Adaptive Planning for Cold and Arid Area on Inner Mongolia Plateau: Hohhot Horinger New Area Case Study

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1. Brief introduction of Pilot Climate - Adaptive Cities in China

China is a country covering vast territory with a large population, complex climatic conditions and fragile ecological environment. Extreme weather and climate change have had and will continue to have significant impact on the sustainable development of cities. Different regions encounter different situations. Arid climate, water shortage, sea level rise, urban heat island effect are long-term issues. Besides, divers extreme weather bring about multiple city emergency, such as fog and haze which bothers Beijing badly in recent years.
Coping with the above problems, it is urgent and necessary for cities to undertake active duty to mitigate climate change and adapt to climatic features. “The Pilot Climate - Adaptive Cities” officially issued at the beginning of 2017 by National Development and Reform Commission, as well as Minister of Housing and Urban-Rural Development in China, embarked on the pilot work in 28 cities to explore practical experience in urban planning, construction and management to improve climate adaptation. Hohhot is one of them.

2. Hohhot Horinger New Area (HNA) as demonstration zone

Hohhot belongs to Mongolia Plateau Continental Climate Zone in China. Winter is long and cold. Rainfall is scarce throughout the whole year and significantly less than evaporation. The cold and arid weather strongly affects people's way of life and the normal work of city.
According to the requirements of “The Pilot Climate - Adaptive Cities”, urban planning based on weather change and vulnerability assessment is essential. As China’s first pilot city, Hohhot takes Horinger New Area (HNA) as a demonstration plot to carry out of climate-adaptive planning, urban design and construction.

HNA, located in the south of Hohhot, is about 35 kilometers from the central city. It encompasses about 598 square kilometers in area. HNA stresses green development, innovation, and cultural continuity. Green lifestyle , low-carbon and high-tech city construction and management methods are strongly encouraged. These patterns contribute to the climate adaptation and sustainable development (Figure 1-1).

Figure 1-1 Location of HNA

Source: HNA Master Plan

3. Research method

The author participated in the HNA Master Plan Project in 2016 and Comprehensive Urban Design Project in 2017, and currently oversees Regulatory Plan Project of HNA Yungu District (core area of HNA). On the basis of above projects, this paper takes HNA as the research object, to study how cold and arid climate influences people's life, as well as what the climate-adaptive planning for city on Inner Mongolia Plateau should be.

For the study, the author conducted site surveys and polled citizens to have a full understanding of how the cold and arid weather influences their living habit. In addition, various data is gathered from HNA Administrative Committee and government departments of the Nei Monggol Autonomous Region. The data is used for climatic, demographic, ecological and spatial analysis. Based on above research, the paper elaborates on the climatic feature and relevant sustainable development path of HNA using a serious of assessment methods, such as bioclimatic chart, GIS and CFD technology. A set of climate-adaptive control models is made on both macro and micro levels to identify each urban subsystem of HNA. Using the models, this paper sets a blueprint for HNA in aspects of land use, urban form, traffic system, energy utilization, ecology environment, public space and architecture, in order to make city more adaptive to cold and arid weather and active in mitigating climate deterioration.

4. Climatic and ecological sensitivity assessment

The first step in adapting to the climate is assessing the climate. We superimposed analysis factors of climate, wind, terrain, region, vegetation, soil and so on to evaluate the climatic and ecological sensitivity of HNA, supporting the planning blueprint for the next step.

4.1 Characteristics of environment and climate

HNA belongs to Eurasia temperate grassland ecosystem, which mainly distributed in Central Asia, East Asia and the western parts of North America (Figure 4-1-1). These areas are cold in winter and hot in summer, causing the annual temperature changes drastically. The average temperature in HNA is above 20 degree Celsius in the hottest month and below 0 degree Celsius in the coldest month. Besides, semiarid is another characteristic of HNA, the average annual rainfall is about 350mm and rainy days are concentrated in summer, while the average evaporation can be up to 1780mm (Figure 4-1-2).

