. At first, micro security condition (such as well lighting, protective fence when needed, etc.) is an essential factor that influences the choice of commuting modes. Then, convenience is another factor of consideration when selecting commuting way, including the accessibility of slow-travel path itself and the mutual connection between pedestrian, bicycling and public transport and corresponding facility nodes. As Litman (2002) also pointed out that a multi-modal area with good transit service, bicycle and pedestrian facilities may encounter fewer problems. Moreover, environmental amenity such as the clear sign system, adjacent appropriate land use with good landscape and well-designed facility placement for recreation also implies attractive. In terms of above, the river-based area is typically an ideal space of inducing and serving slow-travel activities due to its environmental location.

The corresponding intervention strategy framework is shown as following [**Figure3-5**].

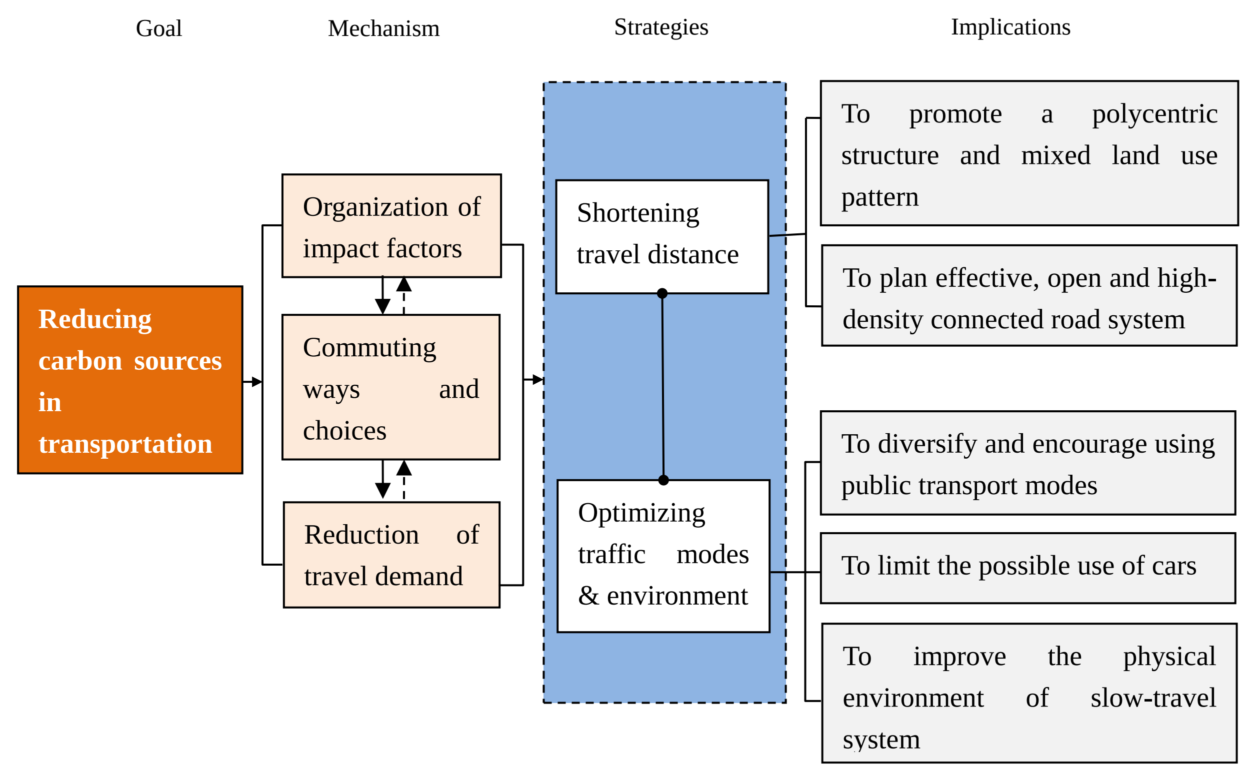


Figure3-5: Intervention strategy framework of reducing carbon sources in transportation
Source: Author' own construct

C Reducing carbon sources in municipal utilities

As previously described (see Section 2.2.1& 3.2.2 C), the flow of energy, water and wastes are the main three materials in urban metabolism, which serves as main physical elements of carbon circulation generating GHG emissions in their running process. At this point, the essence of interventions working in decreasing carbon sources is to optimize the spatial configuration of relative infrastructure facilities, required land areas and design elements in order to impact high-efficiency use of energy resources and promote the operation of a self-circulation metabolism process.

Promoting the operation efficiency of energy systems

Studies have indicated that the aim of high-efficiency operation of energy systems (supply and distribution) for low-carbon cities is to achieve a “3D” situation, namely decarburization, decentralization and demand reduction (Long, Bai & Liang et al, 2010). From the perspective of urban planning, Decarburization needs interventions on potential energy sources that are intended to replace some traditional fossil energy, such as described above (see Section 3.3.3 A); and Demand reduction has also been mentioned in the above (see Section 3.3.3 A and 3.3.3 B); so the strategy here mainly involves Decentralization of energy. Firstly, it is needed to ascertain the corresponding way to supply energy and its supporting facility design by taking different urban locations into account, such as city center, edge, industrial areas, etc., as listed in Section 3.2.2 C. Secondly there is also a need to optimize the way of energy supply and distribution, avoid energy loss in a long-distance distribution process. In this regard, many studies have indicated that a “decentralized concentration” operation way of energy system is relatively effective, which could be supported by mixed land use, improved urban form and well infrastructure placement, etc. (see Section 3.2.2 C).

Recycling renewable energy sources

Apart from other renewable energy like wind and solar, this strategy mainly concerns about the water energy resources. As like the linear metabolism process described in Section 2.2.1, the water consumption of most worldwide cites still adopt a linear model: on the one hand massive water resources have been explored to meet the needs of urban development; on the other hand, the sewage and rainwater are regarded as the waste and then discharged (UN-Habitat, 2011). However, this linear way of water consumption violates the natural rule of water cycle, whose negative results have been mentioned in Section 3.2.2 C.

Hence, as also mentioned in Section 3.3.3 B, the water resource should be regarded as a kind of renewable energy source to promote a way of "minimization, recycling and reutilization". Precisely, a possible intervention is to utilize unconventional water bodies which are often easy to be neglected or directly discharged in combination with spatial planning and landscape design, including flood, rainwater and sewage, industrial waste water, etc. The rationale is to collect and enable more water to be infiltrated and supplement the groundwater and form a circular way as well, strengthening evaporation and reducing surface runoff and further energy consumption in this process. Available measures are diverse, including: through land use control, such as placing stormwater collection basins, constructed wetlands, avoiding building development in flood plains while replacing with parks, open spaces or ecological reserves (Friesecke, Schetke & Kötter, 2012); placing drainage facilities incorporating with landscape elements design to increase water infiltration and reduce impervious area ratio, such as green ground and roofs, rain gardens, swales, detention ponds, etc. (Hoyer, Wolfgang & Kronawitter, 2011).

The following also illustrates this intervention strategy framework [**Figure3-6**].

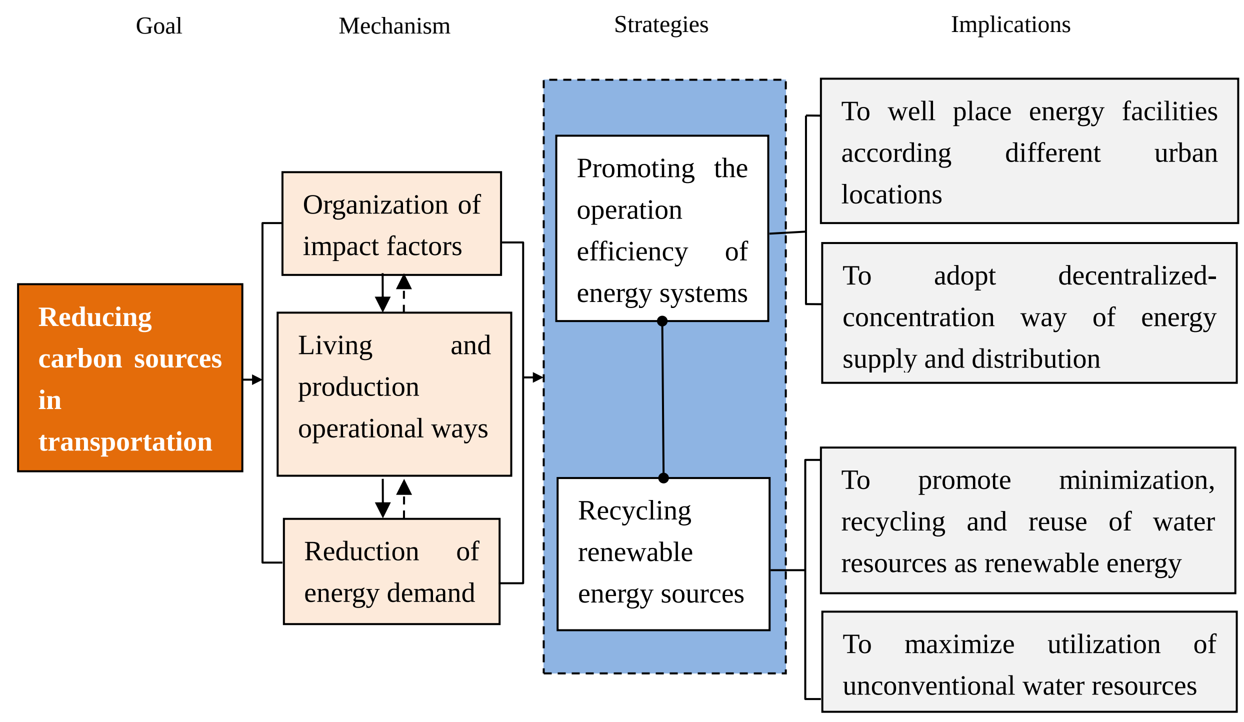


Figure3-6: Intervention strategy framework of reducing carbon sources in municipal utilities

Source: Author' own construct

3.4 Application in River-based Regions

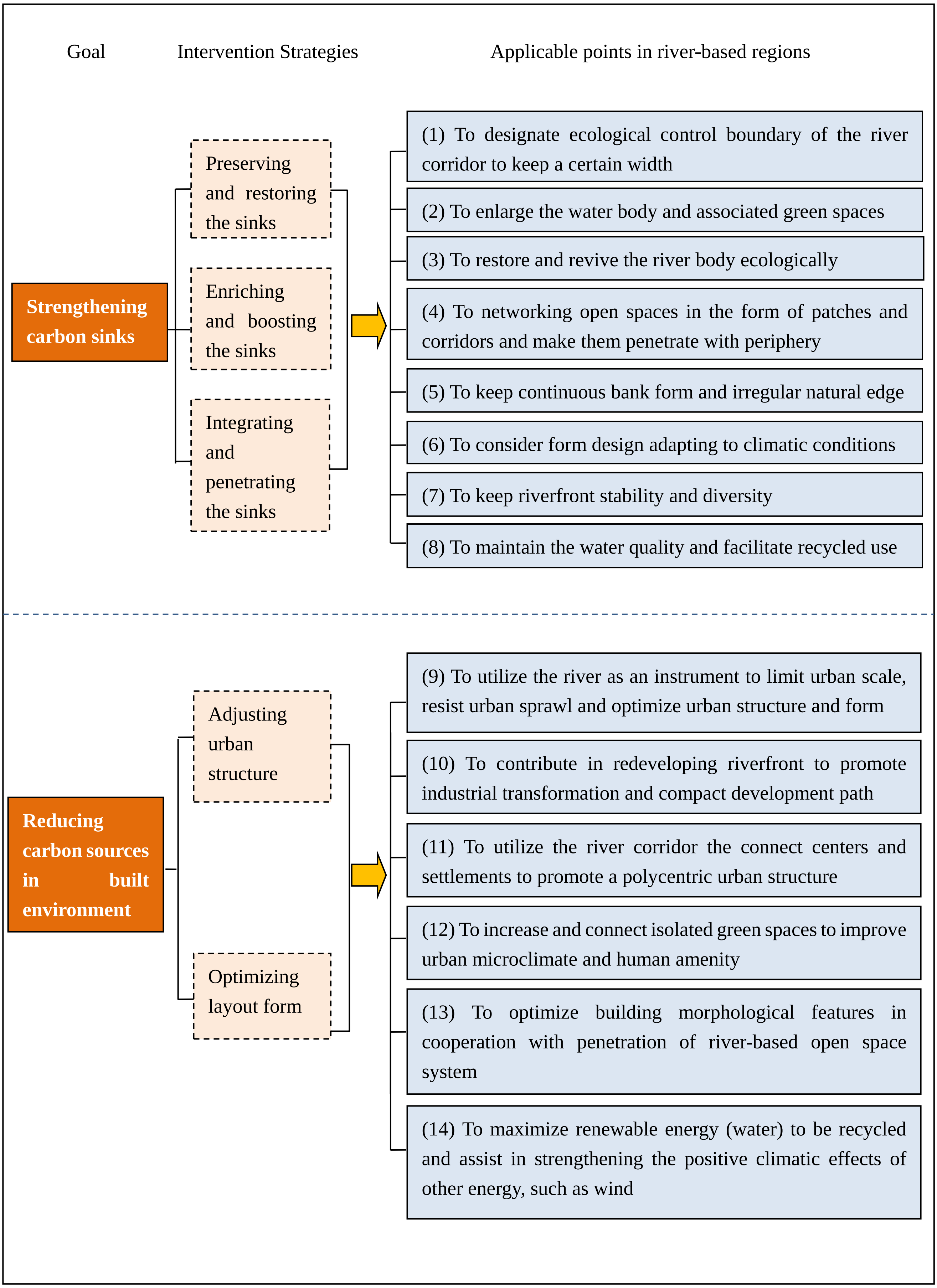
3.4.1 Applicable Points

From the analysis in Section 3.3, their common applicable points could further be reasoned dedicating to the application of low-carbon development in river-based regions. This reasoning is also established based on the understanding of definition and associated characteristics of the river-based region (see Section 2.3.3), here repeats again:

"A kind of city space where the river system meets surrounding urbanized and natural land, whose spatial range covers the river bodies and their adjacent closely-associated terrestrial units as well as peripheral influencing area":

- It owns both natural & man-made properties and thus is a combined system covering natural processes and human interventions including land use, transport, landscaping, infrastructure, etc.
- It is involved in urban metabolism and carbon cycle process with its own features;
- It carries indispensable ecological functions attributed to the river system that is supposed to follow the principle of integrity, heterogeneity, connectivity and stability.
- It serves as an intervention instrument of preference especially when confronted with environmental problems;
- It has always been a typical planning space and action space of highly concern, particularly a kind of preferred urbanization area in China.

The possible applicable points of low-carbon-oriented intervention mechanism in river-based regions can be visualized as the figure shown below [**Figure3-7**]:


Goal
Intervention Strategies
Applicable points in river-based regions
Strengthening carbon sinks
Preserving and restoring the sinks
Enriching and boosting the sinks
Integrating and penetrating the sinks
(1) To designate ecological control boundary of the river corridor to keep a certain width
(2) To enlarge the water body and associated green spaces
(3) To restore and revive the river body ecologically
(4) To networking open spaces in the form of patches and corridors and make them penetrate with periphery
(5) To keep continuous bank form and irregular natural edge
(6) To consider form design adapting to climatic conditions
(7) To keep riverfront stability and diversity
(8) To maintain the water quality and facilitate recycled use
Reducing carbon sources in built environment
Adjusting urban structure
Optimizing layout form
(9) To utilize the river as an instrument to limit urban scale, resist urban sprawl and optimize urban structure and form
(10) To contribute in redeveloping riverfront to promote industrial transformation and compact development path
(11) To utilize the river corridor the connect centers and settlements to promote a polycentric urban structure
(12) To increase and connect isolated green spaces to improve urban microclimate and human amenity
(13) To optimize building morphological features in cooperation with penetration of river-based open space system
(14) To maximize renewable energy (water) to be recycled and assist in strengthening the positive climatic effects of other energy, such as wind

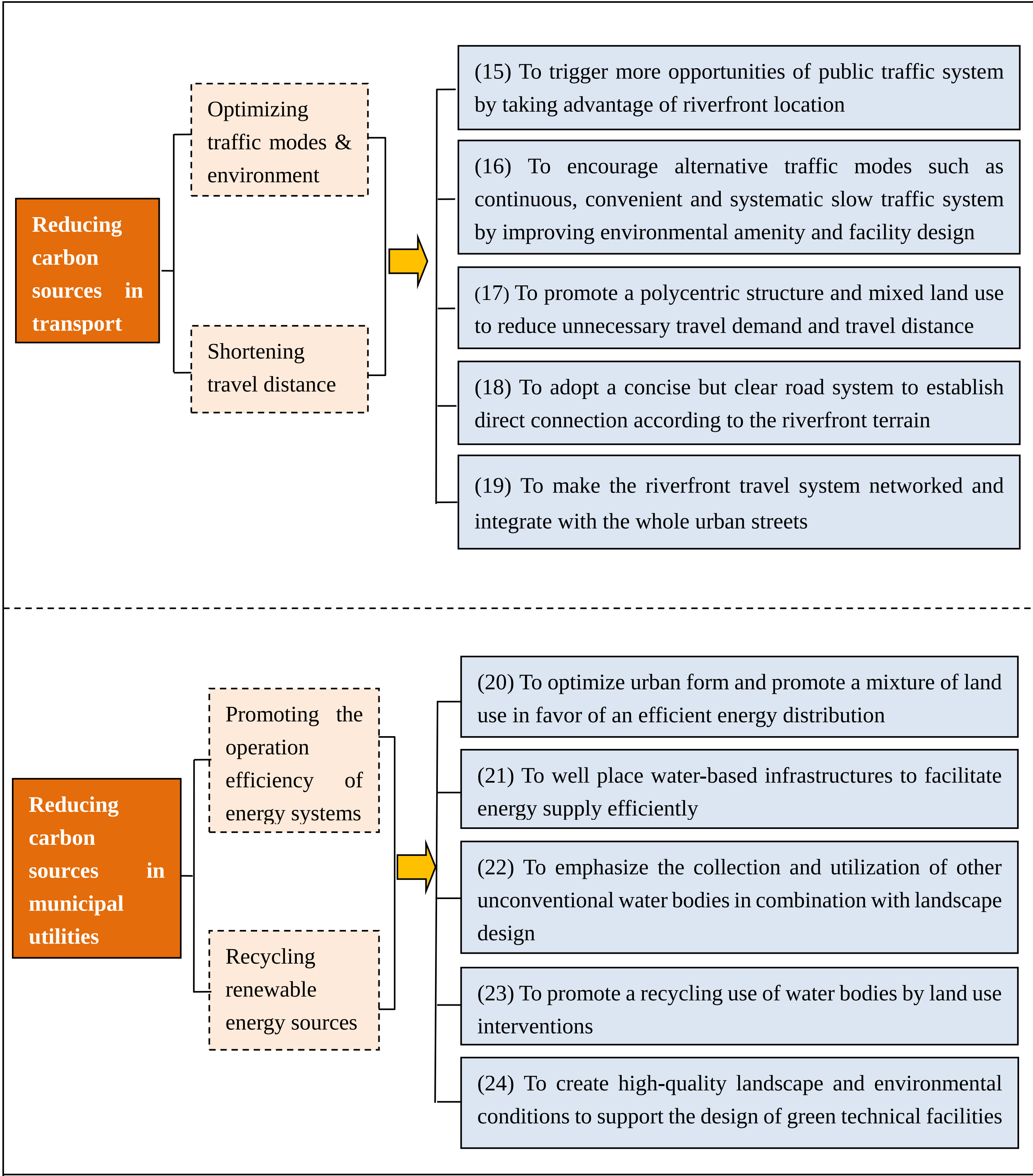


Figure3-7: Comprehensive application framework of low-carbon-oriented intervention mechanism in river-based regions
Source: Author' own construct

3.4.2 Guiding Principles and Guidelines

To sum all previously up, the general low-carbon-oriented guiding principles and corresponding guidelines for interventions on the river-based region for promoting a low-carbon development could be established, as shown in the following [**Table3-6**]:

Table3-6: Low-carbon-oriented guiding principle and guideline framework

Goal	Intervention object (six-layer system)	Guiding principles	Guidelines
Strengthening carbon sinks	Waterside Status	Richness	(1)(2)(3)(5)(7)(8)
	Green space	Biodiversity	(2)(4)(6)(7)(12)(24)
Reducing carbon sources	Urban Structure and land use	Multifunctionality	(9)(10)(11)(12)(17)(20)
	Spatial form	Permeability	(4)(9)(12)(13)(14)
	Traffic network	Public accessibility	(15)(16)(17)(18)(19)
	Municipal utilities operation	Circularity	(8)(14)(21)(22)(23) (24)

* **Guidelines are in correspond with the number of applicable points presented in 3.4.1**

Source: Author's own construct

The above listed guiding principle and guideline framework is supposed to be considered essential to be incorporated into urban planning tools. It can be seen that it is a comprehensive framework involved with comprehensive complex urban systems and factors, which need a powerful integrated planning approach to work. It should also be recognized that these principles cannot work in isolated situation but are intertwined and interactive with each other.

These general low-carbon-oriented guiding principles and guidelines at the strategic level will serve as important theoretical basis and criteria for further analysis in next chapters.

3.5 Summary

Based on the definitions of key words in last chapter, this chapter starts with the involved fields to be intervened in terms of low-carbon development, including carbon sinks in nature setting serving as the subjects of removal and carbon sources (in the built environment, transportation and public utilities) serving as the objects of emissions. After that, it dissects low-carbon-related impact factors and their influencing rationale in terms of each filed, then summarizes low-carbon-oriented intervention strategy framework.

Furthermore, this intervention strategy framework is transferred into the application in river-based regions in the form of low-carbon-oriented guiding principles and guidelines under the goal of strengthening carbon sinks and reducing carbon sources, which serves as the main finding and also theoretical framework for the next chapters [**Figure3-8**].

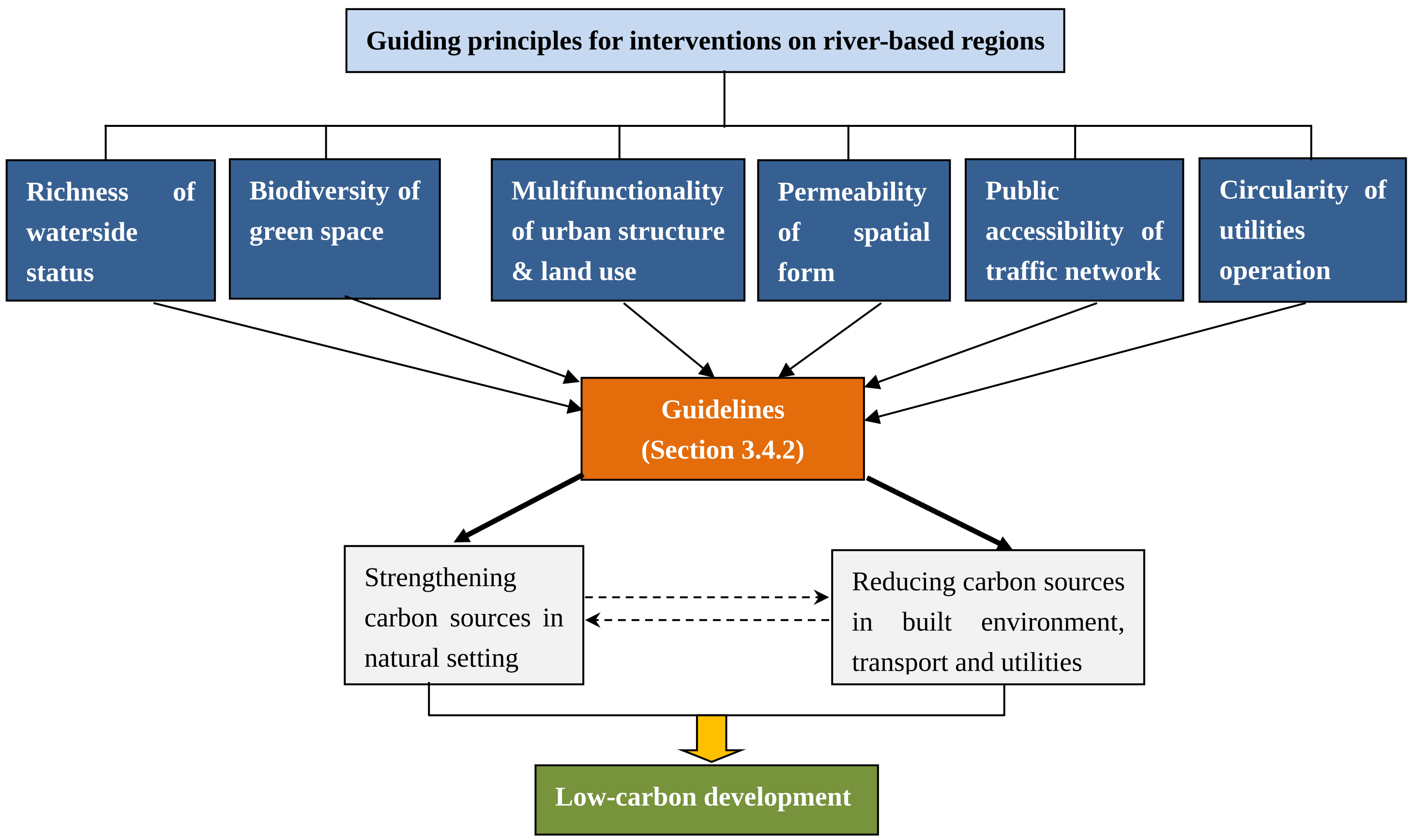


Figure3-8: Theoretical framework regarding low-carbon development in river-based regions

Source: Author' own construct

Chapter 4 Methodology

4.1 Research Questions and Objectives

As mentioned previously (see 1.1), this research topic focuses on the interaction between low-carbon development goal, interventions on the river-based region and the planning integrated approach behind, whose ultimate purpose is to establish an appropriate planning axiology and development path for dealing with river-based regions in order to assist in creating a climate-friendly urban space environment.

This particular emphasis can be placed on two types of designed research question sets:

- Type 1: *What to do at the strategic level?* It refers to what kind of contributions can river-based regions that serve as planning and action spaces make to the low-carbon development;

- Type 2: *How to do at the operational level?* It implies how to realize the above question by using supportive planning approach as guiding tools in terms of specific case study?

These two research question sets are intended to distinguish two aspects of research points, one is regarding the perspective **"general** or **specific"**. The other is regarding the handling level, at the "**strategic level** or **operational level**".

Normally general strategic level (planning principles, strategies, technical measures) has little boundary between regions, which means no matter China or Germany or other countries may adopt the same ideas, concepts and strategies. However, implementing them in reality has to be operated under respective indigenous spatial planning and management context. Therefore, the first type of question set is designed focusing on the general strategic level, which has already been answered through Chapter 2 and Chapter 3. And the second type of question set concerned with operational level will be endowed with answers in the next "**Part II: Analysis**" through specific case study.

The whole research question sets with respective questions and their corresponding research objectives are structured below [**Figure4-1**]:

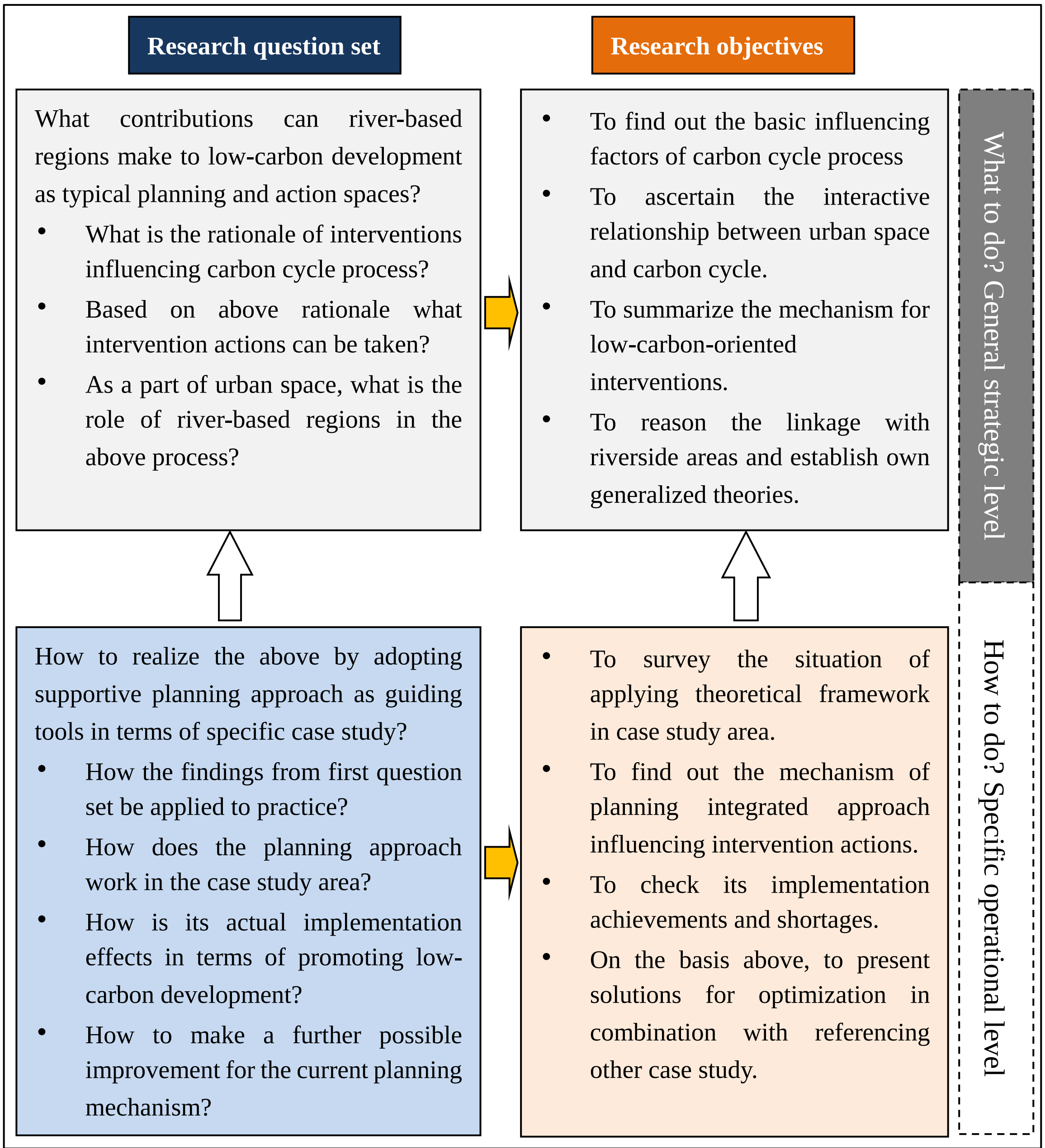


Figure4-1: Research questions and objectives

Source: Author' own construct

4.2 Research Design

According to research questions and objectives, there should be a research design which is a plan that outlines the critical stages to be followed by a researcher when conducting the study (Monette, Sullivan & DeJong, 2010). The main function of research design is to acquire evidence to answer research questions, to test theories or explain phenomenon (de Vaus, 2001). As mentioned in Section 1.2, this Chapter 4 plays a role as a **transitional bridge** between “theory” and next “practice”, between “general part” and “specific part” as well as between “strategic level” and “operational level”. Therefore, it is needed to present the research design that serves as the research clue and logic for the next, as the steps described below:

Step1. Establishment of theoretical framework. The first **Part I** has meet the requirement of answering the type 1 of research question set and corresponding objectives regarding “*what to do at the general strategic level*”. It identifies the external context and definitions of research key words. Then, it established the connection between low-carbon development and interventions in river-based region in the form of theoretical framework as the final finding.

Step2. Selection. Here shows the selection of specific case studies including the reasons why they are selected and basic descriptions as well as the identification of their processing modes: main case and referenced case. Besides, sampling of the targeted interviewee group in terms of the main case study and selection of relative methods used will also be demonstrated. In the next specific case study part the respective planning approach will arise.

Step3. Investigation. This applies to the main case study——Haihe riverside region in Tianjin (China). From here this research goes into the “**Part II: Analysis**”. It is planned to tease out the urban low-carbon context, low-carbon-related intervention actions and running planning approach behind as well as resulted site features, through field work process and interview with selected interviewee group. Here will apply the main finding from “Theory” part as the check principle.

Step4. Assessment. Here it is planned to establish evaluation index system (get “indexation” via selecting indicators) as the evaluation object and then evaluate the implementation achievements of intervention actions in this case study area towards low-carbon goals. In this process the first-hand data collection and designed questionnaire survey with targeted interviewee group play a big role. In addition, the theoretical framework from **Part I** will also be applied here contributing to the evaluation indexation.

Step5. Cause analysis. After Step4, according to the evaluation results, the possible reasons of why such results have been formed are planned to be found, also through interviewing targeted interviewee group with designed questionnaire.

Step6. Reference. Here inserts a German case——IBA Emscher Park in the Ruhr area as the reference, since it has similarities with the Chinese case to some extent. Through review of its intensive intervention process and planning integrated approach behind, the research is planned to explore transferable lessons regarding how did the German system work when confronting similar problems, based on making a comparison between two cases.

Step7. Conclusion. Here accesses the "**Part III: Conception**" for the main case study area. Based on summarizing all previous findings, the author plays the role as an urban planner who would like to propose final recommendations to different action bodies, for possible improvement regarding the mechanism of planning approach influencing practice actions in future Haihe riverside region. Last, the research also depicts outlook for its future spatial development.

The whole framework of research design is illustrated below [**Figure4-2**]:

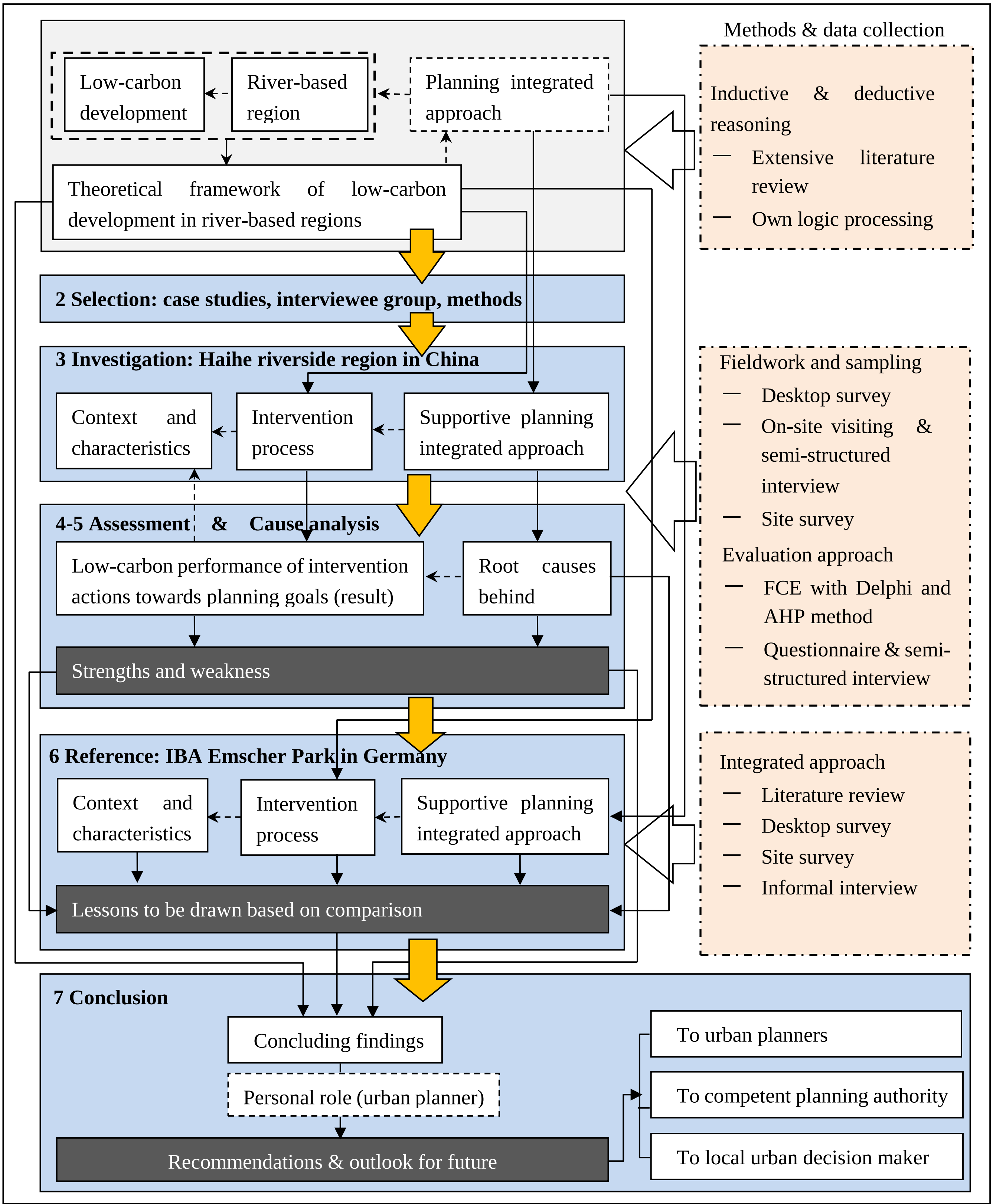


Figure4-2: Framework of research design

Source: Author' own construct

4.3 Selection of Case Study

4.3.1 Criteria of Selection

In terms of the theme of this research, the selection criteria of case study areas are composed of following principles, which serve as the basis for selection reasons:

- **Criterion 1**: A river-based region

The case study area should be a river-across region with both natural setting and built environment in which its river system is a significant factor and has a great influence on its spatial development. In other word, this area is famous for its river system to some extent or even named after its river.

- **Criterion 2**:In a context of low carbon transformation

The case study area should be (or once was) in a relative "high-carbon" environment and is (was) striving to transform into a more low-carbon status, namely this area is moving to a low-carbon and final sustainable development context.

- **Criterion 3**:Intervention actions taken towards low-carbon development

The case study area should be an action space where receives specific intervention actions involving with low-carbon-related impact factors (see Section 3.2.3) and low-carbon-oriented guiding principles and guidelines as well (see Section 3.4.2).

- **Criteria 4**:Planning integrated approach plays a big role

The case study area should also be a typical planning area of highly concern where experiences continuous planning process. This process is based on a given planning system involving with various planning tools, activities and actors influencing specific actions.

- **Criterion 5**:The author's attitude

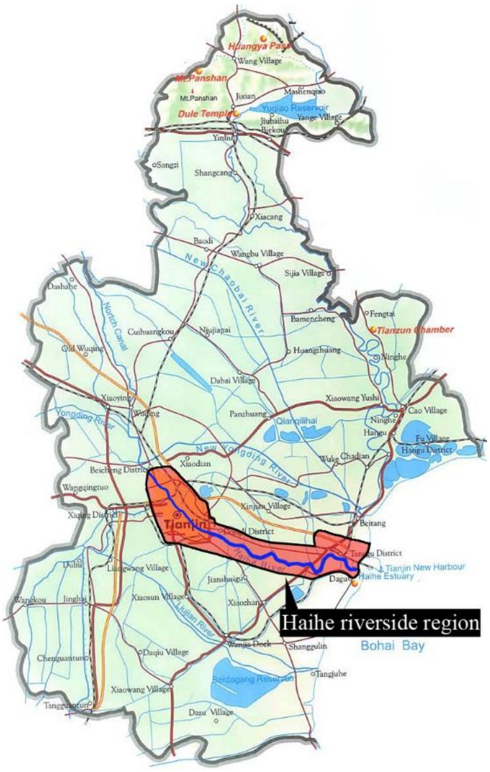
The alternative cases which matches above criteria might be much, but the weight of author's attitude also plays a big role. That is to say, the author's possible ability, cognition and even preference also determine the selection. The case study area should be accessible and available for the author to get information and conduct research.

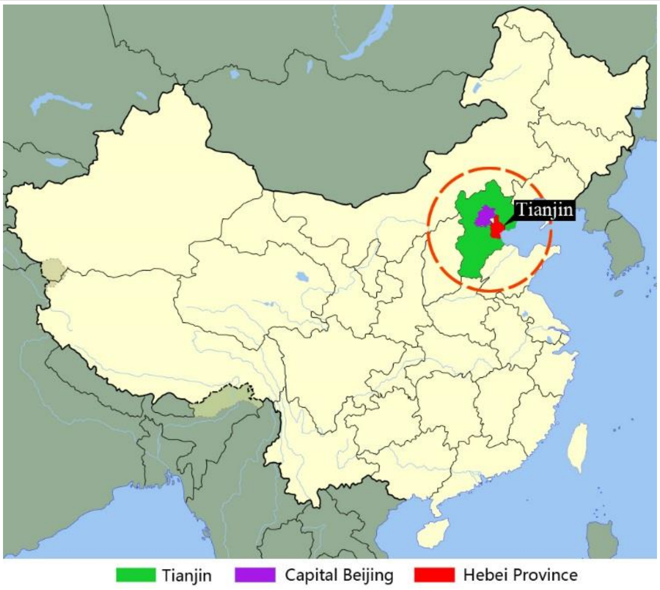
4.3.2 Selection Logic and Result

Based on above criteria, two case studies are selected: Haihe riverside region in Chinese metropolis Tianjin as the main, and IBA Emscher Park in Germany as a referenced. The following reflects the selection reasons by explaining the matching degree of selection criteria, and also describes the basic information of selected case context.

Main case study: Haihe riverside region in metropolis Tianjin, China

The case study area——Haihe riverside region is a sub region located at the central place of metropolis Tianjin [**Figure4-3**], where Haihe river serves as the "mother river" passing through from east to west (**matches Criterion 1**). This study area is a highly urbanized and densely populated region. However, this region has been experiencing industrial transformation from former heavy industries ("high-carbon" context) to service and other industries, in which process creating a low-carbon city is one of its current development visions (**matches Criterion 2**). In addition, this region is a focus area from the perspective of municipal government and also planning authority as well as relevant sectors, in which planning activities and subsequent actions have always been taken around Haihe river intensively since recent 15 years (**matches criterion 3 & 4**). Last, from personal perspective, the author is a Chinese planner and once conducted planning work in this region, and its data collection as well as investigation are possible and accessible for the author (**matches Criterion 5**). Therefore, this region is chosen as the main case study whose analysis will be derived from interview survey and first-hand data collection.





Right—Figure4-4: Tianjin in China

Source:http://upload.wikimedia.org/wikipedia/commons/9/92/China_blank_map.svg

Left—Figure4-3: Haihe riverside region in Tianjin

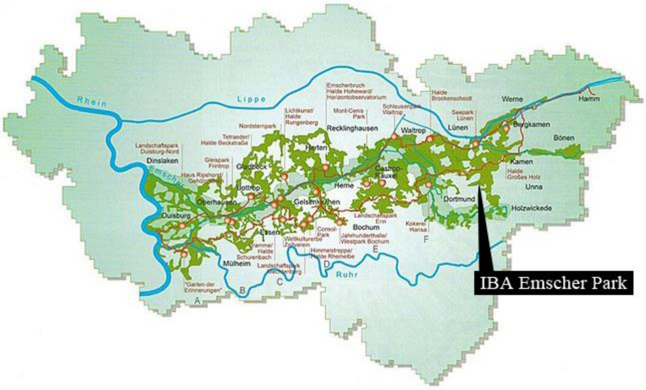
Source: http://www.mappery.com/map-of/Tianjin-Guide-Map-2

To describe more information about Haihe riverside region's peripheral hinterland: Tianjin. Tianjin is a metropolis in northern China bordering the capital Beijing and Hebei Province, which has an total area of 11,946 km^2 and population of 15.16 million (Tianjin Statistical Bureau, 2015) [**Figure4-4**]. It is transforming into a hub city for international shipping, logistics and modern manufacturing and service, etc. Moreover, Tianjin is governed as a direct-controlled municipality of China (similar to the *Stadtstaat* such as Bremen, Berlin, etc) divided further into 16 internal administrative divisions, including 15 urban and suburban districts (*Stadtbezirke*) and 1 peripheral county (*Stadtkreis*), which are all under the direct administration of the central municipal government of Tianjin. In terms of spatial structure, its two main city centers and some sub-centers are located along the Haihe river.

Referenced case: IBA Emscher Park in the Ruhr area, Germany

This referenced case——IBA Emscher Park is a sub region located in the north of the central place (*Hellweg* zone) of the urban agglomeration Ruhr [**Figure4-5**], where the main stream of Emscher river stretches from the west to east (**matches Criterion 1**). Since decades the Emscher region and the whole Ruhr area have been experiencing a structural change from previous coal mining and steel industry (relative "high-carbon" environment) to other diverse industries (**matches Criterion 2**). As one of the important steps of Ruhr's structural change, in 1989 the NRW government initiated a special program——"IBA Emscher Park Initiative" implementing the concept of a "regional park". Since then, a process of over 30-years planning activities and interventions on land use, open space and water management, etc. have been lasting in this region where has been treated as an important planning and action space, in order to lead a more sustainable transformation (**matches Criterion 3&4**). Last but not least, the author has been studying in Germany particularly positioned in this region where surrounded by many touchable related resources, so the author subjectively would like to link this case to learn something to Chinese case, since it has some similarities in terms of above context (**matches Criterion 5**).

Unlike the Chinese main case, this case is treated as a reference because of that it should be first noticed that learning IBA case's experiences has limitation, not everything is applicable, since the institutional system between China and Germany (development stage, economic context, political administrative structure, planning system, organizational way, etc.) is quite differentiated. Besides, objectively due to personal difficulties (lack of German background, language problem, time limitation, etc.) the author is incapable of going too deep. Hence, the point of referencing is not to completely compare them in a juxtaposition range and conclude which is “better” or “worse”, although such comparison can be made. The point is to dig out which German lessons might be applicable to China, ignoring those inapplicable but absorbing its transferability.



Left—Figure4-5: IBA Emscher Park in the Ruhr area

Source: http://www.metropoleruhr.de

Right—Figure4-6: The Ruhr area in Germany

Source: http://upload.wikimedia.org/wikipedia/commons/b/b2/Locator_map_RVR_in_Germany.svg

Here also briefly reviews the hinterland of IBA Emscher Park: the Ruhr area (*Ruhrgebiet*). It is the largest European urban agglomeration located in the federal state of North-Rhine Westphalia (NRW) in Germany, which covers the area of approximately 4.435km² with 5.1 million inhabitants[1] [**Figure4-6**]. It should be first understood that the term “Ruhr area” is defined not based on a politically administrative boundary, however, it refers to the territory bordered between the river Ruhr in the south and the river Lippe in the north, between the Rhine in the west and the Hamm in the east, which represents the administrative range of a regional association——*Regionalverband Ruhr* (RVR). This Ruhr area consists of eleven cities (*Kreisfreie Städte*) and 4 counties (*Kreis*) in a formation of a polycentric spatial structure without a dominant center.

The following lists the basic data of two cases as the end of selection result [**Table4-1**], it can be seen that apart from similar transformation background, they also have similarities in terms of physical spatial dimension (area size, shape, river length, etc.).

