Spatial Construction, Form and Effectiveness Analysis of Large-scale Waterfront Park System in Island-type Cities

——The case of Xiamen, China

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Abstract: The bay is a space barrier for the development of island-type cities and a high-quality waterfront landscape resource. This study takes Xiamen a typical island city in China as an example. First, It use the method of satellite telemetry technology combined with GIS software and spatial syntax, respectively, from the material space level and social space level, to summarize the rapid urbanization process of this city since 1990-2018, focusing on the construction process of three large-scale waterfront park systems in the transition period of inter-island development in it, and comparing the similarities and differences of their spatial forms. Further, from the choice of the axis model and the integrated analysis results, we discuss the spatial efficiency changes. The construction of the three major bay waterfront park systems in this city reflects a huge change in development pattern from lagging construction, synchronous planning, to advanced layout, providing a continuous and variable spatial form for the development of the bay region and improving space efficiency, which one of the important ways to develop and transform island-type cities. We hope to provide the reference for the development including sustainable development of other island cities around the world.

Keywords: island-type city, city park, waterfront area, space syntax

Foreword

There are huge differences in the spatial level between island-type cities and other inland-type cities, leading to different ways of urban park system construction and development characteristics. Compared with inland cities, island cities is relatively small in number. The development and utilization of lake-bay and coastal waterfront areas involves industrial policies, economic development, social attitudes and environmental sensitivity, and further affects traffic evolution and urban patterns. With the rapid growth of the social economy and the continuous increase of the urban population, the island cities in the global coastal areas are facing the severe problems of rapid urban development and transformation without exception. At this stage, how to effectively control and manage the disorderly expansion of the city has been become one of the most important and hottest topics in urban studies（Craigh-Smith, 1995; Ng, 2019; Xu et al., 2019).

Taking Xiamen City of China as an example, this paper mainly discusses the development dilemma faced by island cities in the development process, the strategies adopted and the actual results achieved. This is one of the most typical island cities in the southeastern coastal region of China. The island type and the condition of being surrounded by the mountains make its development extremely limited. In recent years, the influx of migrants and the violent urbanization process have made it faced with huge and urgent development pressure, therefore, in the process of transition from an island city to a bay city, Xiamen City has constructed three large waterfront park systems in three bay areas, improving the the image of the city, enhancing the tourism value, connection and service efficiency of the city's waterfront space, and having high reference significance.

1、Overview of research on waterfront area development and park system of island cities

Spatial expansion of island-type cities is a continuous process of urban renewal development using limited space resources(Yan Tao, Xue Xiongzhi, Cui Shenghui, & Shi Longyu, 2009). The island has clear land boundaries with the surrounding ocean that can be regarded as a natural barrier to control urban expansion and also as a geographic spatial barrier to the natural development of the city (Li et al., 2011). As China's urbanization process accelerates, more and more coastal land is included in the development plan, and the development of island and peninsula resources will become an important part of the future urbanization of the southeast coast of China and will play a greater role. For the development of island-type cities, the waterfront area is an important urban design element and a strategic area for urban development. Due to the continuous changes in social development and population structure, the waterfront space is changed from production space to living space with the waterfront function that should also change with the new needs of the city (Wrenn, 1983)

The term waterfront rejuvenation really began in the more limited sense in North America (Boston, Baltimore, San Francisco) and London in the 1860s. After the 1970s and 1980s, The development of waterfront areas in Sydney, Melbourne, and Japan provided a successful example. After the 1990s, in the newly industrialized countries and some less developed countries, the importance of developing port areas is reassessed, the development and revival of waterfront areas in port cities such as Havana (Cuba), Santos (Brazil), Mumbai (India), Dalian (China) and Singapore has received sustained and extensive attention (Hoyle, 2002). Waterfront area development can reshape the image of the city, helping the public to better experience and use the space at the edge of the ocean, lake or river (Craigh-Smith, 1995) . Chang&Huang (2010) through a successful case study of the Singapore waterfront area, points out that the development of the waterfront area is intended to inject new land uses into the waterfront as an open landscape to the public to