The terrain is flat in HNA except the Mount Manhan in the southeast, bringing about the high frequency of the clam wind (Figure 4-1-3). The weather systems of HNA is entirely in the Asian inland high pressure in winter and changed to the edge of the eastern monsoon region in summer, leading to a high ground wind speed.

What's more, HNA is located in the Yellow River wetland area, which is one of the important migratory passages of birds in China (Figure 4-1-4). Each year from February to April, a large number of birds like cygnets, Eurasian spoonbills, grey cranes and so on fly from Central Asia to India staying here for a rest (Figure 4-1-5).

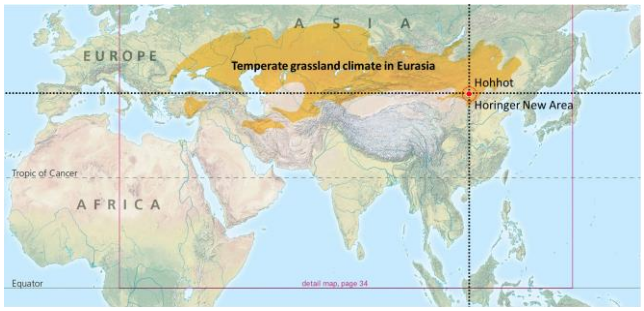


Figure 4-1-1 Climatic characteristics of HNA

Source: HNA Master Plan

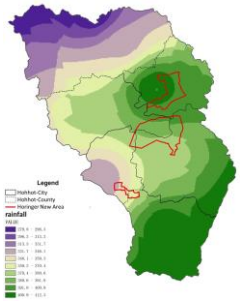


Figure 4-1-2 Average rainfall of HNA

Source: HNA Master Plan

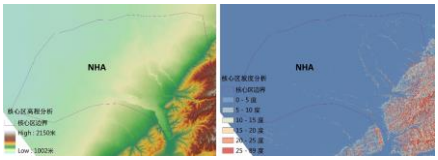


Figure 4-1-3 Elevation and slope analysis of HNA

Source: HNA Master Plan

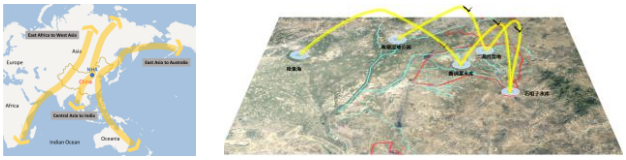


Figure 4-1-4 Migratory passage of birds in China

Source: HNA Master Plan

Figure 4-1-5 Species of migratory birds

Source: HNA Master Plan

4.2 Conditions of vegetation and soil

HNA can be classified as meadow steppe, which contains more mesoxerophytes than savanna. The main vegetation of the grassland are perennial grasses and rhizomatous grasses, most of the trees are low and drought resistant trees. In recent years, ecological construction have been promoted vigorously and vegetation coverage increased year by year in HNA (Figure 4-2-1).

The main problems of the soil in HNA are soil erosion and salinization. Soil erosion is mainly caused by water erosion and wind erosion, while soil salinization is affected by climate, terrain, human activities and so on (Figure 4-2-2, Figure 4-2-3). However, ecological restoration is inefficient and vegetation grows slowly because of high latitudes, droughts and soil barren. The efficiency of photosynthesis and carbon sequestration are relatively low in this area (Figure 4-2-4).