[1] Ruhrgebiet. http://www.metropoleruhr.de

Table4-1: Basic data of two cases

Case study area	Haihe riverside region in Tianjin, China	IBA Emscher Park in the Ruhr area, Germany
Appurtenant level	Local level (involved 9 sub urban districts)	Regional level (involved 20 local cities and municipalities)
Dominant river	Haihe river (72 kilometers)	Emscher river (80 kilometers)
Area	680 km^2	457km^2 (catchment area 800 km^2)
Population	5.9 million	2.2 million
Population density	8676 persons/km^2	2750 persons/km^2
Gross regional product (GRP)	221 billion Euro (the whole city)	149 billion Euro (the whole Ruhr area)
Per capita GRP	14757 Euro (the who city)	29505 Euro (the whole Ruhr area)

Source: Authors' own construct based on desktop survey (August, 2015)

4.4 Methods Used and Data Collection

The approaches for obtaining planned answers in this research are used pertinent to different corresponding contents, as shown in [Figure4-2], including three types mentioned below, incorporated with the reasons of selection.

4.4.1 Inductive and Deductive Reasoning

In the first "Theory" part of the research, when conducting extensive literature review (including academic monograph, articles and papers, research reports, etc.) on the one hand, on the other hand the author was proposing questions in terms of the theme of this topic, such as the question set 1 shown in [Figure4-1]. The answers of questions could not be directly "copied" from literature review, but should be structured and reasoned by incorporating own understanding and logic processing. Therefore, a scientific reasoning way is needed, which is composed of questions or problems requiring involvers to use their conceptual knowledge of a particular phenomenon (Zimmerman, 2000). In this regard, two methods of reasoning (inductive and deductive) are normally frequently-used in a research, and also available for the author to operate, so they are selected. In a word, this kind of approach can help the author in identifying arguments based on basic literature review and establishing own logic framework, which was mainly used in previous Chapter 2 and Chapter 3.

Specifically, as existing definitions explained, "deductive reasoning" has generally been thought of as involving well-defined procedures for drawing out results which follow with certainty or of necessity from some evidence (Lassiter & Goodman, 2015). It is like a "top-down" way working from general to specific (Burney, 2008). This method was used in the way from identifying definitions — finding low-carbon correlation model—reasoning low-carbon-oriented intervention mechanism—further applying in river-based regions. Furthermore, “inductive method” is like a “bottom-up” way from specific observations to generalizations (Burney, 2008). It goes beyond the available evidence, drawing conclusions which might be plausible but are likely or not certain to be true (Lassiter & Goodman, 2015). This method was used to work in concluding the final general theoretical framework (see [Figure3-8]). The linkage of these two approaches is the fact that the river-based region is a unique sub region and a part of a whole city region.

4.4.2 Fieldwork and Sampling

When this research comes into the specific case study part, an in-depth fieldwork was mainly carried out in terms of the main case study area——Haihe riverside region in Tianjin, in order to collect required information and data. The main fieldwork & data collection work conducted including following parts:

A **Desktop study**

Before carrying out actual fieldwork, a desktop survey (DTS) method was adopted at a preparation stage. As its advantage described, the DTS method is composed of collation, integration of project-related information already available for assessment of site conditions and conceptual design by providing a route description (Denis & Nash, 2012). Therefore, the intention of choosing and using this method was to gather historic and present information, quantitative data as well as graphical documents of the case study area through searching website individually and consulting with related colleagues. This way could provide the author with basic background knowledge and helped to identify possible data sources as well as make a pertinent fieldwork plan. In addition, this DTS method was also used in the referenced German case.

B **Sampling of targeted interviewee groups and on-site visiting**

After the desktop survey, the author selected the pertinent targeted interviewee groups as the investigation objects. The reason of sampling such groups was that they served as actual actors who highly involved and also influenced the planning works and implementation of intervention actions in Haihe riverside region and the whole Tianjin. In other word, the required information and data of this case study are grasped in their hands.

Precisely, with the help of China Academy of Urban Planning & Design and Tianjin Planning Bureau, the author was intensively staying in Tianjin for two times, for visiting sampled objects [**Figure4-7**]. According to the local situation of Tianjin, the sample range of these interviewee objects is mainly from municipal management sectors and planning agencies as well as some other related institutions out of Tianjin, as listed in four types below [**Table4-2**].

Figure4-7: On-site visiting during fieldwork process in Tianjin

Source: Author’s own construct

The first on-site intensive visiting process occurred between the end of March, 2014 and end April, 2014 in Tianjin {**Appendix I**}. The purpose of such on-site visiting was to grasp information taking the form of face-to-face semi-structured interview in terms of designed topics{**Appendix II**}, request for offering data and establish contact with them for further possible support. The outcomes of this visiting are contributed to forming Chapter 5 and Chapter 6. In addition, the second wave of on-site visiting & interview process was carried out in April, 2015, which was supplementary and more pertinent aiming at the latter part of Chapter 6, see further **Appendix IX**.

Table4-2: Targeted interviewee groups as visiting objects

Type of institution	Relevance of works with the Haihe riverside region	Title	Responsible fields
Local government	Overall decision making and overriding governance	Tianjin Municipal People's government	All issues
		Tianjin Planning Bureau	Comprehensive plans and

Municipal sectors	Organization of preparing respective planning tools; Implementation of actions in respective responsible field; Management and monitoring		integration of plans
		Land Resources and Housing Management Bureau	Land reserve issue
		Tianjin Urban & Rural Construction Commission	Construction activities
		Tianjin Water Administration	Water resource issue
		Haihe River Water-conservancy Commission	Watershed management of Haihe river
		City and Garden Management Commission	Green and open space issue
		Tianjin Forestry Administration	Green and open space, wetlands
		Tianjin Environmental Protection Bureau	Ecological environment issue
		Tianjin Municipal Transportation Commission	Transport issue
		Tianjin Development and Reform Commission	Industries, projects and essential data
		Tianjin Statistic Bureau	Essential data
Urban planning institutes	Preparation of plans and consultant programs	China Academy of Urban Planning & Design (Beijing)	Formal and informal planning tools
		Tianjin Urban Planning & Design Institute	Formal and informal planning tools
Universities	Research, expertise consultant	School of Architecture and Urban Planning of Beijing University of Civil Engineering and Architecture	Monographic research, informal tools
		Department of Urban Planning of Tianjin University	
		Department of Urban & Regional Planning of Peking University	

Source: Author’s own construct

In a word, these above listed visiting objects’ works and responsibilities are closely linked to the case study area. They serve as a kind of “**think-tank resource base**” and also targeted interviewee group (further interviewees and corresponding questionnaires would be commenced on this basis) playing a vital supportive role in this study.

In addition, informal interviews with relevant persons was also conducted contributing to the contents of Chapter 8 (German referenced case). Especially by taking advantage on attending some special occasions, such as work shop, conference, guided excursion etc. regarding the Ruhr area [**Figure4-8**], the author consulted pertinent German experts whose suggestions were also help in understanding the referenced case.

Figure4-8: Informal interviews during special occasions in Germany

Source: Author's own construct

C **Site survey**

In the meanwhile, during the information and data collection process in Tianjin, site survey was also carried out at the interval of visiting period, in order to acquire intuitive cognition and deepen understanding [**Figure4-9**]. The main techniques used was physically observation and photography, including the water form, land use, construction status, etc. along the Haihe river and selected sites. Moreover, the German IBA Emscher Park case was also endowed with site survey.

Figure4-9: Site survey

Source: Author's own construct

4.4.3 Evaluation Approach

A Selection and description of techniques to be used

As mentioned in the research design (see Section 4.2), this research is intended to make an evaluation in terms of the main case study——Haihe riverside region by establishing index system (get indexation). In order to get desired results, first it is necessary to select evaluation method for processing evaluation model. Normally the multi-index evaluation model is established on the basis of a certain mathematical methods of Geography. In this regard, the commonly-used alternative modern evaluation methods based on the same approach of "get indexation" include: Simple Additive Weighting approach (SAW), Grey Relational Analysis (GRA), Back-propagation Algorithm (BP), and Fuzzy Comprehensive Evaluation (FCE), etc. The author adopts a way of exclusion to help in selection.

For this paper, it should be considered that on the one hand the river-based region itself is a synthesis of both natural and man-made elements, characterized by heterogeneity and complexity. The sense of urban planning and spatial perception play a big role in its evaluation, in which particularly evaluating some qualitative indicators (such as the amenity, compactibility and quality, etc.) have uncertainty and fuzziness. That is to say, such indicators cannot be assessed by using conventional statistics or mathematical methods. On the other hand, in terms of specific operation process for an individual research, the alternative methods mentioned above all have their own advantages and disadvantages, such as (Chen, 2011; Zhang, Xu & Hou, 2014): the SAW method is too rigorous mathematically and thus a relative narrow range of application; BP methods have a relative slow rate of calculation and owns a weakness of "local minimization"; Using GRA method needs to input enormous data and takes much time and sometimes is hard to find out relational laws. However, apart from above methods, the FCE method is relatively suitable to be used especially in the evaluation in the engineering field. "It was designed to supplement the interpretation of linguistic or measured uncertainties for real-world random phenomena. These uncertainties could generate with non-statistical characteristics in nature that refer to the absence of sharp boundaries in information" (Chang, Chen & Ning, 2001). In other word, this method could facilitate some qualitative matters to process a quantitative analysis according to their grade of membership, which has the strength of dealing with matters that are uncertain, fuzzy and hard to quantify (Zhang, Xu & Hou, 2014).

Therefore, the Fuzzy Comprehensive Evaluation (FCE) method is finally selected to evaluate the actual performance of intervention actions towards low-carbon development in Haihe riverside region. This FCE method was first present by Zadeh in 1965, which was to comprehensively evaluate systems involved with multiple indicators by using theory of fuzzy mathematics for helping in decision making (Shao, 2009).

In addition, in the thesis this FEC method is going to be operated in combination with the other two frequently-used techniques: Delphi technique and Analytical Hierarchy Process (AHP) method, since they have following advantages in terms of structuring information and also possible for the author to operate when obtaining and processing data. Precisely: Delphi method was mainly developed by Rand Corporation in the 1950s, which is a communication technique for achieving consensus of opinions by consulting with a structured group of experts who would answer a serious of designed questionnaires in two or even more rounds (Hsu & Sandford, 2007). Analytical Hierarchy Process (AHP) was first proposed by Satty in 1970s, which is described as a structured technique for organizing and analyzing complex decisions based on "one-on-one comparisons between each element of a certain hierarchical level, in which pairwise comparisons are used to assign relative weights on the objectives and criteria in terms of a standard ratio scale" (Siedentop, 2010). One of the main advantages of AHP method is that it is able to process information of different scales, no matter qualitative judgments or quantitative values (Siedentop, 2010), which is especially applicable when hard to quantitatively describe in the case of a complex goal structure (Li, Yu & Qin et al, 2005) .

The following shows the planned steps of operating selected evaluation approach mentioned above (the specific operational contents will be present in Chapter 6):

- ➢ Firstly it is needed to establish a low-carbon index system (get indexation) in urban planning field with selected indicators of Haihe riverside region. For this, the approaches of theoretical analysis based on Chapter 3 and Delphi technique will be adopted here.

- ➢ Second step is to get the relative weight coefficient of the index system established above for the next evaluation, namely weighting. Here the AHP method with Delphi technique will be used, as its characteristic of "pairwise comparison" presented above.

- The last step is to evaluate by using FCE method based on the indictors in the index system and their weight values, then get final results

B **Attached questionnaire techniques to be used**

In can be seen from above that carrying out these evaluation methods all require interview and attached questionnaire to support. Generally there are several basic techniques that can be used for questionnaire survey, including personal interview, telephone interview and mail survey, etc. (Goulias, 1997). For this research, the interview and questionnaire technique used is in a multi way. As mentioned in Section 4.4.2 B, a personal semi-structured interview was first conducted in the fieldwork process. Afterwards, the mail survey and particularly a computer-assisted instant messaging technique based on a special software were used mostly for sending pertinent questionnaires and receiving feedback as well as asking for more communication, since this technique is flexible and fast in terms of the time-space dimension.

4.5 Summary

This chapter plays a role in a “transitional bridge” to link previous general theory part and coming case study part. It first reviews all research questions and corresponding research objectives, then outlines the whole research design framework to reveal further research logic and steps, in correspondence with respective research methods used. After that, it explains the criteria and reasons of selection of two case studies (a main case and a referenced case) associated with the theme of this dissertation. Furthermore, it points out the selection reasons and description of research methods and data collection approach have been and to be used in this study, including: inductive & deductive reasoning based on extensive literature review; fieldwork process composed of desktop survey, on-site visiting based on sampling of targeted interviewee groups as well as site survey; evaluation techniques and attached questionnaire techniques, which will be analyzed in detail in Chapter 6.

From now on, this research accesses into the specific case study.

Part II: Analysis

- Chapter5: Case Study: Haihe Riverside Region in Metropolis Tianjin, China
  - Low-carbon-oriented Transformation Context
  - Site Analysis
  - Low-carbon-related Intervention Actions
  - Supportive Planning Integrated Approach
- Chapter6: Evaluation of Low-carbon Performance of Intervention actions and Cause Analysis
  - Goals
  - Index System for Evaluation
  - Evaluation Process
  - Result
  - Root Cause Analysis
- Chapter7: Referenced Case: IBA Emscher Park in Germany
  - Low-carbon-oriented Transformation Context
  - Low-carbon-related Intervention Actions
  - Supportive Planning Integrated Approach
  - Drawing on Experience

Chapter 5 Case Study: Haihe Riverside Region in Metropolis Tianjin, China

5.1 Low-carbon-oriented Transformation Context

Based on the basic understanding of case study region (see Section 4.3.2), actually in recent years metropolis Tianjin has been making efforts to realize its transformation in order to move into the direction of a more sustainable city.

First, there is a need to explain the historical background and "high-carbon" problems of this region. Tianjin is originated from Haihe river, whose urban evolution is closely linked with the utilization and exploitation around Haihe river. In the early and middle 20th century Tianjin became the largest manufacturing and trade center in the northern China due to Haihe river's convenient land and water transportation condition, and Haihe riverside region had always been the industrial, transport and trade gathering place where could be described as a "busy waterway" [**Figure5-1**].

Figure5-1: Historically central busy waterway—Haihe river
Source: www.tjdag.gov.cn

However, after 1970s along with the urban social & economic recovery, changing traditional shipment mode and calling for flood control regulation were put on the political agenda. Thus, Haihe river lost its important function of water transport, as a result gradually this previous “mother river” started to decline. Especially when entering 1980s, Haihe river that was surrounded by traditional heavy industries (iron & steel, machinery, textile, metal, chemical, shipbuilding, etc.) became an obstacle to the connection of both riversides and turned into a “backyard” of Tianjin [**Figure5-2**]. According to the interview with Tianjin Development and Reform Commission, from 1990-2000 the energy consumption of this region always occupied approximately 75% of the whole Tianjin due to its mono-functional industrial structure. As a consequence, other triggered problems (decline of social vitality, river channel sedimentation, water pollution and adjacent environmental deterioration, etc.) also emerged in succession in this region.

Figure5-2: The once “backyard”—Haihe river
Source: www.tjdag.gov.cn

In the meanwhile from economic perspective, “strong” secondary industry meant the relative “weak” tertiary industry, for which Tianjin was obviously lower that other similar metropolis in China at the same period [**Table5-1**].

Table5-1: Comparison of tertiary industrial indicators (2001)

		Tianjin	Beijing	Shanghai	Guangzhou
Employed persons (ten thousand)		492	679	790	513
Of which	Tertiary industry	202	376	385	220
	Proportion	41.1%	55.4%	48.7%	43%
Gross domestic product (100 million *yuan*)		2050	3212	5408	3000

Of which	Tertiary industry	964	1997	2755	1671
	Proportion	47%	62.2%	51%	55.6%

Source: 2002 China Statistical Yearbook

Actually the problems mentioned above were similar with many waterfront areas in developed western countries during 1970s-1980s to some extent, and waterfront or riverfront redevelopment (such as the river Seine, Thames, etc.) served as a powerful intervention instrument for promoting urban revitalization. These international experiences also motivated Tianjin's political leaders to think about taking actions to "make a change" for the Haihe riverside region, on the one hand solving problems encountered and on the other hand making a new great economic leap.

Under this background, in 2002 Tianjin municipal government officially launched the comprehensive redevelopment movement of Haihe riverside region which has been proceeding till today. The initial overall target of its redevelopment was to transform this region into a local-distinctive, eco-landscape and service ribbon, further facilitating Tianjin in an economic-social-environmental sustainable situation. Especially in terms of this transformation context, recently adopting a "low-carbon development path" as a specific medium-term handtool of achieving final sustainable development attaches increasingly emphasis, accordingly a serious of governmental policy documents has been issued as top-down driving forces. For instance, in 2010 Tianjin municipal government published *Tianjin's Policies and Actions for Addressing Climate Change*, which set the goal of reduction of energy consumption per unit of GDP by 15% by 2015 compared to 2010. And in 2012 China National Development and Reform Commission approved *Action Plans for Pilot Work of Low-Carbon Development in Tianjin*, which set forward the target of reduction of carbon dioxide emissions per unit of GDP by 45% by 2020 compared to its level in 2005, for which the central region of Tianjin was supposed to be the pilot area.

There is no doubt that the whole Tianjin city has been situated in a low-carbon-required context. In this regard, Haihe riverside region is an essential planning and action area taking responsibilities for supporting the whole city's low-carbon development.

Next will first analyze what the characteristics of this region are today.

5.2 Site Analysis

A River system

Overall speaking, the river resources in Tianjin are very developed, which serve as not only natural resources working in water supply, flood control and drainage, etc., but also the essential green infrastructure for recreation, environmental and ecological functions. The whole river system in Tianjin consists 19 main rivers and more than 60 secondary rivers and tributaries, as well as some reservoirs, lakes and other water surfaces distributed [**Figure5-3**]. Among the river system of Tianjin, Haihe river is the most important main stream passing through the city, which is described as the "mother river", "spine" and "spatial axis" of Tianjin's spatial development. Its average width in upstream is 100 meters and in downstream reaches about 300 meters.

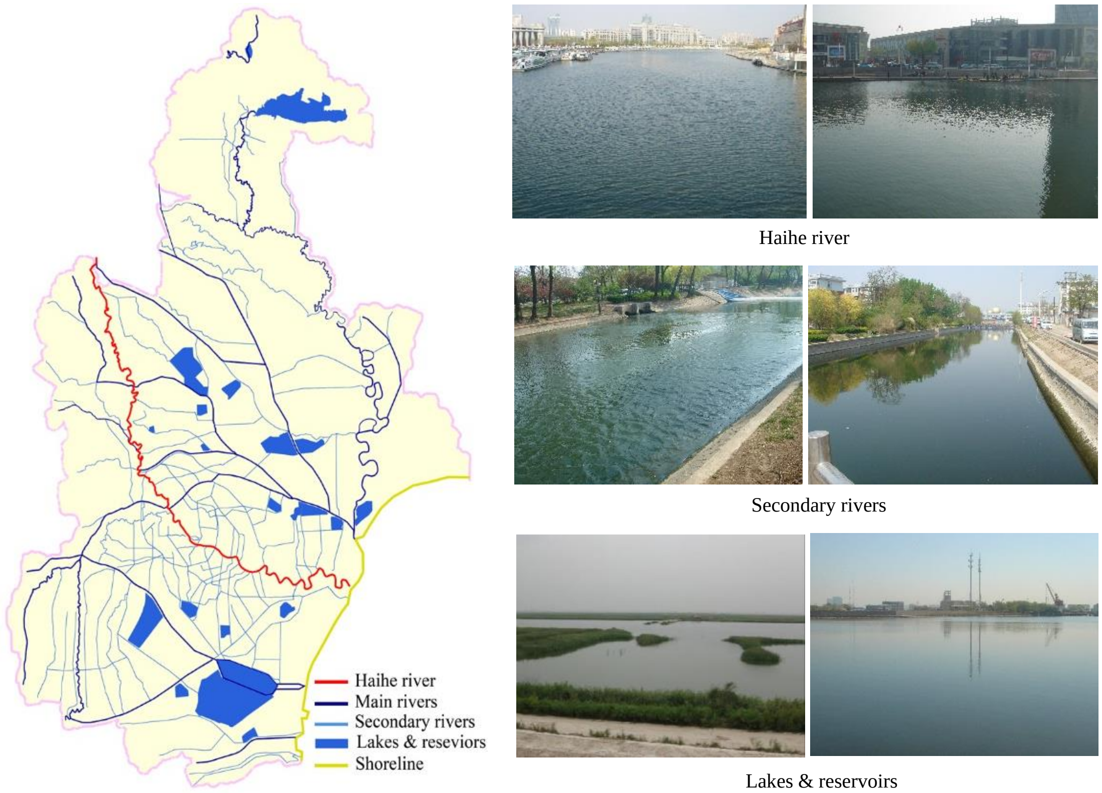


Figure5-3: River system in Tianjin

Source: Left—Water System Planning of Tianjin (2008-2020); Right—Author's own construct

B Spatial structure

In terms of the spatial structure of Haihe riverside region, it could be further divided into 3 sections in correspondence with 3 big sub-areas (*Stadteil*): the upstream section, the middle section and the river mouth section, each has different city image [**Figure5-4**]. Precisely, the upstream section refers to the central urban area (*Kernstadt*) in the west in which Haihe river stretches 25.2 kilometers. This section that covers the historically old town and residential as well as various service facilities concentrates about 40 percent population of the whole. It is the traditional urban center which undertakes comprehensive functions (political administrative, commercial, education, medical treatment, etc.) for the local and regional supply. The river mouth in the east section represents the core area of Binhai New District in which Haihe river stretches 23 kilometers. This section is a relative newly developing urban center which functions mainly in modern high-end industrial service, including trade, high-tech industries, logistics, etc. What is more, the middle section implies the area between above two sections, in which the Haihe river stretches 24 kilometers here. This section serves as a "connective corridor space" which is still occupied by some industrial & warehouse land uses and undeveloped lands today, so it is one of the focus areas of future urban development.

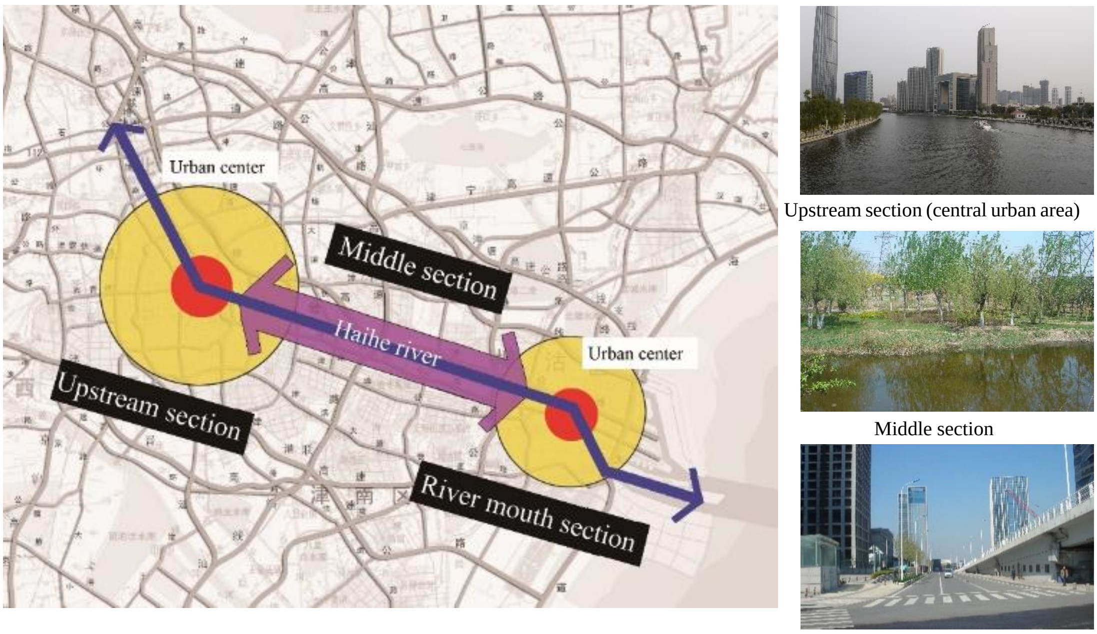


Figure5-4: Spatial structure and city image of Haihe riverside region
Source: Author's own construct

In all, on one hand from the perspective of urban form, Haihe riverside region presents a ribbon form with two main urban centers and other multi urban groups in different functions connected by Haihe river, so it is described as "dual dominant cores in one axis (Haihe river)", and this is also even the portrayal for the whole city. On the other hand from an administrative perspective, this region covers 9 administrative districts consisting of many smaller neighborhoods and streets (*Stadtviertel*, *Quatier*). It should be understood that the division of boundary of this region is constructed not all based on complete boundary of all administrative districts. However, it is based on the range of combined sub-areas (neighborhoods, streets) and road form, in order to be convenient managed for planning management of sectors, as it is a typical planning and action space.

C Land use

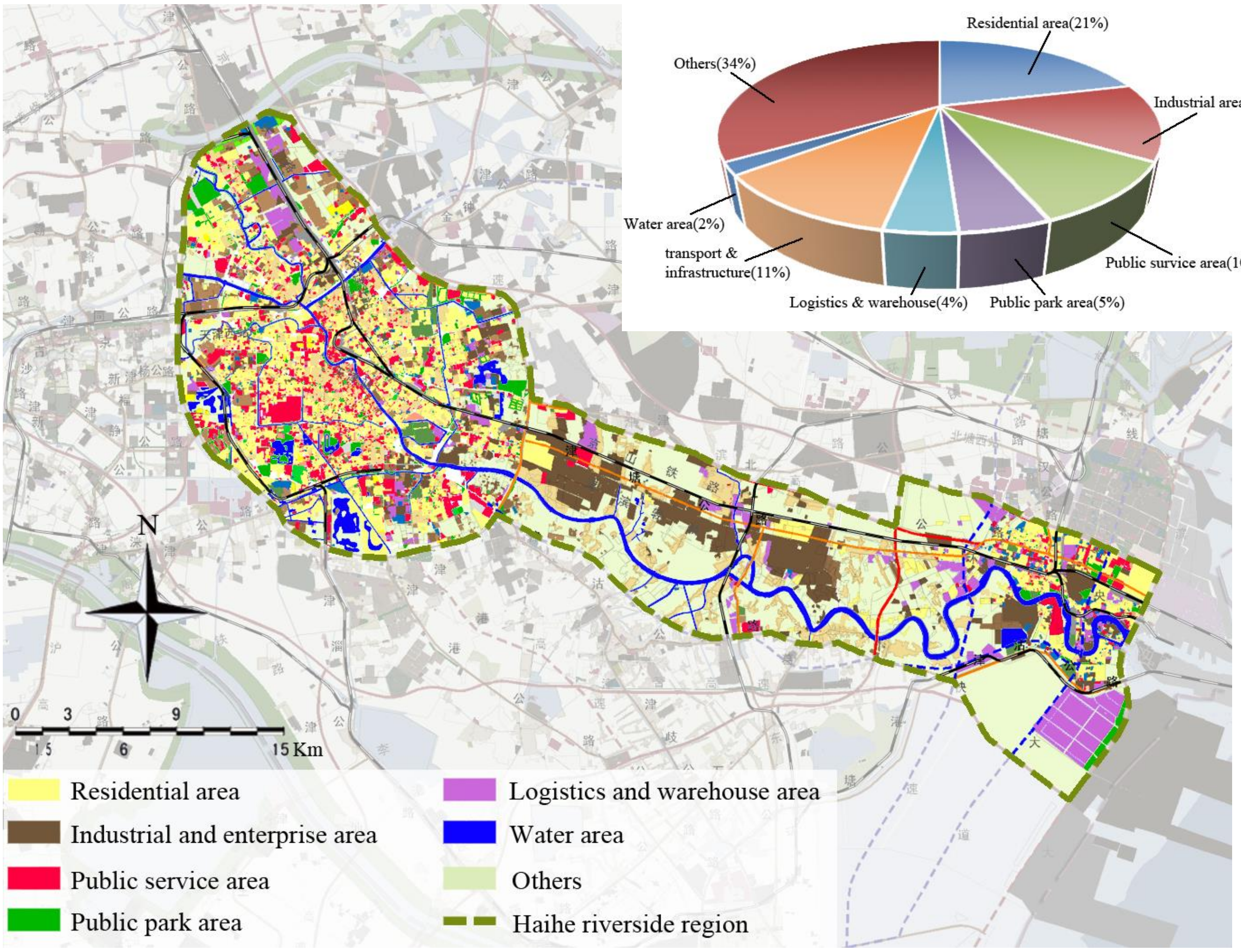


Figure5-5: Existing land use of Haihe riverside region
Source: China Academy of Urban Planning & Design

As to the land use [**Figure5-5**], there are two types: developed lands and undeveloped lands. Developed lands mainly include residential area, public service area (commercial, administrative, education, medical, etc.) industrial and enterprise area, logics and warehouse area, green area (parks, plazas, etc.) as well as transportation and infrastructure area. And undeveloped lands mainly cover water area and other kinds of areas unused for urban construction activities (such as agricultural lands, forests and vacant lands), major of which are concentrated in the middle section. The following illustrates the current land use situation.

In can be seen that currently Haihe riverside region has been formed a mosaic pattern. The formation of above such spatial structure and land use pattern is attributed to the continuous intervention actions and also the planning integrated approach as the driver behind. The next section will dissect recent intervention actions taken in this region from the perspective of promoting low-carbon development.

5.3 Low-carbon-related Intervention Actions

5.3.1 Intervention Process

As mentioned in Section 5.1, from 2002 based on many previous preparation the municipal government of Tianjin officially initiated the intensive “comprehensive redevelopment movement of Haihe riverside region” by implementing a serious of projects that deeply influenced this region. The whole continuous intervention process can be divided into three stages according to different focused intervention area.

A **The first stage—upstream section**

The first stage began from 2002 to 2008, during which period the intervention emphasis was mainly put on the upstream section——central city area.

At the beginning, Tianjin’s government established an agency named “Command of Comprehensive Redevelopment of Haihe River” consisted of Tianjin Planning Bureau, Tianjin Water Administration and other related sectors (as listed in 4.3.2) to uniformly arrange preparation of plans and implementation of projects as well as allocate public funding from the government. That is so say, the Tianjin municipal government (mayors) stood at the top “decision-maker layer”, its affiliated sectors played the role as responsible competent “manager layer”, and according to the overall plans involved administrative districts carried out specific construction works (making land consolidation, implementing arranged projects, attracting investment, etc.) in their respective “sphere of control” serving as the “implementer or enforcer layer”.

Under such intervention operational structure [**Figure5-6**], 10 categories of projects that represented corresponding action fields were uniformly planned and implemented via governmental loan, including river restoration, embankment rebuilt, industrial restructuring, green planting and open space increase and so forth.

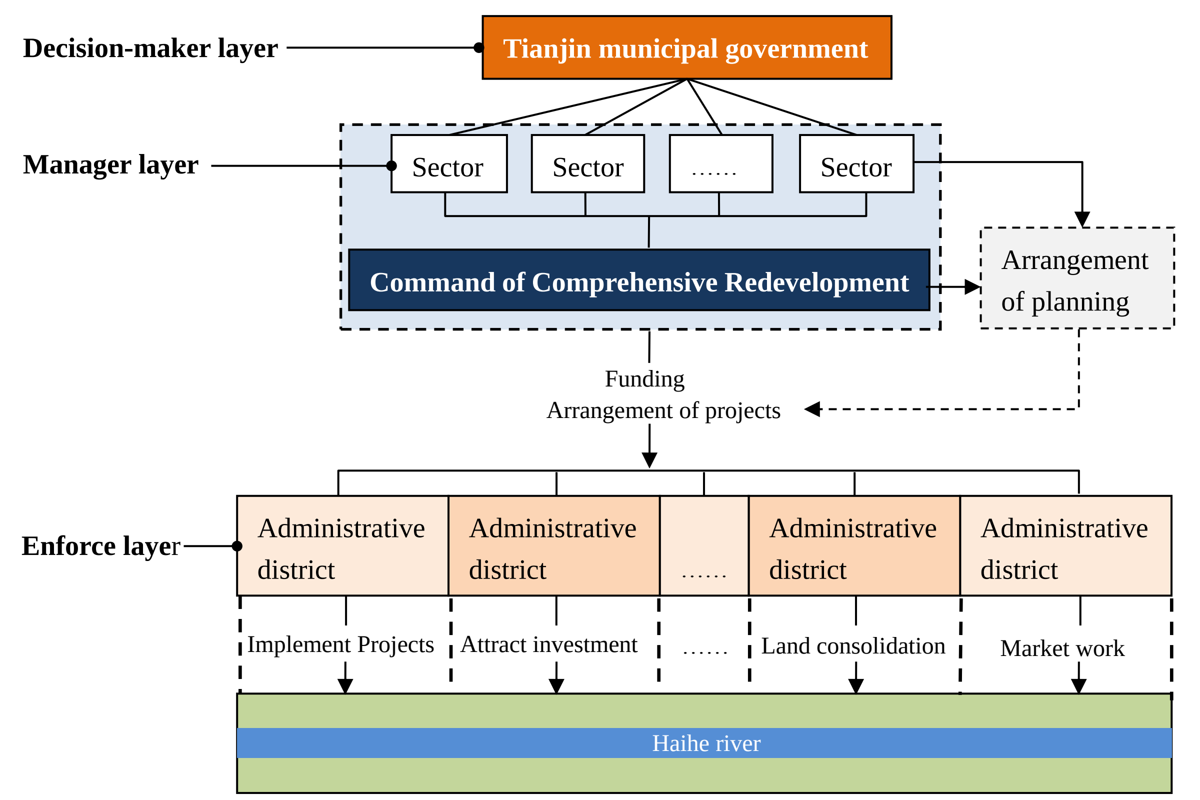


Figure5-6: Operational structure for intervening Haihe riverside region at first stage

Source: Author's own construct

B The second stage—river mouth section

Afterwards, the second stage of intensive interventions occurred between 2008 and 2013. One the one hand, the projects in the first stage was continuing to be implemented, and on the hand the intervention actions started to move focus into the downstream section in the core area of Binhai New District, along with the national strategic policy of "developing and opening Binhai New District in Tianjin". The actions taken during this period were trying to strengthen another main urban center along the Haihe river, so as to form a "dual-dominant-core" spatial structure (see 5.2 B) and also promote a modern brand-new waterfront city image. In 2008 the former agency "Command of Comprehensive Redevelopment of Haihe River" was disbanded and during this period the main construction activities were directed by the central municipal government and its affiliated sectors as well as its branch district government.

These two stages' efforts for acting on Haihe riverside region largely contribute to "make a great leap" for Tianjin, including promotion of land appreciation, improvement of the physical landscape, ecological environment as well as incentive of economic growth of Tianjin, etc. [**Figure5-7**].

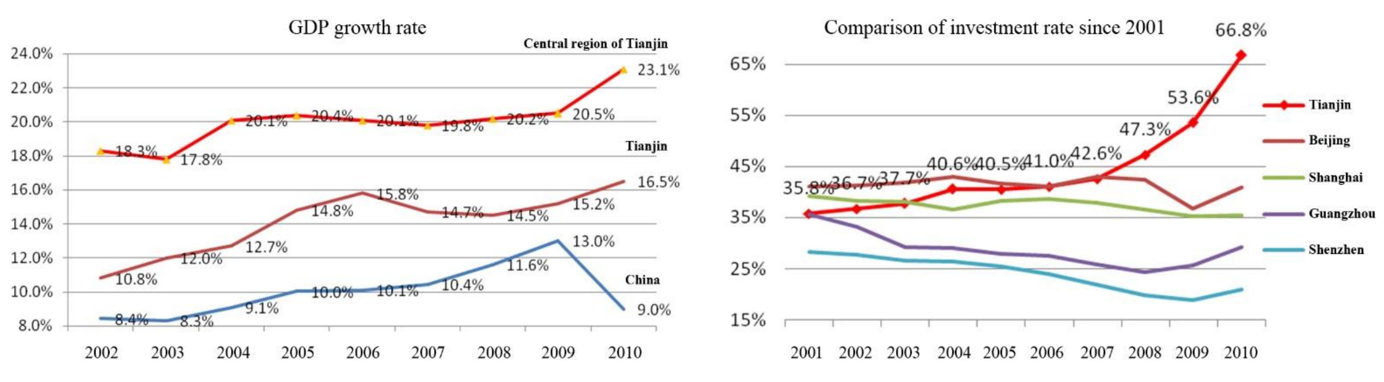


Figure5-7: "Great leap" after comprehensive redevelopment of Haihe riverside region

Source: Tianjin Development and Reform Commission

C The third stage—middle section

Today this region is coming into the third stage, in which period the strengthening of second main urban center (river mouth section) is being proceeded on the one hand, and on the other hand dealing with the middle section would be put on the agenda. This is aimed at: making a better connection between the two main urban centers through the middle section so as to intensify the holism of the whole region, and also creating a future third new urban center in order to form a better polycentric networked structure following a "point-axis" spatial development model rather than past "core-periphery" model [**Figure5-8**].

Through a calculation by the end of 2013 in Haihe river region, approximately 35.14 square kilometers of land consolidation and 3,032,800 square meters of demolition area of dilapidated building as well as 15,000,000 square meters of redevelopment projects have been completed.

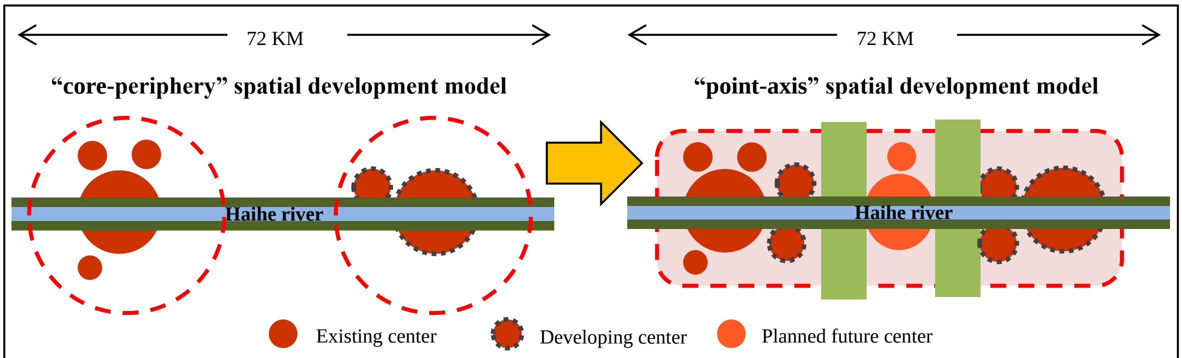


Figure5-8: Main direction of interventions at the third stage

Source: Author's own construct

5.3.2 Adherence to Low-carbon Principles

This section will demonstrate the main actions taken in the form of projects implemented during Haihe riverside region's intervention process from the perspective of promoting low-carbon development, in which the previous theoretical framework (see Section 3.5) will be applied here. Due to the large-scale area, not all detailed projects and technical measures could be present while only abstracting their key points related to the low-carbon guiding principles and guidelines (see Section 3.4.2).

A **Richness of waterside status**

As mentioned above, Haihe river's water quality and neighbouring soil was once environmentally contaminated as the consequence of long-term riverside industrialization (see Section 5.1). Therefore, the first important intervention action was to restore the river and enrich the water body.

River restoration project

Approximately 160-kilometer-long rivers was treated, for which main means adopted include: designating the protection boundary of river corridors; removing part riverfront heavy industrial lands to the east concentrated industrial zone so as to prevent the river body from being contaminated continually; plugging 17 sewage outlets and building 9 new sewage treatment plants; separating 100-kilometr-long rainwater and sewage discharge pipeline system; connecting Haihe main water body with other secondary rivers and tributaries as well as peripheral reservoirs to enable the water system recycled [**Figure5-9**]; dredging the channel and removing harmful weeds along the river [**Figure5-10**]; cultivating more aquatic flora to purify the air to promote the photosynthesis; building peripheral constructed wetlands in combination with public projects development (such as parks) to purify the whole river system, etc.

Left—Figure5-9: River connection　　Right—Figure5-10: River dredging project

Source: Tianjin Water Administration

Source: http://www.cctvhjpd.com/UpFile/Article/201102/1102211115403913.jpg

Embankment rebuilt project [**Figure5-11**]

In order to stabilize the river edge, riverbank reconstruction projects were also implemented in different sections along with river restoration projects according to the coordinated requirements of flood control, water-affinity activities, landscape and ecological effects. For example, in the upstream and river mouth section (both urbanized dense area) the riverbank reconstruction mainly took the form of a compound section in different elevation layer, in which riverfront layer were reserved for design of public spaces while moving the flood wall backward. And in terms of some secondary tributaries, measures were taken to reshape a simulated natural form of river edge as far as possible by referencing the "near-natural control" concept.

Figure5-11: Reconstructed riverfront embankments

Source: Author's own construct

B Biodiversity of green space

Besides ecological remediation of water body, other actions for increasing greening and open spaces as well as strengthening native vegetation system were also taken in Haihe riverside region, which worked in enhancing urban carbon sink capacity and sustaining natural biodiversity.

Open space increase project

The measures used for increasing open spaces include [**Figure5-12**]: 1) Control. Designate control lines of riverfront buffer zone in different width along Haihe river and tributaries to form linear parks; 2) Expansion and renovation. Expand the area of former open spaces and rebuilt to promote the quality. 3) New creation. Build new different-sized open spaces (plazas, green lands, landscape nodes, etc.) in combination with land use adjustment, such as demolition of former factories, triggering of real estate development, etc. 4) Connection. Use the river bodies and tree-lined streets or new planned green lands to link separated open spaces to the river. Under these actions, according the interview with City and Garden Management Commission, till 2012 there had been totally 451.3 hectares of green areas increased in the upstream and river mouth section.

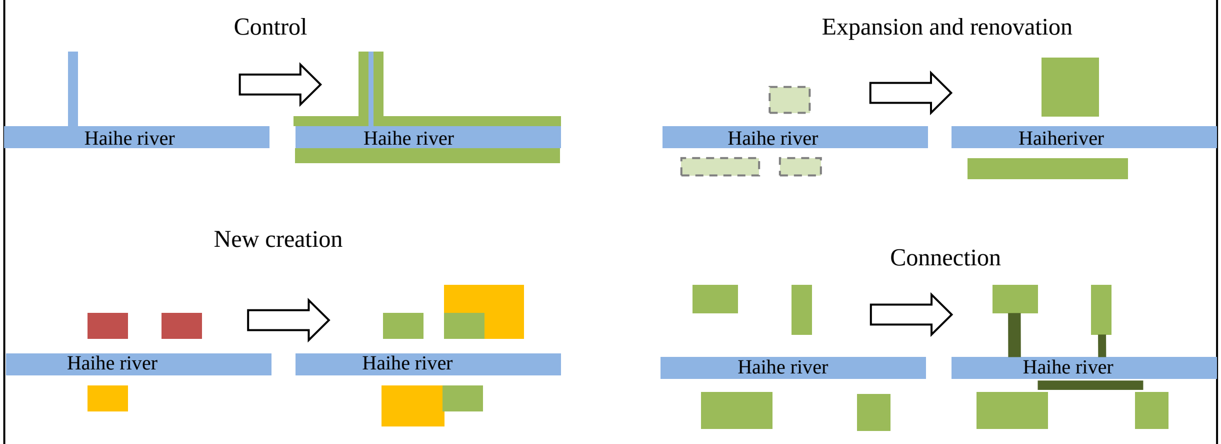


Figure5-12: Model of open space increase project

Source: Author's own construct

Green planting project

Moreover, the re-colonization of vegetation, shrubs and trees in combination with open space projects aiming at increasing the green coverage ratio and promote natural biodiversity was also a big action. Measures especially referred to strengthening native plants to adapt to drought and soil salinization of Tianjin's climatic environment and also introducing some new species to form a stable, diverse and multi-layered (trees, shrubs, grasses, vines, flowers) flora system as well. According the interview with Tianjin Environmental Protection Bureau, due to these green planting projects currently the Haihe riverfront can daily absorb 75 tons of carbon dioxide and release 56 tons of oxygen.

C **Multifunctionality of urban structure and land use**

To transform the industrial and urban spatial structure to further incentive economic growth was actually a big original political intention of intervening this region.

Industrial adjustment project

As mentioned in 5.1, numerous industrial enterprises were once located on both sides of Haihe river owing to the advantage of water transport. The intervention process also aims at the restructuring of urban and industrial structure which represents the energy structure. Based on the interview with Land Resources and Housing Management Bureau, by 2013 this region has removed more than 50 traditional high energy-intensive industrial enterprises (including 15 textile enterprises, 20 chemical enterprises and about 18 metal and steel manufacturing enterprises) out of this region. The lands vacated have been mainly redeveloped into service industries, residential areas as well as other public uses, which has created the value of 23 billion yuan of added service industry and added approximately 250,000 job opportunities. Today this region is transforming towards domination by tertiary industry [**Figure5-13**], although there are still certain proportion of secondary industry especially gathering in the middle section.

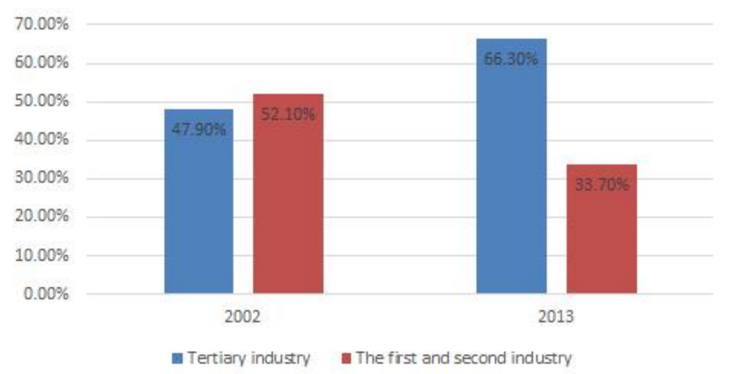


Figure5-13: Change of industrial structure

Source: Tianjin Development and Reform Commission

Spatial restructuring project

As mentioned in Section 5.3.1, along with the industrial adjustment the efforts have been being made to transform from a mono-center into a more polycentric and group-typed spatial structure since the second and third stage of intervention process. Besides the respective planned and developing urban main centers in the river mouth and middle section, a serious of secondary centers in sub areas along the riverside have also been being cultivated to attempt to enhance the polycentricity [**Figure5-14**]. In the meanwhile, a mixture of land use on both riversides has been initially formed.

Figure5-14: Developing urban centers

Source: Author's own construct

D **Permeability of spatial form**

Along with the spatial restructuring, how to optimize a better permeable spatial form has been taken into account.

Green corridor plan

As shown in Figure5-8, in the past the whole Tianjin had been following the traditional "core-periphery" spatial development way——"developing outwards from a single point (main urban center)", which had brought about unordered urban sprawl and thus a big uninterrupted dense "city body". At the overall scale, interventions considered to utilize the river resource and green lines based on restoration and open space project to control green belts and three main green corridors penetrating built environment. These green infrastructure that are vertical to the Haihe river can serve as ventilation corridors and "in-between" space so as to prevent urban groups form further merging together [**Figure5-15**]. At the site scale, reducing building density was also carried out in some site redevelopment projects.