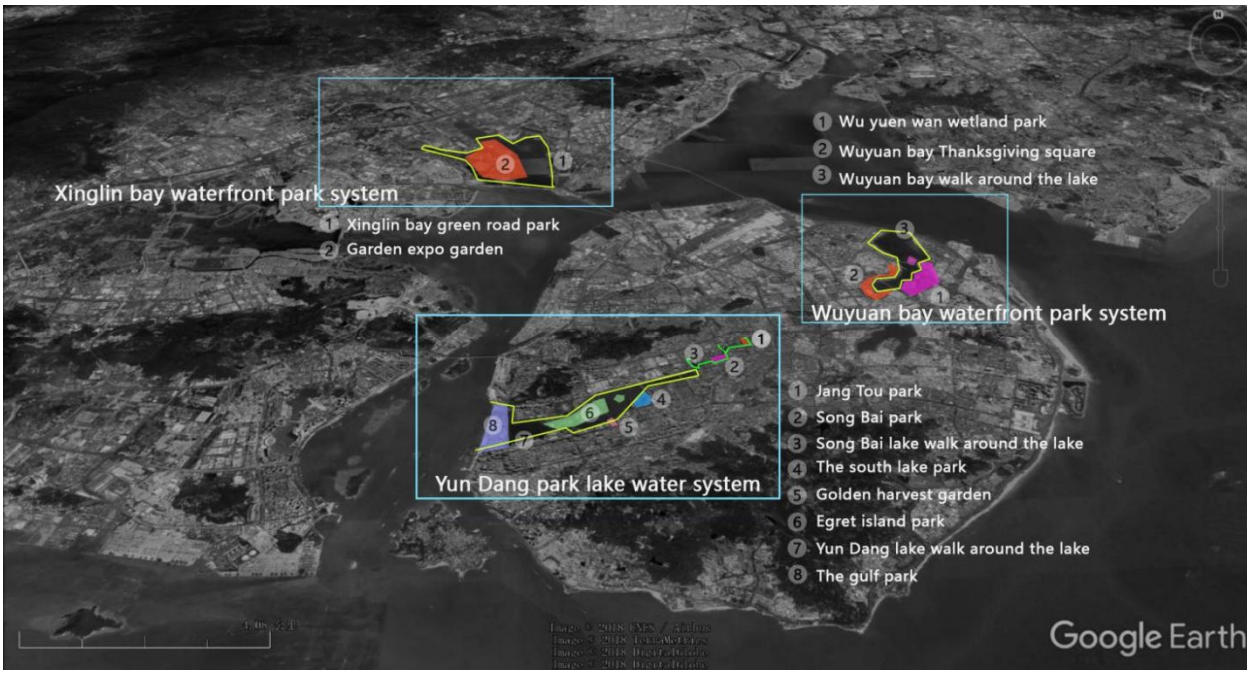
commemorate local culture and history.

The urban park system is an organic wholeness composed of several types of parks connected with each other, a key component of urban ecological infrastructure, also an important part of the urban disaster prevention system. Its quantity, area, proportion and spatial layout so forth directly affect the overall environmental quality of the city as well as residents' leisure recreation activities, and have an important impact on the formation of urban culture and urban features (Lu Yao.2007). In addition, the landscape, historical and entertainment value of urban parks has greatly increased the attractiveness of the city, which, while bringing better economic benefits and creating employment opportunities, can increase the income of local residents and greatly improve the level of urban development(Mincey, 2012) . Urban parks can also promote social cohesion (Peters Elands, & Buijs, 2010) by creating space for social interactions, satisfying the emotional needs of people in high-density cities to relieve repressive feelings (Grahn & Stigsdotter, 2003). Compared with other urban spaces, urban parks are more inclusive and are the preferred location for outdoor activities of urban residents, which can fully meet the social and psychological needs of urban residents (Chiesura, 2004) . In fact, urban parks, boulevards, traffic streets, and urban centers are all means of controlling the development of urban entities (Burgess, 1935) , which are effective measures to control and reform urban development (Cranz, 1982).).