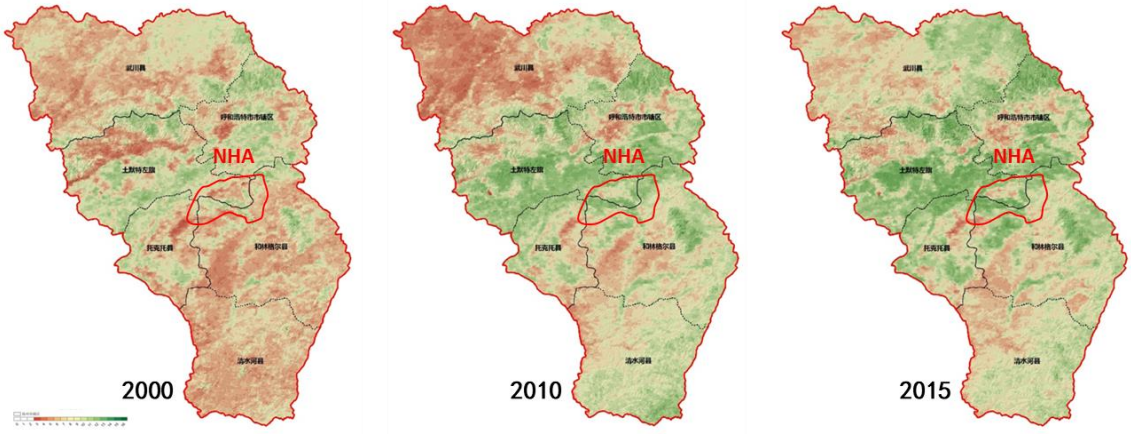


Figure 4-2-1 Vegetation cover of HNA from 2000 to 2015
Source: HNA Master Plan

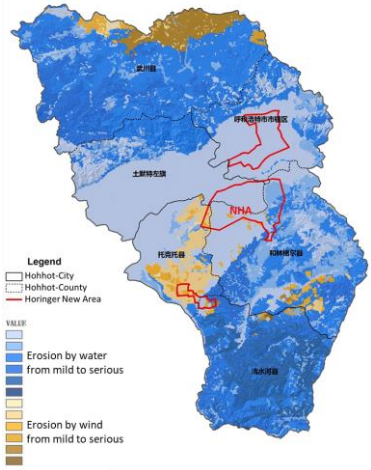


Figure 4-2-2 Soil erosion assessment of HNA
Source: HNA Master Plan

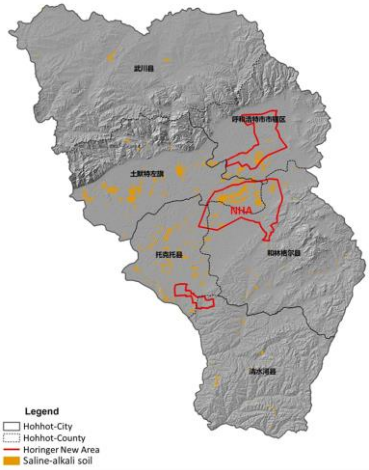


Figure 4-2-3 saline-alkali soil distribution of HNA
Source: HNA Master Plan

Figure 4-2-4 Major plants in HNA
Source: HNA Master Plan

4.3 Structure of land use

The land uses in HNA are Mainly composed of farmland, woodland, grassland, constructive land and other land such as saline-alkali soil or sandy land (Figure 4-3-1). The proportion of farmland is quite high, while this area is not suitable for agricultural activities both in soil and water conditions. Farmland needs to transform into woodland or grassland for a better protection of the ecological environment.

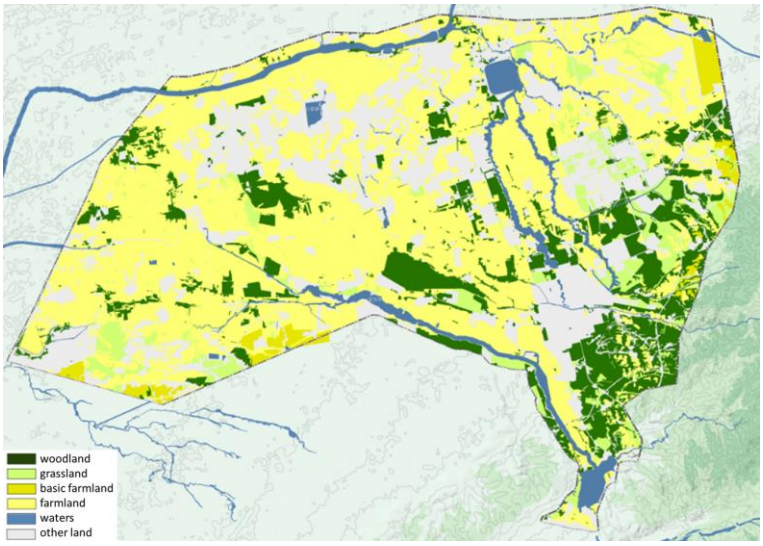


Figure 4-3-1 Land use of HNA

Source: HNA Master Plan

4.4 Climatic and ecological sensitivity assessment

In summary, four kinds of sensitive ecological areas can be delimited by analysising all the ecological factors above. Extreme and highly sensitive ecological areas need more ecological restoration measures, and will be protected strictly in the future (Figure 4-4-1).