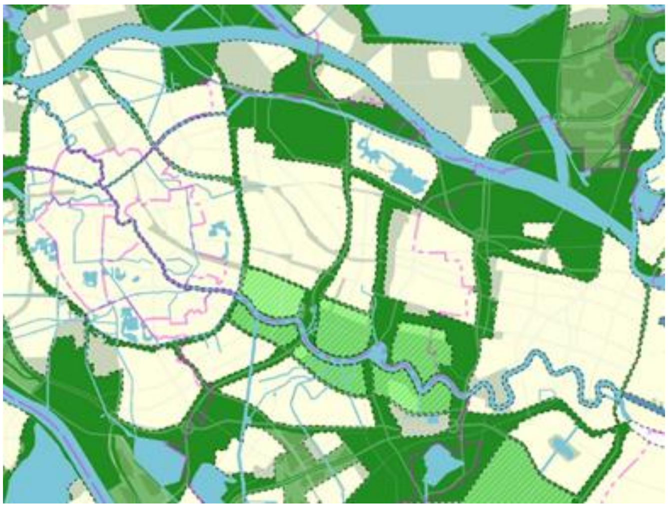


Figure5-15: Green corridors serve as “in-between” space
Source: China Academy of Urban Planning & Design

E **Public accessibility of traffic network & Circularity of municipal utilities operation**

Last but not least, the opportunities of improvement of traffic and utilities system have been optimized during the intervention process in Haihe riverside region.

Transportation improvement project

Firstly, the almost whole road system were rebuilt (such as adjusting the riverfront road pattern to more conform to the river direction; increasing secondary roads vertical to the river) in order to enhance the riverfront direct connection and accessibility. Diverse traffic modes were taken into account intending to form a multi-optional traffic system. Public green traffic modes were largely considered to attract more abandons of private vehicles, although the private cars have still been inevitably increasing [**Table5-2**]. Besides, take the upstream and river mouth section as an example, there were special public traffic lanes and non-motor vehicle system being established in combination with the embankment reconstruction and open space project on both sides of rivers, including independent slow-travel system (riverfront walking trails, bicycle lanes), separated from main motorways. What is more, only in the upstream section there were 16 new connection bridges being built and dividing into different serves for different uses according to their traffic volumes and loading levels as well as use functions, such as buses only, pedestrians and bicycle only as well as mixed use [**Figure5-16**]. In addition, five new subway lines were open passing through this region with total 18 stations, each station served as a hub node conveying pedestrian stream to Haihe riverfront.

Table5-2: Comparison of traffic modes in Haihe riverside region

	Bicycle	Bus and rail	Private vehicle	Total
2000	79.6%	13.8%	6.6%	100%
2013	54.8%	26.6%	18.6%	100%

Source: Tianjin Municipal Transportation Commission

Figure5-16: Improved riverfront slow-travel way and pedestrian & bicycle-only bridge

Source: Author's own construct

Water recycle project

Other efforts were also made for promoting unconventional water recycling use (mainly reusing industrial and living sewage and part of rain water) as a kind of renewable energy, in combination with river restoration and water connection project [**Figure5-17**], as mentioned before.

On the one hand, these measures realized increase of water supply, by 2012 the total available water supply amount reached 3.8 billion cubic meters in this region; on the other hand, facilitating the circular flow of rivers could optimize the metabolism process and thus promote the self-purification capacity of water system.

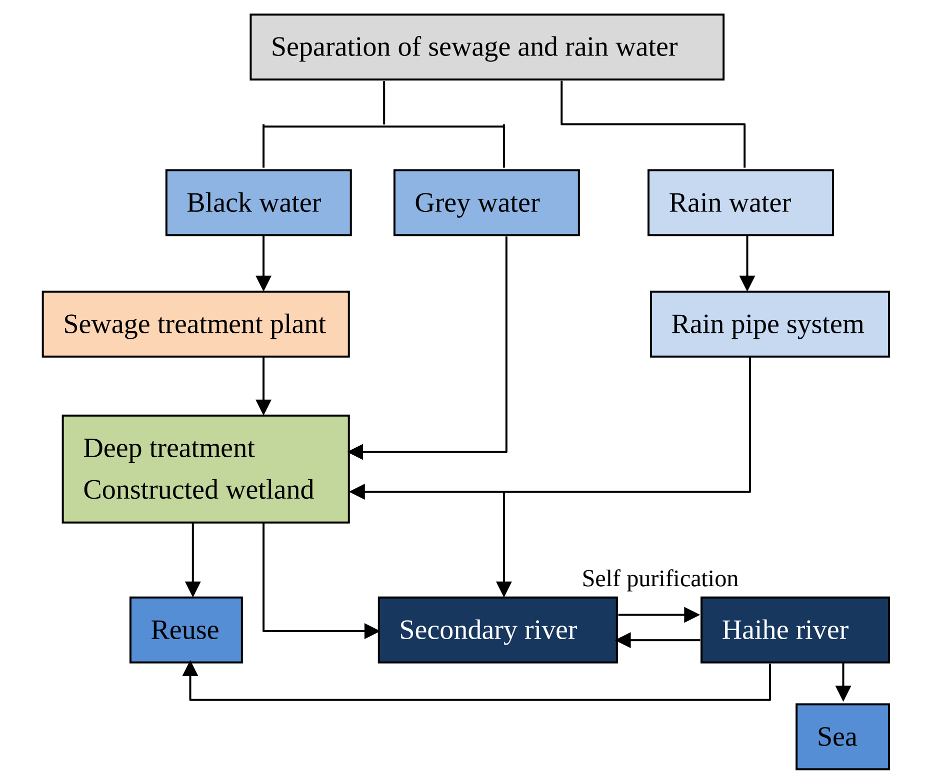


Figure5-17: Water discharge and recycle plan

Source: Tianjin Water Administration

It can be seen above almost all general low-carbon-related guidelines (see Section 3.4.2) were adopted during the intensive intervention process in Haihe riverside region, behind which was the corresponding planning integrated approach serving as the guiding tool and supporter.

5.4 Supportive Planning Integrated Approach

5.4.1 Planning System

By referencing the description of planning tools (see 2.4.1), urban planning system in China also can be classified according to different criterion. Vertically it is involved with national, provincial, local (city and county) level, township and village level; and horizontally it includes formal plans and informal plans. Generally all the planning tools are attempted to lead and regulate spatial development, land uses, landscape shaping, resource and environmental protection as well as construction activities.

As a municipality, the planning system in Tianjin is completely consistent with China's. First it is necessary to understand the planning management system involving competent sectors as main actors who actually manipulates planning activities in Tianjin and Haihe riverside region, as listed in Section 4.3.2 (Table 4-2). Secondly is needed to know that this planning management system is like a "umbrella" structure, almost the same with implementation structure (see Figure5-6), in which the municipal government stand at the "top" layer making final decision regarding planning issues, and affiliated parallel sectors play the role as the "planning managers" responsible for organizing preparation of different planning tools and managing as well as supervising [**Figure5-18**]. The competent urban planning authority (Tianjin Planning Bureau) is responsible for comprehensive planning tools, while others are responsible for corresponding sectoral planning tools.

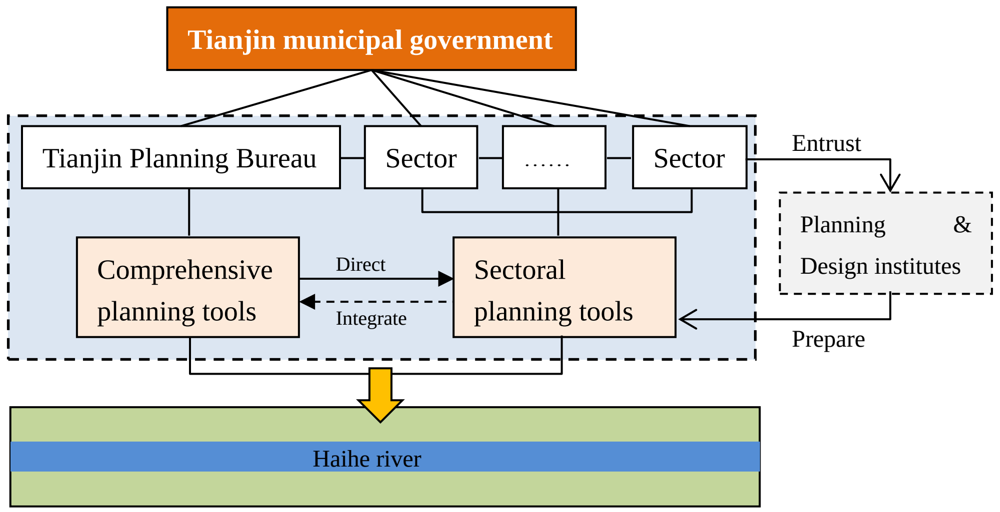


Figure5-18: Planning management structure in Tianjin

Source: Author's own construct

Under such management structure, the planning system in Tianjin that influences Haihe riverside region can be visualized and described as following [**Figure5-19**]:

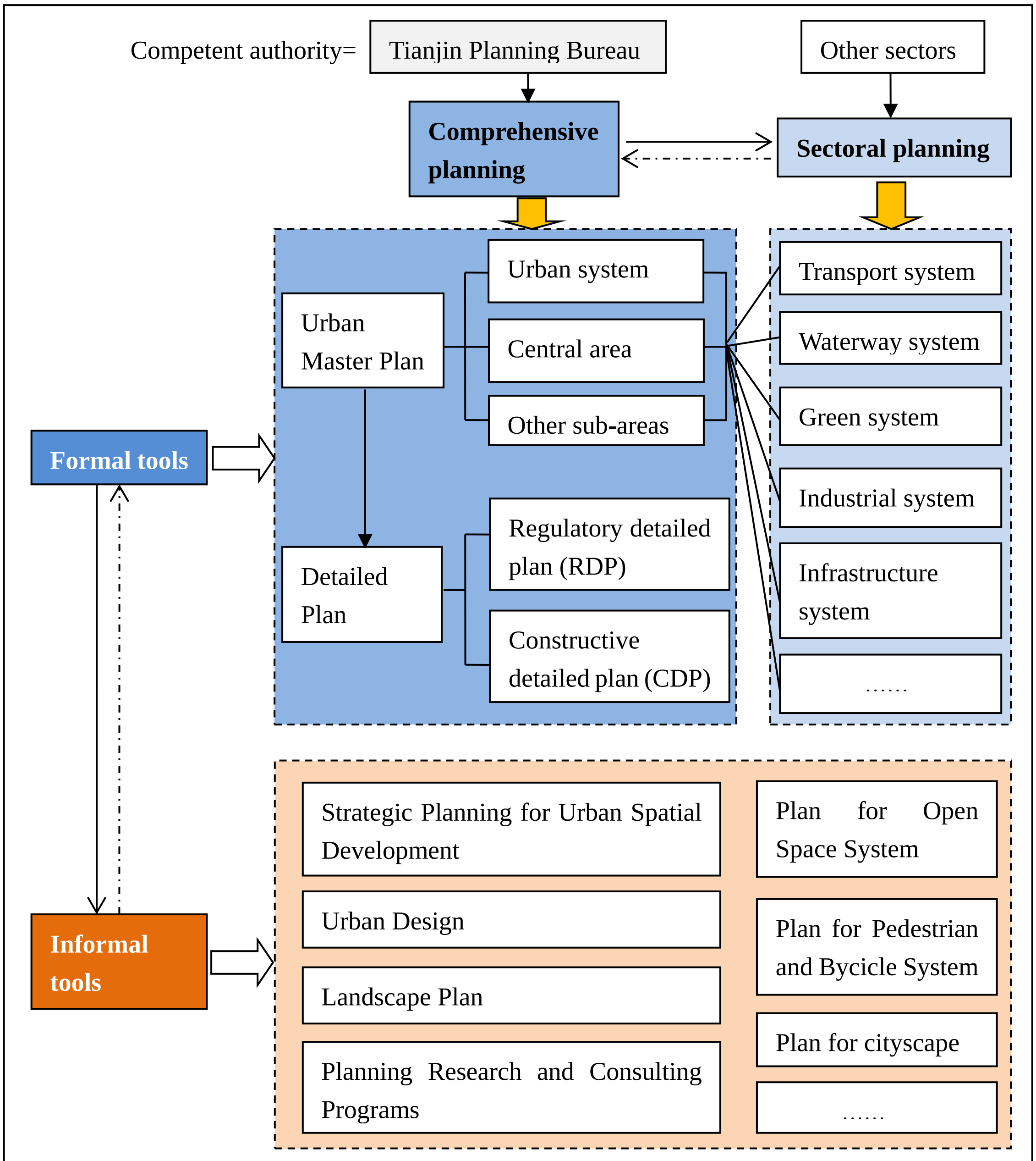


Figure5-19: Planning system in Tianjin

Source: Author's own construct

Formal tools

Formal planning tools are regulated and binding by planning laws and other formal regulations. As shown in the above figure, comprehensive plans mainly include two-tier tools: "Urban Master Plan" and "Detailed Plan", similar to the local land-use planning (*Bauleitplannung: Flächennutzungsplan* and *Bebauungsplan*) in the German planning system to some extent.

Generally speaking, "Urban Master Plan" is the overriding planning tier concerned with a broad, cross-sectoral and foresighted strategy for the spatial structural development, land use and corresponding supporting systems (transport, infrastructure, green space, etc.) at the local level. It is usually prepared aiming at dealing with the entire administrative territory of the city and its key central are (such as Haihe riverside region). The preparation of all other lower-level plans and sectoral plans has to take the Urban Master Plan as the basis and conform to its requirements. On the contrary, urban master plan is also supposed to take into account in weighting all requirements of other sectors and make an integrated planning decision.

“Detailed Plan” is the lower planning tier under urban master plan, which should be prepared based on the urban master plan or its sub-area plan to stipulate the more specific arrangement for the land use, spatial form of buildings and all construction requirements of the planning area. The detailed plan can further be divided into two types: “Regulatory Detailed Plan” (RDP) and “Constructive Detailed Plan” (CDP).

Apart from comprehensive plans, there are sectoral planning tools for specialized systematic projects, including transport, water system, ecological system, etc., which are operated by corresponding sectors. Although comprehensive plans and sectoral plans are on the same hierarchical level, sectoral planners and sectoral plans have to coordinate with comprehensive plans.

Informal planning tools

In addition to above formal planning tools, there are also supplementary not legally binding informal planning tools. The type and form of informal planning tools are strongly oriented according to local specific conditions, which are not fixed and can be flexible and diverse. Currently there are three forms of informal tools attaching the most importance and popularity in the urban planning field of Tianji and even the whole China: “Strategic Plan for Urban Spatial Development”, “Urban Design” and “Urban Landscape Plan”.

Generally speaking, although the informal plan has no statutory binding force, its implement force is supposed to rely on its persuasive power of contents or creative ideas. Its preparation also has to comply with the aims and principles of formal plans. Once informal plans are accepted by “planning managers” or municipal government, only their contents are integrated into formal plans (especially urban master plan and detailed plan) can they be viewed as accessing to implementation. On the other hand, the “planning managers” also have the chance to take the ideas and concepts of informal plans into account when preparing formal plans. That is to say, there is supposed to be an integration process between formal and informal planning tools.

5.4.2 Planning Process

On the basis of above planning system, there is planning integrated approach specifically affecting the intervention actions taken on Haihe riverside region (see 5.3). It is a progressive planning process consisting of a series of formal and informal planning tools, which can be described as following from the perspective of competent urban planning authority.

A **Overall operational mechanism**

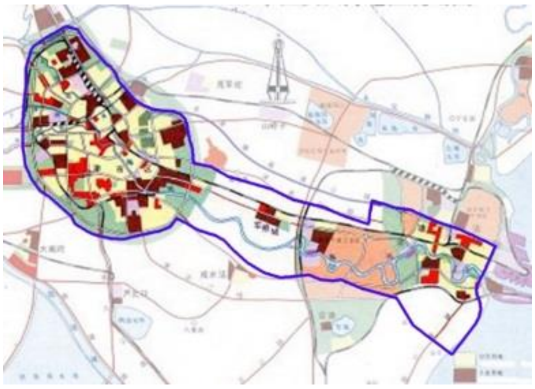
Firstly, the overriding Urban Master Plan was prepared for the whole Tianjin as the overall guidance. Then, based on its development goals and requirements on each subsystem (such as low-carbon-related impact factor system—urban structure and land use, transport, green space, etc.), some informal plans along the riverside were prepared focusing on the human-scale aspects (such as spatial form, building layout, pedestrian system, etc) that could not be concerned in detail in the large-scale Urban Master Plan, and they were also attempted to stimulate aggressive but creative ideas. Moreover, some contents of these informal plans might be incorporated into the next-tier formal plan, such as Regulatory Detailed Plan (RDP). This planning tier worked in further refining detailed land uses and the controlling index system for each land parcel, including the detail requirements and constraint conditions for guiding construction activities and projects. After that, further Constructive Detailed Plans (CDP) regarding site, architecture and micro-environmental design for single land parcel were made on the basis of controlling index system provided in Regulatory Detailed Plan to guide actual implementation. During the above planning operational procedure, relevant sectors also prepared respective sectoral plans according to the requirements of Urban Master Plan. The Urban Master Plan updates almost every ten years and such above planning procedure moves in cycles, in which process previous planning and implementation results serve as pre- and existing conditions to be incorporated into current update of urban master plan.

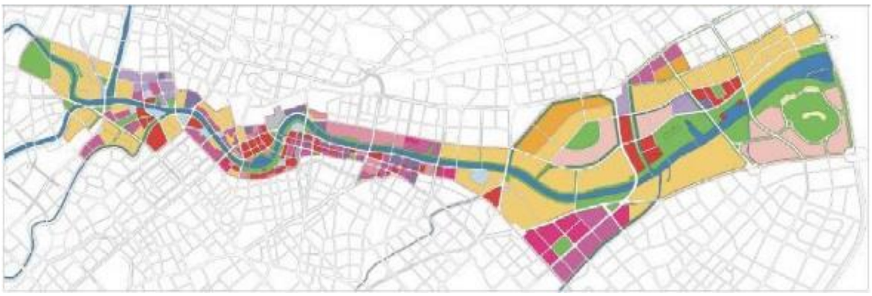
Specifically, this planning process that have essential impacts on interventions in Haihe riverside region can also be divided into three stages, in correspondence with intervention process (see 5.3.1), and each stage owns key planning tools.

B The first stage

Stage 1 was the pre-preparation period between 1996 and 2002. The Urban Master Plan for Tianjin (1986-2000) first put forward that "Haihe river is the spatial development- and natural scenery axis of Tianjin" [**Figure5-20**]. And on this basis the next Urban Master Plan for Tianjin (1996-2010) set the overall goal that "to promote the industrial transformation and make full use the functions of flood control, water supply, tourist and landscaping, etc. of Haihe river, develop Haihe riverside region into a green and landscape axis as well as the centerline running through the politics, economy and culture of Tianjin" [**Figure5-21**]. This overriding urban master plan now could be seen as the planning pioneer that direct and lay the foundation for the interventions in Haihe riverside region contributing in low-carbon development. It firstly pointed out the position, orientation and values of Haihe riverside region as an instrument of interventions to transform the urban and industrial structure as well as land uses for a more sustainable development. The specific concepts in these two master plans included: transferring most separated old industrial lands along the riverside into the eastern coastal planned industrial zone in concentration; planning these previously industrial-used fields in the new uses; planning several new large green parks and plazas along the riverside; and so on.

After that, in order to make further research issues aiming at Haihe riverside region and better implement urban master plans, during 2000-2001 the formal regulatory detailed plan (RDP) for both Haihe riversides and some other informal plans were prepared, in which the representative were the consulting planning programs from Conceptual Design Studio (French) and EDAW. On this basis in 2001, Tianjin Urban Planning & Design Institute integrated these informal plans into a combined plan, including a "Redevelopment Plan for Haihe Riverside Region" (informal) and its associated updated "Regulatory Detailed Plan" (formal) only for the upstream section. The informal "Redevelopment Plan of Haihe Riverside Region" considered the Haihe riverside region as a whole planning space, which systematically proposed conceptual design ideas and guidelines for water system, riverfront pedestrian and public traffic system, open space system, etc. [**Figure5-22**]. And its associated formal Regulatory Detailed Plan (RDP) further specified the land use, development intensity, height control of buildings, green ratio, etc. on both sides of Haihe river, in order to actually implement.





Upper left—Figure5-20: Haihe riverside region in Urban Master Plan for Tianjin (1986-2000)
Upper right—Figure5-21: Haihe riverside region in Urban Master Plan for Tianjin (1996-2010)
Bottom—Figure5-22: Redevelopment Plan for Haihe Riverside Region (2001)
Source: Tianjin Planning Bureau

C The second stage

Stage 2 was the first rapid implementation period between 2002 and 2008. As mentioned previously (see 5.1 & 5.3.1 A), in 2002 Tianjin municipal government officially commenced the comprehensive redevelopment movement of Haihe riverside region, for which planning outcomes prepared in stage 1 (Urban Master Plan, the combined plan) served as the main guiding basis. During this period the intervention actions were intensively taken in the upstream section. In the meanwhile, there were also some new plans emerging with new development ideas. For example, the most influencing Urban Master Plan for Tianjin (2005-2020) proposed that “Haihe river would continue the role as the spatial and landscape axis of Tianjin, along which the central urban area (upstream section) and Binhai New District served as the chief and vice urban centers to form a dual-centric spatial structure” [**Figure5-23**].

This updated version of Urban Master Plan was contributed to emphasizing the service functions along Haihe river through continually adjusting the industrial structure and forming a preliminary polycentric urban structure. In addition, this master plan especially focused on promoting the significance of Haihe river serving as a west-east "ecological corridor" compared to previous orientation of only "landscape and scenery axis". It also pushed Haihe riverside's construction emphasize moving into the river mouth section (Binhai New District).

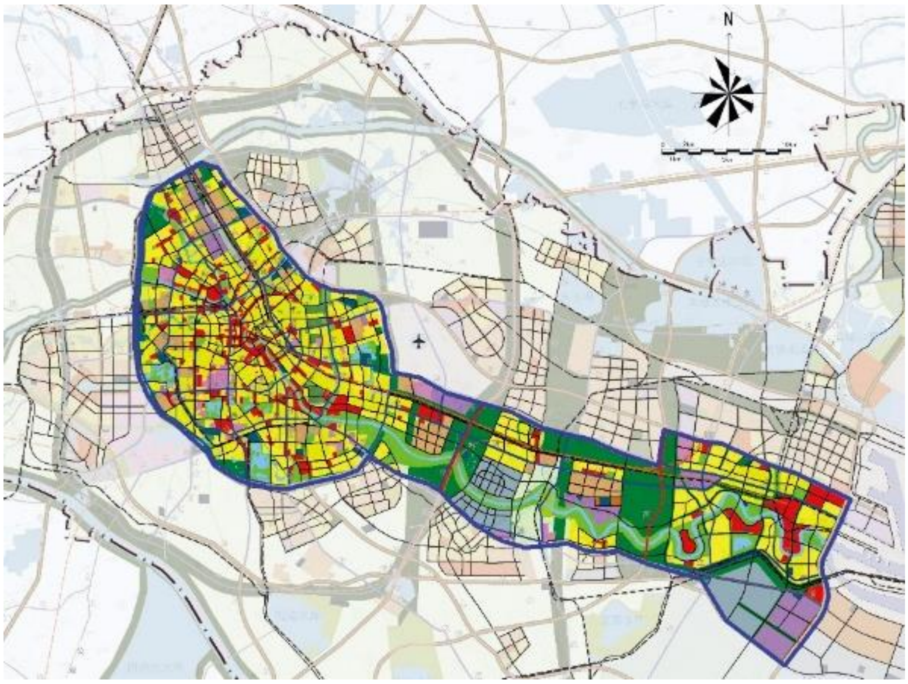
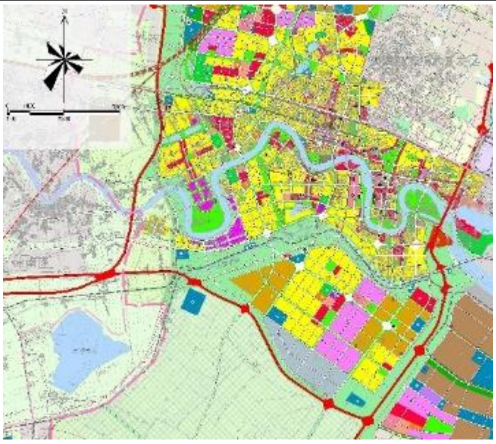


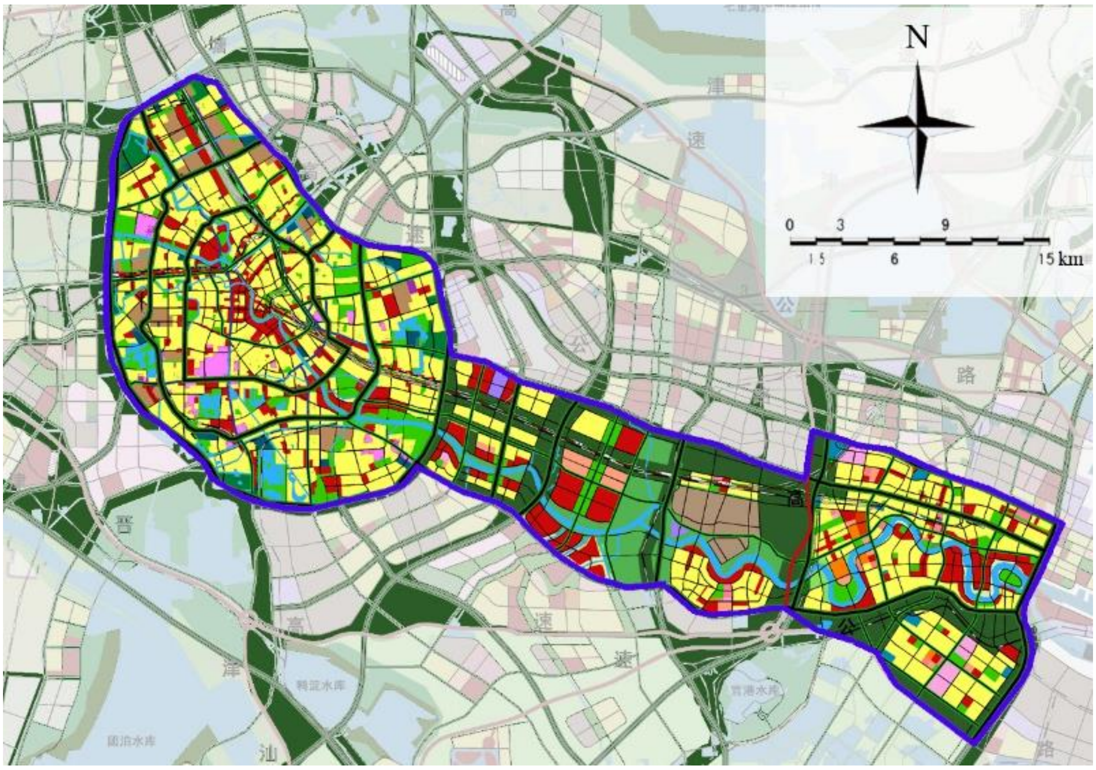
Figure5-23: Haihe riverside region in Urban Master Plan for Tianjin (2005-2020)
Source: China Academy of Urban Planning & Design

D **The third stage**

The next stage 3 refers to the period between 2008 and 2014, in which the construction focus of Haihe riverside region shifted to its river mouth section—Binhai New District.

Under Urban Master Plan (2005-2020), the further sub-area master plan for Binhai New District therefore identified the width of 300-500 meters of blue-green river-based corridor, and also planned some new green areas at different scales [**Figure5-24**]. At the same time, some informal tools were prepared focusing on the design of middle section of Haihe riverside region. Moreover, several sectoral plans also made contributions to Haihe riverside region from the perspective of restoration of river system, flood prevention and drainage, water supply security, etc. After that, the Strategic Planning for Urban Spatial Development of Tianjin (informal) prepared in 2008 [**Figure5-25**] and the revision of Urban Master Plan for Tianjin launched in 2011 [**Figure5-26**] made further optimization and adjustment regarding this region: promoting the middle section of Haihe riverside region to serve as a reserved deputy urban center, so as to form a more polycentric spatial structure with two other centers (central city area and Binhai New District) all connected by Haihe river; emphasizing the south-north multi ecological corridors vertical to Haihe river and liking them to peripheral regional ecological resources (patches and matrix) to enhance a networked ecological landscape pattern; several urban clusters were connected by Haihe river with vertical green corridors between them as spatial breaks.





Upper left—Figure5-24: The river mouth section of Haihe riverside region in Sub-area Master Plan for Binhai New District, Tianjin (2008-2020)

Upper right—Figure5-25: Haihe riverside region in Strategic Planning for Urban Spatial Development of Tianjin (2008)

Bottom—Figure5-26: Haihe riverside region in Urban Master Plan for Tianjin (2011-2020)

Source: China Academy of Urban Planning & Design

Currently is coming into the stage 4, in which period the previous planning outcomes will be continually implemented or adjusted according to the new context. Thus, since 2015 the new Urban Master Plan for Tianjin have been being updated again to adapt to the emerging new context, and in this plan the middle section of Haihe riverside region is the key area of planning.

The whole planning integrated approach is figured as following [**Figure5-27**].

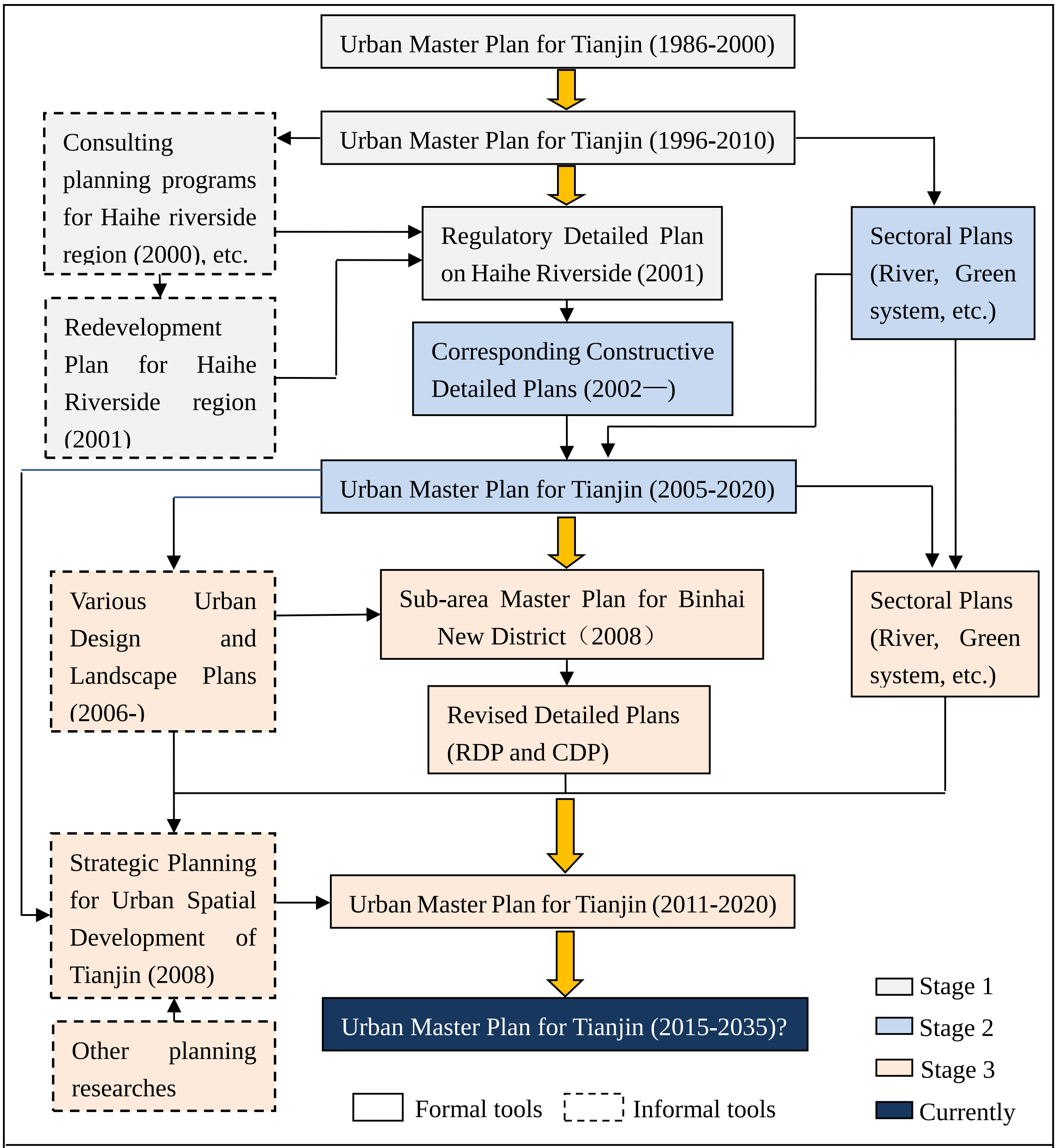


Figure5-27: Planning integrated approach in Haihe riverside region

Source: Author’s own construct

5.5 Summary

This chapter first introduces the transformation context of Haihe riverside region in Tianjin towards low carbon. Then, it analyses current site conditions including river system, spatial structure and land use situation, which can be regarded as the consequence of interventions and planning activities behind. Therefore next it teases out the recent intensive three stages of intervention actions, and extracts those main projects adhered to low-carbon development by applying low-carbon guiding principles and guidelines in previous theoretical framework (see Section 3.4.2 and 3.5). After that, it dissects the supportive planning integrated approach covering planning system, actors and tools in the 3-stage planning process which has been guiding intervention process.

From the whole intervention process and planning integrated approach in Haihe riverside region, some common characteristics of planning integrated approach guiding intervention actions can be seen:

- The way of both taking intervention actions (implementation of projects) and operating planning is essentially a governmental-dominant top-down way;
- The municipal government (mayors) and its affiliated public sectors as well as sub administrative districts serve as the main decision maker and key actors, whose roles are like the "CEO" and "managers" as well as "implementer";
- Taking intervention actions is in a position of a continuous but staged process, each stage owns its focused action area in terms of spatial locations, by following a logic of "locational axiology": separate section—connection [**Figure5-28**];

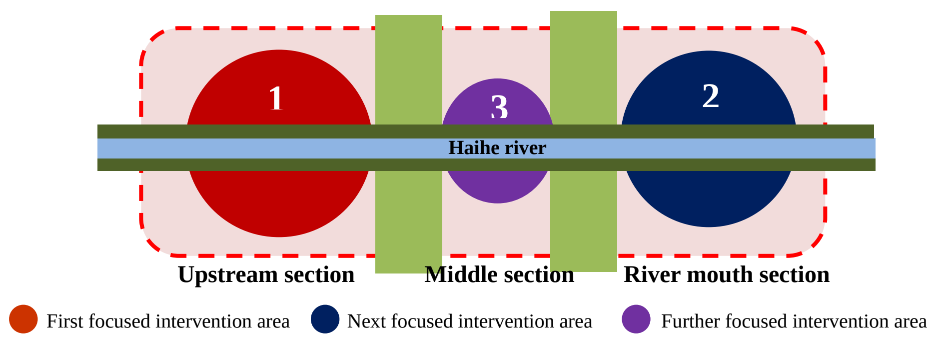


Figure5-28: Intervention logic of "locational axiology"

Source: Author's own construct

- Planning integrated approach is based on traditional local-level Chinese planning system consisting of different kinds of planning tools;

- Formal planning tools represented by Urban Master Plan and Detailed Plan play a dominant role and serve as the main basis of implementing actions, whose essence are “ultimate blueprint” plans;
- Informal planning tools also play a non-ignorable assistant role.

Chapter 6 Evaluation of Low-carbon Performance of Intervention Actions and Cause Analysis

6.1 Goals

Last Chapter 5 has teased out the intervention process of Haihe riverside region under the guidance of planning integrated approach. There are questions might be occurred: Have these actions and efforts really promoted the low-carbon development of this region? In what degree they have actually impacted the low-carbon development? Are their main effects positive or negative in terms of low-carbon development, and why such effects have been produced? And so on.

This chapter will make an assessment of implementation performance of these intervention actions in terms of promoting low-carbon development. The goals of this evaluation would be attempted to find out:

- The degree of “low carbonization” after intensive intervention actions, how this study area meets the need of low-carbon planning goals;
- The aspects to be evaluated which play a positive role and in which aspects there are still big gaps in terms of low-carbon goals;
- The possible causes behind, namely seeing the essence through phenomenon;

For this propose, the approach of “get indexation” (as mentioned in Section 4.2) will be used for assessment, for which the contents of Chapter 3 (theoretical framework) will mainly be applied as the basis.

6.2 Index System for Evaluation

6.2.1 Selection Principles

The evaluation index system to be established is supposed to consist of several interrelated functional groups with hierarchical structure, and each functional group is composed of a set of indicators that have qualitative meaning or quantitative value (such as “ratio’ or “degree” of other units) to reflect the system elements or phenomena.

Selecting indicators and establishing low-carbon evaluation index system for application in Haihe riverside region should follow such principles:

Pertinent: urban river-based region is a complex system, so the indicators should be comprehensively in consistence with the connotation and characteristics of definition of river-based region and low-carbon development (see Section 2.2.3 & 2.3.3).

Local adaptable: the index system should be established conform to the native characteristics within a local context while not completely universal, and should also be representative, applicable and data-available.

Scientific: the indicators within the index system to be established should be both qualitative and quantitative and comparable as well, which could objectively reflect the intention of this evaluation.

6.2.2 Selection Process

According to the principles above, the establishment of low-carbon index system for assessment is derived from following three steps by using Delphi method:

A **Step 1: Theoretical deduction**

To abstract primitive possible indicator layer related to the connotation and characteristics of low-carbon development in river-based region based on the contents of theoretical study in chapter 3 by applying its findings [**Table6-1**].

Table 6-1: Theoretical deduction

Target		Impact factors (3.2.1& 3.2.2)	Intervention mechanism (3.3)	Intervention objects (3.2.3)	Primitive possible Indicator layer
Strengthening carbon sinks		ecological process; green resource	Preserving and restoring the sinks, etc.	Green resource Land use	— Water properties — Green space system;
Reducing carbon sources	Sources in built-up field	Urban scale/industrial structure/ morphological features;	Adjusting urban structure, Optimizing layout form	Urban structure and land use; Spatial form	— Urban structure and density; — Layout of blocks; — Mixture degree of industrial and land use; — Open space;
	Sources in transport	Travel distance; Travel modes /network	Optimizing traffic modes & environment, Shortening travel distance	Transport organization; Urban structure and land use	— Green traffic mode; — Green traffic structure ; — Green traffic accessibility;

	Source in municipal utilities	Energy facilities/ supply/distribution/treatment process;	Promoting the efficiency of energy operation, Recycling renewable energy sources	Utilities operation Urban structure and land use	— Energy sources — Energy structure; — Water reuse;

Source: Author's own construct

B Step 2: Statistical deduction

To statistically collect and compare by referencing a set of indicators from indigenous index systems related to low-carbon development which are made officially under the actual context of China and local Tianjin city and some other indicator systems regarding Chinese waterfront [**Table6-2**]. On this basis, to select those common and high-frequency indicators occurred which have connections with the primitive possible indicator layer listed in above Table 6-1.

Table 6-2: Sources of related indigenous index systems

Referenced indigenous index system related to low-carbon development	
National level	• *Evaluation Method and Index System of Chinese Urban Low-carbon Development (2014)* • *Low-carbon Index System for China (2012)* • *China Sustainable Development Strategy Report 2009——China's Approach towards a Low Carbon Future* • *Construction Index System of Ecological Towns, Municipalities and Provinces (2009)* • *Scientific Evaluation Standard for Chinese Livable City (2008)* • *Evaluation Standard for National Eco- and Garden City (2005)*
Local level	• *Index System of Sino-Singapore Tianjin Eco-City (2010)* • *2010 Action Plan for of Tianjin's Eco-city Construction* • *Low-carbon Index System of Urban Plan of Tianjin (2011)*

Source: Author's own collection

C Step 3: Questionnaire survey

On the above basis, a primary low-carbon index system with previously selected indicators derived from above two steps are designed in the form of semi-open questionnaire, which would be sent to relevant specialists for help in identifying the final index system. This designed primary semi-open questionnaire is a four-layer structure consisting of 40 indicators **{Appendix III}.**

Then, the sampling of targeted specialists who serve as respondents need also to be identified. Delbecq (1975) suggested that 10 to 15 respondents would be sufficient in case their background is homogeneous. However, it is variable (Hsu & Sandford, 2007). And Ludwig (1997) mentioned this number normally should be 15-20. In this paper, the number of 22 experts is finally identified. These 22 experts are based on the "think-tank resource base" listed in Table 4-2 (see 4.4.2 B), including 11 of municipal sectors (planning management), 7 of urban planning institutes (preparation of planning) and 4 of universities (planning research) respectively, who are familiar with Haihe riverside region and whose expertise background are almost homogeneous.

Then, in the first round 1 of Delphi process, the designed semi-open questionnaires were sent by email or computer-assisted instant messaging software at the end April, 2014. Actually before this date those targeted respondents were just interviewed by the author for information and data collection during the fieldwork process (on-site visiting and interviews, see 4.4.2 B). In this interview process (see **Appendix I & II**) the personal connection with respondents was established, they were also requested to offer further possible support. Being benefited from this background, all expected feedback were returned within one to two month, of course during this period some of respondents asked explanations in case the contents not understandable. In terms of the results of feedback of questionnaires, the recommendations had much in common because the respondents had been devoting themselves to working in Tianjin for long time; while some are differentiated due to the different professional background and personal understanding or preference. However, although recommendations from experts serve as important scientific basis, it does not mean every recommendation would be adopted, the own understanding and judgment from the author himself also plays a role. The main common recommendations of first round 1 of Delphi process could be synthesized into three aspects:

- Weighting factor: the "target layer" should also be weighted;
- Structure: in terms of indicator layer, "two-class" is repetitive somewhere and not so necessary, it is better to merge into one level;
- Indicators: some indicators are too detail but not so related to the topic; some indicators are better to be replaced by another one; while some seem to be not data available.

After that, based on modifications the final low-carbon index system with selected indicators can be formalized (see next Section 6.2.3). In addition, the round 2 of Delphi process will be merged with AHP method to be presented in the further corresponding section.

6.2.3 Establishment of Index System

Based on above approach, the index system for assessing low-carbon performance in Haihe riverside region is finally established. Horizontally this index system is divided into three layers: the target layer, criterion layer and indicator layer, as shown below [**Table6-3**].

The target layer system (A) expresses the general goal of low-carbon development, including reducing carbon sources (sources in built environment, transportation and municipal utilities) and strengthening carbon sinks, which corresponds to the theoretical analysis in Chapter 3.

The criterion layer (B) is also consistent with the respective target layer and the theoretical framework in Chapter 3 by applying low-carbon-oriented guiding principles: richness of waterside status, biodiversity of green space, multifunctionality of urban structure and land use, permeability of spatial form, public accessibility of traffic network, circularity of utilities operation. These six layers are mutually interacted.

The indicator layer system (P) is the final result of "get indexation" with selected 26 key qualitative and quantitative indicators. They constitute the most fundamental elements of this low-carbon evaluation index system serving as the main basis for further evaluation. The contents of Chapter 2 and Chapter 3 play a big role in the explanation of these indicators.

Table6-3: Low-carbon evaluation index system in Haihe riverside region

A: Target layer	B: Criterion layer	P: Indicator layer
Strengthening carbon sinks (A_1)	Richness of waterside status (B_1)	* River corridor width (P_1)
		River feature (P_2)
		Water quality (P_3)
		Riverbank stability (P_4)
	Biodiversity of green space (B_2)	* Green areas per capita (P_5)
		* Green coverage ratio (P_6)
		* Native plants index (P_7)
		* recovery rate of degraded lands(P_8)
		Centricity (P_9)
		Compactibility (P_{10})

Reducing carbon sources (A_2)	Multifunctionality of Urban structure and land use (B_3)	* Population density (P_{11})
		* Tertiary Industry per GDP (P_{12})
		*Jobs-housing balance ratio (P_{13})
	Permeability of spatial form control (B_4)	* Building density (P_{14})
		Building enclosure degree (P_{15})
		* Open space ratio (P_{16})
		Open space connectivity (P_{17})
	Public accessibility of traffic network (B_5)	* Green travel ratio (P_{18})
		Green travel quality (P_{19})
		* Coverage rate of slow-travel system (P_{20})
		* Average commute time (P_{21})
	Circularity of Municipal utilities operation (B_6)	Energy efficiency (P_{22})
		* Utilization rate of renewable energy (P_{23})
		* Unconventional water availability (P_{24})
		* Sewage treatment rate (P_{25})
		* Repetition rate of industrial water (P_{26})

Note: the indicators with "*" mean quantitative data, while the rest represent qualitative

Source: Author's own construct

Explanations

B_1 Richness of waterside status

(P_1). River width (m)

It measures how wide the water surface with its adjacent riparian zone of Haihe river is on average. As explained previously from the perspective of landscape ecology (see Section 2.3.2), river corridor exerts ecological functions by impacting the transit and exchange of nutrients, sediments and energy as well, in which process different width of river corridor has different effect on biodiversity conservation and its self-organization ability.

(P_2). River feature

It is involved with the basic morphological characteristics and natural physical property of the water body, including its shape, degree of crook, landscape situation. This is a comprehensive indicator intending to establish an intuitive understanding of Haihe river, since the physical features of water would influence river system's metabolism process from a urbanology perspective (see Section 2.3.1).

(P_3). Water quality

It is an indispensable indicator to reflect the quality and pollution extent of surface water of Haihe river, which is highly related to the life quality and also exertion of river's metabolism of matter and energy cycle as well as ecological functions.

(P_4). Riverbank stability

It refers to the steady-state situation of the riverbank along Haihe river by comprehensively measuring its hydraulic and soil as well as vegetation condition, degree of erosion and canalization, etc. As described previously from a landscape ecological perspective (see Section 2.3.2), riverside stability helps in maintaining the connectivity and integrity of river system and promoting its ecological processes as well as healthy development.

B_2 Biodiversity of green space arrangement

(P_5). Green areas per capita (m^2/person)

It measures the area of public green spaces that each resident share on average in the Haihe riverside region. Public green areas refer to those green lands with recreational facilities open to the public, including water landscape, riverfront parks, gardens, small landscaped lands, etc. This indicator has influences on the effect of GHG reduction and is directly related to the living and ecological environmental quality.

(P_6). Green coverage ratio (%)

It implies the proportion of the summation of vertical projected area of shrubs, trees, grasses and other plants as well as green lands to the built-up area in Haihe riverside region. The same as the above indicator and as described in Section 3.2.1, green coverage plays a vital role as carbon sinks, and this indicator reflects the intensity of carbon sequestration and removal.