2. Research design and process

2.1 Study case selection and related background

Xiamen is a nearly round island as a typical island city surrounded by sea. With length of 13.7km from north to south, width of 12.5km from east to west and an area of about 139 km2, it is located



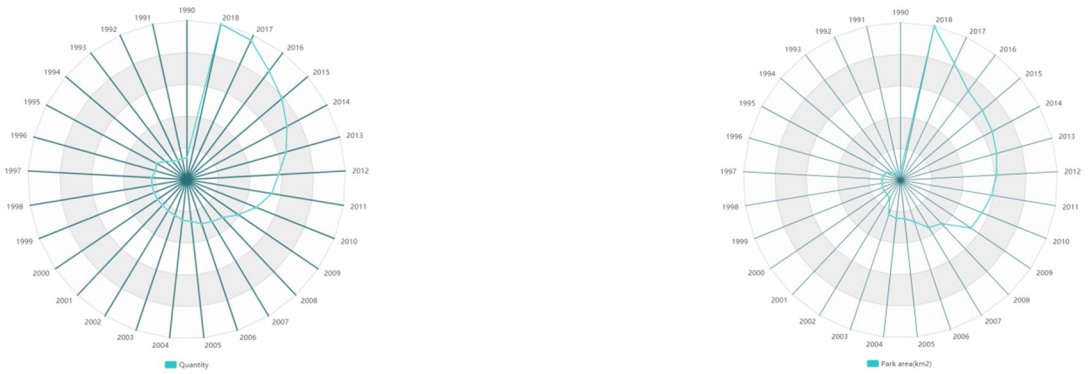
in the southern part of the Taiwan Strait (24° 25' -24° 54'N and 117° 53'-118° 25'E)（Figure 1）, and it is the only sub-provincial city in China with an island as its main body. In the early year of the Ming Dynasty (about the year 980 A.D.), Xiamen City was built to prevent the invasion of the Japanese pirates. Later, it gradually evolved into an important port for foreign exchanges and a famous foreign trade port in the southeastern coastal areas of China. In 1980, it was listed as the Xiamen Special Economic Zone by the Chinese government with the subsequent rapid urbanization of the island and the cross-island expansion being very obvious(Wang Weishan, 2004). After 2000, it officially entered the rapid development of the bay city. The current administrative scope includes the island part (Siming District, Huli District) and the land part (Jimei District, Haicang District, Tong'an District and Xiang'an District). The total length of the coastline is 234km, the sea area 390km, and the administrative area 1699.39km2. As of the end of 2017, the city's permanent population was 4.01 million. Plains and valleys isolated by hilly area are the main spatial element system for urban development. A number of bays, rivers and lakes are the most important regional resource characteristics of Xiamen City and an important constraint factor for urban development.

2.2 Research scope and selection of research methods

2.2.1 Research scope

The three waterfront park systems in Yundang Lake, Wuyuan Bay and Xinglin Bay were built at different time periods of transition from a island-type city to a bay-type city(Figure 2). The development of Yundang Lake New District in the island area after 1982 promoted the transfer of the urban center from the old urban area i.e. Xiamen Port to said New District. The expansion of

Figure3.The number and area of urban park construction in Xiamen from 1990 to 2008



the urban center to the northeastern part of the island in 2005 corresponds to the overall development of the Yundang Lake New District. The development of Xinglin Bay New District in 2007 reflects the change of the urban policy i.e. the development of Jimei New District. 1990-2016 is also a period of rapid development of urban park construction in Xiamen with the number of urban parks increasing from 19 to 120 and the area increasing rapidly from 194hm2 to 2604 hm2 （Figure3.）（Xiamen Municipal Bureau of Statistics official website.2017）. Therefore, with taking the development process, form and energy efficiency of the three major waterfront park systems in Xiamen during this specific time period as the research objectives, this paper conducts the case analysis for the three typical waterfront park systems said above, discusses the spatial form and spatial effectiveness, estimating the whole picture from the local picture and estimating the results from the process. This paper further discusses the development experience from an island-type city to a bay-type city, provides relevant suggestions and a reference for the development of other island-type cities.