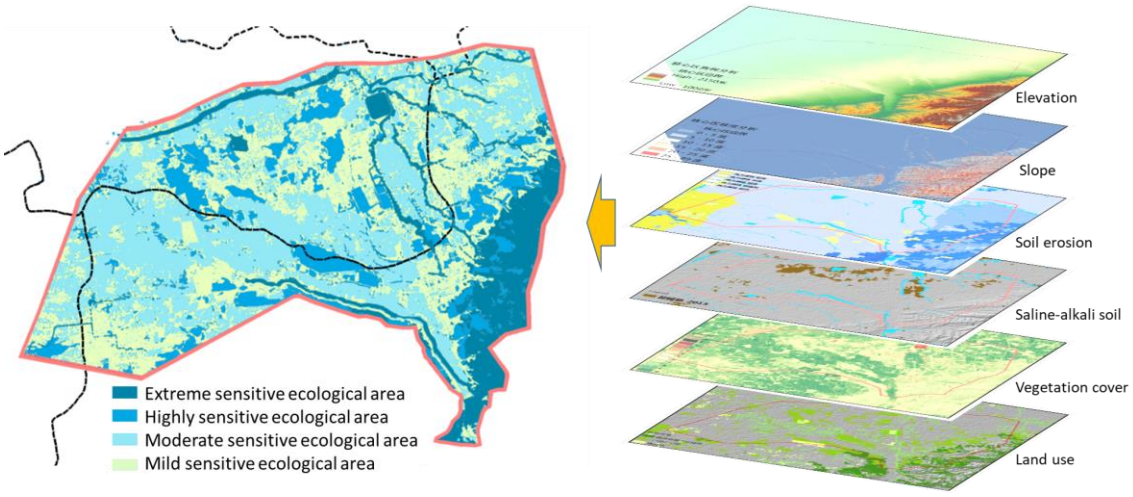


Figure 4-4-1 Ecological sensitivity evaluation of HNA

Source: HNA Master Plan

5. Climate-adaptive blueprint

On the basis of above assessment, suggestions to HNA's climate-adaptive development are given on both macro and micro levels. This paper sets a blueprint for HNA to identify each urban subsystem in aspects of land use and spatial design, ecological restoration, low impact development and *climate-adaptive public space,* in order to make city more adaptive to cold and arid weather and active in mitigating climate deterioration.

5.1 Land use and spatial design

The amount of total construction land in HNA plans to be 198km^2 and divided into 132 units for development, whose function contain living, technology, service, culture and industry, each unit is 1 to 3 km^2 (Figure 5-1-1). This mode helps use land intensively and make ecological indicators in each unit implemented more easily (Table 5-1-1).

In the unit development mode, it can be more convenient to implement adaptive planning. Take the Yungu District in HNA as an example, each unit is connected with green space by means of ecological restoration. We build one Dandai Green Belt (Dandai for short), two Circle Corridor as Yun Inner Circle Corridor (Yun Corridor for short) and Tiyan Outer Circle Corridor (Tiyan Corridor for short), six Vibrant Island with different function as Commercial Island, Financial Island, Sport Island, Information Island, Culture Island and Technological Island (Figure 5-1-2). Different strategies can be implied in different parts.