(P_7). Native plants index

This is a local special indictor which refers to the proportion of native plant species to all plant species. The plant species directly influence the ecological process of carbon sinks and carbon sequestration capacity as a consequent, in which particularly those native plants play a big role in as they are more adapt to the local environment and relatively have stronger growth force and lower mortality.

(P_8). Recovery rate of degraded lands (%)

It measures the recovered proportion of once degraded land spaces due to natural erosion and human economic activities (such as mining, industrialization, etc.). Haihe riverside was highly industrialized previously, so this indicator reflects the degree of pollution control and biodiversity of associated green resource to some extent.

B_3 Multifunctionality of Urban structure and land use

(P_9). Centricity

It refers to the mono-centric or polycentric structure of study area, which is related to the degree of concentration or deconcentration of central places and service facilities as well as other main urban functional zones. As discussed previously (see Section 3.3.3), a polycentric structure has more opportunities to reduce the commuting time and distance between their residential locations and other daily places and thus to reduce energy consumption in transport and built-up areas.

(P_{10}). Compactibility

It refers to how compact the urban structure and form is. As also mentioned previously, a compact urban space environment could promote the land use efficiency and directly influence the traffic energy consumption and carbon emissions (see Section 3.2.2 & 3.3.3). This indicator is mainly linked to the land use pattern of a “decentralized concentration”, which means decentralizing in a large-scale context while emphasizing high-density and –intensity land uses in a relative small-scale context.

(P_{11}). Population density (persons/km^2)

It means the resident and working population per unit area, which is a quantity of type number density. This indicator is also related to the total transport volume and ways which impact the traffic energy consumption and carbon emissions, as indicated in the well-known “Newman - Kenworthy Curve” that the volume of transport energy consumption is in inverse proportion to the population density.

(P_{12}). Tertiary Industry per GDP (%)

It refers to the proportion of tertiary industry (service industry) accounts for of gross domestic product. Under the local context of Tianjin this indicator could reflect the optimization effect of industrial transformation (also land uses) in Haihe riverside region to some extent, from traditional high-intensive industries to relative low energy-consumption industries after its intervention process.

(P_{13}). Jobs-housing balance ratio（%）

It means the proportion of local workers to local labor force resource in a certain area. This indicator measures the degree of working within a short travel distance of residents and also the degree of mixed land use. The higher jobs-housing balance ratio, the larger proportion of working in a short distance and correspondingly less transport demands that influence the GHG emissions can arise as a consequence. An ideal situation is keeping the balance between local working and living.

B_4 Permeability of spatial form control

(P_{14}). Building density (%)

It means the proportion of building coverage area to the whole study area. As mentioned in Section 3.2.2 A, this indicator is highly connected with urban heat island effect, in addition, the higher building coverage in the surface area also influences ventilation and sunlight of building block as well as means lower open space ratio.

(P_{15}). Degree of building enclosure

It describes the spatial relationship between building entities and open spaces horizontally, namely the features of porosity of urban form. Generally the main cause of this indicator is the various building composition modes, which correspondingly brings about different shadowing and ventilation effect through reorganization of local climatic elements such as wind and solar, thus affects the microclimate and further energy usage efficiency of buildings.

(P_{16}). Open space ratio (%)

It measures the proportion of all kinds of open spaces (parks, green lands, water surfaces, plazas, etc.) to the built-up area. As shown previously (see 3.2.1), urban open green spaces largely work in evaporation, cooling and carbon fixation as well as oxygen release. Beyond these functions, this indicator also reflects the permeable rate from "soft" urban surfaces when receiving rainwater compared to "hard" surfaces.

(P_{17}). Open space connectivity

It refers to the degree of connection and integration of open spaces by Haihe river and its tributary and its adjacent greenway system as well. Besides the characteristics of open space itself (such as type and scale), from the perspective of landscape ecology principle (see Section 2.3.2), a connected and integrated open space system may exert better functions above than those fragmented but not systematic isolated open space. And normally in a river-based region the river corridor is supposed to integrate green spaces into a whole blue-green open space system.

B_5 Public accessibility of traffic network

(P_{18}). Green travel ratio (%)

It is also a local characteristic indicator of Tianjin. Green travel implies those relatively low-emission traffic modes except by private car, such as by bus, tram, bicycle, walking, etc. Green travel ratio means the proportion of people who select a green travel mode for commuting to the number all commuters in Haihe riverside region.

(P_{19}). Green travel quality

It is a comprehensive indicator involved with the safety, connectivity, comfort degree, facility arrangement situation of green travel modes. Besides the quantitative supply of routes, as described in Section 3.3.3 C, the quality also determines the preference of selection and usage of green travel modes when people commuting, thus to reduce unnecessary carbon emissions.

(P_{20}). Density of slow-travel system (km/ km^2)

It refers to the length of all kinds of slow-travel modes (pedestrian and cycling trip) per unit area. As discussed in Section 3.3.3 C, the well-planned slow-travel system is intended to stimulate more residents to use as an alternative traffic way and give up choosing private cars in the meanwhile, especially a slow-travel behavior is more likely to take place in a water-based area due to its environmental amenity and linear spatial pattern.

(P_{21}). Average commute time (one-way, minutes)

It measures an average time of how much time local residents spend on travel from home to work in one-way direction, by whatever means, including by foot, bus, car or bicycle, etc. The commute time is related to the commute mode, efficiency of accessibility of traffic system and also the situation of home-jobs balance.

B_6 Circularity of municipal utilities operation

(P_{22}). Energy efficiency

It refers to how efficient the operation of energy supply and distribution. High-efficiency energy is contributed to reduce process carbon sources, as described previously (see Section 3.3.3 C), this is a comprehensive qualitative indictor which takes the “3D situation” (Decarburization, Decentralization and Demand reduction) as the evaluation basis.

(P_{23}). Utilization rate of renewable energy (%)

It implies the proportion of those renewable energy resources (including solar, wind, water energy, etc,) to the energy supply structure in the study area. As discussed before, in terms of a low-carbon development there is a need to facilitate widely use of alternative energy resources (Section 3.3.3 A), for which one approach is to obtain renewable energy as “negative entropy” to make energy circulation more efficient.

(P_{24}). Unconventional water availability (%)

This is also a local characteristic indicator which refers to the proportion of annual usage of unconventional water resources (flood, rainwater, sewage and waste water) to the total amount of water used. As also described previously (Section 3.3.3 C), maximizing the utilization of unconventional waters could work in balancing and recycling water resources to reduce carbon sources in municipal utilities and also creating landscape effects.

(P_{25}). Sewage treatment rate (%)
It measures the proportion of all treated living and industrial water by sewage treatment plants to the total amount of sewage discharge. This indicator reflects the degree of operation of facilities for collecting and treating waste water and the potential of generating renewable energy (reclaimed water, biogas generated in the sewage treatment process) as well as compensation for environmental pollution caused by human activities.

(P_{26}). Repetition rate of industrial water (%)
It is also a local special indicator which measures the proportion of reused water of industry to the total water consumption. Since Haihe riverside region has been experiencing industrial change through its intervention process and the water source of Haihe river partially serves to industrial water use, so this indicator reflects the degree of appropriately use of water resources. The higher this indicator means the lower water consumption and possibilities of water pollution.

6.3 Evaluation Process

6.3.1 Evaluation Weighting

Simply speaking, in terms of the index system established above, it is then to compare the relative importance of the lower-level indicators at their upper level in the form of a hierarchical structure via Analytical Hierarchy Process (AHP) method combined with the round 2 of Delphi technique, and afterwards get the weighted values of each indicator to be applied in further evaluation. The following shows the specific four steps of conducting weighting procedure:

A Step1: Forming hierarchical structure

Firstly, a hierarchical structure of AHP method is formed based on the above index system (see Table 6-3) in the pattern shown below [**Figure6-1**]:

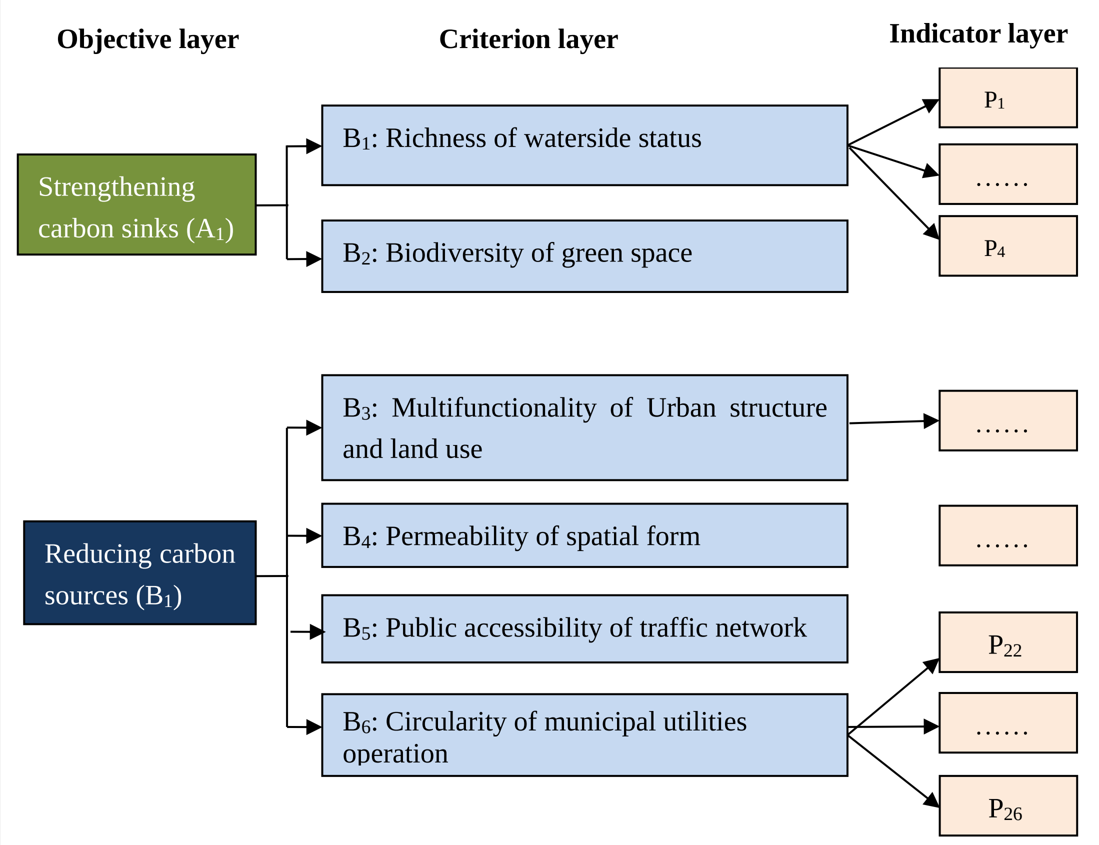


Figure6-1: Formation of AHP hierarchical structure

Source: Author's construct based on (Siedentop, 2010)

B Step2: Building standard scale system and questionnaire

1) An AHP standard scale system of one-on-one comparisons is referenced here serving as the criterion for next judgment, which is then applied in the form of designed comparison tables for questionnaire. For one example, in terms of the criterion layer, when B_1 compares B_2, B_1 is [**Table6-4**] [**Table6-5**]:

Table6-4: AHP standard scale system for pair wise comparison

Scale	Meaning/Interpretation
1	equal important
3 (1/3)	a little bit larger (smaller) or more important (less important)

5 (1/5)	significant larger (smaller) or more important (less important)
7 (1/7)	very strong larger (smaller) or more important (less important)
9 (1/9)	extreme larger (smaller) or more important (less important)
2 (1/2),4 (1/4),6 (1/6),8 (1/8)	Intermediate values of above scale

Source: (Siedentop, 2010).

Table6-5: Example of designed comparison table for questionnaire

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
B_1:Richness for waterside status				√						B_2:Biodiversity of green space

Source: Author's own construct

2) As example shown above, all comparison tables involved with low-carbon index system and the purpose of this survey as well as explanations are formed into a whole questionnaire {**Appendix IV**}. This questionnaire was also sent to 22 judges (the same experts as described in 6.3.2 C) for scoring through filling in all comparison tables independently.

C **Step3: Obtaining primary weighted values**

1) When all questionnaires have been returned, the judgment matrices could be transformed according to the result of each comparison table. For one example, a formed judgment matrix of "criterion layer (B_3, B_4, B_5, B_6)" derived from one questionnaire is shown below [**Table6-6**]:

Table6-6: Example of a formed judgment matrix

	B_3	B_4	B_5	B_6
B_3	1	3	1/3	3
B_4	1/3	1	1/3	1
B_5	3	3	1	3
B_6	1/3	1	1/3	1
summation	4.6667	8	2	8

Source: Author's own collection

2) Based on the mathematical calculation method of Asymptotic Normalization Coefficient (ANC), the judgment matrices are then normalized by using the formula

below, namely each value of each column respectively divided by the summation of this column for normalization. Continue the above example, its normalized matrix is shown in the flowing table [**Table6-7**]. On this basis, the average value of the summation of each line which serves as the primary weighted value could be calculated (e.g. (0.2143+0.375+0.1667+0.375)/4=0.2828).

$$\overline{b_{ij}} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, (i, j = 1,2 \ldots n)$$

Table6-7: Example of above normalized matrix

	B3	B4	B5	B6	Primary weighted values
B_3	0.2143	0.375	0.1667	0.375	0.2828
B_4	0.0714	0.125	0.1667	0.125	0.1220
B_5	0.6429	0.375	0.5	0.375	0.4732
B_6	0.0714	0.125	0.1667	0.125	0.1220

Source: Author's own construct

D **Step4: making consistency check**

1) After the above primary weighted values have been obtained, the consistency index (CI) is needed to be calculated by calculating the sum of weighting matrix and its maximum eigenvalue (λ_{max}), as following process shown by using the same continued example:

$$0.2828 \times \begin{bmatrix} 1 \\ 1/3 \\ 3 \\ 1/3 \end{bmatrix} + 0.1220 \times \begin{bmatrix} 3 \\ 1 \\ 3 \\ 1 \end{bmatrix} + 0.4732 \times \begin{bmatrix} 1/3 \\ 1/3 \\ 1 \\ 1/3 \end{bmatrix} + 0.1220 \times \begin{bmatrix} 3 \\ 1 \\ 3 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.1725 \\ 0.496 \\ 2.0536 \\ 0.496 \end{bmatrix}$$

$$\lambda max = (1.1725 \div 0.2828) + (0.496 \div 0.122) + (2.0536 \div 0.4732) + (0.496 \div 0.122) / 4 = 4.1543$$

Then, the consistency index $(CI) = \frac{\lambda max - n}{n-1} = \frac{\lambda\, max(4.1543) - 4}{4-1} = 0.0514$

2) Next according to the table of the average random consistency index (RI) [**Table6-8**], the consistency ratio (CR) can be calculated by using the formula below (n=4):

Table6-8: Average random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: (Saaty & Vargas, 2002)

$$CR = \frac{CI}{RI} = \frac{0.0514}{0.89} = 0.057$$

After all primary weighed values from one judge have experienced consistency check, the results can be viewed as acceptable (when CR⩽0.1), and then the final weighted values could be confirmed by calculating the geometric mean of the acceptable results of all participated judges.

The final result of weighting of each indicator is shown in **{Appendix V}**.

6.3.2 Graded Standard

Based on the final weighed values of all indicators, the Fuzzy Comprehensive Evaluation (FCE) method will be operated to evaluate the low-carbon performance of intervention actions in Haihe riverside region under planning goals. The first thing is to establish the "factor set" and "evaluation set" in judge.

At first, the factor set "U" is established according to the third-level 26 indicators in above low-carbon index system to serve as the primary evaluation object:

1) $U=\{U_1, U_2, U_3, \ldots U_{26}\}$

Then, an evaluation set "V" is also established, which consists of five-level evaluation criterion: **"very low"**, **"low"**, **"medium"**, **"good"** and "**very good"**. Specifically:

2) $V=\{V_1, V_2, V_3, V_4, V_5\}$={very low, low, medium, good, very good}

As mentioned above, the essence of this evaluation is to assess implementation effects of intervention actions, through the variation of indicators from past to planned future. It is necessary to explain the logic of defining this evaluation set "V", especially its extreme values:

The upper limit value ("very good") of each indicator is taken from the specific actual value (quantitative) or description (qualitative) regarding the study area in terms of its planning goal (in the year 2020), based on various latest running plans prepared in Tianjin, since those plans almost took the year 2020 as the common planning period. It means this indicator is supposed to achieve such a quantitative value or qualitative status in 2020, when nowadays equaling to or even exceeding it can be called as "very good". While the lower limit value ("very low") is taken from the past value of this indicator in the year 2001, which was the previous status of the study area, since after 2001 the Haihe riverside region has been intensively receiving its intervention process through undertaking actions (as described in Section 5.3). It means this indictor is supposed to be better improved currently when compared to its previous status in 2001 because of intervention actions, otherwise in case even worse, it can be called as "very low".

To further transfer this "evaluation set" into a hundred-mark score system: [very low]=[0, 20]; [low]=[20, 40]; [medium]=[40, 60]; [good]=[60, 80]; [very good]=[80, 100]. And then the mid value of this assignment system can be obtained: [10, 30, 50, 70, 90], which will be conductive to identifying the final evaluation results.

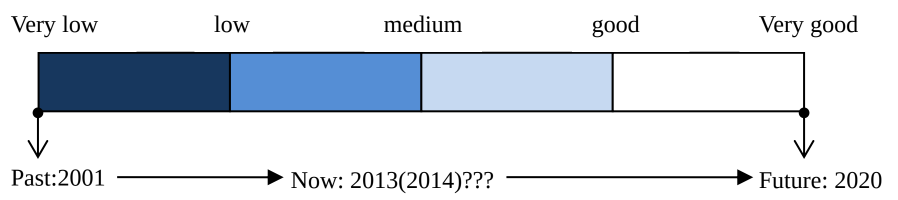


Figure6-2: The logic of defining evaluation set
Source: Author's own construct

Through this comparison of indicators between past, now and future [**Figure6-2**], the low-carbon-related effects caused by intervention actions could be clearly assessed.

3) By summarizing both "factor set" and "evaluation set", the graded standard of indicators can be listed following [**Table6-9**]:

Table6-9: Graded standard of indicators for evaluation

	Very low	Low	Medium	good	Very good
P_1:River corridor width	< 150m	150-200m	200-250m	250-300m	⩾300m
P_2: River feature	Serious channelization of the bank and riverbed ; Channel completely straight	Extensive channelization of the bank; Channel mostly straight	Some channelization Present; channel partly straight	A little bit channelization; channel marginally straight	No obvious channelization, river in natural pattern; channel in curved pattern
	Seriously polluted, no	Polluted in terms of drinking water	Partly polluted in terms of drinking	Partly polluted in terms of drinking	A little polluted in terms of drinking

P_3: Water quality	possible use	standard, only for agricultural use	water standard, only for industrial and landscape use	water standard, for fishery use	water standard, spare drinking water source use
P_4: Riverbank stability	Very Unstable; 80%-100% erosion;	Unstable; 50%-80% erosion;	A little bit unstable, 20%-50% erosion;	Stable, less than 20% erosion;	well stable, less than 5% erosion;
P_5:Green areas per capita	< 5 m²/person	5-7.3 m²/person	7.3-9.6m²/person	9.6-12 m²/person	⩾12 m²/person
P_6: Green coverage ratio	< 30%	30%-36%	36%-42%	42%-48%	⩾48%
P_7: Native plants index	< 0.5	0.5-0.6	0.6-0.7	0.7-0.8	⩾0.8
P_8: recovery rate of degraded lands	< 75%	75%-80%	80%-85%	85%-90%	⩾90%
P_9: Centricity	One main urban center	Two main urban centers with a few sub-area centers	Two main urban centers with multiple sub-area centers	Three main urban centers with a few sub-area centers	Three main urban centers with multi sub-area centers
P_{10}: Compactibility	Low density and intensity of service facilities, single land use around traffic nodes	Low density, mixed land use and intensity of service facilities around traffic nodes	Medium density, mixed land use and intensity of service facilities around traffic nodes	A little high density, mixed land use and intensity of service facilities around traffic nodes	High density, mixed land use and intensity of service facilities around traffic nodes
P_{11}: Population density	6675 persons/ km²	6675-7735 persons/ km²	7735-8970 persons/ km²	8970-10397 persons/ km²	10397-12000 persons/ km²
P_{12}: Tertiary Industry per GDP	< 38%	38%-45%	45%-53%	53%-60%	⩾60%
P_{13}: Jobs-housing balance ratio	< 37%	37%-43%	43%-49%	49%-55%	⩾55%
P_{14}: Building density	>45%	41%-44%	38%-41%	35%-38%	⩽35%
P_{15}: Building enclosure degree	Inpermeable urban form along the river, isolation between buildings and open spaces	Low permeable urban form along the river, medium integration between buildings and open spaces	Medium Permeable urban form along the river, medium integration between buildings and open spaces	Permeable urban form along the river, a little high integration between buildings and open spaces	Good permeable urban form along the river, high integration between buildings and open spaces
P_{16}: Open space ratio	< 31%	31%-34%	34%-37%	37%-40%	⩾40%
P_{17}: Open space connectivity	Poor systematic, isolated, no obvious relation with the river	Basic systematic, partly connection with the river system	Moderate systematic, medium connection with the river system	Good systematic, suboptimal connection with the river system	Highly systematic, good connection with the river system
P_{18}: Green travel ratio	< 41%	41%-49%	49%-57%	57%-65%	⩾65%
P_{19}:Green	Unbearable travel and	Bearable travel and transfer,	Medium travel and transfer,	Comfortable travel and	Very comfortable travel and transfer,

Travel quality	transfer, very crowed environment	crowed environment	medium environment	transfer, loose environment	loose environment
P_{20}: Density of slow-travel system	< 7km/ km²	7-8.6 km/ km²	8.6-10.3 km/ km²	10.3-12 km/ km²	⩾12km/ km²
P_{21}: Average commuting time	>60 min	50-60 min	40-50 min	30-40 min	<30 min
P_{22}: Energy efficiency	Dissatisfactory Decarburization, Decentralization and Demand reduction	A little Decarburization, Decentralization and Demand reduction	Normal Decarburization, Decentralization and Demand reduction	Decarburization, Decentralization and Demand reduction	High Decarburization, Decentralization and Demand reduction
P_{23}: Utilization rate of renewable energy	< 5%	5% -8%	8% -12%	12% -15%	⩾15%
P_{24}: Unconventional water availability	< 15%	15%-20%	20%-25%	25%-30%	⩾30%
P_{25}: Sewage treatment rate	< 75%	75%-82%	82%-89%	89%-95%	⩾95%
P26: Repetition rate of industrial water	< 75%	75%-80%	80%-85%	85%-90%	⩾90%

Source：Author’s own construct

The data collection of indicators in terms of Haihe riverside region therefore plays a big role in the above process, which was benefited largely from the basis of fieldwork process (see Section 4.4.2 B). The qualitative description or specific value of each indicator (past, present and future) were derived from two approaches: one was to search them by looking up collected documentary data, including various existing planning outcomes and annual statistical books of Tianjin as well as governmental reports, etc.; the other was to pertinently consult those sectoral visiting objects of “think-tank resource base” (listed in Table4-2) to obtain required data. Because of the sectoral regulations and public security reasons, it was not possible for governmental administrative authorities to open their database to individual, however, through above approach was possible.

The specific explanation of indicator value and data sources are shown in {**Appendix VI**}.

6.3.3 Evaluation

Next continue to present the specific evaluation steps by using FCE method.

A Step1: Calculating the degree of membership

After the graded standard of indicators has been established (Table6-9), the degree of membership of each individual factor in the above evaluation set "V" is needed to be calculated, so as to establish the single-factor evaluation matrix for next fuzzy matrix. The formation of "single-factor evaluation matrix" is shown below, in which "R" represents the relation matrix composed of factor set "U" and the evaluation set "V": based on above, "j" means 5-level evaluation criterion and "i" means the third-level 26 indicators in low-carbon index system.

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \ldots \\ R_i \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1j} \\ r_{21} & r_{22} & \ldots & r_{2j} \\ \ldots & \ldots & \ldots & \ldots \\ r_{i1} & r_{i2} & \ldots & r_{ij} \end{bmatrix}$$

Specifically, in terms of generating single-factor evaluation matrix, the qualitative indicators and quantitative indicators have to separately acquire the degree of membership by using different calculation methods (Wang, 1992):

1) For qualitative indicators, the degree of membership is identified mainly through questionnaire survey from experts as judges and calculation the result derived from the grade proportion. For one example, in terms of the qualitative indicator "P_2: river feature", according to the evaluation set "V" , 20 judges (from the same 22) also have participated the evaluation, in which 2 judgments are "very good" (10%), 10 judgments are "good" (50%), and 8 judgments are "medium" (40%), the membership degree and also single-factor evaluation matrix of this indicator is: R=[0 0 0.4 0.5 0.1].

2) As to the quantitative indicators, there is a need to calculate the membership degree by relevant membership function of mathematics formulas. The membership function plays a big role in the field of Fuzzy mathematics. By referencing other existing research, the membership function of fuzzy set model is established below [**Figure6-3**]:

There are some explanations and pre-conditions in terms of the calculation of membership functions of this fuzzy set model: U_{ij} means the membership degree of indicator U_i of factor set "U" to the j-level evaluation criterion; V_{ij} represents evaluation set "V", namely the j[th] evaluation criterion of this indicator U_i; and D_{ij} indicates the extreme value of each evaluation standard (i=1,2,3…26, j=1,2,3,4,5). The hypothesis of the fuzzy boundary points (a_{ij}, b_{ij}, c_{ij}, d_{ij}) is:

$$\frac{b_{ij} - D_{ij}}{D_{ij+1} - D_{ij}} = \frac{D_{ij+1} - C_{ij}}{D_{ij+1} - D_{ij}} = 0.2$$

In the meanwhile, there is another hypothesis: when $x=D_{ij}$, $U_{ij}=0.5$.

"X" means the specific value of quantitative indicator to be evaluated.

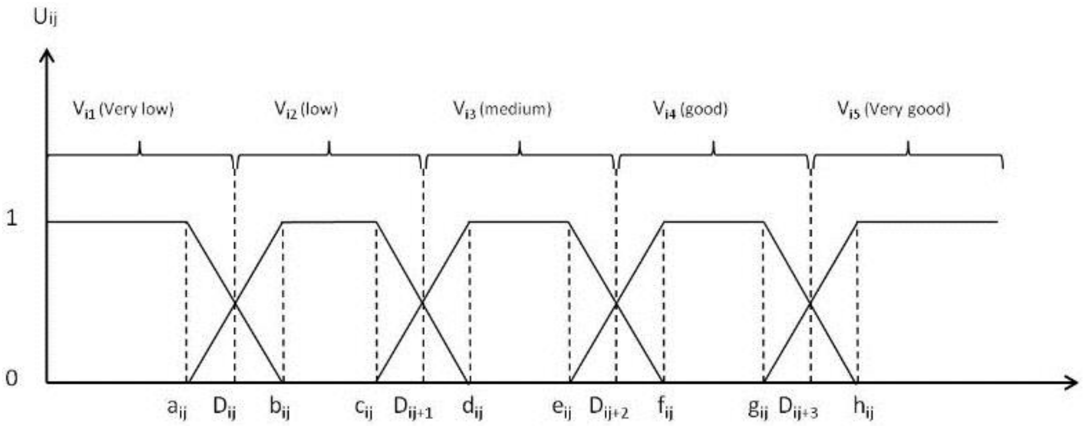


Figure6-3: The membership function of fuzzy set model

Source: Author's construct based on (Jiang, Deng and Chen et al. 2009)

Thus, the value of fuzzy boundary points can be deduced which serves as the basis for calculating membership of each quantitative indicator by using following formulas:

$a_{ij}=D_{ij}-0.2 * (D_{ij+1}-D_{ij})$; $b_{ij}=D_{ij}+0.2 * (D_{ij+1}-D_{ij})$;

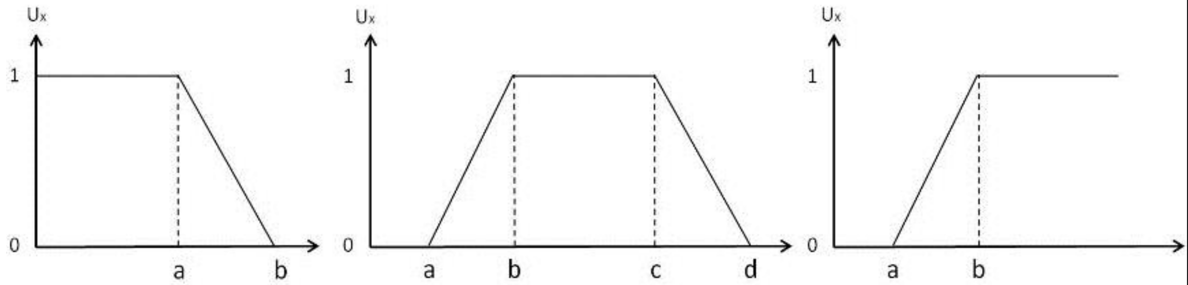
$c_{ij}=D_{ij+1}-0.2 * (D_{ij+1}-D_{ij})$; $d_{ij}= D_{ij+1}+0.2 * (D_{ij+1}-D_{ij})$

Next, three possible trapezoidal function formulas are chosen here to serve to the calculation of membership degree in case needed, as following shown in correspondence with three visualized models respectively **[Figure6-4]**: the both ends are semi-trapezoid distribution function while the middle is trapezoidal distribution function (Yang & Gao, 2006).

$$U_{(x)} = \begin{cases} 1 & x<a \\ \dfrac{b-x}{b-a} & a \le x \le b \\ 0 & b<x \end{cases} \quad ①$$

$$U_{(x)} = \begin{cases} 0 & x<a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ 1 & b<x \end{cases} \quad ②$$

$$U_{(x)} = \begin{cases} \dfrac{x-a}{b-a} & a \le x < b \\ 1 & b \le x < c \\ \dfrac{d-x}{d-c} & c \le x \le d \\ 0 & x<a \text{ or } d<x \end{cases} \quad ③$$



① Right semi--trapezoid distribution function

③ Trapezoid distribution function

② Left semi--trapezoid distribution function

Figure6-4: Three trapezoidal function formulas and models

Source: (Yang & Gao, 2006)

In terms of above process, the specific acquisition of membership degree of indicators is shown in {**Appendix VII**}, including the designed questionnaire form and results of qualitative indicators as well as the calculation of quantitative indicators. Thus, the single-factor evaluation matrix of all indicators can be established, as shown in {**Appendix VIII**}.

B **Step2: making the final evaluation**

When the weighted values of each indicator and the single-factor matrix "R" have been worked out, the next step is to make the final evaluation through operating fuzzy calculation. Generally there are four different fuzzy synthetic calculation methods [**Table6-10**], in which the fourth is finally selected through comparison as the suitable one (Chen, 2011)

Table6-10: Four fuzzy synthetic collation methods

Calculation methods / Contents	M (∧,∨)	M (*,∨)	M (∧,⊕)	M (*,⊕)
Degree of Exerting the role of weighted values	Not obvious	Obvious	Not obvious	Obvious
Degree of utilizing sing-factor matrix R	Insufficient	Insufficient	Insufficient	Sufficient
Comprehensive degree	weak	weak	Strong	Strong
Type	Determined by main factors	Determined by main factors	Unbalanced average	Weighted average

Source: (Chen, 2011)

According to this selected calculation method, the fuzzy resulting vector B_j of the higher layer in the AHP hierarchical structure could be carried out via the following formula, in which "W" represents the weighted vector (in **Appendix V**) while "R" is still the single-factor evaluation matrix (**Appendix VIII**).

$$B = W * R = [W_1, W_2, \ldots W_n] * \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1m} \\ r_{21} & r_{22} & \ldots & r_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ r_{n1} & r_{n2} & \ldots & r_{nm} \end{bmatrix}$$

To take one resulting vector B_1 of the "richness of water status" in criterion layer as an example:

$$B_1 = W * R = [0.0752, 0.1071, 0.2853, 0.5324] * \begin{bmatrix} 0 & 0 & 0.75 & 0.25 & 0 \\ 0 & 0 & 0.4 & 0.5 & 0.1 \\ 0 & 0.05 & 0.55 & 0.4 & 0 \\ 0 & 0 & 0.55 & 0.25 & 0.2 \end{bmatrix}$$

B_1=[0, 0.0143, 0.5490, 0.3196, 0.1172]. Then, transfer this result into the specific score in terms of the hundred-mark score system mentioned previously (see Section 6.3.2), namely D=B_1*[10, 30, 50, 70, 90]=60.799. This score belongs to the range of "[good]=[60, 80]". That is to say, for the criteria "richness for water status", a "good" effect has been achieved in terms of the degree of implementation achievements towards low-carbon planning target, although it just meets.

6.4 Result

By using the same calculation methods described above, the final results of fuzzy comprehensive evaluation of low-carbon index system can be got (see **Appendix VIII)** and further transferred into scores, as following demonstrated [**Table6-11**]:

Table6-11: Final evaluation results

A: Target layer		B: Criterion layer	P: Indicator layer
Low-carbon development **(55.062, medium)**	A_1: Strengthening carbon sinks **(60.587, good)**	B_1: Richness of waterside status **(60.799, good)**	P_1: River corridor width **(55, medium)**
			P_2: River feature **(64, good)**
			P_3: Water quality **(57, medium)**
			P_4: Riverbank stability **(63, good)**
		B_2: Biodiversity of green space **(60.475, good)**	P_5: Green areas per capita **(70, good)**
			P_6: Green coverage ratio **(50, medium)**
			P_7: Native plants index **(40, medium)**
			P_8: Recovery rate of degraded lands **(60, good)**
	A_2: Reducing carbon sources **(51.747, medium)**	B_3: Multifunctionality of Urban structure and land use **(52.601, medium)**	P_9: Centricity **(45, medium)**
			P_{10}: Compactibility **(57, medium)**
			P_{11}: Population density **(50, medium)**
			P_{12}: Tertiary Industry per GDP **(70, good)**
			P_{13}: Jobs-housing balance ratio **(50, medium)**
		B_4: Permeability of spatial form **(47.406, medium)**	P_{14}: Building density **(30, low)**
			P_{15}: Building enclosure degree **(53, medium)**
			P_{16}: Open space ratio **(70, good)**
			P_{17}: Open space connectivity **(39, low)**
		B_5: Public accessibility of traffic network **(52.842, medium)**	P_{18}: Green travel ratio **(50, medium)**
			P_{19}: Green travel quality **(42, medium)**
			P_{20}: Coverage rate of slow-travel system **(65.884, good)**
			P_{21}: Average commute time **(50, medium)**
		B_6: Circularity of Municipal utilities operation **(67.915, good)**	P_{22}: Energy efficiency **(65, good)**
			P_{23}: Utilization rate of renewable energy **(51.668, medium)**
			P_{24}: Unconventional water availability **(60, good)**
			P_{25}: Sewage treatment rate **(68.334, good)**
			P_{26}: Repetition rate of industrial water **(90, very good)**

Source: Author's own construct

From above evaluation results, the scores reflect "phenomenon" in which several characteristics can be clearly seen:

Target layer

- The overall target of "low-carbon development" scores 55.062, which represents a "medium" performance according to the graded standard (see Section 6.3.2).

- Relatively the low-carbon performance of "strengthening carbon sinks" is better than "reducing carbon sources".

Criterion layer

- Three reaches "good" and three are "medium" performance.
- Relatively "circularity of municipal utilities operation" reaches the highest performance while "permeability of spatial form" owns the lowest.

Indicator layer

- Almost all of indicators have been improved and are in a "medium to good" progressive position to different extent, except "building density".
- Relatively the low-carbon performance of quantitative indicators is almost better than qualitative indicators.
- In terms of performance, the most outstanding indicators include "repetition rate of industrial water", "sewage treatment rate", "density of slow-travel system" and "open space ratio", while the relative weak indicators include "green travel quality", "centricity", "open space connectivity" and "building density".

Actually in addition to these indicators in this evaluation, there are some other more immediate indicators' variation also showing the low-carbon performance in Tianjin: energy consumption per unit of GDP and carbon dioxide emissions per unit of GDP. From the year 2001 to 2013, the energy consumption per unit of GDP reaches from 1.53 (tce /ten thousand *yuan*) to 0.77 (tce /ten thousand *yuan*), which has reduced by 49.6%; carbon dioxide emissions per unit per GDP changes from 2.9 (t / ten thousand *yuan*) to 1.6 (t / ten thousand *yuan*), which has decreased by 44.8%, as shown below [**Figure6-5**].

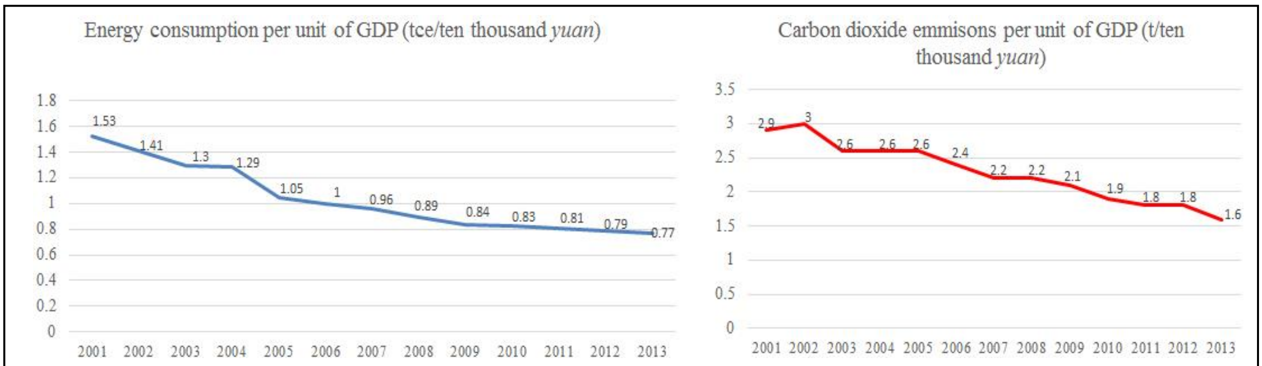


Figure6-5: Variation of other indicators

Source: Tianjin Development of Reform Commission

To sum up, based on the evaluation results above, two sides of effects can be concluded and subsequent thinking might be triggered:

- Positive side

On the one hand, the efforts of intervention actions (see Section 5.3) have made contributions on low-carbon development. In this regard, low-carbon-related impact factor system (urban structure & land use change, spatial form, transportation, municipal utilities and green space, see Section 3.2.3) all have got different degrees of improvement than past and are positioned in a progressive developing way. The additional two indicators' changes (energy consumption per unit of GDP and carbon dioxide emissions per unit of GDP) have also proved this effect.

- Negative side

On the other hand however, in terms of low-carbon performance there is still certain gap existing towards future planning goals (the year 2020), especially some indicators' current status are far from their goals' requirements and seem cannot reach them at that time. That is to say, these efforts that have been made are not enough satisfied yet, more promoted powerful efforts are still in great need.

- Thinking

Actually these efforts of intervention actions cannot be well made without the guidance of planning integrated approach behind, so this operational mechanism of planning integrated approach guiding intervention actions can be viewed as efficient on the one hand. Apart from this positive side, on the other hand the thinking of "why there are still big gaps existing after many efforts" may be triggered. Of course the reasons could be diverse, such as the "time" is one aspect (there is still several years from 2020). Besides this aspect, there must be also some incompetence existing in current operational mechanism, thus questions might be raised:

- Whether the planning goals themselves are rational?
- What problems exist in current operational mechanism of planning integrated approach guiding intervention actions and thus brings about incompetence?
- What are other possible causes?

On the basis of phenomenon (evaluation results), the essence (causes behind) should be found out from the perspective of urban planning field.

6.5 Root Cause Analysis

6.5.1 Analysis Approach

Based on last evaluation results regarding low-carbon performance of intervention actions, a "Root Cause Analysis (RCA)" principle is to be followed in order to find out answers of above questions triggered. Simply speaking, RCA is a process tool designed for investigating and categorizing root causes of events, helping in identification of not only "what and how" they happened, but "why" happened (Rooney & Vanden Heuvel, 2004). For this purpose, the second wave of on-site visiting and specialized semi-structured interviews were further conducted in April 2015 in Tianjin, as mentioned in Section 4.4.2 B. Precisely, this wave of interviews was more pertinent regarding the competence of current planning integrated approach guiding intervention actions in Haihe riverside region (see Section 5.4 & 5.5). Targeted interviewees were also pertinently selected from the "think-tank resource base" (listed in Table4-2). They consisted of 12 participators mainly from Tianjin Municipla People's Government, Tianjin Planning Bureau, China Academy of Urban Planning & Design and Tianjin Urban Planning & Design Institute as well as the author himself, since they represented the major and direct responsible bodies highly involving with planning and implementation management work in Tianjin.

For this semi-structured interview, correspondingly questionnaire with questions were designed to serve as the assistant tool to identify required information for analysis. The questions were directed in three aspects: planning preparation, planning process and planning implementation, following the principle of pertinent, understandable and answerable as well. The designed standardized questionnaire is attached in **Appendix IX**.

Through identifying answers from this wave of interviews and also incorporating the author's own analysis, the possible causes of previous evaluation results could be explored: objective causes and subjective causes.

6.5.2 Objective Causes

The external contextual challenge of a "growing city" is a big objective cause, including continuous growth of population, construction lands, private cars as well as energy demands.

This realistic "growing" tendency should be first understood, which is an inevitable and normal phenomenon in Tianjin and even all Chinese big cities. That is to say, Tianjin is still in rapid economically developing and urbanization stage, whose urbanization rate has been increased to 82% in 2014. In its urbanization process the rural population has been moving into urban areas (especially central place) and influencing the newly increase of construction lands [**Figure6-6**]. For example, the population of this region had increased from 4.54 million in 2001 to 5.9 million in 2014; and the required construction lands surrounding this region had increased 287 square kilometers from 2004 to 2014. At the same time, the triggered use of private vehicles and energy consumption has been also increased [**Figure6-7**].

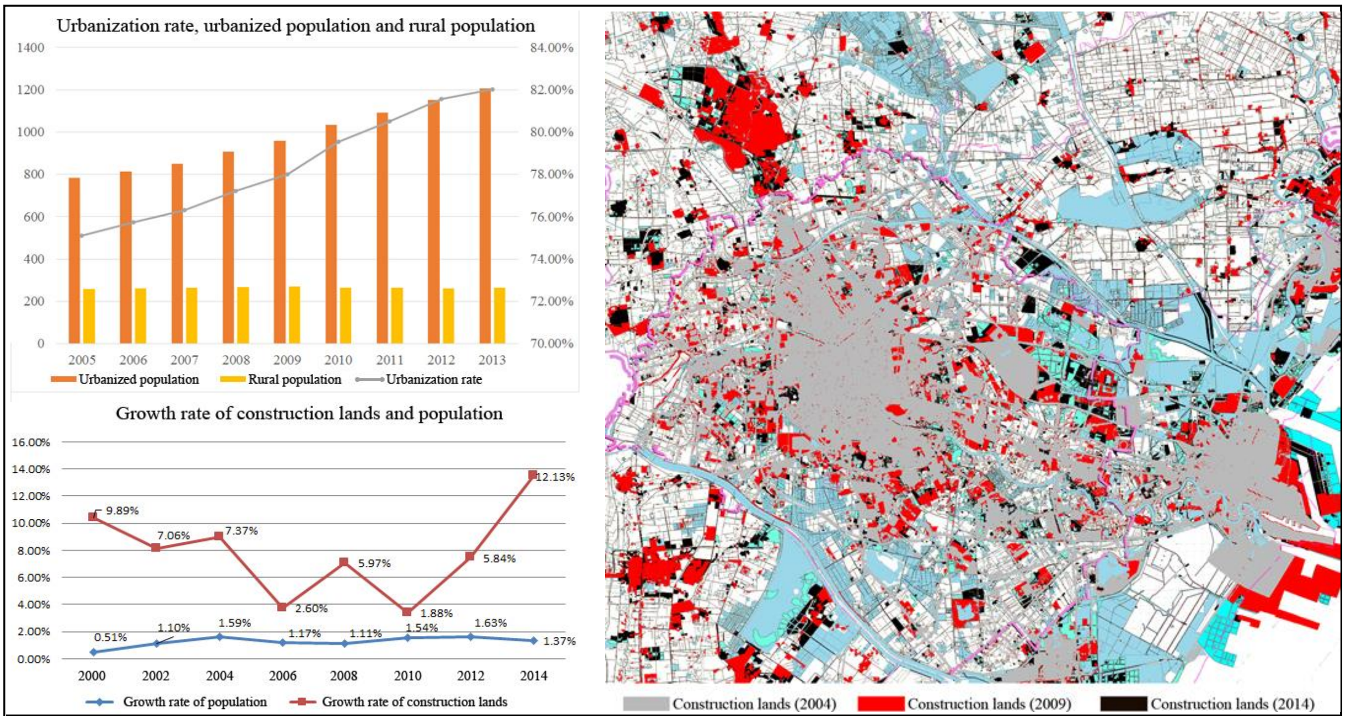


Figure6-6: Growth tendency of urbanization, population and construction lands

Source: China Academy of Urban Planning & Design

From above "growing" tendency it can be said that when the efforts towards low-carbon development have been being made on the hand, at the same time there have always been increasing "carbon sources" bringing pressure on the other hand.

This objective cause of a "growing city" cannot be stopped in current Tianjin and China, which may explain why the low-carbon performance of "strengthening carbon sinks" is better than "reducing carbon sources" to some extent. Under this "growing city" context, the urban planning value orientation has still been following an "incremental development" way.

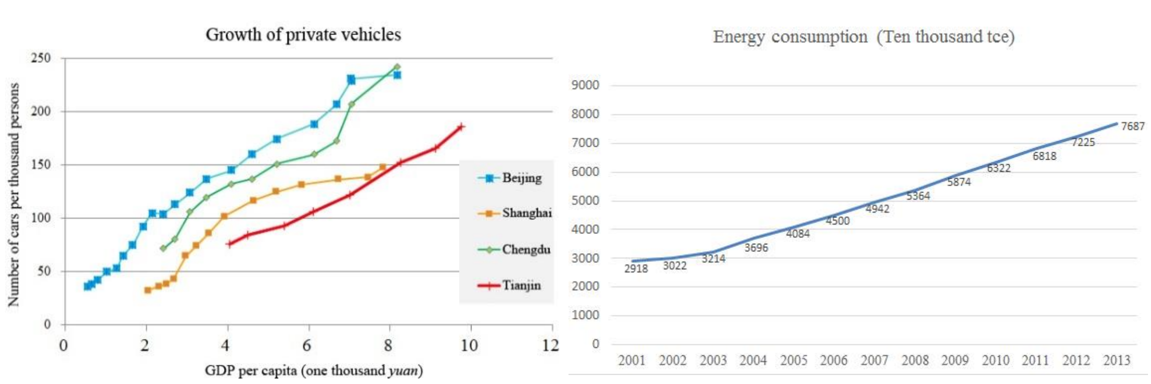


Figure6-7: Growing private vehicles and energy consumption
Source: China Academy of Urban Planning & Design

6.5.3 Subjective Causes

The subjective causes mainly refer to some incompetence of existing planning integrated approach that guides intervention actions (see Figure5-27), which are categorized in three aspects based on information collected in semi-structured interviews (see Section 6.6.1): shortcomings in "plan rationality", "process cooperativity" and "payoff conformity".