2.2.2. Research methods

Urbanization is an important process of modern social and economic development, which will bring about changes in population, economic structure and lifestyle. These will be reflected in the changes in urban land use patterns and areas (Fan Jie, Xu Yudong, & Shaoyang, 2003). Based on the combination with the site survey, this paper obtains the Landsat series remote sensing images of Xiamen City in 1990, 2000, 2009 and 2018, and then uses ARC GIS10.3 software to identify the final land types according to the information collected on the classification purpose, the characteristics of the image data and the classification area. Five types of land are visually distinguished: forest land, water area, cultivated land, urban land, and unused land to assess the spatial change i.e. modification of natural or semi-natural landscapes in the urbanization process, and further divide the area into five types of selection samples needed in the research needs. In order to make the

various types of land samples have better separability, ensure that the classification parameter values are acceptable during operation which are greater than 1.9. According to the actual terrain, the complexity of geographic spatial classification, and the accuracy demand so forth, the Maximum Likelihood is used as the classifier of this paper. The results of the classified images are output and the image processing is performed to draw the land classification analysis map（Table 1）.

Table 1: Four-year sample corresponding parameter values

Age	1990	2000	2009	2018
Overall Accuracy	94.3114%	95.0035%	90.2098%	93.1018%
Kappa Coefficient	0.8678	0.8839	0.7939	0.8646

The urban construction changes at the material space cannot fully reflect the overall development of island-based cities. Urban development should also include the improvement and optimization of social behaviors. Therefore, based on the analysis of Xiamen urbanization using telemetry and GIS software, this paper further uses spatial syntactic theory to relate the material level of Xiamen to the perceived level of human beings, transforms the real urban material space into symbol space, and analyzes the urbanization of Xiamen with human beings are the main subject (B Hillier, Leaman, Stansall, & Bedford, 1976). Moreover, the social space systems of the three major waterfront park systems are quantified and sorted (Bill Hillier & Hanson, 1984) . The Axial Map of spatial syntax can reflect the important topological differences in the spatial layout and development of cities; by simplifying and extracting the complex street forms, spatial details and transitional relationships in urban space, the expression of urban space is purer and clearer. Therefore, this study uses UCL Depthmap10 software to calculate the axial-line relationship between IntegrationR3 and Integration HH in the spatial structure of the whole city of Xiamen, and analyzes Syntactic Synergy to verify the comprehensive evolution in overall spatial development brought by urbanization. Then, with the three waterfront park systems as selected sets, this paper performs Choice R3 and Integratio [HH]R3 calculations, analyzes and discusses the spatial effectiveness of the three specific park systems. Finally, the conclusions are drawn.

2.3 Data and calculation methods

The original data of Xiamen City used for data analysis, including urban construction, population, number of parks, and park area, are taken from the 1991-2017 Xiamen Special Economic Zone Yearbook. The remote sensing image data are taken from the geospatial data cloud website (Geographic Spatial Data Cloud, 2018), and the satellite images with the resolution of Landsat5 or Landsat8 series are selected as the basic data source. The time points selected (which are characterized by the clear weather, a small amount of cloud and convenience in interpreting the images in the area are June 6, 1990, March 5, 2000, June 6, 2009, and March 11, 2018. The statistical data on urban development and land area in Xiamen are collected as auxiliary information for the overall analysis on the process of urban construction in Xiamen.

The Xiamen city map used for space syntax analysis in this study is taken from Google Earth Historical Image Records in 1990, 2000, and 2009. Among them, the data of 2018 comes from the map of Google Street in Xiamen on June 20, 2018 (level 15), with a spatial resolution of 8m and a scale of 25,000:1, which is as an analysis basemap. For the spatial structure of Xiamen City, the Autocad2014 software is used to draw an axis diagram. Finally, UCL Depth map10.0 software is used to calculate the axis model. The variable index of the syntax is assigned to each axis. The red to blue colored temperature gradients are used to visualize the value of the specific spatial variable. The main analysis variable selection is below:

(1) Integration: indicates the degree to which a certain space in a system is agglomerated or dispersed with other spaces, and is used to measure the shape and network of the city; wherein, the degree of global integration indicates the closeness of the connection between a single space and the overall space, and the degree of local integration measures the spatial connection relationship of several topological distances from each space to other units. The calculation formula is:

$$I_i = RA_i = \frac{2(MD_i - 1)}{n - 2}$$

Where MD is the average depth value, n is the sum of nodes in the urban system, and I is the mean of the global integration degrees of all unit spaces.

