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New Sustainable Urban Design Strategies for the Beijing Region's Most Extensive Green, Compact City: Case Study of Bohai Innovation City

Juntaek Kim [1], Uoo Sang Yoo [2]*

1 Skidmore, Owings and Merrill, 224 S. Michigan Ave, Suite 1000, Chicago IL, 60616 USA
2 Chonnam National University, Gwangju 500-757, South Korea, Corresponding Author

* Author to whom correspondence should be addressed; Tel.: +82-2094-1644; Fax: +82-530-1639; E-mail: usyoo@chonnam.ac.kr

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Abstract: The recently released China New Urbanization Plan (2014-2020) encourages creation of transit-oriented, compact cities that create a new model for sustainable, livable city design. It includes infrastructure and plans for utilization of existing natural assets, responsible high-density, green, and park-centered communities. The purpose of this study was to understand new sets of urban design strategies and technologies by reviewing the framework for environmental sustainability, and livability of such residences. In the study we explore this new sustainable urban development model by focusing on the Bohai Innovation City in China. The Bohai Project is a strategic advancement in the policy of building one of the world's most powerful economic regions, the Bohai Rim. It is a major step in the development of the Beijing-Tianjin international business corridor, and is a logical, organic expansion of the national capital's rapidly growing metropolitan economy. The proposal for Beijing Bohai Innovation City leverages numerous existing assets, infrastructure, and plans to create an exciting and attractive new international district. It will be a global showcase of environmental and economic balance in a responsibly high-density, green community designed to encourage human development and commercial innovation. It has a strategic location at the first stop of a high-speed intercity rail line. This, with its highway and transit connections, puts all the region's advanced resources within quick and convenient reach of the new city. From the cutting-edge technologies developed by the world's leading companies, and the districts and neighborhoods in which they settle, to the high-tech urban infrastructure by which they are serviced, the master plan of the Bohai Project embraces innovative sustainable technologies. It is to be a showcase of new urban development in China, including the Beijing region's most extensive storm-water bio-filtration system. The study

explores the following: Urban Growth in China, strategies for Smarter Growth, Integrated Environmental Systems, Comprehensive Green Infrastructure Network, and Connected Neighborhoods.

Keywords: sustainable urban design, smart city, livability, Green Infrastructure Network, Bohai Innovation City

1. Introduction

The idea of the smart city emerged during the last decade as a platform of ideas about how new technologies might improve the function of cities, enhance their efficiency, and improve their competitiveness. It might also provide new ways in which problems of environmental degradation, imbalanced access to public infrastructure, and spatial segregation based on economic separation could be addressed. The essence of the ideas revolves around the need to coordinate and integrate technologies into their program mix that have hitherto been developed separately from one another, but which have clear synergies. They need to be interconnected so that many new opportunities can be realized that could improve the quality of life of residents. This study is based on the new city design project in south Beijing, which was planned carefully using comprehensive strategies and is being implemented in a way that is economically rational, but environmentally resilient.

1.1. Urbanization in Beijing and emerging new cities

The urbanization policies in China after the reform and open-door policy were intended to develop core cities as nodes for rapid economic growth instead of balancing development in rural areas. The mega-city of Beijing was strategically connected to the international port cities, Tianjin and Tanggu. This was intended to expand the Bohai economic belt by linking emerging new cities via intercity rail and highway networks. This mega-city and concentrated development concepts based on theories of "Getting Rich First" and "All Rich Together," intensified the urban development of Beijing to gain global competiveness[1] but it also caused various social problems like urban migration falling quality of urban life.

1.2. Increasing demand for new cities in response to rapid economic growth and urbanization

In 2012, Beijing's economic growth rate was 7.7%, the lowest level in 13 years,[2] but the government tried to use this opportunity to improve the sustainability of its growth. This process was geared towards not only stimulating economic growth, but also promoting attention to new sources of investment, providing better public services with equal accessibility, improving transport, and infrastructure networks, and enhancing more efficient use of resources. However, the soaring office rent in Beijing CBD from $130 per square meter in 2011, to $195 per square meter in 2013, accelerated the flight of multi-national firms from the downtown. Despite the high office rent, the shortage of offices in CBD seems likely to continue due to the investment and growth of foreign companies. In addition, the

continuing rise in population density with increasing urban population is deteriorating accessibility to the urban center by companies and individuals, as well.