A **Shortcomings in "plan rationality"**

Idealization of planning goal setting

Normally the planning goals are put forward by the planners and presented in plans. The basis of goal setting for Tianjin's planning is some derived from the requirements of national (or local) technical standard regarding "Eco city", "Garden city", etc. or by referencing international experiences, especially those quantitative indicators including "green areas per capita", "native plants index", "building density". However, some other goal setting even lack rational scientific basis, which is just a "slogan" or "great vision" but out of current reality, especially the description of qualitative indicators such as "green travel quality", "compactibility", "building enclosure degree". The value orientation of planning goal setting is highly influenced by political propaganda purpose, and this situation makes some goals be set too idealized or too high, in fact they are hard to be really reached in expected planning period (2020), although being developed, such as "green coverage ratio".

This cause can explain why some indicators' actual gaps towards planning goals are so obvious to some extent.

Focus of quantity over quality

Due to the following of the "incremental development" way and also influence of political propaganda purpose, the value orientation of planning approach and its consequent implementation both put much more emphasize on "construction speed" and "increase of quantity". This point also can be seen from the planning goal setting of various specific numbers of indicators, since the numbers (quantity) are current main standard for measuring political achievements, especially indicators regarding GDP (show the economic level), green areas (show city image) and infrastructure (show city running efficiency) . However, in the actual implementation stage when the quantity has received focus, the quality has often been ignored in the meanwhile. For example in terms of the previous evaluation, the indicator "open space ratio" has been improved a lot than past but corresponding quality (such as connectivity) does not reach the same degree.

This cause can explain why the low-carbon performance of quantitative indicators is universally better than qualitative indicators in Haihe riverside region to some extent.

B **Shortcomings in "process cooperativity"**

Lag of implementation due to conflicts

Although there has been a systematic planning integrated approach running in Haihe riverside region (see Figure 5-27), actually conflicts often occur regarding planning elements expressed in planning tools which reflect interests of actors behind. Precisely, land use issue along Haihe river has always been the controversial focus of planning elements, including land use itself (different development purpose); land use and green resource preservation; land use and transport, and so on. Planners are supposed to balance these conflicts based on considering the priority of public interest and environmental effects, however, this value orientation is also affected by intentions from different management sectors or political leaders who pursue their own benefit maximization. Therefore in terms of the same area, different planning tools might produce different results [**Figure6-8**]. This point can also be proved from the data collection process of low-carbon index system by the author, actually the same indicator might have different planning goals in different plans, such as in comprehensive plan and sectoral plan. When there are such conflicts, Tianjin Planning Bureau as the chief planning competent authority would organize standing conference of sectors to coordinate, but often not so easy to reach an consensus since they are all paralleled sectors and lack a third party as a moderator. If agreement cannot be reached, they have to apply for reporting the disputed issue to the executive meeting of municipal government for decision making.

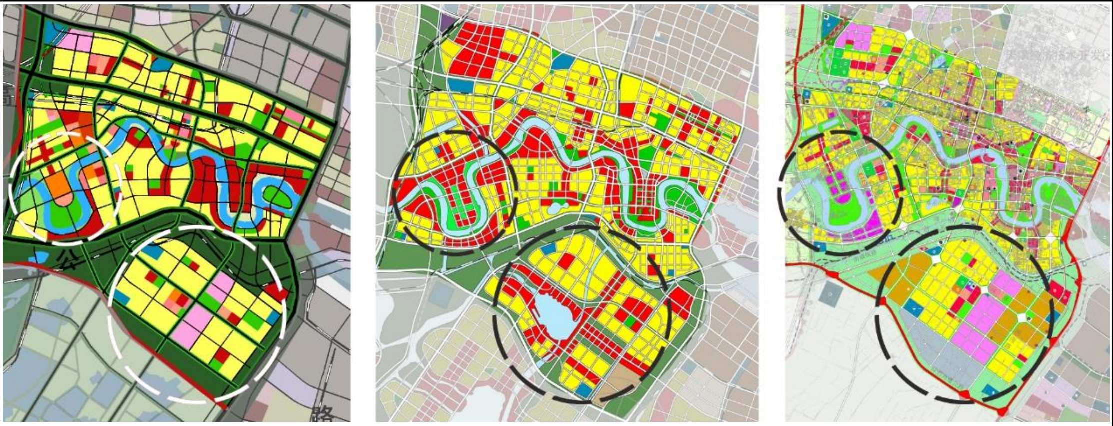


Figure6-8: Different planning results in the same area (river mouth section)
Source: China Academy of Urban Planning & Design

This cause brings procedurally internal friction and consuming of time and thus the lag of implementation.

C **Shortcomings in "payoff conformity"**

Incapability of implementation due to rigidity

It is known that planning integrated approach in Tianjin is dominated by formal comprehensive planning tools (Urban Master Plan and its lower-tier Detailed Plan). However, this kind of planning tools has somehow became mere "formalistic", which is accustomed to describe a "bright blueprint" in the next twenty years (such as various goals in 2020), In addition, it focus on mainly strategic and technical requirements in the form of text and maps, including stipulation of land use arrangement, spatial form control of buildings, etc.

This situation results in that on the one hand, planning approach is weak in corresponding action plan or policy support regarding implementation of projects (such as how to reach the planning goal through step-by-step action, implement which projects, etc.). That is to say, there is often only an "ideal plan" but no appropriate implementation projects based on realistic market needs. Take the indicator "centricity" as an example, towards a more polycentric structure has been being promoted in term of land use arrangement through planning tools and also many efforts have already been made (see Section 5.3.2 C & 5.4.2 D). However in reality, which follow-up development projects would be suitable for filling in these planned and developing "sub centers" are not clear and thus incapable of actual implementation, so they are still far away from expected goals [**Figure6-9**]. On the other hand, this "blueprint" planning mechanism lacks capability of responding to new unpredictable changes such as growth of population and required land spaces, etc., which only has to be frequently revised through formal time-consuming procedure in order to adapt to these new changes. For example, normally the urban master plan updates every 10 years in China, but the update of Urban Master Plan for Tianjin (2011-2020) was carried out 6 years after last master plan (prepared in 2005), and only 4 years later the new update of Urban Master Plan for Tianjin (2015-2035) started again. Of course too frequently revising formal dominant planning tools which serve as implementation basis also affects actual implementation.

Figure6-9: Planned riverside "sub urban centers" and their gaps in reality
Source: Author's own construct

This cause of rigidity in planning approach definitely brings about incapability of implementation in reality in terms of expected planning goals.

Divergence between implementation and planning due to weak surveillance

This point refers to that implementation results are diverged from their planning outcomes in Haihe riverside region. One aspect is the implementation often result breaks through planning requirements. Take the indicator "building density" as an instance, which is hard to be really controlled, since it is usually implemented far exceeding the planning requirements of Regulatory Detailed Plan (RDP) in reality [**Figure6-10**].

Figure6-10: "Building density" breaks through planning control requirements

Source: Author's own construct

Another aspect is that implementation "rejects" to follow planning rules. Precisely, in the planning and projects arrangement process from a top-down way (see Figure 5-6), the implementation bodies (involved administrative districts) might be in a unhealthy competition in order to fight for profitable projects and not willing to implement those unprofitable but public projects. As a consequence, the "holism" and "connectivity" of planning elements, especially linear elements supposed to be connective (such as the indicator open space connectivity, green travel quality) are often obstructed [**Figure6-11**].

The situation mentioned above can be largely ascribed to the weakness in full-fledged planning surveillance system supposed to be. The preparation of plans, planning periodical and final outcomes are mainly popularized in the limited "elite level"—governmental actor group (as listed in Table4-2), which lack more participation and monitoring as well as veto from other potential actor group or the third party (such as private developer, market investor, community and other citizen representative). Although Tianjin Planning Bureau are obligated to publish the planning information and outcomes online for public notification and management sectors are supposed to supervise construction activities in implementation stage, however, which is also little more than a "formality but without feedback" mechanism.

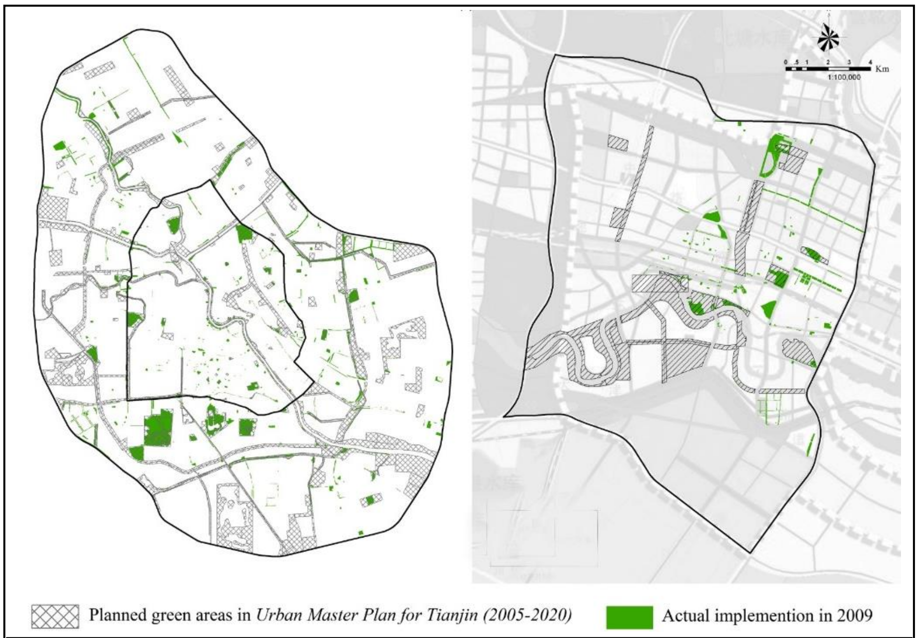


Figure6-11: Implementation "rejects" to follow planning requirements
Source: China Academy of Urban Planning & Design

This is also a cause of indicators' gaps existing in reality when compared to planning goals and also can explain why some indicators are strong in total quantity but relatively weak in quality.

6.6 Summary

This chapter first makes an evaluation of low-carbon performance regarding recent intervention actions (see Section 5.3) taken on Haihe riverside region, in which the theoretical analysis (contents in Chapter 3) is applied as a main basis. It selects related indicators and establishes a low-carbon evaluation index system by means of theoretical deduction, statistical deduction and Delphi method. Then, it makes the weighting for each indicator via using Analytic Hierarchy Process (AHP) method. After that, it sets graded standard for both qualitative and quantitative indicators for evaluation and then make the final evaluation through mathematic calculation by using Fuzzy Comprehensive Evaluation (FCE) method. The final evaluation result reflects both positive and negative effects in terms of low-carbon performance after taking actions. On the one hand, the efforts of intervention actions taken on Haihe riverside region have made significant contributions on achieving low-carbon effect. Most of evaluated indicators have been promoted than past and are positioned in a progressive developing way, this point could also be seen from another two direct indicators (energy consumption per unit of GDP and carbon dioxide emissions per unit of GDP). However on the other hand, there are still big gaps existing among some indicators towards their future planning goals that could not achieved at the scheduled time, which implies current efforts of intervention actions are still in great need of being strengthened or optimized.

According to evaluation results as the phenomenon, the possible causes behind as the essence are further analyzed by following a Root Cause Analysis principle, including objective and subjective causes. Objective causes refer to the normal external context of a "growing city" tendency, including rapid growth of population, construction lands, private cars as well as energy demands serving as increasing carbon sources, which brings great challenges and pressure to low-carbon development. Subjective causes are mainly resulted from some incompetence regarding the operational mechanism of planning integrated approach guiding intervention actions. Based on the second wave of semi-structured interviews such incompetence could be identified and categorized in three aspects: shortcomings of "plan rationality", "process cooperativity" and "payoff conformity".

In all, it can be concluded that there is "breakage and discontinuity" existing in current traditional planning integrated approach in Haihe riverside region and even the whole Tianjin, which serves as the substantial root cause [**Figure6-12**].

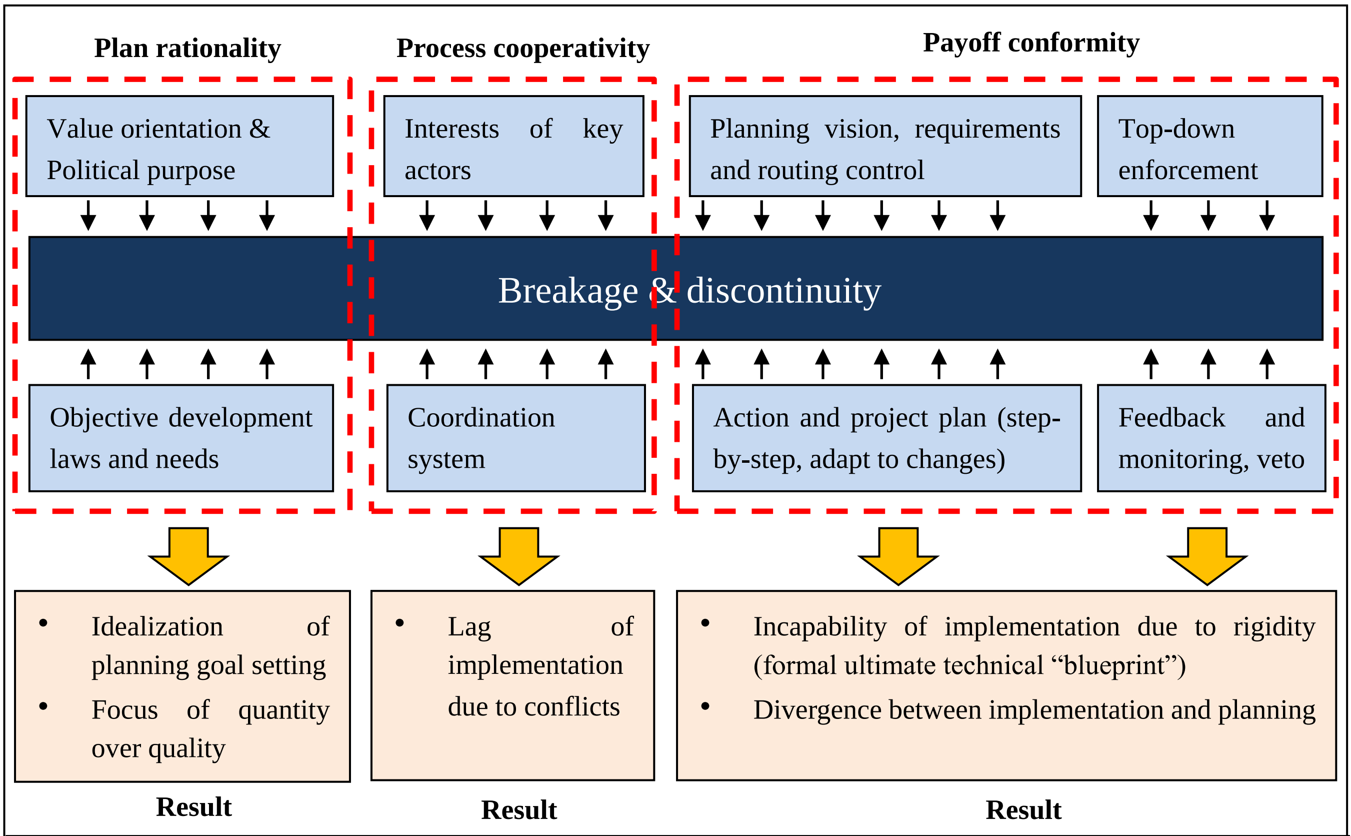


Figure6-12: Rationale of "breakage and discontinuity" in Tianjin's planning integrated approach

Source: Author's own construct

Chapter 7 Referenced Case: IBA Emscher Park in Germany

7.1 Low-carbon-oriented Transformation Context

As mentioned previously (see Section 4.3.2), the development experience of IBA Emscher Park in Germany has some similarities with Haihe riverside region in many aspects, among which first of all is the transformation background.

At first, there is a need to briefly introduce the background of Ruhr area where IBA Emscher Park is located inside as a sub-region. The Ruhr area was once the German and one of the worldwide largest "industrial heart", which had experienced industrialization for more than one century. In particular the Ruhr area specialized in "smoke-stack" industries such as coal, iron and steel (which were dominant and most powerful) and others such as heavy engineering, textiles and shipbuilding (Hospers, 2004). It is imaginable that how obvious a "high-carbon" context this region was situated at that time [**Figure7-1**]. However after the Second World War, since 1950s and 1970s the coal mining and iron & steel industries successively entered the crisis due to the change of worldwide resource market. The decline of heavy industries and triggered problems (unemployment, environmental deterioration, etc.) made the Ruhr area become a large "brownfield site" in need of restoration (Labelle, 2001).

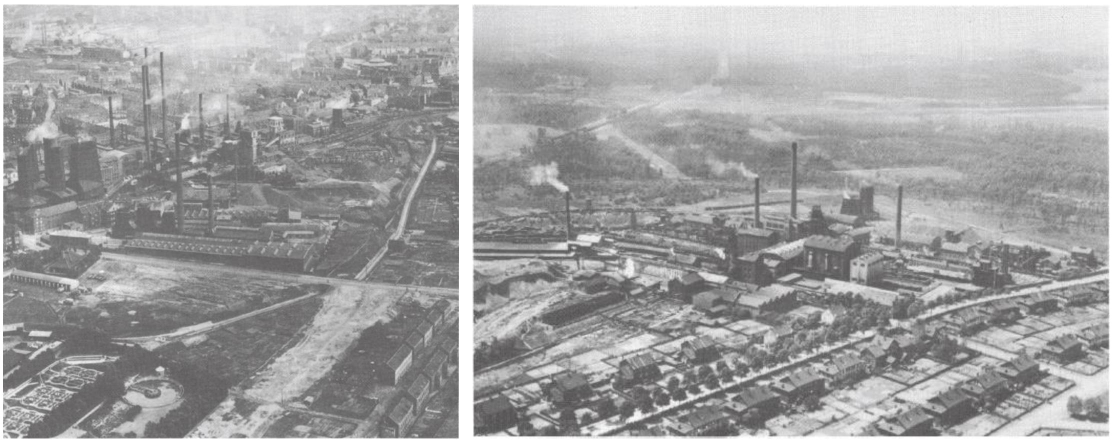


Figure7-1: Historically "high-carbon" context in the Ruhr area
Source: (Reiss-Schmidt, 1990)

During the industrialization process of the Ruhr area above, Emscher river located in the core industrialized area was once used for industrial & living sewage discharge and therefore was in position of "division of work" with the other two main rivers of Ruhr (Ruhr river in the north for water supply; Lippe river in the south for industrial water demand). Actually since the mid of 19 century the Emscher region began to receive attention and at that time the flood hazard was its main problem, which was further aggravated by ground subsidence and inflow of mine water caused by mining activities. Moreover, increasingly waste water resulted from population expansion due to industrialization was directly discharged into Emscher river and its tributaries (Langner, 2011). For water management, the authorities once channelized and canalized the Emscher river rather than installing underground sewers that might be breached due to technical (land subsidence) and economic reason, so an "open sewer" carrying both industrial and human waste as well as rainwater was formed (Labelle, 2001) [**Figure7-2**]. Gradually this Emscher region became a devastated area with following problems (Grohe´ & Kunzmann, 1999): inaccessible spaces due to barriers such as road and railway network, vast number of abandoned industrial lands, unattractive landscapes, high pollution of environment, ecological deterioration, and so on. It could be said that both the landscape and economy of Emscher region (where takes its name of the river running through it) were dominant by coal, iron and steel and their related structures, leaving little scope or possibility, for alternatives (Shaw, 2002).

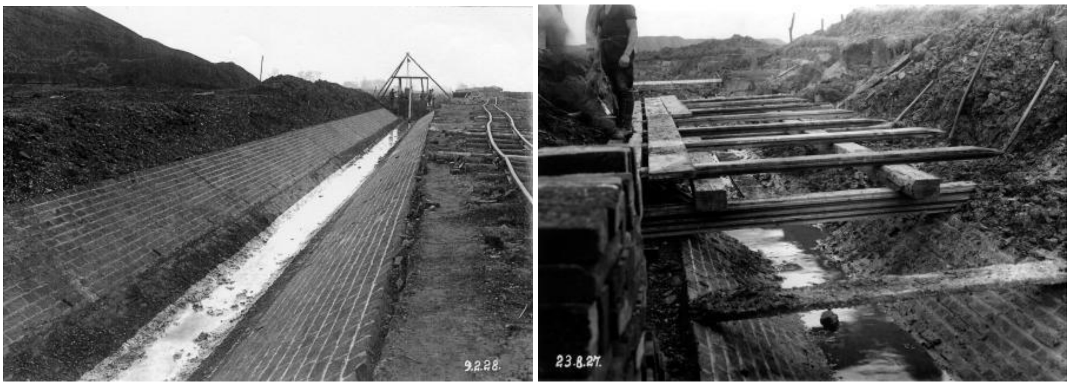


Figure7-2: Historically channelized Emscher river served as an "open sewer"

Source: http://www.emscherplayer.de/playMedia.yum?mediaID=46588&search=

It is obvious that Emscher region was in need of powerful approaches to make a change towards sustainable and also low-carbon development along with the structural transformation of the whole Ruhr area.

7.2 Low-carbon-related Intervention Actions

7.2.1 Intervention Process

In order to reverse context described above, also similar to the Haihe riverside region of Tianjin, the Emscher region that covered approximately 800 Km^2 was treated as whole planning space and action space massively starting its "way of transformation" by receiving continuous intervention actions. It can be said that its intervention process covers three development decades in accordance with three stages: IBA period (1989-1999), the second decade (2000-2010) and the third decade (2010-), in which the first decade——IBA period was relatively the most well-known.

A **IBA period—Emscher Landscape Park**

From 1989, the state government of North Rhein-Westfalen set up a special program named "IBA Emscher Park Initiative (*Internationale Bauausstellung Emscher Park*)" which lasted 10 years till 1999. The overall goal of initiating this program was: urban development, social, cultural ecological measures as the basis for economic change in an old industrial region (Shaw, 2002). In terms of the intervention operational structure, this IBA initiative promoted itself as a "workshop for the future of industrial areas", which was more like a "platform or network" connecting different actor groups from regional and local level to "sit together" (preparing plans, implementing projects, funding, etc.) via an non-traditional planning and organizational system (see further Section 7.3) (Fürsta & Kilperb, 1995) [**Figure7-3**].

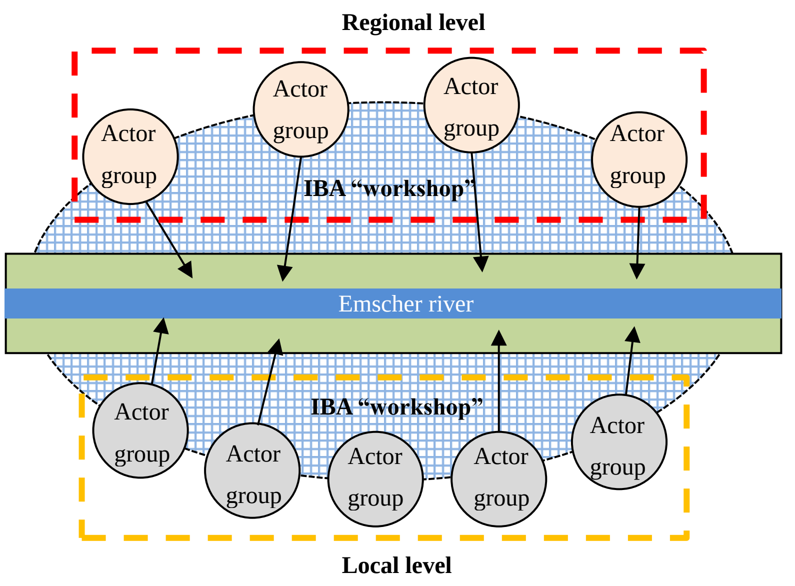


Figure7-3: Invention operational structure of IBA Emscher Park Initiative

Source: Author's own construct

During this IBA period, 17 cities, municipalities and other organizations were participating in carrying out approximately 120 single projects that could be classified in six types (action fields): Emscher landscape park (structurally revitalize derelict landscape); Ecological restoration of the Emscher river system (re-naturalize rivers); Working in the park (promote brownfield redevelopment) and so on (Kunzmann, 2004; Reicher, Niemann & Uttke, 2008). Among these thematic project types (each type contains related single projects), the Emscher Landscape Park (ELP) was the central project type which was based on the concept of creating a holistic "regional park" that covered 320 square kilometers with the 70-kilometer Emscher river passing through [**Figure7-4**].

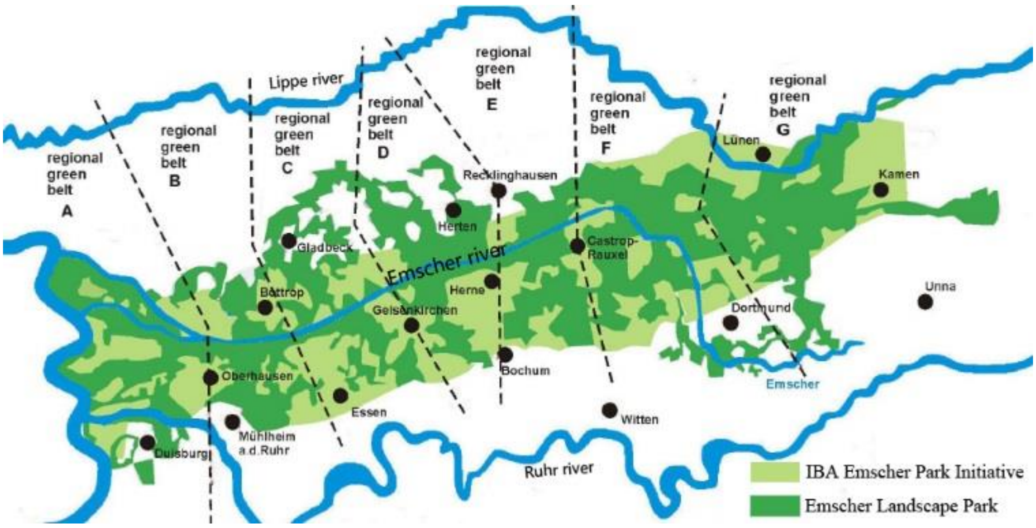


Figure7-4: The project type "Emscher Landscape Park" in "IBA Emscher Park Initiative"
Source: (Gruehn, 2013 a)

In conclusion, a German expert has summarized "what has been achieved during the period of "IBA Emscher Park Initiative" (Kunzmann, 2010): a new regional park, promotion of alternative energy, rebirth of rivers, new lives of considerable brownfields, new uses for industrial heritage, and so forth.

B **The second & third decade—Extending ELP and Emscher Regeneration**

At the end of the IBA period in 1999, actually not all planned projects had completely been implemented. Therefore since the second decade of Emscher Park, one the one hand those uncompleted projects had been keeping ongoing, and on the other hand some new extended projects had been identified, such as Phoenix See in Dortmund. As a planning and action space the Emscher landscape park was expanded from previous 320 square kilometers to 457 square kilometers, especially penetrating into cities and through links to neighboring urban centers (Reicher, Niemann & Uttke, 2008). In this period besides extending Emscher Landscape Park, another parallel focus of intervention was to continue regenerating the main stream of Emscher river itself (some tributaries had been done during the IBA period). Therefore, a new flagship project type named “New Emscher vally (*Neues Emschertal*)” was proposed. This “New Emscher valley” viewed Emscher blue-green corridor as a west-east central development axis with length of 80 kilometers of the Ruhr area, which was divided into three action fields also containing respective major projects[1]: core area (flood protection, ecologically restoration of Emscher river), integration area (development and linkage of riverfront open spaces) and complementary area (incorporation with peripheral environment) [**Figure7-5**]. Through this “New Emscher Vallry” the extension of Emscher Landscape Park and regeneration of Emscher river were working together, in which process totally 20 cities (three new added) were involved in actions on this region with the guidance of two new master plans and changed organizational system (see further Section 7.3.2).

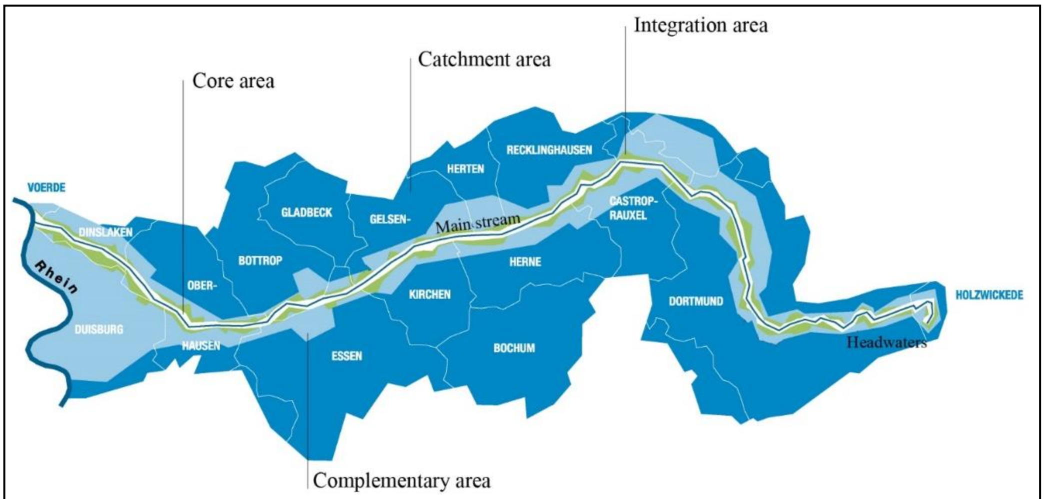


Figure7-5: The project type “New Emscher Valley”

Source: *Masterplan Emscher-Zukunft: Das Neue Emschertal* (Emschergenossenschaft, 2006)

Today is the third decade of IBA Emscher Park, the intervention actions are focusing on continually implementing the “New Emscher Vally” and strengthening the whole regional park’s management and maintenance (such as infrastructure and information system) as well as spreading its paradigm to other regions.

[1] http://www.eglv.de/emschergenossenschaft.html. (Website of “Emschergenossenchaft”, accessed in August 2015)

7.2.2 Adherence to Low-carbon Principles

Like the Haihe riverside region, here also briefly abstracts the main actions taken in the intervention process of IBA Emscher Park related to the low-carbon-oriented principles by applying previous theoretical framework (see Section 3.4.2 & 3.5).

A Richness of waterside status

As mentioned before (see Section 7.1), the river Emscher was once in used for waste water discharge in the industrialization process, as a consequence its water quality was highly contaminated with pollutants including sulphates and polyaromatic hydrocarbons (Salian & Anton, 2011). There is no doubt that the ecologically restoration of the river system has always been a key task along with the IBA Emscher Park Initiative and subsequent “New Emscher Valley”. The related actions taken in the form of projects included:

Restoration of the water quality

Four huge sewage treatment plants (planned eight) have been installed in the catchment areas from river source to the mouth. Besides in parallel, building underground sewage pipe system became another focus (due to the stop of land subsidence after ending of mining, this work became more possible and feasible). Initiatively 400-kilometer-long sewage canal system was planned along with the main stream of Emscher and its tributaries, of which 50 kilometers were constructed in the IBA period and 274 kilometers have been constructed by 2014, most of them were constructed along tributaries. In addition by 2011, 23 kilometers along the Emscher itself (main stream) had been converted (Website of “Emschergenossenschaft”, accessed in August 2015) [**Figure7-6**].

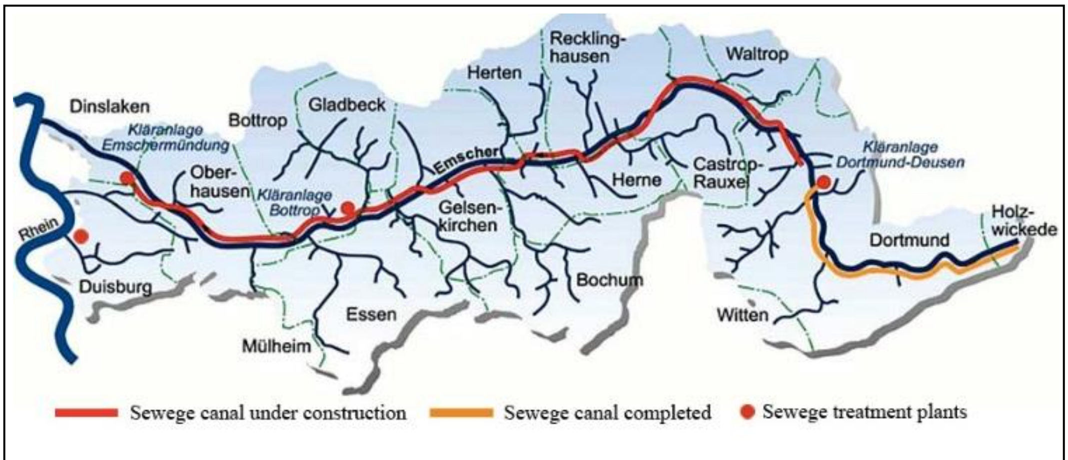


Figure7-6: Underground sewage channel along Emscher river
Source:http://www.abwasserkanal-emscher.de/de/abwasserkanal emscher/projektinformationen/abwasserkanal-emscher.html

Other near-natural control means

Along with dealing with the sewage discharge there were also accompanied other planning and implementing measures according to the geomorphological conditions of different river sections. For example, many of the previously concrete river banks that had been channelized were dismantled; some sections were created meanders so as to redesign into a nature-simulated minding flow form [**Figure7-7**]. Other actions included (Robinson, 2003): raise the elevation of river bottom; enlarge shallows and ponds as well as storm water basins to enrich the water volume; increase riverfront green spaces or recreational spaces, etc., which were also taken in consideration of combining with flood prevention.

Figure7-7: A non-revitalized section (left) and a near-natural section (right)
Source: (Gruehn, 2013 b)

In a word, an integrated water management approach (combining waste water disposal, flood protection, storm water collection, landscape effects and more together) was used around the river Emscher.

B Biodiversity of green space

Besides remediation of river system, another associated concern of IBA projects was to integrate river and associated open spaces, which would be largely contributed to strengthening carbon sink system.

Regional green corridors

At the regional level, there were seven regional green corridors (*Regionale Grünzüge* A-G, as illustrated in Figure7-4) originated from 1920s being defined at an early stage to structure the whole region. These regional green corridors made of farmlands, forests, grasslands, etc. served as large wind corridors penetrating north to south and combined with east-west blue-green corridor ("New Emscher Valley") framing the main open space system. It should be noticed that these green corridors were not in an "empty" status, actually many local single projects (as mentioned in Section 7.2.1 A, classified in six types) were just developed within these green corridors following a principle of actively protective utilization rather than negatively preservation (Robinson, 2003) [**Figure7-8**].

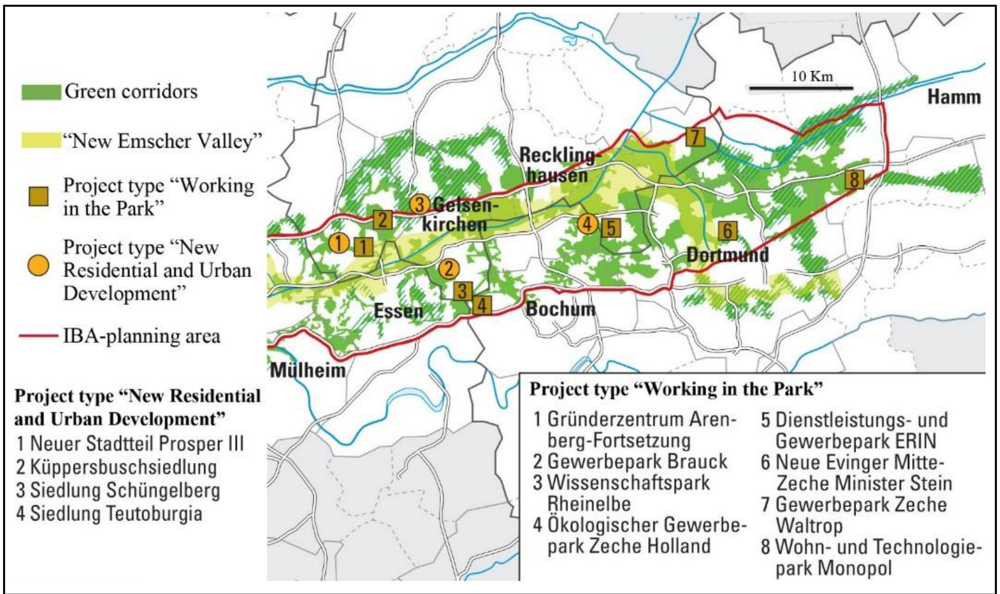


Figure7-8: Local projects developed in green corridors (part)

Source: (Wehling, 2007)

River-based open spaces

In addition to the regional level, river-based open space projects also attached great importance at the local level during both the IBA period and subsequent "New Emscher valley" period. Compared with Haihe riverside region (see 5.3.2 B), the implementation methods used for open space projects could be summarized, as shown below [**Figure7-9**]: 1) Transformation. Transform the previous brown fields into public parks with landmarks, such as the project "Landschaftspark Duisburg-Nord". 2) Re-identification. Re-identify potential riverfront open spaces and re-design them in order to acquire a promoted quality. 3) Connection and network. Connect original isolated open spaces via recovered Emscher river bodies, and networking themselves as well as with regional green corridors by linear trail system. 4) New creation. Newly build additional open spaces along the river body to strengthen the connection.

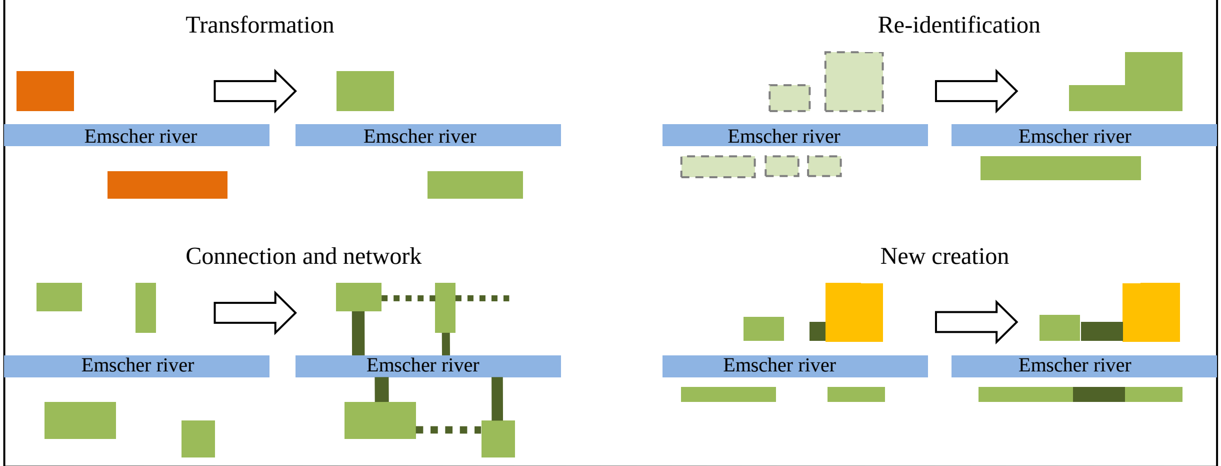


Figure7-9: Model of open space project

Source: Author's own construct

C Multifunctionality of urban structure & land use

Keeping polycentric structure and promoting mixed land uses were the mainly contributions in terms of this kind of low-carbon guiding principle.

Polycentric structure

`Due to the special mining history, the Ruhr area was developed based on originally separated mining and industrial settlement, which had a "natural" polycentrism" consisting of many small-sized cities but without one dominant city center. During the intervention process of IBA Emshcer Park, this polycentric character had always been a consensus framework that should be continually kept and further promoted rather than supporting expansion of some "big cities or centers", such as the measure of utilizing regional green corridors to limit urban sprawl [**Figure7-10**]. As someone commented, the Emscher region's development is closely linked with the Ruhr areas polycentric structure and the idea of strengthening connecting axes between centers (Lucas, Vallentin & Venjakob, 2013).

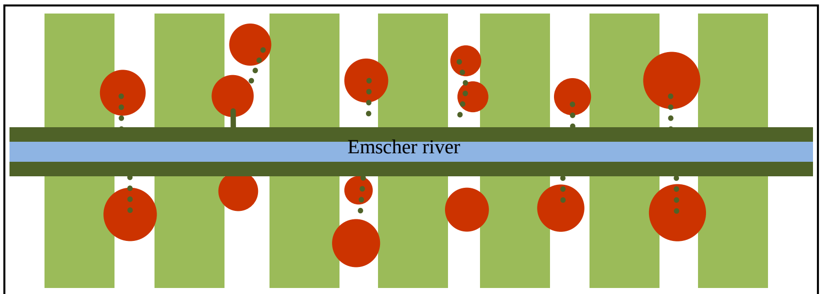


Figure7-10: Keeping polycentric characteristic

Source: Author's own construct

This paradigm is differentiated with Haihe riverside region in Tianjin, the latter has nevertheless been making efforts to "create" new centers based on its previous mono-centric structure (as illustrated in Section 5.3.1 C and 5.3.2 C).

Mixed land use

By taking advantage of the pre-condition of "natural polycentrism", besides transforming former brown fields into open spaces, the project types "working in the park", "new residential and urban development", "new facilities for social, culture and sporting activities" operated in IBA Emscher Park all largely demonstrated a key principle of promoting a mixture and diversity of land use in combination with reuse of brown fields and vacated lands but with little "new spatial growth". As a consequence, the IBA Emscher Park and even the whole Ruhr is characterized by small-scale compact "mosaic" spatial pattern mixing functions like residential, working, recreation and etc.

This principle is called as "**follow-up type** (*Nachfolgetypen*)", which is a development model that does not trigger new increase of construction lands but increasing construction density and partially the amount of green spaces (Polívka & Roost, 2011).

D **Permeability for spatial form control**

In addition of above keeping polycentric structure, optimizing a permeable urban spatial form is also a considered principle in the IBA Emscher Park.

Inner edge

Actually besides large-scale regional corridors, there were also amount of green and open spaces as the "in-between spaces *(dazwischen*)" being preserved between the settlements, urban quarters in the Ruhr area to prevent those small-scale urban groups from merging together. In terms of this spatial character, the transitional interface from built environment to green area served as the "meeting line (*Begegnungslinie*) was called "Inner edge (*Innerer Rand*)". Their existences reflect the close interactive connection between built area and natural landscape setting. During the IBA period and, especially during the ongoing project "New Emscher Vally", this endemic characterized feature was largely kept and also optimized through supplement (Polívka & Roost, 2011) [**Figure7-11**]. This character was greatly contributed to the low-carbon guiding principle of sustaining a permeable urban spatial form.

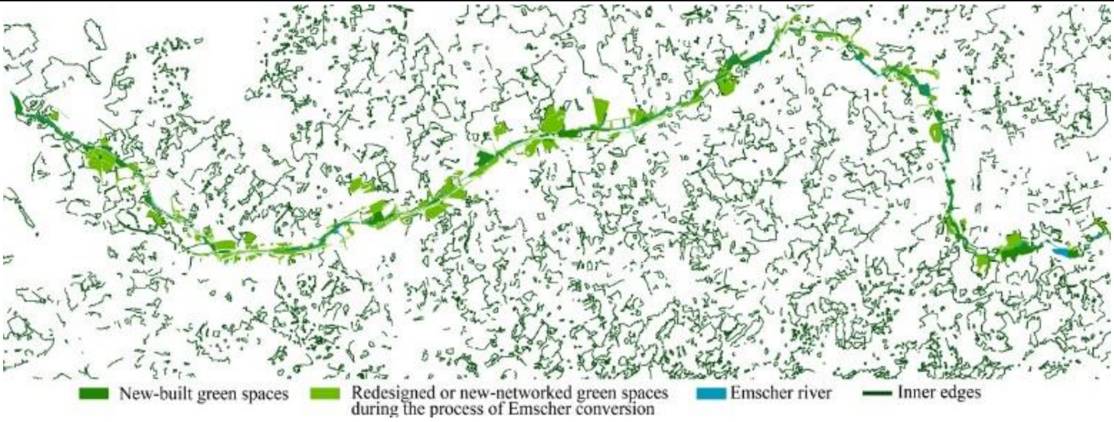


Figure7-11: Inner edges and new identified open spaces in the Emscher region
Source: (Polívka & Roost, 2011)

E **Public accessibility of traffic network & Circularity of municipal utilities operation**

Unquestionably the construction of cycle and pedestrian path system is the most matched project for this guiding principle.

Cycle and pedestrian path

A 230-kilometer looped cycle path and walking path of 130 kilometers (about 120 kilometers of which along watereays)was planned and being developd in the IBA Emscher Park in order to connect those sepeared single projects and attractive places (Lucas, Vallentin & Venjakob, 2013). Especially the cicycle path (*Emscher Park Radweg*) was built largely based on utilizing previous railways and forest ways as well as quiet roads, etc. (Reicher, Niemann & Uttke, 2008), as shown in Figure7-13. This combined cycle and pedestrain system that serves as an alternative traffic mode is inlined to trigger more slow-travel activities and facilitate more public accessiblity. Nowdays the cycle path system is being enhanced linkages inside.

Rainwater collection and utilization

In addition to reuse of land resource, especially how the water resource that serves as a kind of renewable water energy could be recycling used was a key point accompanying the regeneration of Emscher river system based on the concept of sustainable water management. Many IBA projects can be regarded as models demonstating new ways of handling rainwter,such as Holland business and residential park in Bochum and so on (Reicher, Niemann & Uttke, 2008). In a word, the rainwater was largely considered to be collected and facilitated infiltration as well as channelled into drainage system via various design and technical mesures (such as dealing with green roofs, detension ponds, designed trenchs, etc.) in terms of different on-site situation (industrial, buisness, residential area, etc.) [**Figure7-12**]. These sollutions for rainwater utilization were also designed in combination with public spaces and thus created landscape effects.