(2) Choice: Based on the number of spatial connections and obtained by mathematical averaging, it indicates the possibility that a certain space in the system is traveled by other shortest paths. The calculation formula is:

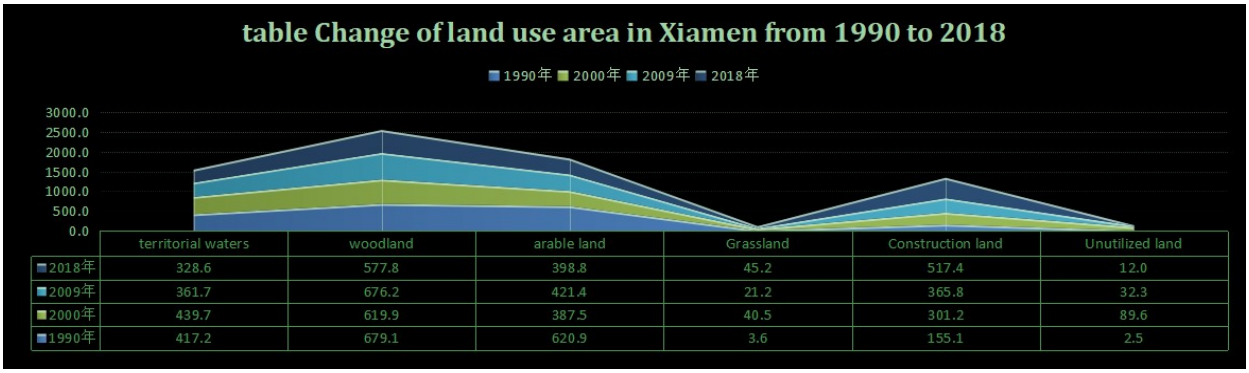
$$Ctrl_i = \sum_{j=1}^{k} \frac{1}{c_j}$$

Where k is the number of nodes directly connected to the i-th node, j(j=1, 2,..., k) is the node directly connected to node i, and Cj is the connection value of the j-th node .

(3) Syntactic Synergy represents the regression fitting line of IntegrationR3 and IntegrationHH parameters. The intelligent value R^2 is used to measure the degree of synergy. In urban systems with high intelligent values, there is a high level of urban system space accessibility information directly obtained from any local space; and in those with low intelligent values, a low level. R2<0.5 means that the comprehensibility of the overall space system is poor. 0.5<R2<0.7 means that the local space has a good development synergy relationship with the overall space system. 0.7<R2<1.0 means that the space system of the whole city not only has extremely high comprehensibility & coordinated development and that the entire social relationship show a positive and efficient development trend.

$$R^2 = \frac{\left[\sum (C_i - \bar{C})(I_i - \bar{I})\right]^2}{\sum (C_i - \bar{C})^2 \sum (I_i - \bar{I})^2}$$

Table 2: Changes in land use types in Xiamen, 1990, 2000, 2009, and 2018



	territorial waters	woodland	arable land	Grassland	Construction land	Unutilized land
2018年	328.6	577.8	398.8	45.2	517.4	12.0
2009年	361.7	676.2	421.4	21.2	365.8	32.3
2000年	439.7	619.9	387.5	40.5	301.2	89.6
1990年	417.2	679.1	620.9	3.6	155.1	2.5

Where C is the mean of connection values for all of unit spaces, and I is the mean of the global integration degrees for all of unit spaces.