1.3. Rapid increase in population

The return to the cities of those once expelled during the Cultural Revolution, and the increasing migration from rural to urban area due to mitigation of household-registration system have resulted in the over-crowding in urban areas and the deterioration of urban function. The natural rate of population increase and the rate of population movement in Beijing are 1.19 and 13.49, respectively. This is much higher than in rapidly growing cities in the Bohai economic belt (e.g., Tianjin 0.72 and 5.04. respectively). This rapid increase in urban migration contributes to the current industrial system in Beijing, but most unskilled employees are spread around in shadowy urban areas, even in illegal communities in the green belt area.

2. Problems and solutions of a new city design

2.1. Urban growth in China

The unplanned urban expansion in such a short period brought excessive population density, excessive demand for physical space and quantitative control, which resulted in blocking the diversity in urban spaces. This monolithic spatial organization in turn, causes deterioration of traffic and living conditions, and difficulties in management of the urban infrastructure. Most new town development caused severe spatial segregation of society by income level and upscale housing developments pushed the lower income employees to the outskirts of the city.

Table 1. Cities as problems and solutions[3].

Cities as problems	Cities as solutions
• Environmental degradation • Loss of agricultural land • Pressure on natural resources • Pressure on housing and employment • Consumptive patterns • Urban sprawl • Social alienation • Damaging urban-rural linkage	• Driving forces in economic development • Efficient use of energy and infrastructure • Easier delivery of health and education services • Centers for culture and tradition • Efficient use of natural resources • Creative social capital • Potential centers of innovation and experimentation

The Beijing new town developments took on an important role in preventing excessive population density, and were fairly successful in terms of industrial distribution. However, they failed to redistribute the population, so job and housing discord got worse.[4] The 12th Five-Year Plan (2011-2015), particularly put stress on the quality of growth, and looked for creative methods for rational distribution of elements composing the urban character. This new plan, based on urban diversity, calls for a new urban planning strategy, as well as a wide functional and spatial network connecting neighboring regions to improve functional congestion in the central region. For the success of this new plan, an integrated urban design is needed, in which the various resources of the urban area can be allocated in a comprehensive fashion.

2.2 Strategies for smarter growth

The promise of advancements in engineering and technology has yet to provide systemic change in the urban environment. In part, this is because of the limited application of technology and the piecemeal adaptation to readily available opportunities. Now there are many cities in which digital technology is imbedded from the outset, by which we might create environmentally smarter cities. What if we aligned urban form and architecture with technology and responsive infrastructure? Could we create a city that positively encourages community as well as environmental sustainability?

City planners and designers have already discovered a wide range of approaches and descriptions that promote the concept for a smarter city. Mostly, these suggest the implementation of cutting-edge infrastructure involving mobile apps, interactive monitoring, citizen-initiated sensing, real-time data collection/display, urban mapping/analytics, and even public art installations. What is commonly missing is the view of the city as a larger framework.[5] By looking at the ecology as well as the economy of the city, using systems thinking and holistic strategies, it is possible to design a city that is not only technologically innovative, but also smart in every aspect of contemporary urban living and sustainability.

The success of a smart city can often be measured on multiple levels. Interestingly, the cities most identified as being successful are those that place great importance on achieving and maintaining the highest quality of life for those who live, work, and visit. Most of these cities adhere to the importance of city planning and the alignment of resources to support the civic elements that offer real value in the daily life of the community.[6] As a result, this focus and prioritization have extended their value to attracting people, talent, and investment while creating distinctive positioning to be the best in the global competition. Regarding urban design practices (Table 2), several common relevant themes have become associated with livable cities that have demonstrated innovation, and cultivated a high quality urban environment.

Table 2. Urban design strategies for smart city.