Table 5-1-1 Ecological indicators in each unit

Source: HNA Master Plan

Class	Index	Indicators	Unit	Goal	Type
Ecological Environment	1	park space per capita	Square meter per capita	12	Force
	2	total control rate of annual surface runoff	%	80	Force
	3	classification and collection rate of urban and rural domestic waste	%	100	Expect
	4	carbon emission intensity of unit GDP	ton per million yuan	⩽25	Expect
Resource Use	5	utilization of underground space	%	10	Expect
	6	groundwater in water use	%	15.8	Force
	7	utilization of non-traditional water resources	%	25.9	Force
	8	proportion of renewable energy use	%	27	Expect
	9	proportion of charging pile	%	100	Expect
Green Building	10	proportion of passive ultra low energy consumption green building	%	10	Expect
	11	Proportion of green building in industrial buildings	%	50	Expect
Green	12	proportion of green travel	%	80	Force

Traffic	13	500 meter coverage of bus stations	%	100	Expect
	14	proportion of public transport travel	%	60	Expect
	15	proportion of new energy vehicles	%	90	Expect

Figure 5-1-1 Unit division in HNA

Source: HNA Master Plan

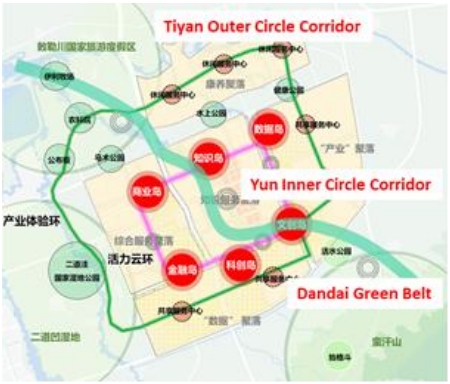


Figure 5-1-2 Structure of Yungu District

Source: Regulation Plan of HNA Yungu District

5.2 Ecological restoration

A series of measures implemented to restore the existing ecological problems in HNA, including controlling the proportion of construction land within 40%, returning farmland to woodland and grassland, delimiting the Ecological Protection Area (EPA for short) in ecological space according to sensitivity assessment. All construction activities are strictly prohibited at the A level EPA, construction activities that may undermine the ecosystem are prohibited at the B level EPA, construction activities that may pollute the environment are prohibited at the C level EPA (Figure 5-2-1).

As the Dandai Green Belt in Yungu District belongs to C level EPA, we reallocation the proportion of trees, shrubs and grasses in it, making the plants more adaptive for the climate (Figure 5-2-2, Figure 5-2-3). Measures as ecological treatment for riverbeds, building rainwater and purity infiltration wetlands are implemented to reduce the water requirement in Dandai, ensuring a safe habitats for migratory birds in this area (Figure 5-2-4).

To adapt the water shortage in this arid area, multiple water sources such as rain, sewage, reclaimed water and groundwater are used to meet the supply of water in river in this arid area. On the one hand, the city build the rainwater network systems to help collect the rainfall runoff, on the other hand, constructors dredge the upstream drainage ditch on Mount Manhan to collect mountain flood resources, also water conservancy projects such as sluice, rubber dam and so on are built for intercepting and storing flood in rainy seasons (Figure 5-2-5).

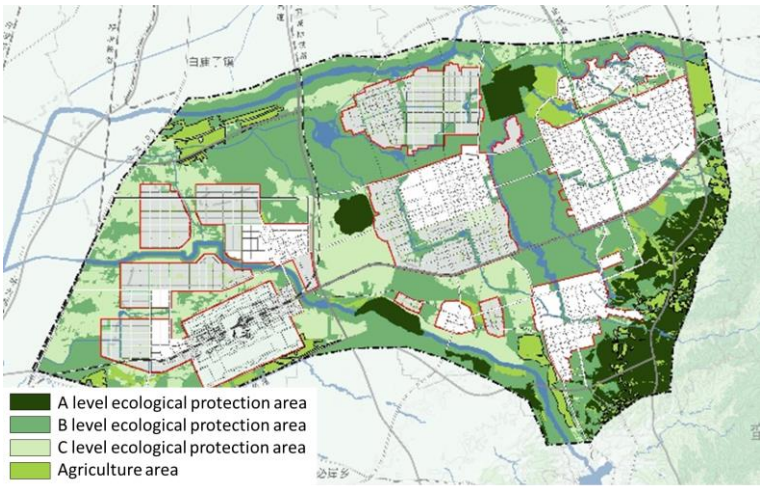


Figure 5-2-1 Classification of ecological protection area
Source: HNA Master Plan