3. Urbanization process of Xiamen Island and construction of waterfront park system

3.1 Urbanization process of Xiamen City expanding from island to bay city

3.1.1 Process of transformation and development of Xiamen Island from perspective of material space

In the past 30 years, the urban construction and development of Xiamen Island has utilized a large area of forest land, farmland, waters and coastal wetlands, causing tremendous pressure on the surrounding natural and semi-natural ecosystems(Ramachandra, Aithal, & Sanna, 2012), resulting in the decline in the value of ecosystem services as well as the significant separation of the landscape pattern (Lin, Xue, Shi, & Gao, 2013). From the results of the change in the area of land use in Xiamen from 1990 to 2018, it can be seen that, in 1990（Table 2）, the main urban construction land in Xiamen was concentrated in the southwest of the island, centering on the western old urban area and the area around Yundang Lake; in the northeast, centering on the cultivated land. In the same period, in the administrative areas around the bay outside the island, basically cultivated land types were used with the construction volume that can be neglected. It is in the initial stage of the

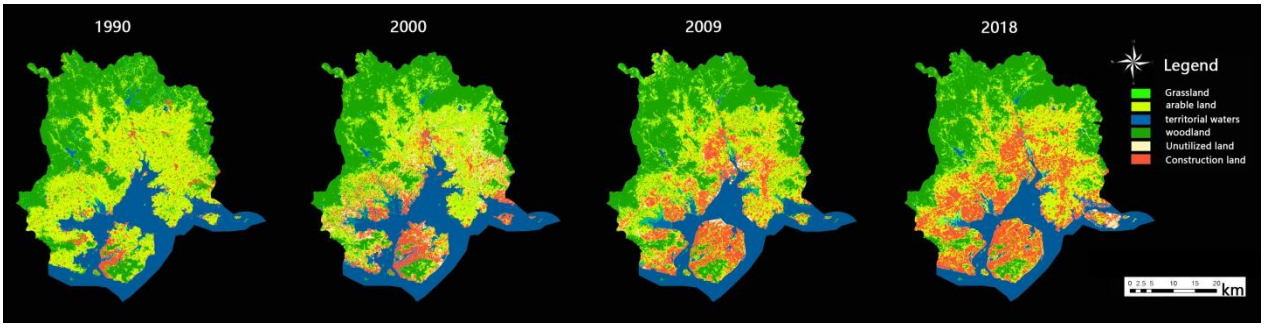


Figure 4 Changes in land use types in Xiamen, 1990, 2000, 2009 and 2018

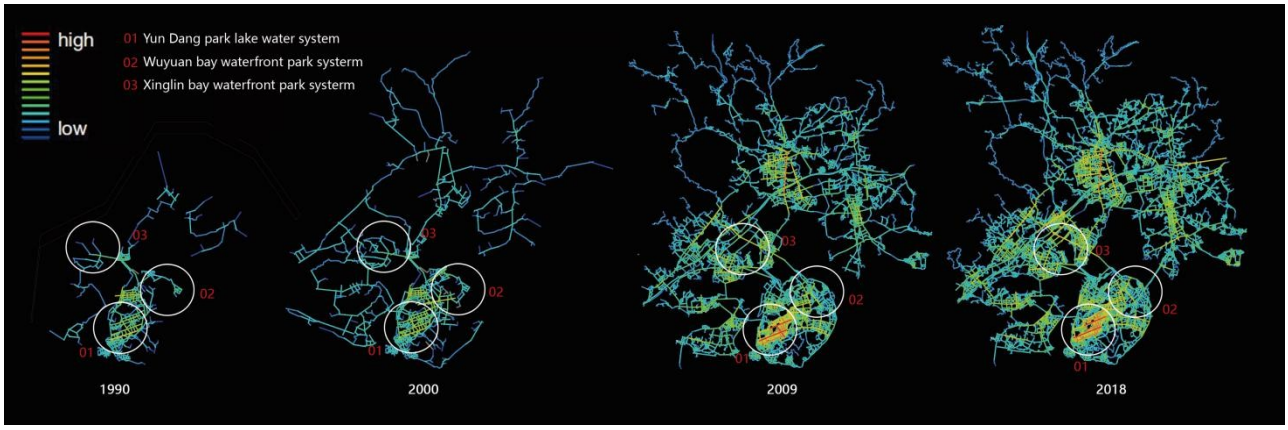


Figure 5: Spatial distribution of IntergrationR3 in Xiamen, 1990, 2000, 2009, 2018 (integrated by red to blue)