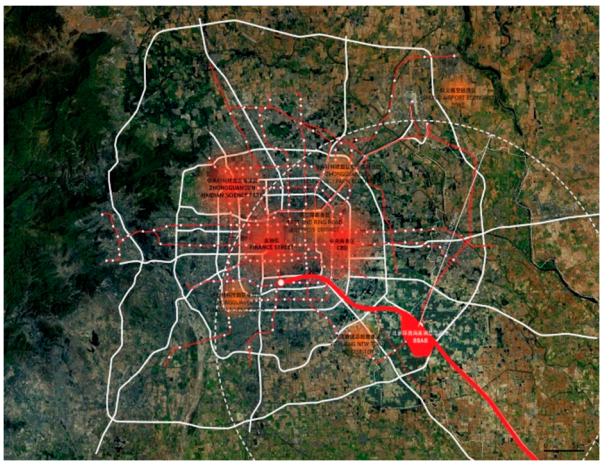
Issues of Urban Design in China	The Strategies for Smart City Design
• Quantifiable area based design control - Site coverage, population, FAR, green ratio, height limit • Maximum development under allowable land use permit • Disconnected single land use character • Limited research and planning within a project boundary • Rely on centralized urban infrastructure and government service • Public service followed by demand • Design from a Tabula rasa	• Performance based design • Compact and walkable development • Higher density with convenient transportation that is aligned with a mix of land uses • Transit as the first choice and the first investment • Innovative design adapted from regional context and an authentic sense of place • Networked public spaces of all kinds and scales • Information based public service • Visible display of “newness” and making technological innovations feel approachable • Holistic commitment to sustaining the quality and integrity of the larger ecosystem • Aesthetic consideration and locality

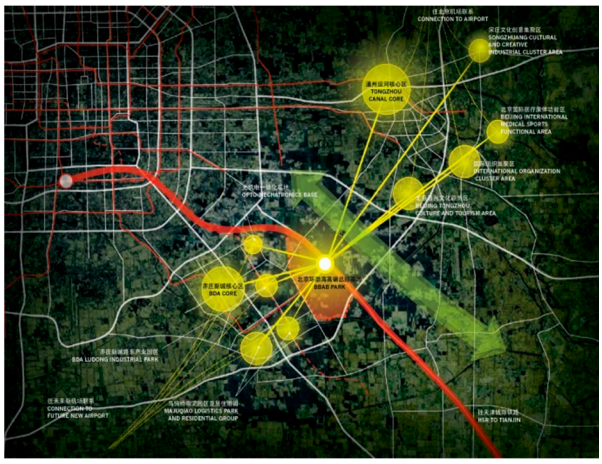
The strategies for the new city design pursue creation of flexible frameworks that provide smart platforms. These are intended to support not only emerging new technologies for infrastructure but also to enhance the performance through a comprehensive system of networks.

3. Bohai Innovation City as a Smart City

The Bohai Project follows a Smart City concept rather than the Mega City concept. This allows urban diversity by existence of various functional and spatial networks among regions, reduces social expenses (e.g., traffic congestion), excessive land price, and urban environmental pollution, and secures predictable urban management systems.

Figure 1. Aspects of development of Beijing: (a) Developments of new towns, (b) Regional function and spatial networks.





In the Bohai Innovation City, the urban design strategies for a smart city (Table 2) are applied to its urban spatial design to maximize the strategic advantage of the Bohai region and to provide better quality of life and sustainable urban development*. The network idea is critical for organizing other smart design strategies that were developed for this project:

- Comprehensive transit network for compact walkable district and connected neighborhoods
- Integrated environmental network with interconnected Green Infrastructure, and
- High-performance urban design for resource management.

3.1. Comprehensive Transit Network for compact walkable districts and connected neighborhoods

The master plan framework modifies the street grid to incorporate existing road alignments, to enhance connectivity to the high-speed rail station and surroundings, and to create special view corridors to landmark developments. Neighborhood streets are realigned to a north-south grid to optimize residential development and reduce energy consumption. A variety of block sizes is provided to allow

* The definition of "Sustainable development" is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Report, UN 1987), and at the 2005 World Summit, it was noted that sustainable development requires the compromise of social equity, economic feasibility, and environmental capacity.

for various development typologies, with smaller blocks in the urban core and larger blocks in the surrounding neighborhoods.

Figure 2. (a) Compact core and neighborhoods, **(b)** Land use plan.