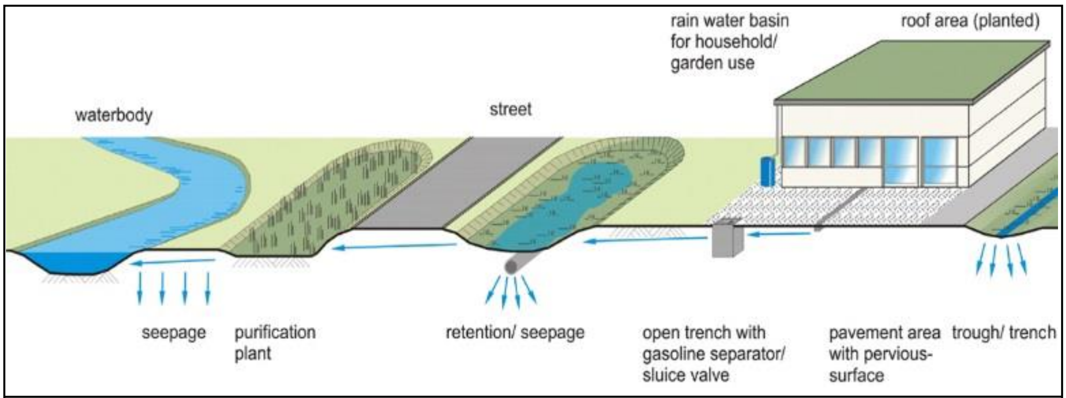


Figure7-12: Model of on-site solutions for rainwater utilization
Source: http://www.eglv.de/emschergenossenschaft.html

These all intervention actions mentioned above has promoted the formation of today's whole IBA Emscher Park [**Figure7-13**], for which there is also the pertinent planning integrated approach serving as the supporter and guidance behind.

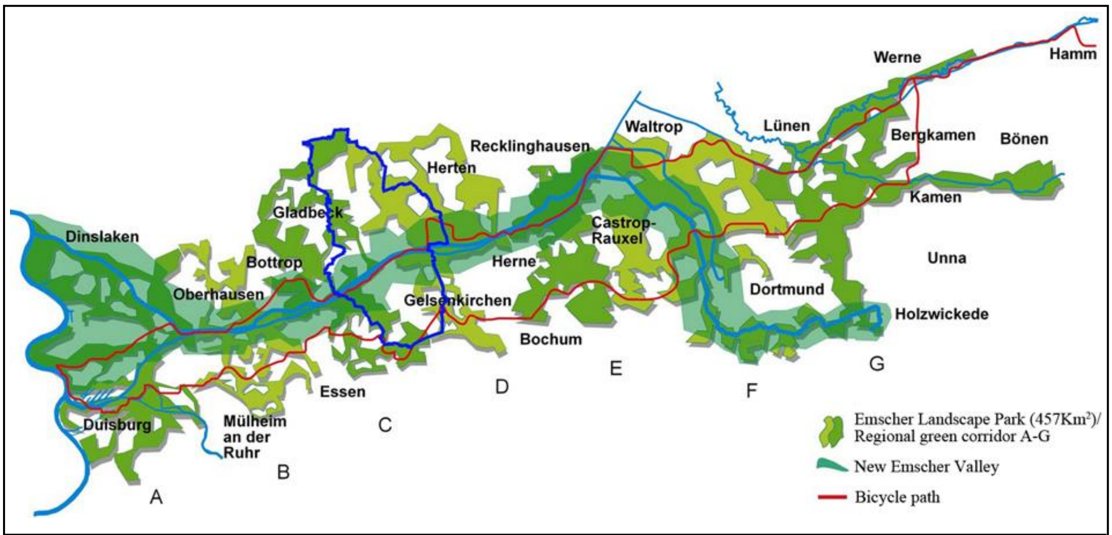


Figure7-13: Development vision of IBA Emscher Park
Source: http://www.metropoleruhr.de/

7.3 Supportive Planning Integrated Approach

7.3.1 Planning System

It is needed to first understand the main management organizations that previously existed in the Emscher region. They served as involved actors influencing planning issues before the IBA Emscher Park Initiative, as the selective shown below [**Table7-1**]:

Table7-1: Management organizations established in Emscher region before IBA Initiative

Scale	Competent organizations	Main responsible tasks
Regional level	State government of North Rhine-Westphalia	Overall issues
	Three decentralized State administrative authorities (*Regierungsbezirke*): Münster, Dusseldorf and Arnsberg	Economic and environmental legislation, sub-regional plans
	Two intercommunal associations (*Landschaftsverbände*): Rheinland(LVR), Westfalen-Lippe(LWL)	Development of open spaces and regional promotion
	Regional planning organization: *Kommunalverband Ruhrgebiet* (KVR) whose predecessor was *Siedlungsverband Ruhrkohlenbezirk* (SVR) and successor is Regional Association Ruhr (*Regionalverband Ruhr*, RVR)	First protection of open spaces, afterwards regional promotion by regional planning tools
	Emscher Cooperative (*Emschergenossenschaft*)	Sewage discharge and water management
Local level	17 local cities and municipalities with each respective public sectors, departments	Various local affairs
Others	Chambers of trade, industry and crafts, and number of regional and local corporations, enterprises, etc.	Diversified regional and local issues

Data source: Construct based on *The International Building Exhibition Emscher Park: Another Approach to Sustainable Development* (Grohè & Kunzmann, 1999)

When compared to the local centralized management system of Haihe riverside region in Tianjin (see Figure5-6 & Figure 5-18), it is obvious that Emscher region has a much more complicated system with decentralized various organizations from both regional and local level, although the two cases have similar spatial scale. This means that lack of common opinions, and mutual competitions as well as conflicts certainly existed among these actor groups when dealing with a once complicated and also problematic Emscher region (see Section 7.1).

In terms of such situation, despite the State efforts, the traditional German spatial planning system (see [**Figure7-14**]) was not able to find appropriate way to hand such complicated planning problems (Shaw, 2010). Particularly at that time a unified "Regional Plan" for the whole region was not possible to work, although there was supposed to have such planning tool at the regional level in terms of German planning system[1].

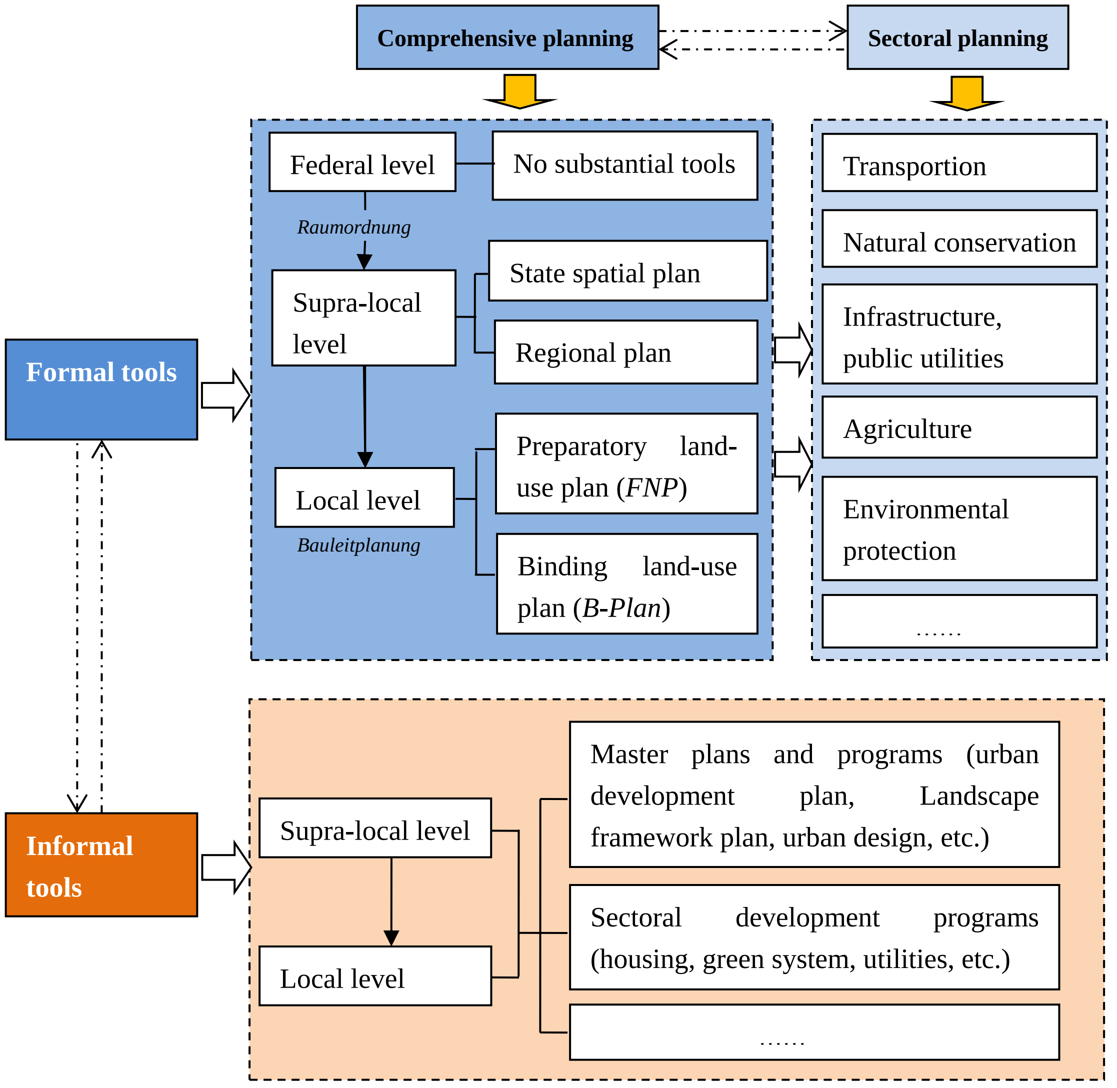


Figure7-14: Traditional German spatial planning system

Source: Author's construct based on (Pahl-Weber & Henckel, 2008)

As a consequence, a new unconventional planning approach was adopted along with the intervention process of IBA Emscher Park, in which the planning system was dominated by informal planning tools based on a moderation mechanism between regional and local level.

[1] The region planning organization *Siedlungsverband Ruhrkohlenbezirk* (SVR) lost the preparation right of formal Regional Plan in 1975, afterwards the Regional Plan for Ruhr area was replaced by three separated sub-regional plans dominated by three regional authorities. In 1979 and 2004, SVR was reorganized into *Kommunalverband Ruhrgebiet* (KVR) and then current *Regionalverband Ruhr* (RVR). In 2009, RVR obtained the preparation right of Regional Plan again (Münter & Prossek, 2011).

7.3.2 Planning Process

To continue above, there are two main stages in terms of the planning process involving respective planning integrated approach in the IBA Emscher Park. .

A IBA period

Actually at a pre-preparation stage (in about 1988) there was first a comprehensive feasibility study (*Machbarkeitsstudie*) being prepared by the regional planning organization *Kommunalverband Ruhrgebiet* (KVR), which designated the range of planning space of potential Emscher Park and served as a platform putting forward issues for discussion . On this basis afterwards in the early 1990, the planning integrated approach was carried out based on a 3-level paralleled planning system (Reiss-Schmidt, 1990; Kilper, 1999; Reicher, Niemann & Uttke, 2008):

The first planning level was a "Head Plan (*Leitplanung*)" on a map scale of 1:50000 prepared by KVR [**Figure7-15**]. This "Head Plan" viewed the IBA Emscher Park as a whole and demonstrated its overall development goals and key ideas regarding natural conservation, open space and landscape as well as recreation, etc., which connected regional and local level together.

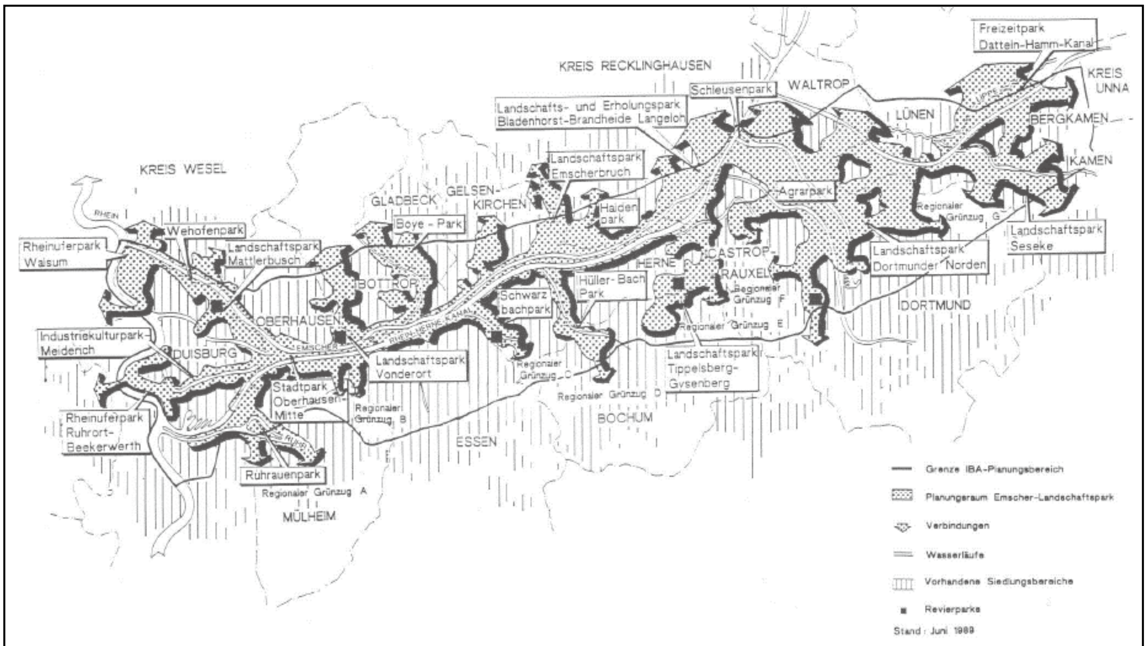


Figure7-15: Head Plan (*Leitplanung*)
Source: (Reiss-Schmidt, 1990)

The second planning level consisted of 7 "Frame Plans (*Rahmenplänen*)" on the map scale of 1:10000 prepared by contracted planners in the form of 7 intercommunal working groups (*Interkommunalen Arbeitsgemeinschaften*, IKAG's). These "frame plans" were in correspondence with 7 regional green corridors A-G mentioned previously, and each of them involved 3-4 participating cities by incorporating local projects (see Section 7.2.2 B). They stipulated design guidelines and principles on land use, infrastructure, etc. and implementation strategies as well as coordinating solutions of probable conflicts (such as bordering space between cities). They also provided important basis for revising formal plans (such as *FNP*, *B-Plan*, as shown in Figure7-14).

The third level was local on-site design for single projects in the form of various national or international competitions operated by local governments or organizations, called as "stepping stones (*Trittsteine*)". These design competitions interacted with the above two planning levels and were tended to find most creative design schemes, in which a well-known competition case is the Duisburg North Landscape Park. The further implementation of these single projects had to meet a number of strict social, environmental and cultural criterions for the region, including high architectural quality, energy conservation, accessibility to public transport, conservation of eco-systems, etc. (Kunzmann, 2004).

It should be emphasized that among above planning levels there was an IBA Company established by the state government of North Rhein-Westfalen at the end of 1980s playing the vital role as a "moderator" to promote IBA Emscher Park Initiative. This means that IBA Company itself did not prepare any above planning tools and implement associated specific projects, but to organize and coordinate in order to reduce conflicts and reach consensus between the regional and local, between projects and between involved actor groups (like shown in Figure7-3). For example, one strong moderation tool was the economic leverage, since IBA Company had the right to allocate public finance for using in its moderation cost and some of design competitions and implementation of projects.

B After IBA

After the IBA Emscher Park Initiative was finished and IBA Company was shut in 1999, the actors in this region continued to work on "IBA model" based on two newly created informal master plans.

First significant timeline was the emergence of the "Master Plan for Emscher

Landscape Park 2010 (*Masterplan Emscher Landschaftspark 2010*)" [**Figure7-16**]. It was presented by Project Ruhr Company in 2005 based on a 5-year coordinating process among major involved actors, which also viewed Emscher Park as a whole and proposed the expansion of the park area as well as the conceptual project type "New Emscher Vally" (see Section 7.2.1 B). This master plan contained more than 400 single projects (including previous projects) which were planned to be completed during the next two decades. During this planning process, a new agency named "Project Ruhr Company" which was established by the state of North Rhein-Westfalen assumed the "moderator role" like former IBA Company (Lethmate & Spiering, 2003). However, this organization only lasted from 2000-2006 and was shut due to political reason. After that, the successor of KVR—Regional Association Ruhr (*Regionalverband Ruhr*, RVR) took the responsibility of managing this master plan with new added three cities and other actors.

Figure7-16: Master Plan for Emscher Landscape Park 2010
Source: *Masterplan Emscher Landschaftspark* 2010 (Project Ruhr GmbH, 2005)

Furthermore at the same time, another significant timeline was the emergence of a "sister plan" named "Master Plan for Future Emscher—the New Emscher Valley (*Masterplan Emscher Zukunft —Das Neue Emschertal*)" presented by Emscher Cooperative (*Emschergenossenschaft)* in 2006 [**Figure7-17**]. This master plan was also developed in a continuous dialogue with relevant actors, which focused more on technical issues regarding regeneration of Emscher river system (such as planning underground sewage channel system, see 7.2.2 A) in order to optimize the "new Emscher valley". On the basis of above two master plans, since 2006 Emscher Cooperative and RVR have been cooperating in the "New Emscher Valley" working group. What is more, Emscher Cooperative is now working with another sewage management company Lippe Association (*Lippeverband*) to make technical and ecological solutions in terms of water management including Emscher river system within 30 years.

Figure7-17: Master Plan for Future Emscher—the New Emscher Valley
Source: *Masterplan Emscher Zukunft—Das Neue Emschertal* (Emschergenossenschaft, 2006)

C **Review**

The following figure illustrates the mechanism of planning integrated approach guiding intervention actions in IBA Emscher Park [**Figure7-18**], whose characteristics could also be summarized, like Haihe riverside region in Tianjin (see Section 5.5):

- The way of both operating planning and taking intervention actions is a top-down strategy-guided in combination with bottom-up project-oriented way;
- The actor group is very broad and complex from regional and local level, involving governmental sectors, intercommunal various organizations and private companies, etc.;
- Taking intervention action is in a position of continuous step-by-step process, by following a logic of "Dissemination (single projects)—Networking (regional coherence) — Consolidation (spreading)" [**Figure7-19**].

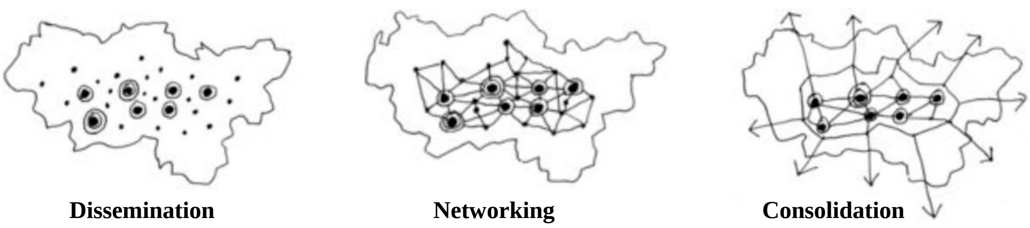


Figure7-19: Intervention logic of "Dissemination—Networking—Consolidation"
Source: (Kunzmann, 2010)

- Planning integrated approach is based on a newly established planning system consisting of different levels of planning tools;
- Informal planning tools serve as the main dominant tools, which serve as the platform and basis conveying visions, ideas and strategies for cohering actors;
- The “moderator mechanism” plays a vital role in both planning level and action process;

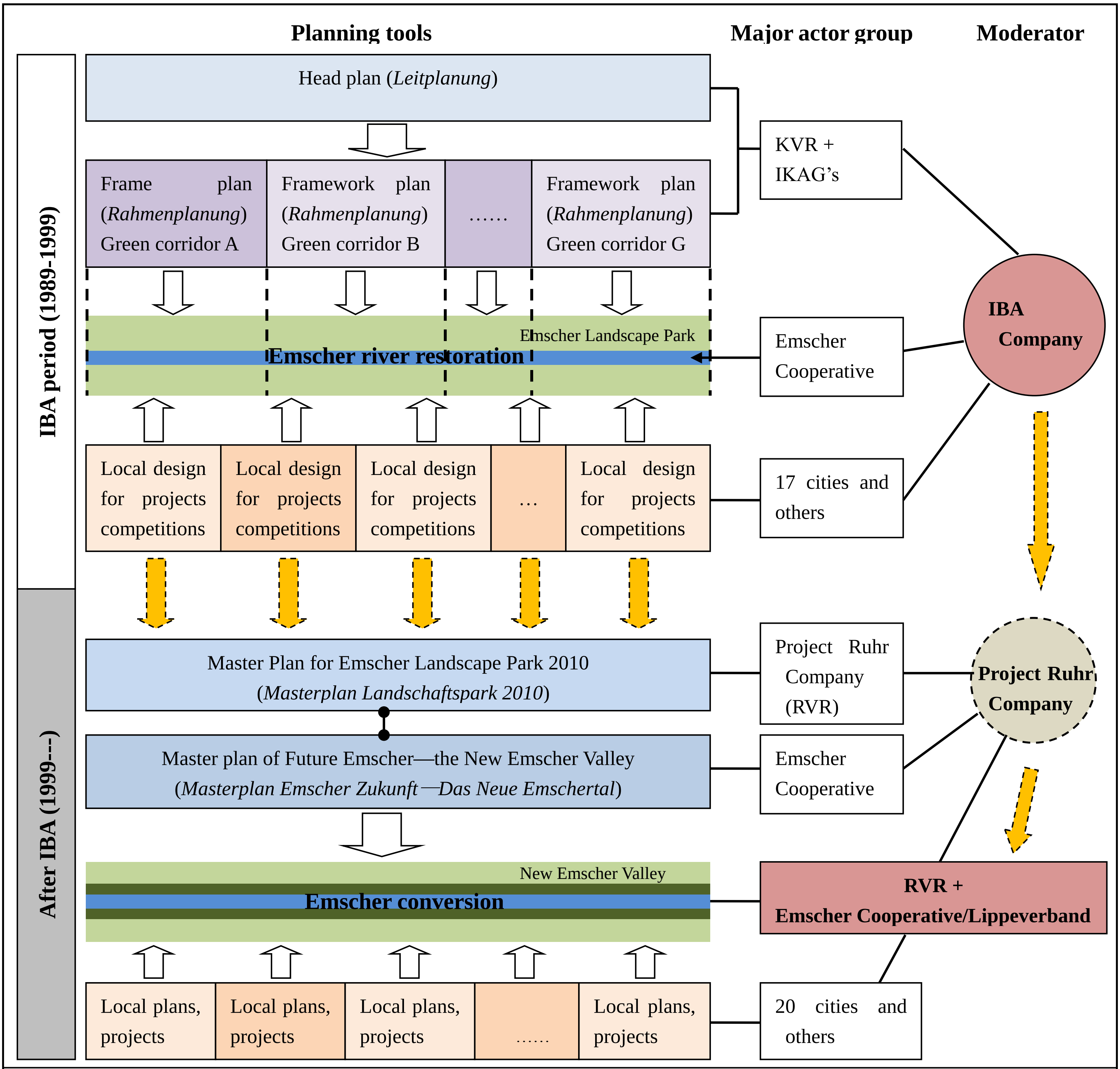


Figure7-18: Planning integrated approach in IBA Emscher Park

Source: Author's own construct

7.4 Drawing on Experience

7.4.1 Comparison between Two Cases

Based on all present above, a comparison of abstracting key points could be made between IBA Emscher Park and Haihe riverside region [**Table7-2**]. As mentioned previously (see Section 4.3.2), it is hard to establish an absolute juxtaposition comparison presenting all details of these two cases, so this comparison is relative and its result should be viewed selectively and objectively.

Table7-2: Comparison between two cases

	IBA Emscher Park (Ruhr area, Germany)	**Haihe riverside region (Tianjin, China)**
Spatial dimension		
Main overall spatial Characteristics	— Emscher river dominates and its tributaries distribute — Regional polycentric with small-scale urban bodies, no dominant center — Continuous but loose decentralized built environment (Mosaic land use) — 7 green corridors — Networked traffic form	— Haihe river dominates and its tributaries distribute — Large compact urban body with two dominant centers and one planned urban center as well as other growing centers (Intra-urban polycentric) — Continuous and dense intensive built environment (Mosaic land use) — Planned 2 green corridors — Networked traffic form
Low-carbon-oriented transformation context		
Original industrial basis	High-carbon context: heavy industry (coal mines, iron & steel as the main, and others including engineering, textiles and shipbuilding)	Hign-carbon context: heavy industry (iron &steel, chemical, machinery, water transport as the main, and others including textiles, metal, shipbuilding)
Problems encountered	— Industrial crisis, unemployment — Land subsidence due to mining activities, river pollution due to sewage discharge, flood risk — Other associated: abandoned brownfields, ecological deterioration, degraded landscape, etc.	— Water transport decline due to development of landway transport and flood risk — River pollution due to industrial discharge and ignorance — Other associated: recession of social vitality, river channel sedimentation, environmental deterioration, degraded landscape, etc.
Motivation of transformation	Above problem-oriented and also upper political goal-oriented requirements (change a new appearance, etc.)	Upper political goal-oriented (economic leap, city image, etc.) and above problem-oriented requirements
Direction of transformation	— Sustainable development, adapt to climate change — Post-industrial society (Service, knowledge, creative and cultural and other diverse industries)	— Ecological city, low-carbon development in response to climate change — Customer society (tertiary industry, residential, recreational and leisure industries, etc.)
Low-carbon-related intervention actions		
Intensive intervention process	Stage 1: 1989-1999; Stage 2: 2000—2010; Stage 3: 2010—	Stage 1: 2002-2008; Stage 2: 2008-2013; Stage 3: 2014—
Intervention logic	Dissemination—Networking—Consolidation	Locational axiology: separate section—Connection
Action field (project type)	Six: regional landscape, river system, housing, industrial heritage, etc.	Ten: river system, riverfront embankment, green planting, open space, transport, etc.
Richness of waterside status	— Water quality restoration: underground sewage canal system, sewage plant, etc. — Other near-natural control measures: deal with channelized riverbanks, create meanders, enlarge storm water basins, etc.	— River restoration: separate discharge system, dredge, connect rivers, sewage plant, etc. — Embankment rebuilt: reshape the simulated natural form of river edge by referencing the “near-natural control” concept, etc.

Biodiversity of green space	— Regional green corridors: vertical to horizontal blue-green corridor — Other river-based open spaces: measures including transformation, re-identification, connection & network, new creation	— Green planting: re-colonization of vegetation, shrubs and trees to increase green coverage ratio — Other river-based open spaces: measures including control, expansion & renovation, new creation, connection
Multifunctionality of urban structure & land use	— Polycentric structure: keep this original nature and further enhance it — Mixed land use: reuse of brownfields without new land growth	— Spatial restructuring: cultivate more centers to promote more "polycentricity" — Industrial adjustment: demolish or remove industries and redevelop lands vacated, with new land growth in the meanwhile
Permeability of spatial form	Inner edge: preserve internal in-between open spaces, penetrative interface between built environment and nature	Green corridor: plan large-scale greenways serving as gap spaces between urban bodies
Public accessibility of traffic network	Cycle and pedestrian path: looped, based on former railways, much of them along waterways	Transportation improvement: road and bridge rebuilt, increase public traffic mode, create slow-travel lanes, etc.
Circularity of municipal utilities operation	Unconventional water resource: on-site rainwater collection and utilization combined with public spaces and landscape design	Unconventional water recycle: reuse of purified sewage and industrial water in combination with water restoration measures
Implementation performance	A region from "grey" to "green", with exemplary single projects	As evaluated in Section 6.4
Supportive planning integrated approach guiding intervention actions		
Planning process	Continuous, with design-by-process actions	Continuous, with periodical intensive actions
Planning system	New, special unconventional approach	Traditional approach
Contributing planning tools	Informal planning tools: IBA period (three-level planning tools); After IBA (two regional masterplans)	Formal planning tools: Urban Master Plan for Tianjin with next tier of Detailed Plan dominates in each stage
Essen of these planning tools	— Policy and guidance platform, with development vision — Principles, guidelines serve as common direction and criterion	— Technical blueprint with development vision after 20 years — Fixed stipulation, control requirements
Key actor group	Broad and complex (regional and local level, public sectors and private corporations)	Limited and specialized (local government, public sectors, experts)
Operation path	— Top-down strategy-guided combined with bottom-up project-oriented — In dialogue, cooperation — Moderation mechanism	— Top-down routing control — Command, tier-to-tier enforcement — Final decision-making mechanism
Funding source	Public budget (EU, Germany, NRW, Local) with part of private investment	Public budget (Local, sectors) through bank loan based on a "land sale economy"
Popularity to the society	— Considerable citizen involvement (such as public appeal for ideas at the beginning) — Unified document recording as "project library" (such as *Katalog der Projekte 1999*)	— Weak citizen involvement (publish results but low feedback channel) Static blueprint — No unified and systematic document recording, but separated
Potential problems	— Too broad actor group might bring conflicts that are hard to coordinate — Too diverse dialogue and cooperation might bring about "overlap" and difficulty for decision making — After all informal tools lack legislative binding force, sometimes hard to constrain	As analyzed in Section 6.5.3

Source: Author's own construct

7.4.2 Paradigm Shift

Of course not all experiences of IBA Emscher Park are adaptable to Haihe riverside region because of two totally different national context, institutional system, economic development stage, cultural background, etc. between Germany and China, as mentioned in Section 4.3.2. In addition, it should be also noticed that the IBA case is a special or even extreme case, not conventional. However, sometimes “unconventional” signifies “innovation”, and “differentiation” implies “more possibilities”. Moreover, the IBA case itself is not a completely perfect case, which also has its own drawbacks (such as weak in job creation, some single projects are good at design quality and landscape effect but not so closely connected to daily life, etc.). Hence, the point of referencing in this dissertation is to find out its possible lessons and transferable models to the future exploration way of the Chinese case.

Through above comparison, it can clearly be seen that actually in terms of intervention actions towards low-carbon development at the strategic level, there is not too much difference regarding ideas, measures used between the two cases, only except some micro fields (such as the rainwater utilization, etc.). In other word, the biggest difference is the paradigm characterized by planning integrated approach guiding intervention actions. Previously has already summarized the planning paradigm in Haihe riverside region, in which there is “breakage and discontinuity” existing in current planning integrated approach which results in problems (see Section 5.4, 5.5, 6.5.3 & 6.6). Now look at the IBA case again, its paradigm can be refined and described as a “Two-Scale Urbanism——connection between regional strategic and local project-oriented approach” (Reicher, 2015). This paradigm of “Two-Scale Urbanism” further involves three models which are just the shortcomings of the Chinese paradigm and can make up for its “breakage and discontinuity”. To be more precise:

- “**Inventory planning model** (follow-up type, *Nachfolgetypen*, quality first)” rather than “incremental planning model (new growth, quantity first)” applies to making up for shortcomings in “plan rationality”.
- “**Moderation model** (dialogue, cooperation)” rather than “command model (tier-to-tier routing control, arrange) applies to making up for shortcomings in “process cooperativity”.
- “**Gradual & flexible model** (design-by-process, feedback and track)” rather than “ultimate & rigid model (blueprint, enforcement without surveillance) applies to making up for shortcomings in “payoff conformity”.

This mechanism of paradigm shift is figured in the following [**Figure7-20**].

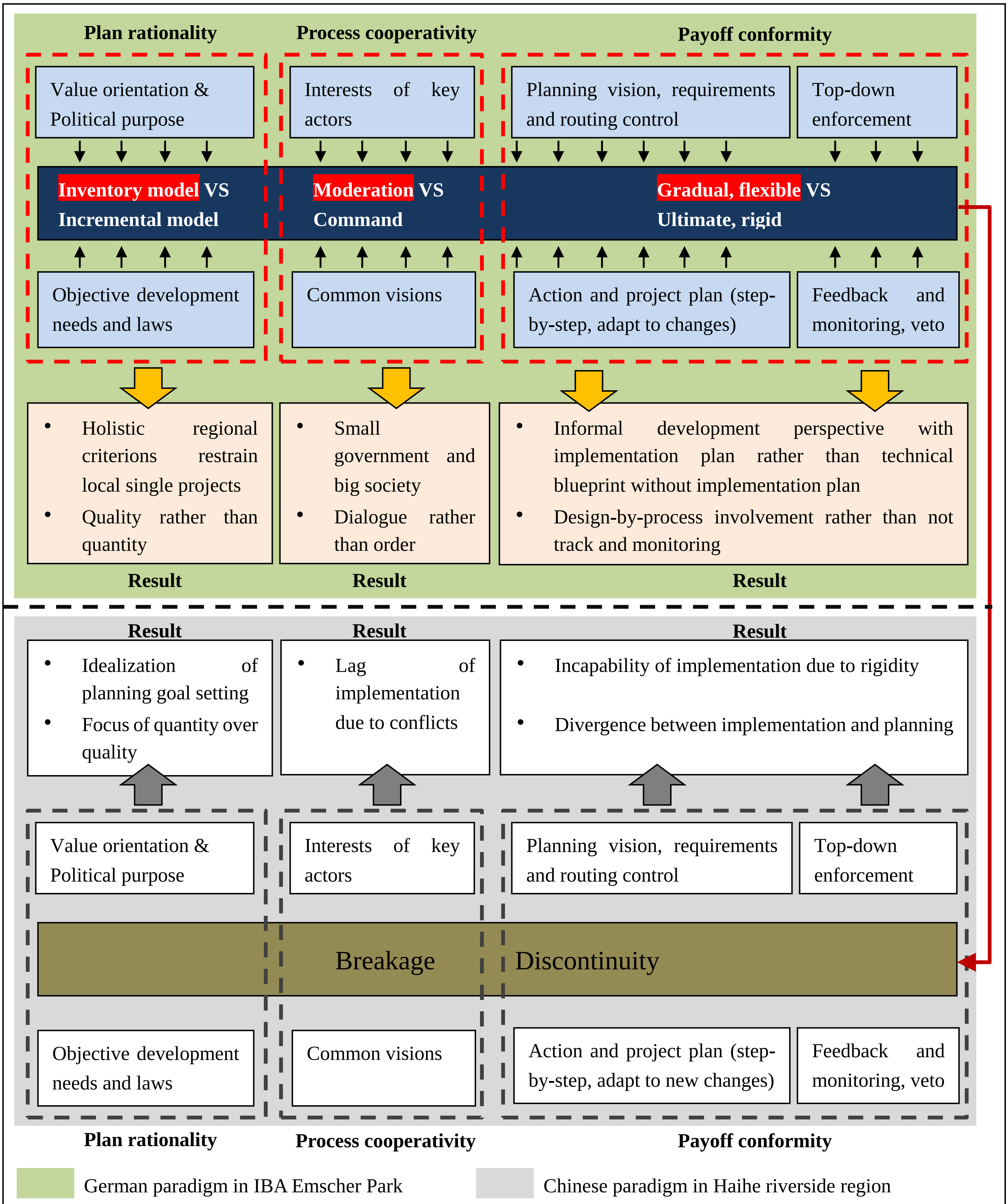


Figure7-20: German paradigm makes up for Chinese planning "breakage and discontinuity"

Source: Author's own construct

7.5 Summary

Like Chapter 5, this chapter first presents the transformation context from past “high carbon” to “low carbon” and problems encountered of Emscher region located in the Ruhr area. Then, it introduces the special program for Ruhr transformation—IBA Emscher Park, teasing out the intensive three decades of intervention actions and extracting their adherence to low-carbon development by applying previous theory in Chapter 3. After that, it analyzes the mechanism of supportive planning integrated approach guiding intervention process and summarized its characteristics.

On above basis furthermore, this chapter makes a comparison between the two cases regarding spatial dimension, transformation context and low-carbon-related intervention and planning integrated approach behind as well. Through comparison it can be seen that there is no obvious difference at the strategic level, but big difference exists at the operational level in terms of the planning integrated approach. It is further founded that the German paradigm of “Two-Scale Urbanism” in IBA Emscher Park involving three models (inventory planning, moderation, gradual and flexible) could make up for the breakage and discontinuity in Chinese paradigm analyzed in Section 6.5.3 and 6.6.

Of course, the experiences in IBA Emscher Park cannot be directly “copied and shifted” to the Chinese case, and its paradigm, models are also under exploration by Germans themselves. However, they provide enlightenment of improvement direction and more possibilities to the Chinese case, which is the significance of reference. Next it will see in what circumstances this “paradigm shift” can work in terms of Chinese local context.

Part III: Conception

- Chapter8: Conclusion and Recommendations
  - Concluding Findings
  - Recommendations for Optimizing Paradigm
  - Future Prospects

Chapter 8 Conclusion and Recommendations

8.1 Concluding Findings

According to all contents analyzed above, the main findings in this research can be extracted:

Establishment of theoretical system info

This research makes its own definitions and key concepts of research objects based on related existing theories, including low-carbon development (strengthening carbon sinks & reducing carbon sources), river-based region (a kind of planning and action space owns highly concern of intervention) and planning integrated approach (a planning process involving planning system, tools, actors to guide intervention actions).

This research further works on the connection between low-carbon development and river-based regions, establishing its theoretical framework in the form of six-layer guiding principles and corresponding guidelines, including richness of water side status, biodiversity of green space, multifunctionality of urban structure & land use, permeability of spatial form, public accessibility of traffic network as well as circularity of municipal utilities operation. This theoretical framework can be viewed as general strategies applicable to taking intervention actions in river-based regions.

The conclusion here would be: the river-based region is a complex compound system that covers natural processes and human activities, and low-carbon-oriented guiding principle & guideline framework is also involved with comprehensive complex systems and impact factors. Therefore, a powerful and transboundary planning approach (cross-scale, cross-sector, cross-element) is needed to be able to integrate multi systems, factors and thus guide appropriate intervention actions.

Identification of the position of the main case study area

In the subsequent empirical case study part, this research analyzes the current situation involving low-carbon-related intervention actions and planning integrated approach as well as their implementation performance of Haihe riverside region, through deep investigation by applying theoretical findings and further evaluating as well as analyzing causes behind.

Through these analysis, what the position is the case area in in terms of promoting a low-carbon development in the future could be concluded here, in the form of SWOTs (strengths, weaknesses and opportunities as well as challenges), as shown below [**Figure8-1**]. It can be seen that this case area is in the position of facing both achievements and shortcomings, both challenges and opportunities at the same time.

Strengths	• Rich resources: both natural and man-made landscape, such as the river system, mosaic land use (see 5.2). • Many efforts of intervention actions related to low carbon have been made (see 5.3.2), which have acquired positive effects in terms of low-carbon performance (see 6.4). • Planning integrated approach that guides intervention actions can be viewed as efficient
Weaknesses	• These efforts are snot enough, there are still certain gaps of results of intervention actions towards expected goals in terms of low-carbon performance (see 6.4). • There are shortcomings in running planning integrated approach which serving as the subjective causes (see Section 6.5.3), which can be further concluded as the breakage and discontinuity existing in current planning paradigm (see 6.6).
Opportunities	• Being positioned in a low-carbon-required transformation context and progressive way (see 5.1 & 6.5). • Adopting a low-carbon development path serves as a specific handtool and medium-term step of achieving long-term sustainable development, which is focused and supported by governmental policies (see 5.1).
Challenges	• Growing population and required growing construction lands, private vehicles and energy consumption (see 6.5.2)

Figure8-1: SWOTs analysis of Haihe riverside region towards low-carbon development

Source: Author's own construct

Exploration of the transferability of other case study area

This research also references a German case as an example: IBA Emscher Park in the Ruhr area, teasing out its low-carbon transformation background, related intervention actions and planning integrated approach, structured in correspondence with the Chinese case. After that through the comparison, this research further finds out the referencing points, especially at the operational level.

The conclusion would be: this German case has its own applicable conditions and not all experiences can be directly "copied" to the China due to different context. However, its paradigm of "two-scale urbanism" involved with three models (inventory planning model, moderation model, gradual and flexible model) can enlighten the direction of improvement to the Chinese planning paradigm, which are just the Chinese deficiencies.

8.2 Recommendations for Optimizing Paradigm

On the basis of all concluding findings above, the authors plays the role as a comprehensive urban planner (not sectoral planner or landscape planner) proposing recommendations regarding the mechanism of planning integrated approach guiding actions in Haihe riverside region towards low-carbon development to different actor group, in order to explore future improvement points and also arouse awareness.

8.2.1 To Urban Planners

This kind of recommendation is proposed to urban planners who work for planning institutes researching and preparing comprehensive planning tools (such as Urban Master Plan and Detailed Plan).

Uphold the concept of "inventory development model"

Although Tianjin has been in a position of rapid urbanization and industrialization tendency, its urbanization rate reaches near 90% in 2015 and the GDP reaches 1.22 trillion *yuan* (equals to 174 billion Euro) in the central area. This means Haihe riverside region is coming into a stable and economically developed stage. Therefore, it is the time to rethink about adopting an "inventory planning and development" path (namely follow-up type-*Nachfolgetypen*), not focusing only on "incremental development model (new growth, urban sprawl)", but focusing on how to deal with those existing planning elements. This would be the greatest contribution on low-carbon development, especially on reducing carbon sources.

Focus on quality equaling to quantity

This recommendation is attached to above. When the "quantity" stands at a certain level, it is also the time to rethink about how to further promote their "quality" in the meanwhile. This means when dealing with planning elements, the planning value orientation should be not only emphasize "how much they occupied" but also consider "how they can optimize their service functions", particularly those elements (such as green areas, open spaces, slow-travel way, etc.) only in a connective and networked situation can they maximize their contributions on low-carbon development. This point can be reflected in the setting of rational planning goals of quantitative indicators, apart from their "numbers", their corresponding quality standard is also supposed to be attached as the judgement criteria in planning tools.

Optimize the two-tier planning tools

Only when those general low-carbon-oriented guiding principles and guidelines in theoretical framework (see Section 3.4.2) are integrated into planning tools can they actually work. The German paradigm of "Two-Scale Urbanism" in IBA Emscher Park which emphasizes a connection between regional strategy-guilded level and local project-oriented level can be transferred into an experience here: **holistic scale and site scale cooperate together** to accommodate those principles and guidelines.

According to the local planning system in Tianjin, it is known that the Urban Master Plan which looks on the whole large scale and Detailed Planning that deals the site scale are the two dominant tiers of formal comprehensive planning tools (see Section 5.4.1 & 5.5). On this basis, some improvement points are still needed to be further emphasized and strengthened in terms of the evaluation results (see Section 6.4) and German experiences, as listed below [**Table8-1**].

Table8-1: Optimization points of current two-tier planning tools

Low-carbon guiding principles	Urban Master Plan for Tianjin (holistic scale)	Regulatory Detailed Plan(site scale)
Richness of waterside statues	• Designate "blue line" and stipulate requirement of water quality standard • Designate land use type of permanent prohibited construction along the river • Designate location and scale of sewage treatment plants	• Stipulate design forms of riverfront embankment (man-made, near-natural, compound, etc.) • Propose section design scheme for riverfront embankment
Biodiversity of green space	• Designate "green line" and green types • Stipulate land use type of permanent prohibited construction inside and allowable functions • Stipulate requirement of connectivity and networking	• Stipulate related indicators regarding green roofs • Subdivide allowable land use inside and stipulate corresponding construction requirements • Propose urban design guidelines for landscape effect, vegetation, etc.
Multifunctionality of urban structure & land use	• Designate "Urban Growth Boundary" to limit urban sprawl • Stipulate location and development	• Stipulate ratio of mixed land use and its prohibited functions • Subdivide land use and propose specific

	direction of centers as well as areas supposed to be promoted in high density	functions of centers
Permeability of spatial form	• Designate "Space Control Zoning" (prohibited construction zone, limited construction zone, etc.) • Stipulate overall "Density Zoning"	• Stipulate "Paste Line Rate" of street • Stipulate building coverage ratio • Propose urban design guidelines for architectural form
Public accessibility of traffic network	• Rearrange land use of areas out of the service radius of public traffic corridors • Designate the lane system of green travel model (bus, slow-travel system) • Stipulate requirement of connectivity and networking	• Stipulate section design scheme • Propose urban design guidelines for the quality and equipment of slow-travel way, such as materials, facilities, etc.
Circularity of municipal utilities operation	• Designate rainwater and sewage pipeline system and stipulate requirements of reclaimed water • Designate natural resources which accommodate flood retention spaces and rainwater ponds, and stipulate their land use requirement	• Stipulate indicators regarding absorption of rainwater, such as material, ground penetration ratio, run-off control rate, etc. • Stipulate allowable construction rate and prohibited construction types • Propose urban design guidelines for landscape effect, vegetation, etc.

Source: Author's own construct

8.2.2 To Competent Urban Planning Authority

This kind of recommendation is directed to the competent urban planning authority (Tianjin Planning Bureau) who organizes and manages the preparation and functioning of comprehensive plans and their implementations.

Explore a "Synergic interactive" planning integrated approach

Also in terms of the breakage of current planning mechanism and by referencing German models (see Figure7-17), there is a need to make a reformation for exploring the organization of planning integrated approach in Haihe riverside region, lowering its "ultimate and rigid" factor but increasing "gradual and flexible" factor, so as to play an improved guiding role in future intervention actions towards low-carbon development.

Precisely, a "**synergic interactive**" planning integrated approach would be recommended to establish on the basis of existing planning system, which emphasizes on interaction between formal and informal planning tools as well as between static and dynamic planning process. Its ideal operational model and steps are conceived as following [**Figure8-2**]:

1). First prepare an informal plan such as "Strategic Development Plan for Haihe

Riverside Region" based on consulting programs and research, similar to the "Redevelopment Plan for Haihe Riverside Region" in 2001 (see 5.4.2). This informal plan should view Haihe riverside region with its peripheral larger space as a whole planning area, incorporating low-carbon guidelines and proposing ideas and development visions as well as cohering with actor groups.

2). Under this guidance, on the one hand continue to prepare its sub-area development plans and urban design and project market planning as well as , which are all informal tools. On the other hand, prepare the revision of traditional formal tool "Urban Master Plan for Tianjin" in discussion with other sectors.   .

3). In the preparation process of Urban Master Plan, on the one hand prepare its low-tier formal Regulatory Detailed Plan in big land unit covering the whole planning area, which aims at further decomposing the Urban Master Plan, stipulating control requirements and proposing urban design guidelines through incorporating informal sub-area urban design. On the other hand, prepare the "Short-term Construction Plan" which should identify the key intervention area within next 5 years.

4). Under the guidance of full coverage of Regulatory Detailed Plan and Short-term Construction Plan, prepare the "Annual Implementation Plan" which should indicate the specific project scheme and construction body and schedule in the key intervention area every year. This annual implementation plan should also be in accordance with governmental land supply and investment plan as well as consider the informal project market planning.

5). The outcome of Annual Implementation Plan should serve as a feedback to the Regulatory Detailed Plan as a kind of tracking and maintenance service, on this basis modify the corresponding control requirements and urban design guidelines of Regulatory Detailed Plan in terms of key areas to be constructed in short term (5 years).

6). Under the guidance of Annual Implementation Plan and Regulatory Detailed Plan, prepare the formal Construction Detailed Plan (CDP) of involved land parcels.

In the above "synergic" planning model, the dominant role of traditional formal system "Urban Master Plan—Detailed Plan" still remains unchanged, however, the role of flexible informal planning at an initial stage and the role of action planning as a dynamic gradual maintenance at the middle stage are supposed to be strengthened serving as important supplements.