urbanization process. After a 10-year construction period, by the year 2000, the area of urban construction land on the island increased sharply. Except for some areas in the northeastern coast that were not developed, the cultivated land area accounting for nearly half of the island was converted into construction land, and the spatial structure was broken extremely seriously. After 2000, the northeastern part of the island also began to urbanize. In 2009, Haishu, Jimei, Tong'an, Xiang'an and other groups outside the island developed in a scale and order, showing a better center-spoke urban spatial structure. As of 2018, Xiamen City has gradually formed a new bay-type urban structure of one main area (i.e. the island) plus four auxiliary areas (i.e. Haicang, Jimen, Tongan, and Xiang'an)（Figure 4）.

3.1.2 Analyzing the process of Xiamen Island's transformation and development from perspective of social space

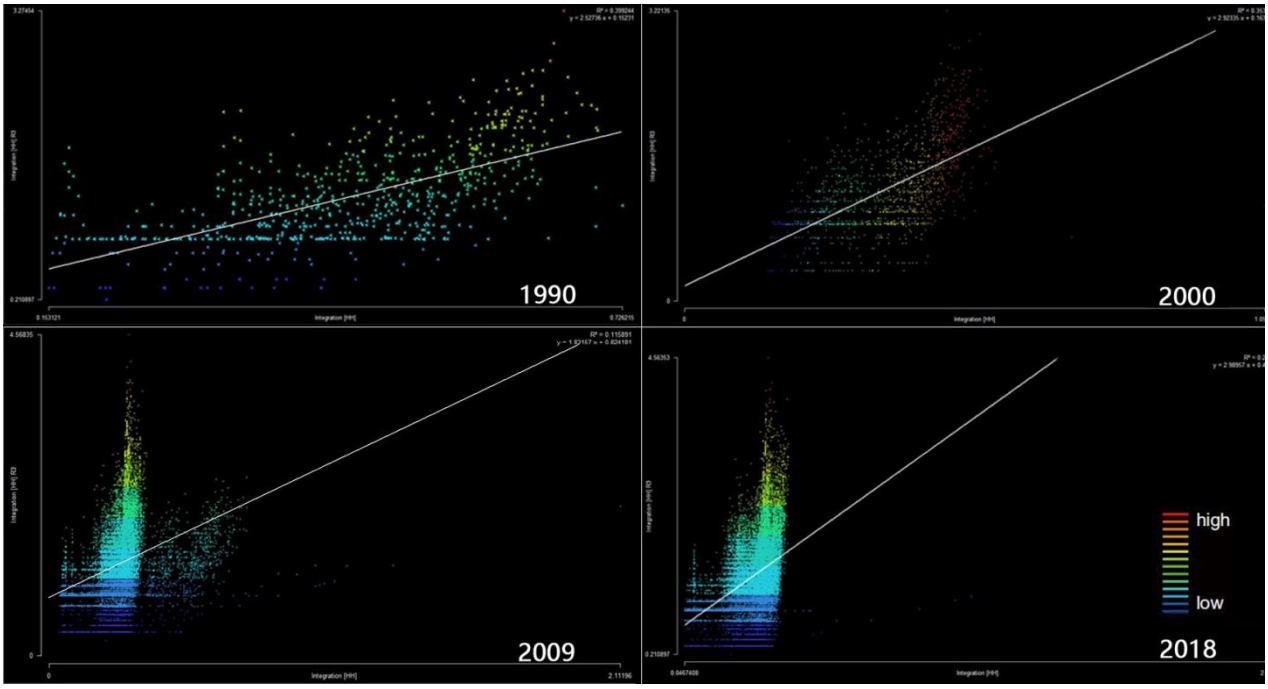


Figure 6 Changes in urban synergy in Xiamen, 1990, 2000, 2009, and 2018

In 1990（Figure 5）（Figure 6）, the integration value of the surrounding water system of Yundang Lake was significantly higher than that of other urban spaces with the synergy parameter reaching the highest point in history (R2=0.399244), reflecting the huge resource accumulation advantage within the high-density urban area of the island. In 2000, the integrative core surrounding the Yundang Lake area was expanded in spatial scope and further strengthened in extent. However, the overall coordination degree of the city declined. According to the analysis, the natural bay had extremely serious space constraints on urban development, and the ways to connect Xiamen Island with outer areas were only the three channels i.e. Gaoji Seawall, Jimei Bridge and Haicang Bridge. The urbanization process of the northeastern part of the island and the outer group of the island was less affected by the integrative core of the island center. The lack of paths and nodes led to the limited spatial capacity of urban expansion and development and led to no ability for producing rapid catalytic action and continuous propulsion, and the urbanization process was slow. By 2009, the cross-island development had made the structure of urban space inside and outside the island more dispersed, and the value of synergy reached the lowest value (R2=0.115891). Each group outside the island had strengthened its regional integration center, but the correlation between each other is weak due to the division of natural landscape elements. In 2018, the overall integration value of the city did not change, but the regional integration value increased and the degree of synergy rebounded. The analysis shows that in this period the overall structure of Xiamen as a bay city is clearer and the growth of the urban form network is good. The increase in integrative core values in each spoke center has caused the increase in local integration values; the interpretability and predictability of urban space to the overall space has been strengthened. In other words, with the further improvement of the cross-island transportation system, the connectivity of each area is further strengthened and the negative impact of the bay on urban development further reduced（Table 3）.