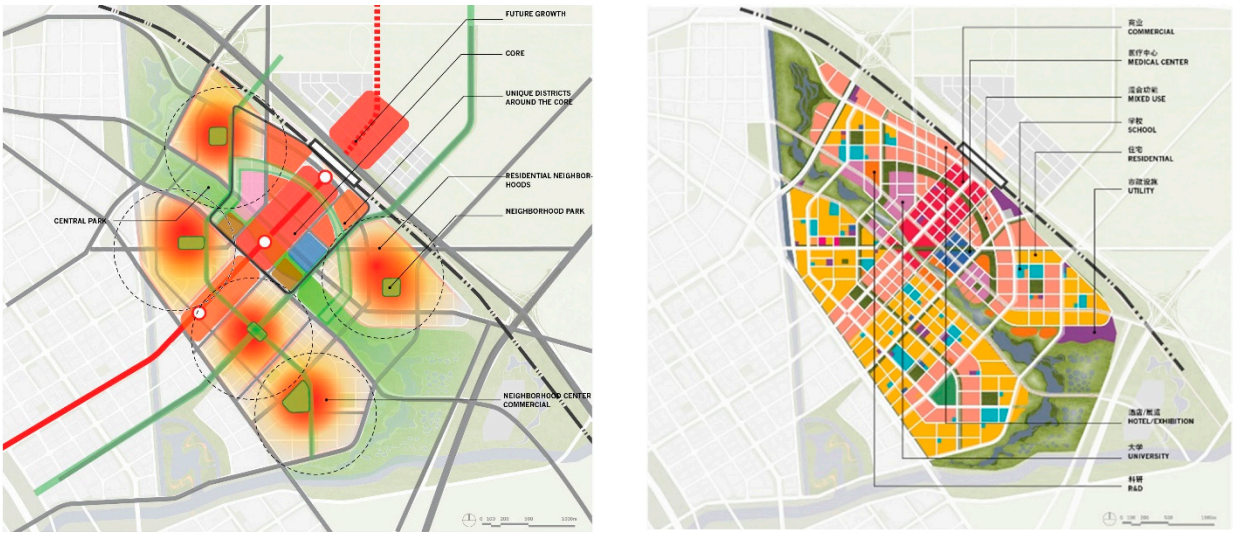


Figure 3. (a) Development density and function, **(b)** Comprehensive transit network.

All modes of transit serve to optimize transit coverage through the district. Internal transit systems provide convenient connections to external modes of transit for fast connections to the Beijing-Tianjin region. All streets are designed to accommodate bikes and pedestrians and land uses are distributed such that walking and biking become primary means of circulation. In the future, the Beijing Bohai Innovation City will become a major crossroads for access to both of Beijing's airports and the South Rail Station.

3.2. Integrated Environmental Network

The fabric of a city is the result of many intertwined ecological systems of relations between nature and artificial environments. One of the key insights for understanding the city is in understanding the structure of these networks of various ecological and infrastructural systems.

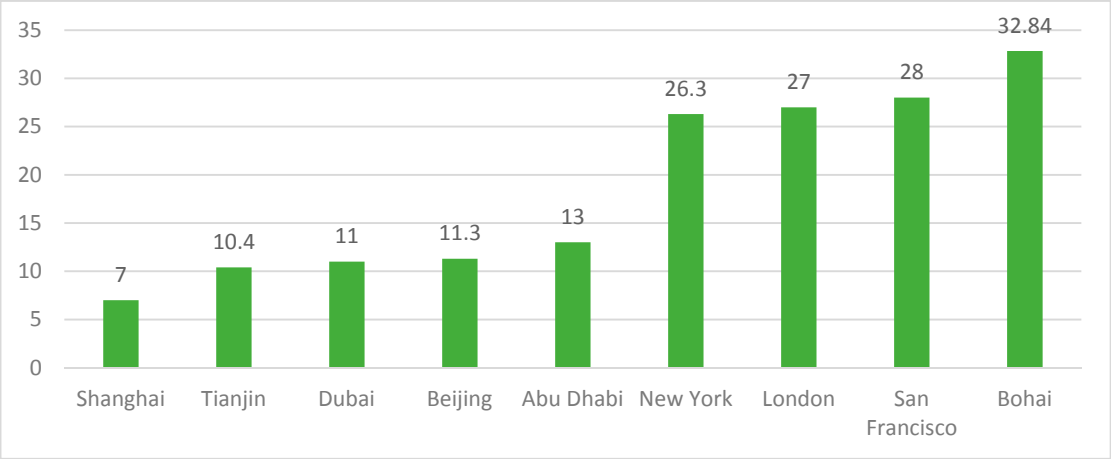
In terms of the urban environment, the health and environmental indexes indicate poor conditions in the Beijing region. There is also conflict between economic development and environmental protection that results in unbalanced resource distribution.