Figure 5-2-2 Sketch Map of Dandai
Source: Regulation Plan of HNA Yungu District

Figure 5-2-3 Vision Drawing of Dandai
Source: Regulation Plan of HNA Yungu District

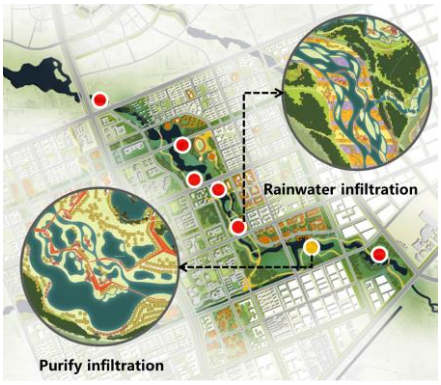


Figure 5-2-4 Measures to reduce the water requirement
Source: Regulation Plan of HNA Yungu District

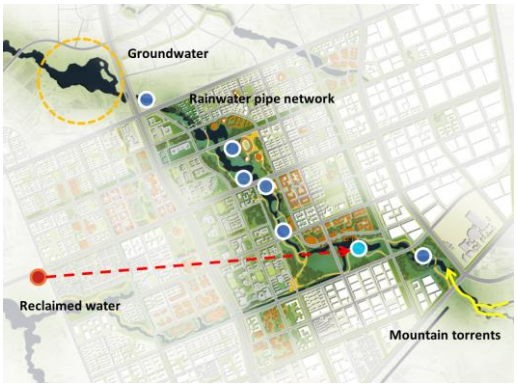


Figure 5-2-5 Multiple water sources
Source: Regulation Plan of HNA Yungu District

5,3 Low impact development

In order to reduce the impact of construction on the environment, we control the size, height and density of buildings to form natural ventilation system and regulate urban microclimate (Figure 5-3-1). Besides, urban construction and ecological construction are also carried out at the same time to help build a spongy city that we can achieve the goal of seeing the street parks in 3 minutes, seeing the city parks in 5 minutes and seeing the country parks in 15

minutes. In these ecological space, much attention are paid to the methods including infiltration, retention, storage, purify, use and drainage (Figure 5-3-2).

Units in HNA are linked with urban express tracks, metros and medium volume buses. We build the integrated transfer systems with important stations to improve the utilization efficiency of traffic hub (Figure 5-3-3). Two Circle Corridor are designed as the slow-moving system for each unit to bring about a green traffic system for fast arrival and slow experience (Figure 5-3-4). This measure also can reduce the negative effects of traffic discharge on the environment.