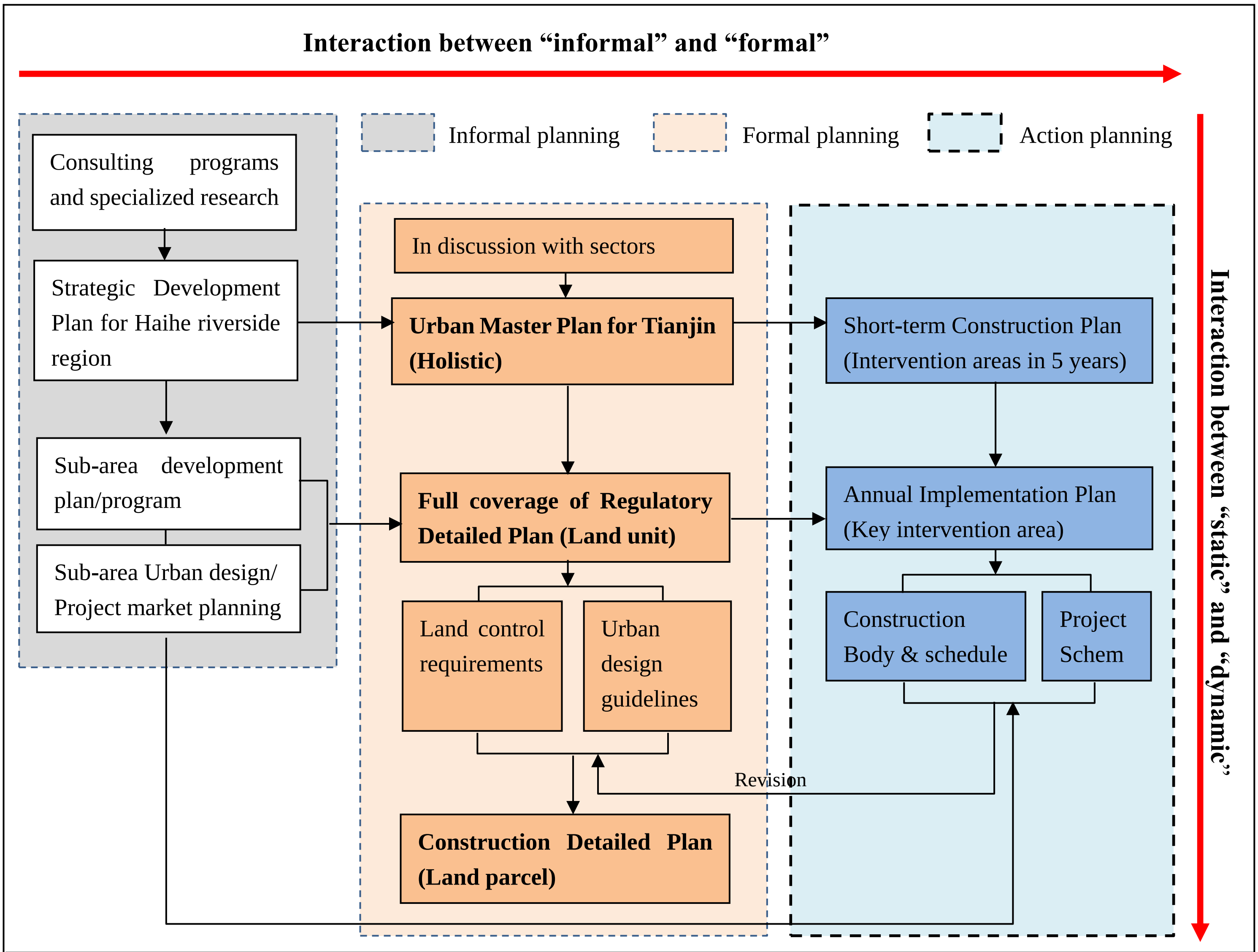


Figure8-2: Conceptual model of "synergic interactive" planning integrated approach

Source: Author's own construct

8.2.3 To Urban Decision Maker

This kind of recommendation is suggested to the municipal government of Tianjin (composed of mayors) who make final decision for everything.

Improve into a formal institutional "planning coordination" mechanism

By reviewing the German IBA models, a "moderation mechanism" (such as the once IBA Company, Project Ruhr Company) plays a vital role in coordinating stakeholders during the planning and implementation process, which is also the institutional weakness of China. As mentioned before (see Section 6.5.3 B), currently the planning issues mainly rely on Tianjin Planning Bureau to organize standing conference of public sectors. And this situation is normally difficult to coordinate, since they are paralleled sectors and when there are conflicts only have to report to the mayors waiting for decision. Therefore, a formal "planning coordination" mechanism is needed to be explored and improved in order to promote planning efficiency and reduce conflicts.

Due to the national and local institutional condition, it would be not possible to establish a completely new "moderation" organization by a third party. However, a possible expected way is to set a "joint leading group or working group" [**Figure8-3**], in which the mayor and deputy mayor assume the position of group leaders, the relevant responsible persons from main public sectors and also administrative districts play the role as members. This "joint working group" takes fully responsibility to coordinate holistic planning issues and timely makes decision as well as modifies policies. In addition, it should also set "branch offices" in each involved administrative district, tracking and monitoring the specific implementation, projects can be well connected in each section as well as timely giving feedback.

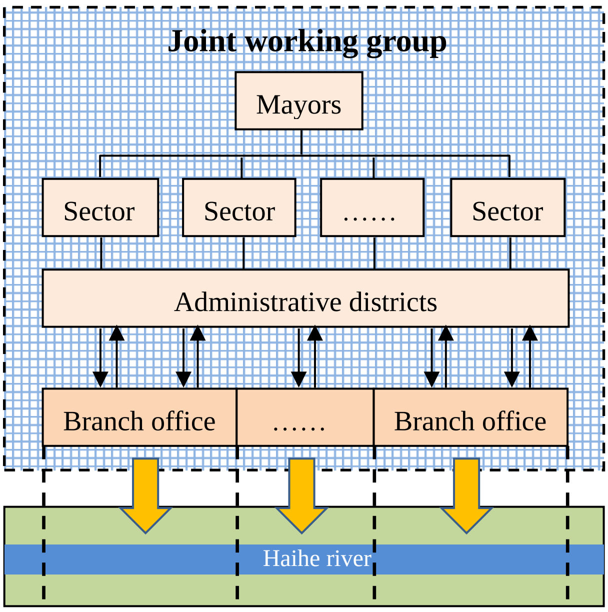


Figure8-3: Conceptual "planning coordination" mechanism
Source: Author's own construct

This "joint working group" is similar to the previous agency "Command of Comprehensive Redevelopment of Haihe River" (which only lasted 6 years, see Section 5.3.1 A) to some extent, however, it is better improved, which transforms from past "only tie-to-tier command structure" into a "coordinative network structure". This institutional mechanism should be formalized and solidified in the future, although it needs time, energy and courage to be perfected.

Encourage more social capital involvement

In Tianjin and even the whole China, almost all major urban public projects, such as the projects in planned urban centers and especially projects related to infrastructure system (such as water-based infrastructure, public transportation, green infrastructure) are "monopolized" by the government in a top-down way, including planning, investment, construction, improvement and maintenance, etc. However as a result, the "holism" and "connectivity" of some low-carbon-related linear elements (green way, slow-travel system, river course, etc.) and also gaps of planned centers often confront deficiencies in actual implementation stage (as mentioned in Section 6.5.3 B&C).

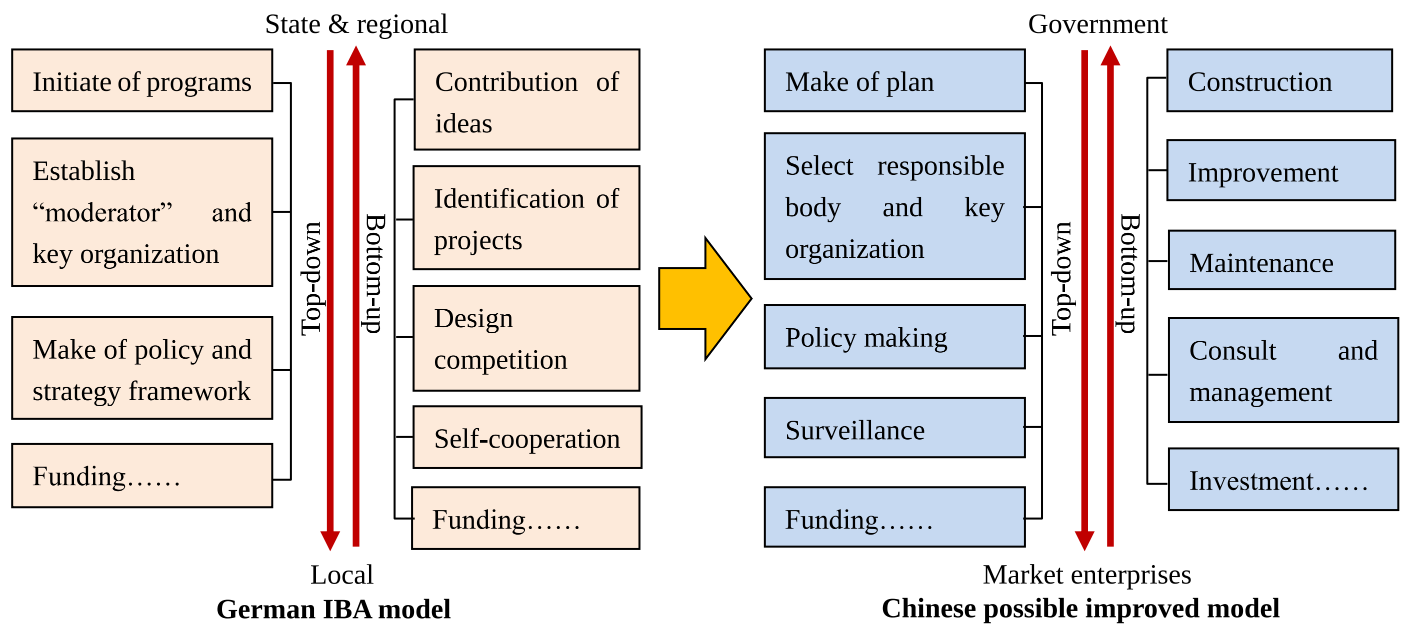


Figure8-4: Conceptual model of "open to the market"

Source: Author's own construct

Through looking at German IBA paradigm, which is a combination of "top-down" of "bottom-up" way. Actually this model cannot be directly "transplanted", since China cannot reach such a civil participation degree covering so much broad complex social organizations as actor groups (public sector, semi-public corporation, private company, NGO, etc.) at this moment. However, a possible transferred direction for reformation is to "open to the market" [**Figure8-4**], such as adopting "PPP (public-private partnership) model". Precisely, the government still uniformly plan those low-carbon-related infrastructure systems, and select capable enterprises to assume the responsibilities of their improvement, consulting, management, etc. in a marketable operation way, as well as making policies to indicate the potential available profits as the support that may attract more. In turn, the government makes the surveillance as a supervisor. In case the marketable competition is introduced, the "connectivity" and quality of projects can be "automatically" improved.

8.3 Future Prospects

8.3.1 Spatial Development Perspective

It can be said that Tianjin is now in a position of adopting a "low-carbon development path" as a specific handtool and medium-term step of achieving final sustainable development, for which Haihe riverside region that serves as the densely-urbanized central region and pioneering area is definitely supposed to take essential responsibilities. What is more, actually this region is not a closed area and should not be a viewed in segregated perspective. This means that next its inner low-carbon-related intervention systems (water system, green system, infrastructure system, etc.) also need more well-integrated with its peripheral areas, so as to expand the functions of reducing carbon sources and strengthening carbon sources.

Based on the discussion of the author with Chines colleagues during the preparation process of latest *Urban Master Plan for Tianjin* (2015-2035), also based on the author's feelings and insights of some German concepts when studying in Germany, the following depicts the future expanded conceptual development perspective of creating a "great Haihe riverside park" in form of development visions (*Leitbilder*), with key characteristics described in correspondence with low-carbon guiding principles [**Table8-2**] [**Figure8-5**]:

- A **landscape city** (*Landschaftsstadt*): towards an ancient Chinese term "Shan-shui" city, which implies an development model combining the man-made construction and the natural environmental landscape such as mountains (Shan) and the water (Shui);
- A **polycentric network city** (*Polyzentrische Netzwerkstadt*): group-typed urban cluster form with multi centers and with in-between open spaces, connected by public transport and infrastructure corridors;

- A **short-distance city** (*Stadt der Kurzen Wege*): compact urban clusters with relative high density, balanced and mixed functions of residential, working, education and recreation, etc. inside.

- A **Car-free city** (*Autofreie Stadt*): high-quality and networked slow-travel system along the river system and green ways, high-capacity rail transit system with optimized land uses along, limitation of car parking ratio;

- A **Sponge city** (*Schwammstadt*): emphasis of the concept of "sustainable rain water management", underlying surface and other facilities can facilitate the infiltration, storage and reuse of stormwater combined with landscape design.

Table8-2: Development visions most in favor of low-carbon guiding principles

	Richness of waterside status	Biodiversity of green space	Multifunctionality of Urban Structure and land use	Permeability of spatial form	Public accessibility of traffic network	Circularity of municipal utilities
Landscape city	√	√	——	√	——	——
Polycentric network city	——	√	√	√	√	√
Short-distance & car-free city	——	——	√	——	√	——
Sponge city	√	√	——	——	——	√

Source: author's own construct

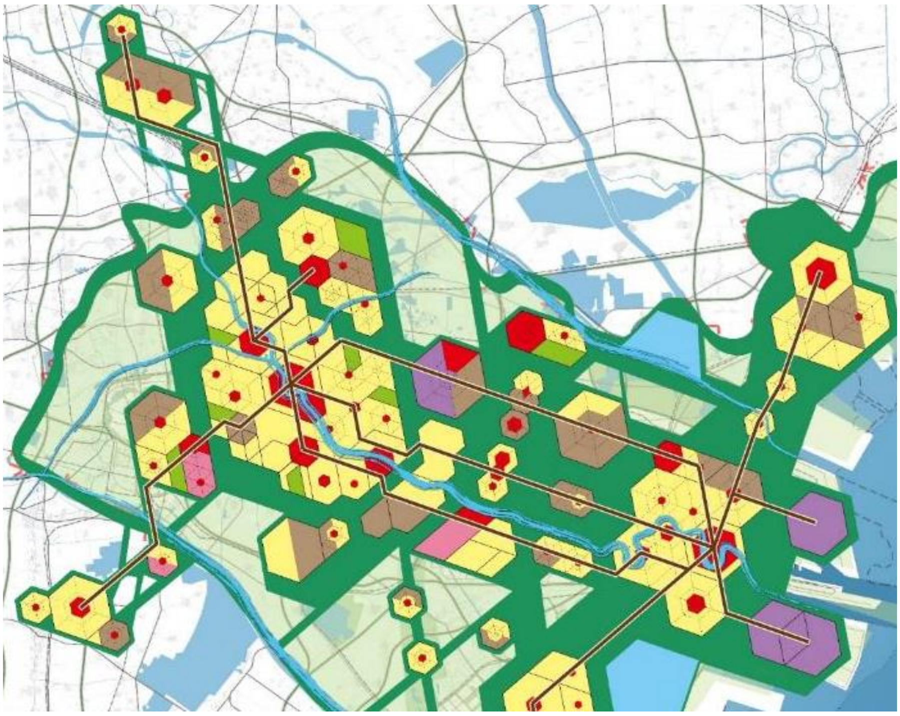


Figure8-5: Conceptual spatial development perspective of "great Haihe riverside park"

Source: China Academy of Urban Planning & Design

8.3.2 Further Research Perspective

In all, this study takes towards low-carbon development as the goal orientation and theme discussing theories, practicable approaches and operational mechanism in river-based regions from urban planning field based on an individual research possibility and available research support. However, it cannot take a part as a generalization for the whole, which only plays a role in a "starting point" for triggering further more extended and in-depth research. The agenda for further research exploration would be:

- New evaluation methods regarding carbon emissions. Although this study conducts evaluation of low-carbon performance by working out investigation of variations of planning indicators, more advanced quantitative methods regarding assessing performance of carbon emissions (such as in combination with GIS, model simulation system, carbon sink measurement system, etc.) benefited from new techniques and software are still needed to explored.

- Extending of research area type. This research selects the spatial type of river-based region as the object, since it is the typical concerned planning and action space of priority and especially a pioneering urbanization area in China. However, next still needs to explore how those not so preferred and "hot" area such as peripheral rural areas can meet the needs of supporting low-carbon development.

- More comprehensive guiding instruments. This study focuses on the mechanism of urban planning approach guiding practical intervention actions. Actually in addition to urban planning approach which serves as the motivator and supporter behind, the integration of economic incentive, policy making and legislative guaranteen also can influence intervention actions. Therefore, much broader and comprehensive guiding tools in coordination are still needed to be considered.

- Expansion of dimension from low-carbon development to sustainable development. This research defines its own definition and connotation of low-carbon development, from a relative narrow sense focusing on strengthening carbon sinks and reducing carbon sources. Actually as explained before, low carbon is only a branch while sustainable development would be the long-term final value orientation. That is to say, in addition to environmental dimension, the economic and social dimension are still in need of consideration. Especially for developing countries, how to balance environmental needs (such as response to climate change) and the needs of economic development, urbanization and social employment and culture as well is the key challenging issue, since they are probably contradicted somewhere. This can further be reflected in the exploration of sustainable guiding principles, guidelines and index system.

The end

Appendices

Appendix I The first intensive on-site visiting & interview plan

- Contributed to the contents of Chapter 5 & Chapter 6

Date	Time	Visiting objects
27.03.2014	Moring	China Academy of Urban Planning & Design
	Afternoon	China Academy of Urban Planning & Design
28.03.2014	Moring	China Academy of Urban Planning & Design
	Afternoon	China Academy of Urban Planning & Design
	Evening	Beijing University of Civil Engineering and Architecture
31.03.2014	Moring	Tianjin Planning Bureau
	Afternoon	Tianjin Planning Bureau Tianjin Urban Planning & Design Institute
01.04.2014	Moring	City and Garden Management Commission
	Afternoon	Tianjin Environmental Protection Bureau
02.04.2014	Moring	Tianjin Water Administration Haihe River Water-conservancy Commission
	Afternoon	Site Survey
03.04.2014	Moring	Site survey
	Afternoon	Tianjin Forestry Administration
04.04.2014	Moring	Tianjin Statistic Bureau
	Afternoon	Land Resources and Housing Management Bureau
05.04.2014	Moring	Site survey
	Afternoon	Site survey
06.04.2014	Moring	Individual sorting
	Afternoon	Individual sorting
07.04.2014	Moring	Tianjin Development and Reform Commission
	Afternoon	Site survey
08.04.2014	Moring	Land Resources and Housing Management Bureau
	Afternoon	Tianjin Municipal Transportation Commission
09.04.2014	Moring	Tianjin Urban & Rural Construction Commission
	Afternoon	Site survey
	Evening	Tianjin University
10.04.2014	Moring	Tianjin Urban Planning & Design Institute—Binhai Branch Institute
	Afternoon	Site survey
11.04.2014	Moring	Tianjin Municipal People's government
	Afternoon	Tianjin Planning Bureau
15.04.2014	Evening	Peking University

Appendix II Designed interview topics during the first on-site visiting

- Contributed to the contents of Chapter 5

In terms of Haihe riverside region, I would like to consult following topics, please offer guidance from your responsible field or professional field.
This interview is only used for the purpose of personal doctorial study.
Thank you!

(1) The background of transformation of Haihe riverside region.

(2) Its current status and problems.

(3) The main intervention actions (implementation of projects) have been proceeded in this region and their organizational way.

(4) The main supportive planning approach (planning system, tools, process, actors) that influences these intervention actions.

(5) The actual implementation situation of above plans prepared and projects.

(6) The future plans and strategies for promoting a low-carbon development.

(7) Acquisition of documentary data involved and contact way for further research needs.

Postscript
This is a basic interview framework for gathering information in the fieldwork process, which means not all conversations are completely the same when interviewing, but flexibly adjusting the topic in terms of interviewees' respective responsible fields (such as ecological landscape conservancy, open space, land use, industrial development, transportation, infrastructure).

Appendix III Primary Low-carbon index system for evaluation (Questionnaire)

■ Contributed to the contents of Section 6.2

This questionnaire would be greatly contributed to my individual doctoral research. Please fill it out based on your professional knowledge and objective stance according to the following instructions.
I highly appreciate your help and support! In case there are questions, do not hesitate to contact me!

1 The purpose of this survey

This survey is to help in establishing a low-carbon index system with selected indicators. Its results will be contributed to the further evaluation of implementation achievements towards low-carbon development in Haihe riverside region resulted from recent intervention actions.

2 Instructions of questionnaire

■ Primary index system and indicators

The author has initially selected relevant indicators and established a primary low-carbon index system for assessment via the methods of theoretical deduction and reference of other related index system (the sources are shown below).

Referenced related indigenous index system	
National level	*Evaluation Method and Index System of Chinese Urban Low-carbon Development* (2014); *Low-carbon Index System for China* (2012); *China Sustainable Development Strategy Report 2009——China's Approach towards a Low Carbon Future*; *Construction Index System of Ecological Towns, Municipalities and Provinces* (2009); *Scientific Evaluation Standard for Chinese Livable City* (2008); *Evaluation Standard for National Eco- and Garden City* (2005)
Local level	*Planning Framework of Eco-City Construction of Tianjin* (2008), *2010 Action Plan for of Tianjin's Eco-city Construction*; *Index System of Sino-Singapore Tianjin Eco-City* (2010)

■ Explanation

This primary low-carbon index system is divided into three layers: the target layer, criterion layer and indicator layer.

The target layer expresses the overall goal of low-carbon development, including strengthening carbon sinks and reducing carbon sources.

The criterion layer consists of six groups interactive layers: richness of waterside statues, biodiversity of green space, multifuctionality of urban structure & land use, permeability of spatial form, public accessibility of traffic network, circularity of municipal utilities operation.

The indicator layer can be further divided into two levels: 9 first-class indicators with 40 second-class qualitative and quantitative indicators in total. They are all derived from above referenced source and are the main issues to be discussed.

This primary index system will take the form of following **form**, please **fill out the form** to select indicators according to the principles of **pertinent**, **local adaptable** and **scientific**.

Specifically, in case you think indicators are **suitable** for this assessment, please make **ticks (" √ ")** in the blank, on the contrary, in case you think indicators are **not suitable**, please leave the blank space and give **recommendations** (such as delete or adjustment direction) if possible.

Target layer	Criteria layer	Indicator layer	Whether suitable	Possible recommendations
Strengthening carbon sinks	1 Richness of Waterside status			
		1.1 Water side characteristics		
		1.* River width		
		2. Water feature		
		3. Water quality		
		4. Riverbank stability		
		5. Degree of crook		
		6. * Natural rate of riverbank		
		2.1 Green system		
		1. *Area of green spaces		

	2 Biodiversity of Green space	2.* Green areas per capita		
		3. * Green coverage ratio		
		4. * Native plants index		
		5. The net loss of wetlands		
		6. Integrity of vegetation belt		
Reducing carbon sources	3 Multifunctionality of Urban structure and land use			
		3.1 Urban pattern		
		1.Centricity		
		2. Compactivity		
		3. Urban growth way		
		4. * Population density		
		3.2 Mixture degree of land use		
		1. * Tertiary Industry per GDP		
		2. *Jobs-housing balance ratio		
		3. Concentration degree of service facilities		
		4. Concentration degree of industrial lands		
	4 Permeability of spatial form			
		4.1 Block layout		
		1. * Building density		
		2. Building enclosure degree		
		3. * Green building proportion		
		4.2 Open space		
		1.*Area of open spaces		
		2. * Open space ratio		
		3. Open space connectivity		
		4. Open space amenity		
		5.1 Traffic structure		
		1. * Green travel ratio		
		2. Green travel		

	5 Public accessibility of traffic organization	quality		
		3. * Sharing rate of public transport		
		4. Coverage rate of slow-travel system		
		5.2 Traffic accessibility		
		1. * Average commute time		
		2. * Average speed in peak hours		
		3. Convenience of transfer		
	6 Circularity of municipal utilities operation			
		6.1 Energy supply and distribution		
		1. Energy efficiency		
		2. * Popularizing rate of pipelines		
		3. * Popularizing rate of centralized heating		
		4. * Utilization rate of renewable energy		
		6.2 Water resources utilization		
		1. * Unconventional water availability		
		2. * Sewage treatment rate		
		3. Ground water quality		
		4. * Repetition rate of industrial water		
		5. * Water saving ratio		
Other recommendations:				

Note: the indicators with "*" mean quantitative data, while the rest represent qualitative

Appendix IV Questionnaire for weighting of index system

- Contributed to the contents of Section 6.3.1

This questionnaire would be greatly contributed to my individual doctoral research. Please fill it out based on your professional knowledge and objective stance according to the following instructions.
I highly appreciate your help and support! In case there are questions, do not hesitate to contact me!

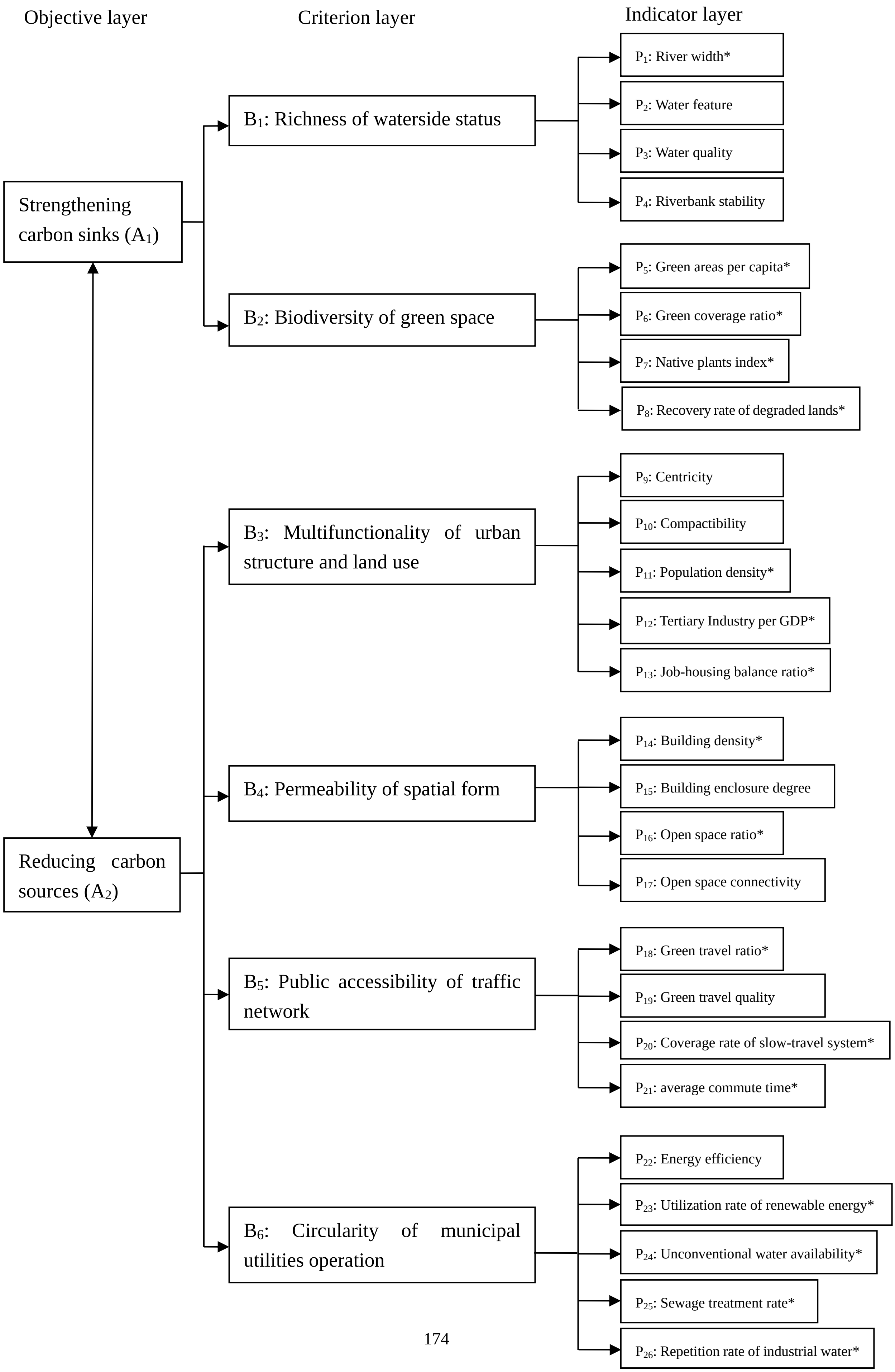
1 The purpose of this survey

This survey is to help in judging the relative importance between indicators in terms of established low-carbon evaluation index system (last survey) and getting weighted values. Its results will serve as basis for the next evaluation. In this survey the same experts are collected as the judgments based on using **AHP method** in combination with round 2 of Delphi technique.

2 Instructions of questionnaire

- Hierarchical structure for judgment

Following is the AHP **hierarchical structure** of low-carbon index system in Haihe riverside region, which serves as the object for this survey. It consists of “object layer”, “criterion layer (6)” and “indicator layer (26)”. In terms of the specific detail meanings of each indicator, please see the content of Chapter 6 (6.2.3) of the dissertation or ask me.


Objective layer
Criterion layer
Indicator layer
Strengthening carbon sinks (A_1)
Reducing carbon sources (A_2)
B_1: Richness of waterside status
B_2: Biodiversity of green space
B_3: Multifunctionality of urban structure and land use
B_4: Permeability of spatial form
B_5: Public accessibility of traffic network
B_6: Circularity of municipal utilities operation
P_1: River width*
P_2: Water feature
P_3: Water quality
P_4: Riverbank stability
P_5: Green areas per capita*
P_6: Green coverage ratio*
P_7: Native plants index*
P_8: Recovery rate of degraded lands*
P_9: Centricity
P_{10}: Compactibility
P_{11}: Population density*
P_{12}: Tertiary Industry per GDP*
P_{13}: Job-housing balance ratio*
P_{14}: Building density*
P_{15}: Building enclosure degree
P_{16}: Open space ratio*
P_{17}: Open space connectivity
P_{18}: Green travel ratio*
P_{19}: Green travel quality
P_{20}: Coverage rate of slow-travel system*
P_{21}: average commute time*
P_{22}: Energy efficiency
P_{23}: Utilization rate of renewable energy*
P_{24}: Unconventional water availability*
P_{25}: Sewage treatment rate*
P_{26}: Repetition rate of industrial water*

- Explanation

Please make a pairwise **one-on-one comparison** regarding relative importance according to your own judgment based on your professional knowledge and practical experiences as well as the understanding of Haihe riverside region in Tianjin.

Scale	Meaning/Interpretation
1	**equal** important
3 (1/3)	**a little bit** larger (smaller) or more important (less important)
5 (1/5)	**significant** larger (smaller) or more important (less important)
7 (1/7)	**very strong** larger (smaller) or more important (less important)
9 (1/9)	**extreme** larger (smaller) or more important (less important)
2 (1/2),4 (1/4),6 (1/6),8 (1/8)	Intermediate values of above scale

Please see the above **judgment criteria**, and then fill the results of judgment in the form of **ticks (“ √ ”) or other marks** in the following **tables**. For example, when A compares B, in case you think A is a little bit more important than B, remark “3” on the left side; on the contrary, in case you think A is a little bit less important than B (B is a little bit more important than A), remark “1/3” on the right side.

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
A				√						B

Comparison tables

1 Weighting of objective layer

Left						Right			
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
A_1:Strengthening carbon sinks										A_2:Reducing carbon sources

2 Weighting at the level of “strengthening carbon sinks”

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
B_1:Richness of waterside status										B_2:Biodiversity of green space

3 Weighting at the level of “reducing carbon sources”

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
B_3:Richness of waterside status										B_4: Permeability of spatial form
B_3:Richness of waterside status										B_5: Public accessibility of traffic network
B_3:Richness of waterside status										B_6: Circularity of municipal utilities operation
B_4: Permeability of spatial form										B_5: Public accessibility of traffic network
B_4: Permeability of spatial form										B_6: Circularity of municipal utilities operation
B_5: Public accessibility of traffic network										B_6: Circularity of municipal utilities operation

4 Weighting at the level of “richness of waterside status”

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_1:River width										P_2: Water feature
P_1:River width										P_3: Water quality
P_1:River width										P_4: Riverbank stability
P_2: Water feature										P_3: Water quality
P_2: Water feature										P_4: Riverbank stability
P_3: Water quality										P_4: Riverbank stability

5 Weighting at the level of "biodiversity of green space"

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_5:Green areas per capita										P_6: Green coverage ratio
P_5:Green areas per capita										P_7: Native plants index
P_5:Green areas per capita										P_8: Recovery rate of degraded lands
P_6: Green coverage ratio										P_7: Native plants index
P_6: Green coverage ratio										P_8: Recovery rate of degraded land
P_7: Native plants index										P_8: Recovery rate of degraded land

6 Weighting at the level of "multifunctionality of urban structure & land use"

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_9:Centricity										P_{10}: Compactibility
P_9:Centricity										P_{11}: Population density
P_9:Centricity										P_{12}: Tertiary Industry per GDP
P_9:Centricity										P_{13}: Job-housing balance ratio

P_{10}: Compactibility										P_{11}: Population density
P_{10}: Compactibility										P_{12}: Tertiary Industry per GDP
P_{10}: Compactibility										P_{13}: Job-housing balance ratio
P_{11}: Population density										P_{12}: Tertiary Industry per GDP
P_{11}: Population density										P_{13}: Job-housing balance ratio
P_{12}: Tertiary Industry per GDP										P_{13}: Job-housing balance ratio

7 Weighting at the level of "permeability of spatial form"

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_{14}:Building density										P_{15}:Buidling enclosure degree
P_{14}:Building density										P_{16}:Open space ratio
P_{14}:Building density										P_{17}:Open space connectivity
P_{15}:Buidling enclosure degree										P_{16}:Open space ratio
P_{15}:Buidling enclosure degree										P_{17}:Open space connectivity
P_{16}:Open space ratio										P_{17}:Open space connectivity

8 Weighting at the level of "public accessibility of traffic network"

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_{18}:Green travel ratio										P_{19}:Green travel quality
P_{18}:Green travel ratio										P_{20}:Coverage rate of slow-travel system
P_{18}:Green travel ratio										P_{21}:Average commute time
P_{19}:Green travel quality										P_{20}:Coverage rate of slow-travel system

P_{19}:Green travel quality										P_{21}:Average commute time
P_{20}:Coverage rate of slow-travel system										P_{21}:Average commute time

9 Weighting at the level of "circularity of municipal utilities operation"

Left						Right				
	9	**7**	**5**	**3**	**1**	**1/3**	**1/5**	**1/7**	**1/9**	
P_{22}:Energy efficiency										P_{23}: Utilization rate of renewable energy
P_{22}:Energy efficiency										P_{24}: Unconventional water availability
P_{22}:Energy efficiency										P_{25}: Sewage treatment rate
P_{22}:Energy efficiency										P_{26}: Repetition rate of industrial water
P_{23}: Utilization rate of renewable energy										P_{24}: Unconventional water availability
P_{23}: Utilization rate of renewable energy										P_{25}: Sewage treatment rate
P_{23}: Utilization rate of renewable energy										P_{26}: Repetition rate of industrial water
P_{24}: Unconventional water availability										P_{25}: Sewage treatment rate
P_{24}: Unconventional water availability										P_{26}: Repetition rate of industrial water
P_{25}: Sewage treatment rate										P_{26}: Repetition rate of industrial water

Appendix V Weighted values of index system

■ Contributed to the contents of Section 6.3.1

A: Target layer	Weighting (W)	B: Criterion layer	Weighting (W)	P: Indicator layer	Weighting (W)
Strengthening carbon sinks (A_1)	0.375	Richness of waterside status (B_1)	0.3467	* River corridor width (P_1)	0.0752
				River feature (P_2)	0.1071
				Water quality (P_3)	0.2853
				Riverbank stability (P_4)	0.5324
		Biodiversity of green space (B_2)	0.6533	* Green areas per capita (P_5)	0.5045
				* Green coverage ratio (P_6)	0.3013
				* Native plants index (P_7)	0.0781
				* recovery rate of degraded lands(P_8)	0.1161
Reducing carbon sources (A_2)	0.625	Multifunctionality of Urban structure and land use (B_3)	0.4175	Centricity (P_9)	0.3472
				Compactibility (P_{10})	0.3528
				* Population density (P_{11})	0.1048
				* Tertiary Industry per GDP (P_{12})	0.0931
				*Jobs-housing balance ratio (P_{13})	0.1021
		Permeability of spatial form (B_4)	0.0955	* Building density (P_{14})	0.1576
				Building enclosure degree (P_{15})	0.0924
				* Open space ratio (P_{16})	0.2752
				Open space connectivity (P_{17})	0.4748
		Public accessibility of traffic network (B_5)	0.2752	* Green travel ratio (P_{18})	0.4117
				Green travel quality (P_{19})	0.2058
				* Coverage rate of slow-travel system (P_{20})	0.2826
				* Average commute time (P_{21})	0.0999
		Circularity of municipal utilities operation (B_6)	0.1578	Energy efficiency (P_{22})	0.1260
				* Utilization rate of renewable energy (P_{23})	0.1195
				* Unconventional water availability (P_{24})	0.2890
				* Sewage treatment rate (P_{25})	0.2622
				* Repetition rate of industrial water (P_{26})	0.2033

Appendix VI Values and data sources of evaluation indicators

■ Contributed to the contents of Section 6.3.3

[1] P_1 (River corridor width): In 2001 the average width of the water surface of Haihe river is about 120 meters, and according to the landscape ecological perspective, the width of 30m of riverside riparian zone is often regarded as an effective minimum value. Thus, the whole 150m is taken as the lower limit value.

* Data source of existing value (245m, 2013): Haihe River Water-conservancy Commission
* Data source of planning goal (300m, 2020): Master Plan for Tianjin (2011-2020)

[2] P_2 (River feature): By referencing the standard of "physical character assessment" of *Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers* (Barbour et al. 1999) and considering Chinese actual situation.

* Description of planning goal (2020): Sectoral Plan for River and Lake System in Tianjin (2008-2020)

[3] P_3 (Water quality): In accordance with the existing local technical standard *Environmental Quality Standards for Surface Water* (GB3838, 2002).

* Description of planning goal (2020): Water Functional Zoning Plan for Haihe River Basin, Tianjin (2009-2020).

[4] P_4 (Riverbank stability): By referencing the standard of "physical character assessment" of *Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers* (Barbour et al. 1999) and considering Chinese actual situation.

* Description of planning goal (2020): Sectoral Plan for River and Lake System in Tianjin (2008-2020).

[5] P_5 (Green areas per capita): * Data source of past value (6 m²/person, 2001): Tianjin Planning Bureau
* Data source of existing value (11 m²/person, 2014): Tianjin Planning Bureau
* Data source of planning goal (12 m²/person, 2020): Master Plan for Tianjin (2011-2020)

[6] P_6 (Green coverage ratio): * Data source of past value (24%, 2001): City and Garden Management Commission of Tianjin
* Data source of existing value (35%, 2014): City and Garden Management Commission of Tianjin
* Data source of planning goal (48%, 2020): Master Plan for Tianjin (2011-2020)

[7] P_7 (Native plants index): * Data source of past value (0.5, 2000): City and Garden Management Commission of Tianjin
* Data source of existing value (0.6, 2013): City and Garden Management Commission of Tianjin
* Data source of planning goal (0.8, 2020): Sectoral Plan for Green System in Tianjin (2014-2020)

[8] P_8 (Recovery rate of degraded lands): * Data source of past value (75%, 2000): Tianjin Environmental Protection Bureau
* Data source of existing value (85%, 2013): Tianjin Environmental Protection Bureau
* Data source of planning goal (90%, 2020): Water Pollution Prevention Plan for Haihe River Basin (2011-2015)

[9] P_9 (Centricity): * Description of planning goal (2020): Master Plan for Tianjin (2011-2020)

[10] P_{10} (Compactibility): * Description of planning goal (2020): Master Plan for Tianjin (2011-2020)

[11] P_{11} (Population density): * Data source of past value (4.54 million persons, 2001): Tianjin Statistic Yearbook
* Data source of existing value (5.9 million persons, 2014): Tianjin Statistic Yearbook
* Data source of planning goal (7.1 million persons, 2020): Master Plan for Tianjin (2011-2020)

[12] P_{12} (Tertiary Industry per GDP): * Data source of past value (38%, 2001): Tianjin Development and Reform Commission
* Data source of existing value (55%, 2014): Tianjin Development and Reform Commission
* Data source of planning goal (60%, 2020): Sectoral Plan for Industrial System in Tianjin (2009-2020)

[13] P_{13} (Jobs-housing balance ratio): * Data source of past value (37%, 2001): Tianjin Statistic Bureau
* Data source of existing value (47%, 2013): Tianjin Statistic Bureau
* Data source of planning goal (55%, 2020): Sectoral Plan for Industrial System in Tianjin (2009-2020)

[14] P_{14} (Building density): * Data source of past value (45%, 2000): Regulatory Detailed Plan for Haihe Riverside Region (2002)
* Data source of existing value (42%, 2013): Tianjin Urban & Rural Construction Commission
* Data source of planning goal (35%, 2020): Tianjin Urban & Rural Construction Commission

[15] P_{15} (Building enclosure degree): * Description of planning goal (2020): Regulatory Detailed Plan for Haihe Riverside (2002)

[16] P_{16} (Open space ratio): * Data source of past value (31%, 2001): City and Garden Management Commission of Tianjin
* Data source of existing value (37.8%, 2014): Tianjin Planning Bureau
* Data source of planning goal (40%, 2020): Sectoral Plan for Green System in Tianjin (2014-2020)

[17] P_{17} (Open space connectivity): * Description of planning goal (2020): Sectoral Plan for Green System in Tianjin (2014-2020)

[18] P_{18} (Green travel ratio): * Data source of past value (41%, 2001): Tianjin Municipal Transportation Commission
* Data source of existing value (51%, 2014): Tianjin Planning Bureau
* Data source of planning goal (65%, 2020): Sectoral Plan for Comprehensive Transportation

System in Tianjin (2010-2020)

[19] P_{19} (Green travel quality): * Description of planning goal (2020): Sectoral Plan for Comprehensive Transportation System in Tianjin (2010-2020)

[20] P_{20} (Density of slow-travel system): * Data source of past value (7 km/km², 2000): Tianjin Municipal Transportation Commission
* Data source of existing value (10.5km/km², 2013): Tianjin Municipal Transportation Commission
* Data source of planning goal (12km/km², 2020): Sectoral Master Plan for Comprehensive Transportation System in Tianjin (2010-2020)

[21] P_{21} (Average commuting time): * Data source of past value (60 min, 2001): Tianjin Municipal Transportation Commission
* Data source of existing value (45 min, 2013): Tianjin Municipal Transportation Commission
* Data source of planning goal (30 min, 2020): Sectoral Master Plan for Comprehensive Transportation System in Tianjin (2010-2020)

[22] P_{22} (Energy efficiency): * Description of planning goal (2020): Clean Energy Action Plan for Tianjin (2002-2020)

[23] P_{23} (Utilization rate of renewable energy): * Data source of past value (5%, 2001): Tianjin Development and Reform Commission
* Data source of existing value (11.5%, 2014): Tianjin Development and Reform Commission
* Data source of planning goal (15%, 2020): Sectoral Plan for Industrial System in Tianjin (2008-2020)

[24] P_{24} (Unconventional water availability): * Data source of past value (15%, 2001): Tianjin Environmental Protection Bureau
* Data source of existing value (25%, 2014): Tianjin Environmental Protection Bureau
* Data source of planning goal (30%, 2020): Tianjin "13th Five-Year Plan" For Environmental Protection (2015-2020)

[25] P_{25} (Sewage treatment rate): * Data source of past value (75%, 2001): Tianjin Environmental Protection Bureau
* Data source of existing value (90%, 2013): Tianjin Environmental Protection Bureau
* Data source of planning goal (95%, 2020): Tianjin "13th Five-Year Plan" For Environmental Protection (2015-2020)

[26] P_{26} (Repetition rate of industrial water): * Data source of past value (75%, 2000): Tianjin Water Administration
* Data source of existing value (92.2%, 2013): Tianjin Water Administration
* Data source of planning goal (90%, 2020): Sectoral Plan for Industrial System in Tianjin (2009-2020)

Appendix VII Acquisition of membership degree of indicators

- Contributed to the contents of Section 6.3.3

Questionnaire for obtaining membership degree of qualitative indicators

> This questionnaire would be greatly contributed to my individual doctoral research. Please fill it out based on your professional knowledge and objective stance according to the following instructions.
> I highly appreciate your help and support! In case there are questions, do not hesitate to contact me!

1 The purpose of this survey

This survey is to continue previous case study of Haihe riverside region, in which the membership degree of 9 qualitative indicators is expected to be acquired in terms of existing low-carbon index system. This survey is being operated based on the method of Fuzzy Comprehensive Evaluation (FCE).

2 Instructions of questionnaire

- Factor Set and Evaluation Set (qualitative indicators)

The factor set “U” and evaluation set “V” of low-carbon indicators have been established by continuing previous survey.

The qualitative indicators of this factor set which serve as the evaluation objects are extracted corresponding to the five-level graded evaluation criterion (evaluation set).

- Explanation

The upper limit value (“very good”) is derived from the description of this indicator in terms of its planning goal——its expected status in the year 2020 from various current running plans in Tianjin. It means this indicator is supposed to achieve such a status till 2020, when currently equaling to or exceeding it can be said “very good”.

Please see the **form below**, in terms of each vertical qualitative indicator please **make a judge** regarding its **present status** (2014) according to the corresponding horizontal description of five-level graded criterion. In case you think one description of this indicator fits with its current status, please make **boldface**.