3.2.1. Environmental Sustainability

China's urban green land area per capita was only 11.18 square meters.[7] Compare this to 25-30 square meters per capita for international cities around the world considered densely populated along with significant tourist attractions, and highly livable. At present, with the acute shortage of construction land, expanding and protecting green space has become an urgent and arduous task throughout China.

The Bejing Bohai city plan aims to ensure that the city is people-centered. This means creating enough public open space for leisure and recreation, and providing safe pedestrian walkways and connected bike paths. This entails mixed-use development so that residents can work and shop in the communities where they live. This project will provide open public space of about 760 ha including 145 ha of water bodies. This will provide residents with about 32.84 m^2/capita of open public space. In addition to this, there is a requirement for 30% green space on developable land that is expected to provide open space and living conditions comparable to those in noteworthy international cities.

Table 3. Public urban green land area per capita[8].

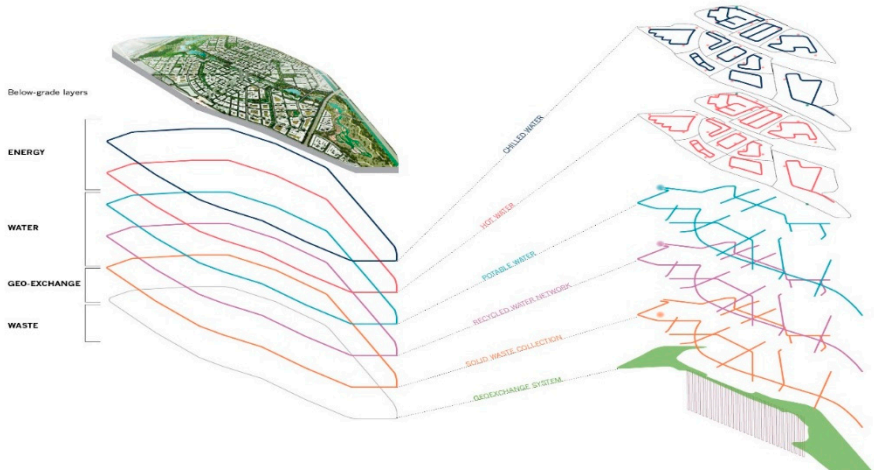


3.2.2. Interconnected Green Infrastructure

Networks are the infrastructure by which this plan is intended to provide collective reduction of costs while increasing density with great efficiency. However, increasing urbanization in certain areas causes tension surrounding the compromise between reliability and resilience.

An enhanced district utility network allows a closer look at each utility provided, to discover expanded uses for each resource, to optimize redundancies, and to minimize energy use. Services that are traditionally produced at the building level can be better provided at the district level by achieving economies of scale. An enhanced utility network with interconnected district nodes provides cooling, heating and power to the entire development. It also supplements the city utility grid with on-site cogeneration systems involving renewable energy, rainwater management, and vegetation.

Figure 4. Interconnected infrastructural system.



In addition, an interconnected green infra-structure is essential for keeping water resources reliable and for maintaining quality in the wider ecological system in this region. The Green Infrastructure Network, in particular, is counted as a key design element organizing the other infrastructural networks listed above, to create a livable urban environment as a part of a regional eco system.

3.3. High Performance Design for smart resource management

3.3.1. Green infrastructure intervened with water management system

Water scarcity in China is not a new issue since 20% of the world population here, must share only 7% of the water in the world. However, in Beijing, this critical issue has been rapidly getting worse. Even though rapid urbanization has reduced surface water by 35% in the last 50 years, the population is expected to double in 25 years (to 20 million). It is evident that, not only could this hinder the growth of city, but would also decrease quality of life. It is of great concern that water and air quality have already become major issues related to urban migration.