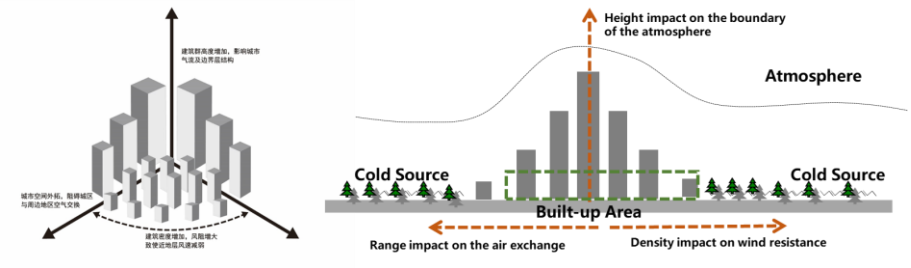


Figure 5-3-1 Natural ventilation system

Source: HNA Master Plan

Figure 5-3-2 Guidance of Spongy City

Source: HNA Master Plan

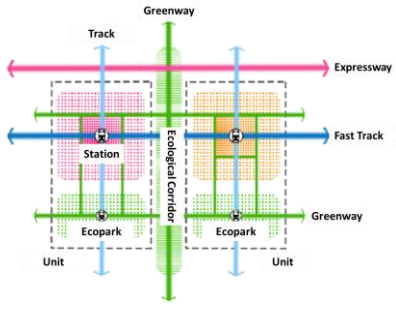


Figure 5-3-3 Traffic organization of HNA

Source: HNA Master Plan

Figure 5-3-4 Design of Yun Corridor

Source: Regulation Plan of HNA Yungu District

5.4 Climate - adaptive public space

Winter is long and cold with strong northwest wind. Summer is short but hot with sun exposure. As a result, it is important for the public space to intensify heat preservation and protect against cold wind in winter, as well as strengthen sun protection in summer. Various measures are adopt in HNA to make increase environmental amenity.

Smaller blocks with small streets make biking, walking, and public transportation more feasible. For example, the original block size in Commercial Island is 350m*300m in the Master Plan, and after the climate-adaptive renovation, it reduced to 170m*130m in Regulation Plan with more branch roads. The green transportation can play an important role in bringing about cleaner air and mitigating greenhouse gas emissions. Buildings are set up along streets with internal courtyards in the middle of small blocks to reduce wind speed. All-weather transportation service facilities are applied in order to protect people from the cold winter wind and strong summer sunshine.

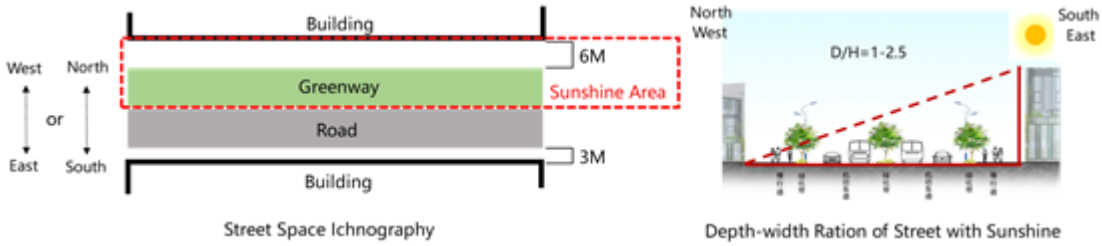
In winter, sunshine duration is longer on the north/west side of street than the south/east in HNA, thus, building setback restriction is extended on the north or west side of street, and designed as greenway with high environmental quality. At the same time, restaurants and shops are arrangement along greenway. This kind of asymmetrical street, named Vibrant Street, obtains winter-friendly applicative effectiveness. In HNA's winter, it is comfortable for citizens to take a walk and enjoy services along the Vibrant Street in the warm sunshine (Figure 5-4-1).

Commercial Island and Financial Island, with large flow of people, have underground public space system which is not affected by seasons and pedestrian overpass system with winter-adaptive facilities, such as automatic glass roof and heating equipment (Figure 5-4-2).

Commercial Island in Master Plan: 350m*300m Commercial Island in Regulatory Plan: 170m*130m

Figure 5-4-1 Block size of Commercial Island before and after climate-adaptive design

Source: Regulation Plan of HNA Yungu District



Street Space Ichnography Depth-width Ration of Street with Sunshine

Figure 5-4-2 Block size of Commercial Island before and after climate-adaptive design

Source: Regulation Plan of HNA Yungu District

6. Conclusion

As a typical city in Mongolia Plateau Continental Climate Zone in China, the cold and arid weather strongly affects people's way of life in HNA. To be climate-adaptive, the city planning and construction should concentrate on both macro and micro levels. From the macroscopic point of view, reasonable land use, ecological restoration and low impact development play important role in formatting sustainable city pattern and climatic environment. From the micro perspective, people-oriented spatial design and energy-efficient architecture can help improve microclimate.

The climate-adaptive planning of HNA is still ongoing, more attempt in each urban subsystem needs to put into practice to mitigate climate deterioration and improve urban livability.

This research is applicable to adaptive planning and construction for cold and arid cities.

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