Table: Graded evaluation criterion of qualitative indicators

	Very low	Low	Medium	good	Very good
River feature	Serious channelization of the bank and riverbed ; Channel completely straight	Extensive channelization of the bank; Channel mostly straight	Some channelization Present; channel partly straight	A little bit channelization; channel marginally straight	No obvious channelization, river in natural pattern; channel in curved pattern
Water quality	Seriously polluted, no possible use	Polluted in terms of drinking water standard, only for agricultural use	Partly polluted in terms of drinking water standard, only for industrial and landscape use	Partly polluted in terms of drinking water standard, for fishery use	A little polluted in terms of drinking water standard, spare drinking water source use
Riverbank stability	Very Unstable; 80%-100% erosion;	Unstable; 50%-80% erosion;	A little bit unstable, 20%-50% erosion;	Stable, less than 20% erosion;	well stable, less than 5% erosion;
Centricity	One main urban center	Two main urban centers with a few sub-area centers	Two main urban centers with multiple sub-area centers	Three main urban centers with a few sub-area centers	Three main urban centers with multi sub-area centers
Compactibility	Low density and intensity of service facilities, single land use around traffic nodes	Low density, mixed land use and intensity of service facilities around traffic nodes	Medium density, mixed land use and intensity of service facilities around traffic nodes	A little high density, mixed land use and intensity of service facilities around traffic nodes	High density, mixed land use and intensity of service facilities around traffic nodes
Building enclosure degree	Inpermeable urban form along the river, isolation between buildings and open spaces	Low permeable urban form along the river, medium integration between buildings and open spaces	Medium Permeable urban form along the river, medium integration between buildings and open spaces	Permeable urban form along the river, a little high integration between buildings and open spaces	Good permeable urban form along the river, high integration between buildings and open spaces
Open space connectivity	Poor systematic, isolated, no obvious relation with the river	Basic systematic, partly connection with the river system	Moderate systematic, medium connection with the river system	Good systematic, suboptimal connection with the river system	Highly systematic, good connection with the river system
Green Travel quality	Unbearable travel and transfer, very crowed environment	Bearable travel and transfer, crowed environment	Medium travel and transfer, medium environment	Comfortable travel and transfer, loose environment	Very comfortable travel and transfer, loose environment
Energy efficiency	Dissatisfactory Decarburization, Decentralization and Demand reduction	A little Decarburization, Decentralization and Demand reduction	Normal Decarburization, Decentralization and Demand reduction	Decarburization, Decentralization and Demand reduction	High Decarburization, Decentralization and Demand reduction

Results of membership degree of qualitative indicators

For each qualitative indicator, the degree of membership is derived from above questionnaire survey from 20 judges ("think-tank" resource base) and calculation the result of proportion in terms of respective graded standard.

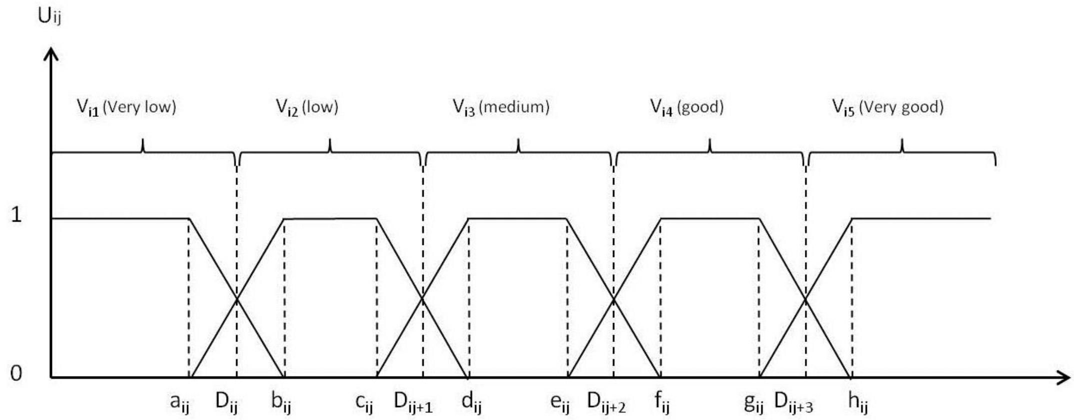
For one example, in terms of the qualitative indicator "river feature", according to the evaluation set "V" 20 judges have participated the evaluation, in which 2 judgments are "very good" (10%), 10 judgments are "good" (50%), and 8 judgments are "medium" (40%), the membership degree and also single-factor evaluation matrix of this indicator is: R=[0 0 0.4 0.5 0.1].

Table: Membership degree of qualitative indicators

	Very low	Low	Medium	good	Very good
P_2: River feature	0	0	0.4	0.5	0.1
P_3: Water quality	0	0.05	0.55	0.4	0
P_4: Riverbank stability	0	0	0.55	0.25	0.2
P_9: Centricity	0	0.3	0.65	0.05	0
P_{10}: Compactibility	0	0.15	0.35	0.5	0
P_{15}: Building enclosure degree	0	0.1	0.65	0.25	0
P_{17}: Open space connectivity	0	0.55	0.45	0	0
P_{19}: Green Travel quality	0	0.45	0.5	0.05	0
P_{22}: Energy efficiency	0	0	0.35	0.55	0.1

Calculation of membership degree of quantitative indicators

- Calculation model of membership degree of fuzzy set model



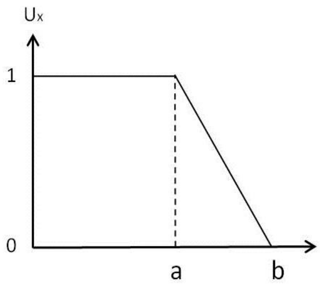
The hypothesis of the fuzzy boundary points (a_{ij}, b_{ij}, c_{ij}, d_{ij}) is:

$$\frac{b_{ij} - D_{ij}}{D_{ij+1} - D_{ij}} = \frac{D_{ij+1} - C_{ij}}{D_{ij+1} - D_{ij}} = 0.2$$

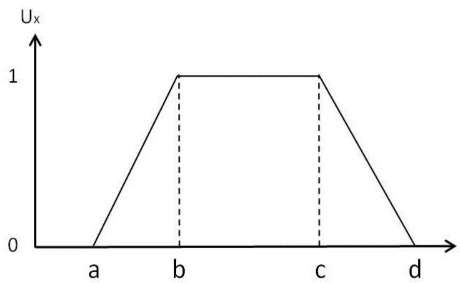
Formula: $a_{ij}=D_{ij}-0.2 * (D_{ij+1}-D_{ij})$; $b_{ij}=D_{ij}+0.2 * (D_{ij+1}-D_{ij})$;

$c_{ij}=D_{ij+1}-0.2 * (D_{ij+1}-D_{ij})$; $d_{ij}= D_{ij+1}+0.2 * (D_{ij+1}-D_{ij})$

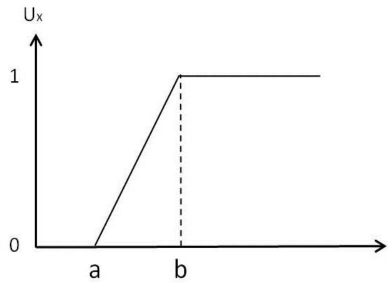
When $x=D_{ij}$, $U_{ij}=0.5$



①Right semi--trapezoid distribution function



③Trapezoid distribution function



② Left semi--trapezoid distribution function

$$U_{(x)} = \begin{cases} 1 & x<a \\ \frac{b-x}{b-a} & a \le x \le b \\ 0 & b<x \end{cases} \quad ①$$

$$U_{(x)} = \begin{cases} 0 & x<a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1 & b<x \end{cases} \quad ②$$

$$U_{(x)} = \begin{cases} \frac{x-a}{b-a} & a \le x < b \\ 1 & b \le x < c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & x<a \text{ or } d<x \end{cases} \quad ③$$

■ Calculation process

The upper limit value (D_4: “very good”) of quantitative indicator is taken from the specific value in terms of its planning goal in the year 2020. It means this indicator is supposed to achieve such a quantitative value in 2020, when nowadays equaling to or even exceeding it can be called as “very good”. While the lower limit value (D_1: “very low”) is taken from the past value of this indicator in the year 2001. It means currently this indictor is supposed to be better improved when compared to its previous status in 2001 because of intervention actions, otherwise in case no change or even worse, it can be called as “very low”. All the data source and values can be seen in Appendix VI.

Then, based on the collected present value of indicator (2013 or 2014) and according to the calculation model and formula present above, the membership degree of quantitative indicators can be obtained.

Table: specific values of quantitative indicators in calculation model

	a	D_1	b	c	D_2	d	e	D_3	f	g	D_4	h	Present value
P_1: River corridor width (m)	140	150	160	190	200	210	240	250	260	290	300	310	245
P_5: Green areas per capita (m^2)	5.6	6	6.4	7.6	8	8.4	7.6	10	10.4	11.6	12	12.4	11

P_6: Green coverage ratio (%)	22.4	24	25.6	30.4	32	33.6	38.4	40	41.6	46.4	48	49.6	35
P_7: Native plant index	0.48	0.5	0.52	0.58	0.6	0.62	0.68	0.7	0.72	0.78	0.8	0.82	0.6
P_8: Recovery rate of degraded lands (%)	74	75	76	79	80	81	84	85	86	89	90	91	85
P_{11}: Population density (persons/ km²)	6463	6675	6887	7488	7735	7982	8685	8970	9255	10075	10397	10717	8676
P_{12}: Tertiary Industry per GDP (%)	36.6	38	39.4	43.4	45	46.6	51.6	53	54.4	58.6	60	61.4	55
P_{13}: Jobs-housing balance ratio (%)	35.8	37	38.2	41.8	43	44.2	47.8	49	50.2	53.8	55	56.2	47
P_{14}: Building density (%)	45.8	45	44.2	41.6	41	40.4	38.6	38	37.4	35.6	35	34.4	42
P_{16}: Open space ratio (%)	25.4	31	31.6	33.4	34	34.6	36.4	37	37.6	39.4	40	40.6	37.8
P_{18}: Green travel ratio (%)	39.4	41	42.6	47.4	49	50.6	55.4	57	58.6	63.4	65	66.6	51
P_{20}: Density of slow-travel system (km/ km²)	6.68	7	7.32	8.26	8.6	8.94	9.96	10.3	10.64	11.66	12	12.34	10.5
P_{21}: Average commuting time (min)	62	60	58	52	50	48	42	40	38	32	30	28	45
P_{23}: Utilization rate of renewable energy (%)	4.4	5	5.6	7.2	8	8.8	11.4	12	12.6	14.4	15	15.6	11.5
P_{24}: Unconventional water availability (%)	14	15	16	19	20	21	24	25	26	29	30	31	25
P_{25}: Sewage treatment rate (%)	73.6	75	76.4	80.6	82	83.4	87.8	89	90.2	93.8	95	96.2	90
P_{26}: Repetition rate of industrial water (%)	74	75	76	79	80	81	84	85	86	89	90	91	92.2

Appendix VIII Final evaluation result

- Contributed to the contents of Section 6.3.3
- Single-factor evaluation matrix

$$R=\begin{bmatrix}R_1\\R_2\\R_3\\R_4\\R_5\\R_6\\R_7\\R_8\\R_9\\R_{10}\\R_{11}\\R_{12}\\R_{13}\\R_{14}\\R_{15}\\R_{16}\\R_{17}\\R_{18}\\R_{19}\\R_{20}\\R_{21}\\R_{22}\\R_{23}\\R_{24}\\R_{25}\\R_{26}\end{bmatrix}=\begin{bmatrix}0 & 0 & 0.75 & 0.25 & 0\\0 & 0 & 0.4 & 0.5 & 0.1\\0 & 0.05 & 0.55 & 0.4 & 0\\0 & 0 & 0.55 & 0.25 & 0.2\\0 & 0 & 0 & 1 & 0\\0 & 0 & 1 & 0 & 0\\0 & 0.5 & 0.5 & 0 & 0\\0 & 0 & 0.5 & 0.5 & 0\\0 & 0.3 & 0.65 & 0.05 & 0.1\\0 & 0.15 & 0.35 & 0.5 & 0\\0 & 0 & 1 & 0 & 0\\0 & 0 & 0 & 1 & 0\\0 & 0 & 1 & 0 & 0\\0 & 1 & 0 & 0 & 0\\0 & 0.1 & 0.65 & 0.25 & 0\\0 & 0 & 0 & 1 & 0\\0 & 0.55 & 0.45 & 0 & 0.1\\0 & 0 & 1 & 0 & 0\\0 & 0.45 & 0.5 & 0.05 & 0\\0 & 0 & 0.2058 & 0.7942 & 0\\0 & 0 & 1 & 0 & 0\\0 & 0 & 0.35 & 0.55 & 0.1\\0 & 0 & 0.9166 & 0.0834 & 0\\0 & 0 & 0.5 & 0.5 & 0\\0 & 0 & 0.0833 & 0.9167 & 0\\0 & 0 & 0 & 0 & 1\end{bmatrix}$$

- Fuzzy resulting vector B

$$B=W*R=[W_1,W_2,\dots W_n]*\begin{bmatrix}r_{11} & r_{12} & \dots & r_{1m}\\r_{21} & r_{22} & \dots & r_{2m}\\\dots & \dots & \dots & \dots\\r_{n1} & r_{n2} & \dots & r_{nm}\end{bmatrix}$$

B_1=[0, 0.0143, 0.5490, 0.3196, 0.1172] B_2=[0, 0.0391, 0.3984, 0.5626, 0]
B_3=[0, 0.1571, 0.5561, 0.2869, 0] B_4=[0, 0.4280, 0.2737, 0.2983, 0]
B_5=[0, 0.0926, 0.6727, 0.2347, 0] B_6=[0, 0, 0.3199, 0.4642, 0.2159]

- Transfer to hundred-mark score system D

For B_1: D= [0, 0.0143, 0.5490, 0.3196, 0.1172] * [10, 30, 50, 70, 90]=60.799
For B_2: D= [0, 0.0391, 0.3984, 0.5626, 0] * [10, 30, 50, 70, 90]=60.475
For B_3: D= [0, 0.1571, 0.5561, 0.2869, 0] * [10, 30, 50, 70, 90]=52.601
For B_4: D= [0, 0.4280, 0.2737, 0.2983, 0] * [10, 30, 50, 70, 90]=47.406
For B_5: D= [0, 0.0926, 0.6727, 0.2347, 0] * [10, 30, 50, 70, 90]=52.842
For B_6: D= [0, 0, 0.3199, 0.4642, 0.2159] * [10, 30, 50, 70, 90]=67.915

For A1: D= [0.3467, 0.6533] * [60.799, 60.475]=60.587
For A2: D= [0.4175, 0.0955, 0.2752, 0.1578] * [52.601, 47.406, 52.842, 67.915]=51.747

Appendix IX Designed Questionnaire for the second-wave semi-structured interview

■ Contributed to the contents of Section 6.5.3

In terms of the mechanism of planning approach guiding implementation in Tianjin, I would like to consult following topics, please offer your help. Thank you!

一 **Planning preparation:**

- Who set the planning goals of various qualitative and quantitative indicators?
- What are the main scientific basis (methods), value orientation and factors to be considered in making such planning goals?
- Who can assess the rationality of planning goals?
- To what extent the planning goals can adapt to the local objective development tendency, based on your opinion?
- In case the planning goal cannot be reached in the stipulated planning period (2020), what to do?
- In case the planning goals have been achieved in advance, what to do?
- How do you think our current planning system in Tianjin, in terms of its strengths and weakness?

一 **Planning process**

- Which type of contradictions normally existing among planning elements (e.g. land use, green space, transportation, infrastructure)?
- When there are contradictions of planning contents, which would be the basis in terms of guiding corresponding intervention actions?
- Who take the responsibility for coordinating contradictions?
- Who makes the final decision and what are the criteria for weighting?

- Besides your side, is there other key actor group involved in planning process?
- How the actors can know about the planning results and convey opinions?
- When there are different opinions, how to coordinate?
- What are the main problems you confronted in planning (management) process?

— **Planning implementation**

- In what degree are the actions (projects) implemented in this region really consistent with planning outcomes?
- What is the main kind of inconsistences of projects in reality when compared to their plans?
- What are the causes of those inconsistences?
- What are the potential impacts of such inconsistences and how to further handle?
- Who take the responsibility for supervising the actual implementation of projects according to planning outcomes?
- Who take the responsibility for supervising the actual implementation of projects according to planning outcomes?
- Through what procedure can the planning outcomes be recognized by the society, and afterwards they can do what?
- What are other main problems in terms of implementing projects according to planning outcomes, from a management perspective?

References

Akbari, H. (2002). Shade Trees Reduce Building Energy Use and CO_2 Emissions from Power Plants. *Environmental Pollution*, 116, pp.119-126.

Alberti, M. (2008). *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*. New York: Springer Verlag.

Barles, S. (2007). Urban Metabolism and River Systems: an Historical Perspective—Paris and the Seine, 1790–1970. *Hydrology and Earth System Sciences*, 11(7), pp.1757-1769.

Beatley, T. (2000). *Green Urbanism: Learning From European Cities*. Washington, DC: Island Press.

Bhiwapurkar, P. (2013). *Determinants of Urban Energy Use: Density and Urban Form*. Proceedings of Architectural Research Center Consortium Conference 2013: The Visibility of Research, pp.608-616.

Black, T. A. & Harden, J.W. (1995). Effect of Timber Harvest on Soil Carbon Storage at Blodgett Experimental Forest, California. *Canadian Journal of Forest Research*, 25(8), pp.1385-1396.

Boston Landmarks Commission Study Report. (1989). *Emerald Necklace Parks: Jamaica Pond, Olmsted Park and the Riverway*. City of Boston. http://www.cityofboston.gov/images_documents/142%20Emerald%20Necklace%20Parks_tcm3-39660.pdf

Bowler, D. E., Buyung-Ali, L. & Knight, T. M., et al. (2010). Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence. *Landscape and Urban Planning*, 97, pp.147-155.

Burney, S. M. A. (2008). *Inductive & Deductive Research Approach*. Department of Computer Science. University of Karachi. http://www.drburney.net/INDUCTIVE%20&%20DEDUCTIVE%20RESEARCH%20APPROACH%2006032008.pdf

Carmona, M., Heath, T. & Oc, T., et al. (2003). *Public Places-Urban Spaces: The Dimensions of Urban Design*. Translated by Feng, J., Yuan, Y. & Fang, Q., et al. (2005). Nanjing: Jiangsu Science and Technology Press.

Cervero, R. (1989). Jobs-Housing Balancing and Regional Mobility. *Journal of the American Planning Association*, 55(2), pp.136-150.

Cervero, R & Kockelman, K. (1997). Travel Demand and the 3Ds: Density, Diversity and Design. *Transportation Research*, 2(3), pp.199-219.

Chang, N. B., Chen, H. W. & Ning, S. K. (2001). Identification of River Water Quality Using the Fuzzy Synthetic Evaluation approach. *Journal of Environmental Management*, 63, pp.293-305.

Chen, Y. G. (2011). *Mathematical Methods for Geography: Basis and Application*. Beijing: Science Press.

Cullingworth, B. & Nadin, V. (2006). *Town and Country Planning in the UK*. Fourteenth edition. London: Routledge.

Darido, G., Montoya, M. T. & Mehndiratta, S. (2009). *Urban Transportation and Carbon Dioxide Emissions: Characteristics of Chinese Cities*. Working Paper for the World Bank, pp.5.
http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/07/21/000334955_20100721034450/Rendered/PDF/557730WP0CHINE0June020090EN005jan10.pdf

Davidson, M. (2009). Urban Geography—Waterfront Development. In: N. Thrift & R. Kitchen (eds). *International Encyclopedia of Human Geography*. Oxford: Elsevier.
http://wordpress.clarku.edu/mdavidson/files/2012/03/Waterfront.pdf

Davies, Z. G., Edmondson, J. L. & Heinemeyer, A., et al. (2011). Mapping an Urban Ecosystem Service: Quantifying Above-ground Carbon Storage at a City-wide Scale. *Journal of Applied Ecology*, 48(5), pp.1125-1134.

de Vaus, D. A. (2001). *Research Design in Social Research*. London: Sage Publications.

Denis, R. & Nash, I. (2012). Desktop Study: the Un-exploited Resource. *World Pipelines Magazine*, (3).
http://www.fugrogeoconsulting.com/news-and-events/210931/fugro-desktop-study-article

Dhakal, S. (2010). GHG Emissions from Urbanization and Opportunities for Urban Carbon Mitigation. *Current Opinion in Environmental Sustainability*, 2(4), pp.277-283.

Dong, Z. J. (2010). The Territorial Planning under the Concept of Low Carbon. *Urban Studies*, 17 (7), pp.1-5.

Dramstad, W. E., Olson, J. D. & Forman, R. T. T. (1996). *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning*. Washington: Harvard University Press and Island Press.

European Environment Agency (EEA) Technical Report. (2013). Achieving

Energy Efficiency through Behaviour Change: What Does It Take?, (5), pp.8-27. http://dalengroup.com/wp-content/uploads/2013/04/RESOURCES-Achieving-energy-efficiency-through-behaviour-change.pdf

Fathejalali, A. & Masoudi, M. (2011). *Corridor Plans: An Opportunity to Develop Low Carbon Open. Spaces Network-The Case Study in Tehran, Iran*. Contribution of the 47th ISOCARP Congress 2011. http://www.isocarp.net/Data/case_studies/1902.pdf

Federal Interagency Stream Restoration Working Group (FISRWG). (1998). *Stream Corridor Restoration: Principles, Processes, and Practices*. USDA-Natural Resources Conservation Service. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044574.pdf

Feng, Z. J. & Zhou, R. (2010). Low Carbon Economy: A Basic Path to Green Development. *China Population, Resources and Environment*, 20(4), pp.1-7.

Forman, R. T. T. (1983). Corridors in Landscape: Their Structure and Function. *Ekologia*, 2(4), pp.375-387.

Forman, R. T. T. & Godron, M. (1986). *Landscape Ecology*. Newyork: Wiley.

Forman, R. T. T. (1995). Some General Principles of Landscape and Regional Ecology. *Landscape Ecology*, 10(3), pp.133-142.

Friesecke, F., Schetke, S. & Kötter, T. (2012). *Urban Planning for Climate Change – Position Paper of Working Group 8.1*. FIG Working Week 2012—Knowing to manage the territory, protect the environment, evaluate the cultural heritage. Rome. http://www.fig.net/resources/proceedings/fig_proceedings/fig2012/papers/ts07g/TS07G_friesecke_schetke_et_al_6025.pdf

Fürsta, D. & Kilperb, H. (1995). The Innovative Power of Regional Policy Networks: A Comparison of Two Approaches to Political Modernization in Northrhine-Westfalia. *European Planning Studies*, 3(3), pp.287-304.

Glaeser, E. L. & Kahn, M. E. (2003). Sprawl and Urban Growth. In: J. V. Henderson & J. F. Thisse (eds.). *Handbook of regional and urban economics* (pp.2481-2527). Elsevier: Amsterdam.

Glaeser, E. L. & Kahn, M. E. (2010). The Greenness of Cities: Carbon Dioxide Emissions and Urban Development. *Journal of Urban Economics*, 67(3), pp.404-418.

Golley, F. B. (1998). *A Primer for Environmental Literacy*. New Haven: Yale University Press.

Goulias, K. G. (1997). *Surveys Using Multiple Approaches*. Resource Paper for Workshop on Multi-method and Multi-instrument Surveys. TRB Transportation Research Circular E-C008: Transport Surveys: Raising the Standard. Proceedings of an International Conference on Transport Survey Quality and Innovation. http://onlinepubs.trb.org/onlinepubs/circulars/ec008/workshop_a.pdf

Grazi, F., Bergh, J. C. J. M. & Ommeren, J. N. (2008). An Empirical Analysis of Urban Form, Transport, and Global Warming. *The Energy Journal*, 29(4), pp.97-117.

Grohè, T. & Kunzmann, K. R. (1999). The International Building Exhibition Emscher Park: Another Approach to Sustainable Development. In: N. Lutzky., et al. *Strategies for Sustainable Development of European Metropolitan Regions*. European Metropolitan Regions Project. Evaluation Report. Urban 21: Global Conference on the Urban Future.

Groth, P., Miller, R. & Nadkarni, N., et al. (2008). Quantifying the Greenhouse Gas Benefits of Urban Parks. Prepared for The Trust for Public Land White Paper. San Francisco.
http://cloud.tpl.org/pubs/benefits_greenhouse_gases_and_parks_whitepaper.pdf

Gruehn, D. (2013) a. *Paradigm Shift in the Ruhr Region: From Industry to Innovation- From Grey to Green*. Contribution of Scientific Conference on Spatial Transformation Processes in Central Europe in XXI Century. Faculty of Geography, Taras. Shevchenko National University of Kyiv, Kiev (Ukraine), pp.26-31.
http://geokyiv.org/pdf/reports/3_Gruehn.pdf

Gruehn, D. (2013) b. *Planning Smarter Cities towards a Better Quality of Life*. Presentation at the 2013 International Conference on Smarter Cities, University of the Philippines, November 2013, Manila.

Hospers, G. J. (2004). Restructuring Europe's Rustbelt: The Case of the German Ruhrgebiet. *Intereconomics: Review of European Economic Policy,* 39, pp.147-156.

Hoyer, J., Wolfgang, D. & Kronawitter, L., et al. (2011). *Water Sensitive Urban Design—Principles and Inspiration for Sustainable Stormwater Management in the City of the Future*. Berlin: jovis Verlag GmbH.

Hsu, C. C. & Sandford, B. A. (2007). The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation*, 12(10).
http://pareonline.net/pdf/v12n10.pdf

Integrated Transport Research Center of China (ITRCC). (2009). *Energy Consumption, Emissions and their Comparison among Different Transport Modes*. Beijing Jiaotong University.
http://www.efchina.org/Attachments/Report/reports-efchina-20110317-1-zh/2009_BJU_%E4%B8%8D%E5%90%8C%E4%BA%A4%E9%80%9A%E6%96%B9%E5%BC%8F%E8%83%BD%E8%80%97%E4%B8%8E%E6%8E%92%E6%94%BE%E5%9B%A0%E5%AD%90%E5%8F%8A%E5%85%B6%E5%8F%AF%E6%AF%94%E6%80%A7%E7%A0%94%E7%A9%B6.pdf

Intergovernmental and Legal Affairs, Climate Change Secretariat. (2006). *United Nations Framework Convention on Climate Change (UNFCCC): Handbook*. Bonn: Climate Change Secretariat.
http://unfccc.int/resource/docs/publications/handbook.pdf

Intergovernmental Panel on Climate Change (IPCC). (2007 a). *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

Intergovernmental Panel on Climate Change (IPCC). (2007 b). *Climate Change 2007: Synthesis Report*. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Switzerland: Geneva.
https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

Intergovernmental Panel on Climate Change (IPCC). (2013). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Groups I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Switzerland: Geneva.
https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SummaryVolume_FINAL.pdf

Japanese River Management Center. (1994). *Design Ideas and Practices of Waterfront Natural Landscape*. Translated by: Liu, Y. J. (2004). Beijing: China Architecture & Building Press.

Jiang, W. G., Deng, L. & Chen, L. Y., et al. (2009). Risk Assessment and Validation of Flood Disaster based on Fuzzy Mathematics. *Progress in Natural Science*, 19, pp.1419-1425.

Jo, H. K. (2002). Impacts of Urban Greenspace on Offsetting Carbon Emissions for Middle Korea. *Journal of Environmental Management*, 64, pp.115-126.

Karakiewicz, J. (2011). Urban Metabolism of Low Carbon Cities. Contribution of 47th ISOCARP Congress 2011.
http://www.isocarp.net/Data/case_studies/1874.pdf

Kennedy, C. A., Cuddihy, J. & Engel-Yan, J. (2007). The Changing Metabolism of Cities. *Journal of Industrial Ecology*, 11(2), pp.43-59.

Kilper, H. (1999). *Die Internationale Bauausstellung Emscher Park : eine Studie zur Steuerungsproblematik komplexer Erneuerungsprozesse in einer alten Industrieregion*. Opladen: Leske + Budrich.

Konijnendijk, C. C., Nilsson, K. & Randrup, Th.B., et al. (2005). *Urban Forests and Trees*. New York: Springer Verlag.

Kunzmann, K. R. (2004). Creative Brownfield Redevelopment: The Experience of the IBA Emscher Park Initiative in the Ruhr in Germany. In: Greenstein, Roslalind and Yesim Sungu-Eryilmaz (eds). *Recycling the City: The Use and Reuse of Urban Land* (pp.201-217). Cambridge: Lincoln Institute of Land Policy.

Kunzmann, K. R. (2010). *Industrial Heritage: an Asset for Structural Change in Old Industrial Regions—The Ruhr in Germany 10 Years after the IBA Emscher Park*. Contribution of International Symposium: A History and a Future Industrial Heritage for the Whole World. Sesto San Giovanni. http://www.sestosg.net/convegno_unesco/KUNZMANN_PDF.pdf

LaBelle, J. (2001). Emscher Park, Germany — Expanding the Definition of a "Park". *Crossing Boundaries in Park Management: Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands* (pp.222-227). Michigan: The George Wright Society.

Lang, J. (1994). *Urban Design: The American Experience*. Translated by Wang, C. P. & Hu, L. J. (2008). Beijing: China Architecture & Building Press.

Langner, S. (2011). Landschaftsmaschine—Landschaftsproduzierende Kräfte im Ruhrgebiet. In: C. Reicher, K. R. Kunzmann & J. Polívka., et al (eds.). *Schichten einer Region—Kartenstücke zur Räumlichen Struktur des Ruhrgebiets* (pp.138-139; 144-145). Berlin: ȷovis Verlag GmbH.

Lassiter, D. & Goodman, N. D. (2015). How Many Kinds of Reasoning? Inference, Probability, and Natural Language Semantics. *Cognition*, 136(3), pp123-134.

Lei, H. P., Zhuang, G. Y. & Zhang, C. (2011). *Diagnosing the Development of Chinese Low Carbon Cities—Strategies and Methods.* Beijing: China Environmental Science Press.

Lethmate, G. & Spiering, H. (2003). *Emscher Landscape Park - a New Regional Park in the Ruhr Area (Germany)*. Contribution of the International Symposium on Metropolitan and Periurban Natural and Rural Spaces—The System of Open Spaces in the Articulation of Metropolitan Areas (pp.45-50). Barcelona. http://www.forumtools.biz/Fedenatur/upload/ENG_III_Simposi.pdf

Li, L. (2008). The Compact Strategy of the EU Countries: Examples from the UK and Netherlands. *Urban Planning International*, 23(6), pp106-115.

Li, C. Z., Yu, F. L. & Qin, D. Y., et al. (2005). Health Fuzzy Comprehensive Evaluation for Rivers based on AHP Method. *Advances in Science and Technology of Water Resources*, 25(1), pp24-27.

Lin, D., Allan, A. & Cui, J. Q. (2013). Does Polycentric Urban Spatial Development

Lead to Less Commuting: A Perspective of Jobs-housing Balance. Contribution of the 49th ISOCARP Congress 2013.
http://www.isocarp.net/Data/case_studies/2382.pdf

Litman, T. (2002). The Costs of Automobile Dependency and the Benefits of Balanced Transportation. Victoria Transport Policy Institute.
http://vtpi.org/autodep.pdf

Liu, J. (1999). The Successful Cases of Urban Waterfront Redevelopment. *Urban Planning International*, 18(1), pp.36-38.

Long, W. D., Bai, W. & Liang, H., et al. (2010). Urban Form and Energy Version on Low-carbon Cities. *Building Science*, 26(2), pp.13-19.

Lu, B. & Sun, T. (2013). Study on Spatial Form Compactness from Low-carbon Perspective. *Geographical Research,* 32(6), pp.1057-1067.

Lucas, R., Vallentin, D. & Venjakob, J. (2013). Innovation as an Impetus for the Region. In: Wuppertal Institut für Klima, Umwelt, Energie GmbH. *Emscher 3.0: From Grey to Blue or, How the Blue Sky over the Ruhr Region Fell into the Emscher* (pp.98-124). Bönen: Verlag Kettler.

Ludwig, B. (1997). Predicting the future: Have you considered using the Delphi methodology? *Journal of Extension, 35* (5), pp.1-4.

Lu, L., Tian, Y. & Zhang, L., et al. (2011). Study on Low-carbon Assessment Indicator System of Urban Planning of Tianjin. *City Planning Review*, 35(1), pp.26-31.

Marshall, J. D. (2008). Energy-efficient Urban Form. *Environmental Science & Technology*, 42, pp.3133-3136.

McHarg, I. L. (1971). *Design with Nature*. Translated by: Rui, J. W. & Ni, W. Y. (1992). Beijing: China Architecture & Building Press.

Monette, D. R., Sullivan, T. J. & DeJong, C. R. (2010). *Applied Social Research: A Tool for the Human Services*. Belmont: Brooks/Cole, Cengage Learning.

Münter, A. & Prossek, A. (2011). Handlungsräume und Raumbilder—Räumliche Muster von Regionalisierungen im Ruhrgebiet. In: C. Reicher, K. R. Kunzmann & J. Polívka., et al (eds.). *Schichten einer Region—Kartenstücke zur Räumlichen Struktur des Ruhrgebiets* (pp.186-187). Berlin: jovis Verlag GmbH.

Naiman, R. J. & Turner, M. G. (2000). A Future Perspective on North America's Freshwater Ecosystems. *Ecological Applications*, 10(4), pp.958-970.

Nave, L. E., Vance, E. D. & Swanston, C. W., et al. (2010). Harvest Impacts on Soil Carbon Storage in Temperate Forests. *Forest Ecology and Management*, 259, pp.857-866.

Newman, P. & Kenworthy, J. R. (1989). *Cities and Automobile Dependence: A Sourcebook*. Aldershot: Gower Technical.

Newman, P. W. G. (1999). Sustainability and Cities: Extending the Metabolism Model. *Landscape and Urban Planning*, 44, pp.219-226.

Oliveira, S., Andrade, H. & Vaz, T. (2011). The Cooling Effect of Green Spaces as a Contribution to the Mitigation of Urban Heat: A Case Study in Lisbon. *Building and Environment*, 46(11), pp.2186–2194.

Owens, S. (1986). *Energy, Planning and Urban Form*. London: Pion Ltd.

Pahl-Weber, E. & Henckel, D. (2008). *The Planning System and Planning Terms in Germany: A glossary*. Hanover: Akademie für Raumforschung und Landesplanung (ARL).
http://shop.arl-net.de/media/direct/pdf/ssd/ssd_7.pdf

Pan, H. X., Tang, Y. & Wu, J. X., et al. (2008). Spatial Planning Strategy for Low Carbon Cities in China. *Urban Planning Forum*, 178(6), pp.57–64.

Paoletti, E., Bardelli, T. & Giovannini, G., et al. (2011). Air Quality Impact of an Urban Park over Time. *Procedia Environmental Sciences*, 4, pp.10-16.

Peng, B. F., Shi, Y. S. & Wang, H. F., et al. (2013). The Impacting Mechanism and Laws of Function of Urban Heat Islands Effect. *Acta Geographica Sinica*, 68(11), pp.1461-1471.

Polívka, J. & Roost, F. (2011). Kerne, Adern und Ränder—Siedlungs- und Bebauungsstruktur des Ruhrgebiets. In: C. Reicher, K. R. Kunzmann & J. Polívka., et al (eds.). *Schichten einer Region—Kartenstücke zur Räumlichen Struktur des Ruhrgebiets* (pp.50-55; pp.61-67). Berlin: jovis Verlag GmbH.

Qiu, H. (2011). *Strategies of Low-carbon-oriented Urban Design*. Harbin: Harbin Institute of Technology.

Reicher, C., Niemann, L. & Uttke, A. (2008). *International Building Exhibition Emscher Park—The Projects 10 Years Later*. Essen: Klartext Verlag.

Reiss-Schmidt, S. (1990). Der Emscher Landschaftspark: Freiraumentwicklung im Rahmen der Internationalen Bauausstellung Emscher-Park als Beitrag zur ökologischen und ökonomischen Erneuerung. *Vermessung, Photogrammetrie, Kulturtechnik: VPK = Mensuration, photogrammétrie, génie rural*, 88(10), pp.586-591.

Robinson, K. J. (2003). Exploring Urban Ecosystems in the Ruhr Region of Germany: Implementation Strategies. Translated by Wang, H. H. (2003). *Urban Planning International*, 18(6), pp.3-25.

Rodriguez-Iturbe, I., Caylor, K. K. & Rinaldo, A. (2011). Metabolic Principles of River Basin Organization. *Proceedings of the National Academy of Sciences*, 108 (29), pp.11751-11755.

Rooney, J. J. & Vanden Heuvel, L. N. (2004). Root Cause Analysis for Beginners. Quality Progress, 37 (7), pp.45-53.

Saaty, T. L. & Vargas, L. G. (2000). *Models, Methods, Concepts and Applications of the Analytic Hierarchy Process*. Boston: Kluwer Academic Publishers.

Salian, P. & Anton, B. (2011). *The Emscher Region-The Opportunities of Economic Transition for Leapfrogging Urban Water Management*. Freiburg: ICLEI European Secretariat GmbH.
http://www.switchtraining.eu/fileadmin/template/projects/switch_training/files/Resources/Salian_2011_Leapfrogging_urban_water_management_for_economic_transition_-_Achievements_in_the_Emscher_Region.pdf

Schipper, L. & Meyers, S. (1993). *Energy Efficiency and Human Activity: Past Trends, Future Prospects.* Cambridge: Cambridge University Press.

Schäfer, A. (2012). *Introducing Behavioral Change in Transportation into Energy/Economy/Environment Models*. Policy Research Working Paper 6234 of the World Bank.
http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-6234

Schrödinger, E. (1967). *What is Life? The Physical Aspect of the Living Cell & Mind and Matter*. Cambridge: Cambridge University Press.

Shao, C. Y. (2009). The Implication of Fuzzy Comprehensive Evaluation Method in Evaluating Internal Financial Control of Enterprise. International Business Research, 2(1), pp.210-214.

Shaw, R. (2002). The International Building Exhibition (IBA) Emscher Park, Germany: A Model for Sustainable Restructuring? *European Planning Studies*, 10(1), pp.77-97.

Shaziman, S., Usman, I. M. S. & Tahir, M. (2010). *Waterfront as Public Space: Case Study—Klang River between Masjid Jamek and Central Market, Kuala Lumpur*. Contribution of the 6th WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD' 2010) and 3rd WSEAS International Conference on Landscape Architecture (LA' 2010). Politehnica University of Timisoara, Romania.
http://www.wseas.us/e-library/conferences/2010/TimisoaraP/EELA/EELA-56.pdf

Siedentop, S. (2010). Locating Sites for Locally Unwanted Land Uses: Successfully Coping with NIMBY Resistance. In: A. C. P. Filho & A. C. Pina (eds.). *Methods and Techniques in Urban Engineering* (pp43-59). Vukovar: InTech.

Simonds, J. O. (1978). *Earthscape: A Manual of Environmental Planning and Design*. Translated by: Cheng, L. R. (1990). Beijing: China Architecture & Building Press.

Stead, D & Marshall, S. (2001). The Relationships between Urban Form and Travel Patterns. *European Journal of Transport and Infrastructure Research*, 1(2), pp.113-137.

Strohbach, M. W., Arnold, E. & Haase, D. (2012). The Carbon Footprint of Urban Green Space—A Life Cycle Approach. *Landscape and Urban Planning*, 104, pp.220-229.

Sulzman, E. W. (2000). The Carbon Cycle. Contribution of Global Change Instruction Program of the University Corporation for Atmospheric Research. http://www.ucar.edu/communications/gcip/m2ccycle/m2pdf.pdf

Sun, P. & Wang, Z. F. (2000). The Natural Landscape of the River Design. *City Planning Review*, 34(9), pp.19-22.

Sun, Y. & Jiang, L. (2013). Energy Consumption Group of Urban Residents and Behavior Features. *Urban Problems*, 218(9), pp.95-99.

Thorne, R., Sankey, W. F. & Alexander, A. (2003). Transportation. In: R. Thomas. (eds). *Sustainable Urban Design: An Environmental Approach* (pp.21-31). London: Spon Press.

Tibaijuka, A. K. (2007). *The Future in our Hands: Addressing the Leadership Challenge of Climate Change*. Contribution of the United Nations Human Settlements Program. UN-HABITAT. New York. https://sustainabledevelopment.un.org/content/documents/habitat_2may_cc.pdf

Tong, H., Liu, H. Z. & Li, Y. M., et al. (2005). Actuality of Urban Summer Heat Island and the Impact of Urban Planning “Wedge-shaped Greenland” to reduce the Intensity of Urban Heat Island in Beijing. *Journal of Applied Meteorological Science*, 16(3), pp.357-365.

Town and Country Planning Association in conjunction with the Combined Heat and Power Association (TCPA & CHPA). (2008). *Community Energy—Urban Planning For a Low Carbon Future*. Oldham: RAP Spiderweb Ltd. http://www.tcpa.org.uk/data/files/ceg.pdf

Turner, M. G (1989). Landscape Ecology: the Effect of Pattern on Process. *Annual Review of Ecology and Systematics*, 20, pp.171-197.

Turner, M. G., Gardner. R. H. & O'Neill. R. V. (2001). *Landscape Ecology in Theory and Practice:Pattern and Process*. New York: Springer.

UK Government. (2003). *Energy White Paper—Our Energy Future: Create a Low Carbon Economy*. London: The Stationery Office.

http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file10719.pdf

United Nations Human Settlements Programme (UN-HABITAT). (2011). *Cities and Climate Change: Global Report on Human Settlements 2011*. London: Earthscan. pp.52-62.
http://www.zaragoza.es/contenidos/medioambiente/onu/538-eng-ed2011.pdf

United States Environmental Protection Agency (EPA). (2008). *Reducing Urban Heat Islands: Compendium of Strategies*. Chapter 1: Urban Heat Island Basics (pp.7-13).
http://www2.epa.gov/heat-islands/heat-island-compendium

van Hove, L.W.A., Steeneveld, G. J. & Jacobs, C. M. J., et al. (2011). *Exploring the Urban Heat Island Intensity of Dutch Cities*. Contribution of Alterra Report 2170. Wageningen. pp.19-32.
http://www.met.wau.nl/medewerkers/steeneveld/Hove_etal_CityWeathers-2011.pdf

Vermont (DEC) River Management Program (VRMP). (2005). *Defining River Corridors*. Fact Sheet (2).
http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_definingrcfactsheet.pdf

Vettorato, D. (2011). *Bridging Urban Morphology and Energy Performance Analysis —A Case Study within the Alpine Region*. Contribution of the 47th ISOCARP Congress 2011.
http://www.isocarp.net/data/case_studies/2012.pdf

Völker, S., Baumeister, H. & Classen, T., et al. (2013). Evidence for the Temperature-Mitigating Capacity of Urban Blue Space—A Health Geographic Perspective. *Erdkunde*, 67(4), pp.355-371.

Waisman, H., Guivarch, C. & Lecocq, F. (2013). The Transportation Sector and Low-carbon Growth Pathways: Modelling Urban, Infrastructure and Spatial Determinants of Mobility. *Climate Policy*, 13(1), pp.2-30.

Wang, J. G. (2004). *Urban Design*. Nanjing: Southeast University Press.

Wang, Q. (1992). *Applied Fuzzy Mathematics*. Beijing: Science and Technology Literature Press.

Wang, J. G. & Lv, Z. P. (2001). The Experiences and Process of Worldwide Waterfront Development. *City Planning Review*, 25(7), pp.41-46.

Wang, Y. & Gong, Y. B. (2003). Calculation method of Carbon and Oxygen Balance of Urban Green Areas. Ecological Economy, 3, pp.62.

Watson, B. G. & Bentley, I. (2007). Reinforcing Bostons Emerald Necklace. In: B. G. Waston & I. Bentley. *Identity by Design* (pp.209-234). Burlington: Elsevier Ltd.

Wegener, M. (2013). *Polycentric Europe: More Efficient, More Equitable and More*

Sustainable?. Contribution of the International Seminar on Welfare and Competitiveness in the European Polycentric Urban Structure: Which Role for Metropolitan, Medium and Small Cities?. Istituto Regionale Programmazione Economica dellaToscana (IRPET). Florence.
http://www.spiekermann-wegener.de/pub/pdf/MW_IRPET_161113.pdf

Wehling, H. W. (2007). Projekte der Städtebaulichen Erneuerung im Rahmen der Internationalen Bauausstellung Emscher Park. In: H. Heinz, K. Temliz & A. Mayr, et al. *Westfalen Regional-Aktuelle Themen*, *Wissenswertes und Medien über die Region Westfalen-Lippe* (pp.290-291). Münster: Geographische Kommission für Westfalen, Siedlung und Landschaft in Westfalen.
https://www.lwl.org/westfalen-regional-download/PDF/S290_EmscherPark.pdf

Word Bank. (2012). *Sustainable Low-Carbon City Development in China*. Edited by A. Baeumler, E. Ijjasz-Vasquez. & S. Mehndiratta. Washington DC.
http://siteresources.worldbank.org/EXTNEWSCHINESE/Resources/3196537-1202098669693/4635541-1335945747603/low_carbon_city_full_en.pdf

Wu, J. G. (2000). *Landscape Ecology—Pattern, Process, Scale and Hierarchy*. Beijing: Higher Education Press.

Wu, Z. X., Xie, X. J. & Wang, S. P. (2012). The Influence of Economic Development and Industrial Structure to Carbon Emission Based on China's Provincial Data. *Chinese Journal of Management Science*, 20(3), pp.161-165.

Yang, L. B. & Gao, Y. Y. (2006). *Rationale of Fuzzy Mathematics and Its Application*. Guangzhou: South China University of Technology Press.

Yang, Y. F. (2012). The Values and Meanings of the Waterfront Development in Chinese Cities during Economic Transformation. *Urban Planning International*, 27(2), pp.108-113.

Yao, R. M., Steemers, K. & Li, B. Z. (2006). *Sustainable Urban and Architectural Design*. Beijing: China Architecture & Building Press.

Yu, K. J. & Li, D. H. (2003). *The Way of Urban Landscape*. Beijing: China Architecture & Building Press.

Yu, Y. H., Zheng, X. Y. & Zhang, L. (2011). Carbon Dioxide Emission and Economic Development: A Panel Data Analysis. *Economic Theory and Business Management*, 79 (3), pp.72-80.

Yuan, J. C. & Zhang, L. L. (2013). *Ecological Thinking and Practices of European Riverfront Planning*. Beijing: China Architecture & Building Press.

Zhang, J. X. (2005). *The Western Urban Planning Thought*. Nanjing: Southeast University Press.

Zhang, L. J., Xu, Y. T. & Hou, H. M. (2014). Application of Fuzzy Comprehensive Evaluation to High-tech Enterprises Assessment. *Science and Technology Management Research*, 28(8), pp.56-59.

Zhang, Q. (2011). *Low-carbon Ecology and Urban Rural Planning*. Beijing: China Architecture & Building Press.

Zhao, C. J. & Liu, X. M. (2010). The Role of Urban Green System in Low-carbon City. *Chinese Landscape Architecture*, 26(6), pp.23-25.

Zhong, Y. G., Ge, Y. S. & Zhang, Q. H., et al. (2010). Correlation Analysis of Urban Scale and Carbon Emissions. *Modern Urban Research*, 25 (5), pp.65-69.

Zhou, G. S. (2003). *The Global Carbon Cycle*. Beijing: China Meteorological Press.

Zhou, L., Zhang, J. X. & Cui, S. P., et al. (2010). Eco-city Planning and Construction in Low-carbon Era. Beijing: China Architecture & Building Press.

Zhu, G. P., Wang, X. R. & Wang, M., et al. (2006). Research on Near-natural Comprehensive Control on Urban Rivers. *Science of Oil and Water Conservation*, 4(2), pp.92-97.

Zhu, Q., Yu, K. J. & Li, D. H. (2005). The Width of Ecological Corridor in Landscape Planning. *Acta Ecologica Sinica*, 25(9), pp.2407-2411.

Zimmerman, C. (2000). The Development of Scientific Reasoning Skills. *Developmental Review*, 20, pp.99-149.

Zuo, Q. T. & Wang, Z. G. (2006). Modern Hydrology. Zhengzhou: The Yellow River Water Conservancy Press.