To ensure that this city has an attractive sustainable living environment, the plan provides for a smart water-management system with an active green infrastructure network to address:

- Scarcity (harvest, reuse, efficiency)
- Flooding (natural and open system storage)
- Quality (treatment)

3.3.2. Enhanced Green Network System

In Bohai City, the green areas are designed to form a green network system that connects open spaces with nature systematically through the Green Infrastructure System[9]. The Green Infrastructure can be classified into plane type and linear type: The plane type is composed of parks, forests, wet lands, farmland, virgin land, and public facility outdoor areas. These will be organically linked through the Linear Type Green Infrastructure (e.g., pedestrian paths, green streets, water streams, and eco-corridors).

Figure 5. Smart water management system.

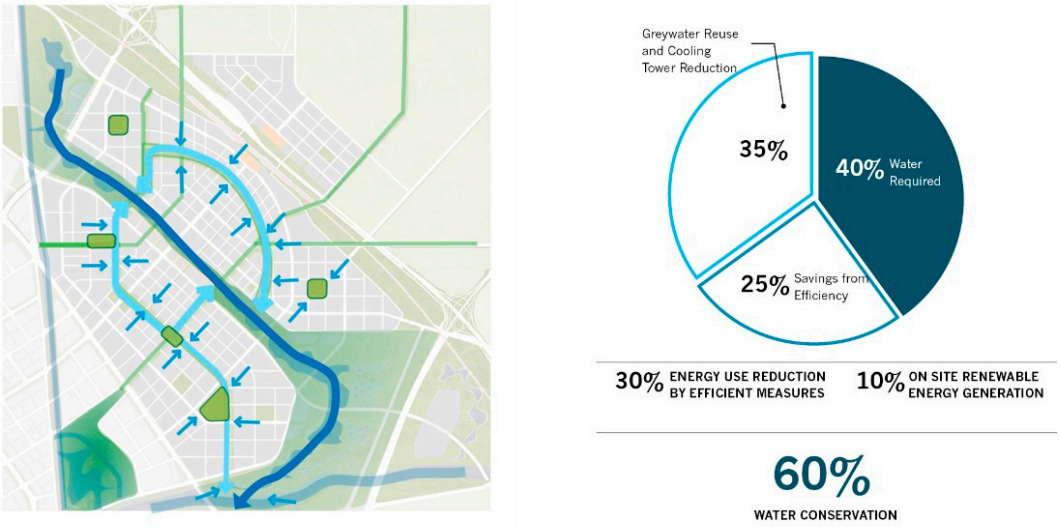
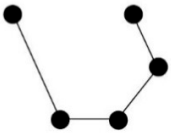
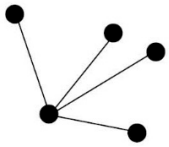
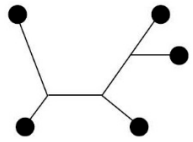
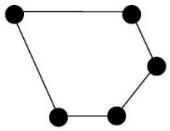
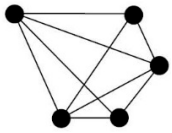
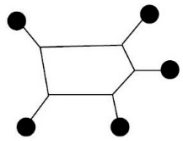


Figure 6. Various public open spaces and Green Infrastructure Network.

- Plane Type: An expanded network of green spaces, including the iconic Crescent Park running through the core, allows additional opportunities to collect and clean storm water run-off through natural systems. Helping to conserve precious water resources and the energy typically needed for water treatment, this comprehensive water-based landscape will become a model for sustainable urban landscape plan. Wetlands are proposed to be located at both the South and North ends of the city. They will occupy 23% of the total area, and provide 55% of the open space. The largest man-made wet area among new cities planned around Beijing, this wetland will be able to maintain biological diversity and perform as an urban micro climate control. The wetland also functions as a detention facility to protect against flooding disasters caused by the Summer Monsoon.

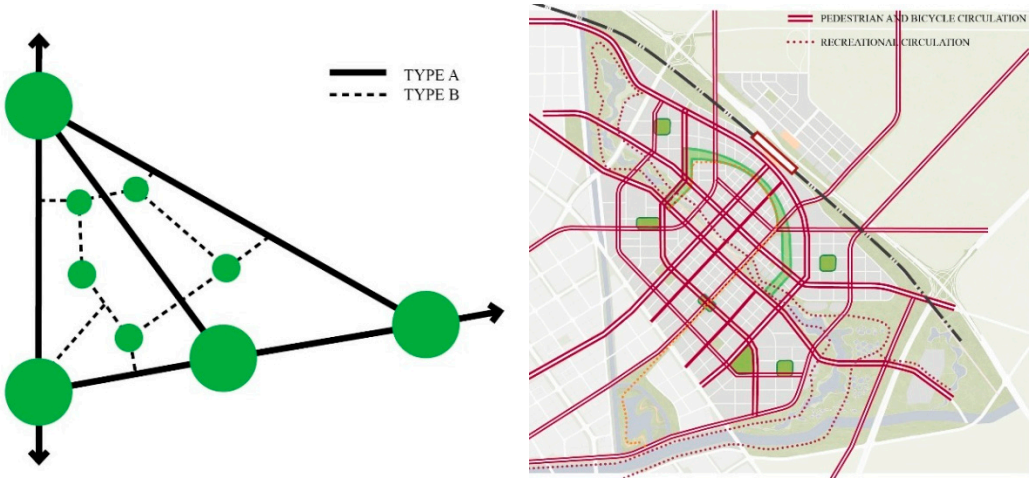
- Linear Type: As connectors among the major plane type open spaces, this green infrastructure includes eco-corridors, wind-corridors, view-corridors, water streams, promenades, and green pedestrian paths. These open spaces provide essential green connections between various open spaces to support natural systems and essential wind flow patterns. The various kinds of open spaces are to create an integrated network to amplify the synergy. Here again, the connection types of the green infrastructure proposed by network theory can be divided into two groups. One is the branching network type commonly observed in the natural landscape; the other is the circuit network type which includes most network types found in urban settings.[10]

Figure 7. Greenway network typology[11].

Branching Networks			Circuit Networks		
Paul Revere	Hierarchical	Least Cost to Builder	Traveling Salesman	Least Cost to User	Bechman Typology
					

The Green Infrastructure Plan (Figure 6) introduces two different types of linear connection. Type "A" reinforces the idea of connectivity to expand to a regional-scale ecological system, and to provide continuous natural ecological paths, like a central water channel. Type 'B" emphasizes the idea of community, accessibility and sociability using linked small blocks and neighborhood parks connected with green streets.

Figure 8. Open space typology and pedestrian and bicycle network.



The type A is more like "Traveling Salesman" which will be more suitable for recreational purposes, in that it leads back to the start point. The type B is closer to a modified "Bechman Typology*" that

* Bechman typology connects major nodes with green pathways. In this project, neighborhood parks are connected by boulevards and artificial green way, which extended to regional ecological corridors linking major public parks and wet lands.

could improve the connectivity of green infrastructure and also enhance the public approach to each open space in terms of providing convenient connections between the neighborhood nodes.

4. Conclusion - Smart growth and sustaining the city

Smart growth is a movement that implies we can achieve greater efficiencies by coordinating the forces that lead to laissez faire growth, using guidelines to avoid market-dictated sprawl development. The Chinese urban development pattern is evolving to accommodate socio-economical sustainability while pursuing environmentally livable places. This will be done using innovative technologies and management systems. This study reviewed the key urban design issues in China and explored new urban design strategies that stress the quality of growth.

Once early-phase districts and buildings are completed in the Bohai Innovation City, numerous key indicators will be established, allowing for the adjustment and optimization of the infrastructure and systems as required from the optimal distribution of energy, to enhanced performance, and integration of the transit and mobility networks. Over time, extensive network systems like transit, open space, infrastructure, and an upgraded management system will help to maintain a sustainable and highly livable place.

An integrated open space network and intelligent water management system will further contribute energy savings, and optimize the re-use and re-cycling of water by balancing the supplies and demands through centralized point-of-use treatment technologies. The smart city will also effectively monitor the hydrology and ecological performance of its watershed to efficiently replenish aquifers and restore a sustainable balance of water resources throughout the region using the proposed wetland system.

The Bohai Project has the potential to provide a broader view of the future “smart city” and to define what that may imply. In this paper, we have explored diverse drivers shaping the role of smart cities and assessed the implications that these may have on new city designs and the delivery of cutting-edge green infrastructure.

Conflict of Interest

The authors declare no conflict of interest.

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