3.2 Bay area development and waterfront park system construction

3.2.1 Disorderly development and park construction in the waters of Yundang Lake during expansion of old urban area

Table 3 Syntactic structure statistics of Xiamen, 1990, 2000, 2009 and 2018

Age	Number of axes	Integration [HH] mean	Integration [HH]R3mean	Axial Synergy R2	Formula X=Integration （HH）R3 y= Integration （HH）
1990	701	0.455312	1.30 305	0.399244	y=2.527 36x+0.152 31
2000	1293	0.368617	1.24 106	0.353778	y=2.923 35 x+0.163 461
2009	15668	0.254057	1.2895	0.115891	y=0.0632742x+0.172465
2018	24093	0.280627	1.32852	0.201495	y=2.98957 x+0.489565

YUNDANG Lake Waterfront Park System is located in the southwestern part of Xiamen Island,

adjacent to the historic old urban area（Figure 2）. This lake has a water surface of about 171.55 hm2 and has a long and narrow lake path of 6.5 km which extends into the urban area. This lake was built in the 1970s by isolating by the sea. The lack of systematic planning and scientific and effective management of water ecosystems led to serious health hazards and ecological dilemmas. To this end, Xiamen Municipal Government, while performing water pollution elimination and ecological restoration, improved the landscape efficiency of urban waterfront areas through urban parks and continuous circular bay trails. After nearly 20 years of construction and transformation, the YUNDANG Lake Trail System connects Jiangtou Park, Songbai Park, Songbai Lake Trail, Bailuzhou Park, Nanhu Park, Jiahe Garden and YUNDANG Belt Park so forth from east to west, which are serial urban parks of different scales and types and form a coherent and systematic urban park system in the southwestern part of the island（Table 4）. It is the core landscape of Xiamen (Guo Jingyan, 2012)[25] and is an important ecological natural resource and tourist landscape of Xiamen Island.

Table 4 Statistics on the park situation of the three major waterfront park systems

Gulf water system	city park	Area	Built time	Types
Yun Dang park lake water system	The gulf park	20km^2	2005	Municipal comprehensive park
	Yundang lake walk around the lake	15Kilometer	2013	Strip park
	Egret island park	39.66km^2	1993	National park
	The south lake park	16km^2	1995	Municipal comprehensive park
	Songbai Lake walk around the lake	3.14Kilometer	2017	Strip park
	Songbai Park	7.2km^2	1996	Community park
	Golden harvest garden	1.8km^2	1988	Community park
	Jiangtou Park	6.02km^2	1999	Community park
Wuyuan bay waterfront park systerm	Wuyuanwan Wetland Park	85km^2	2009	Wetland park
	Wuyuan Bay walk around the lake	8Kilometer	2015	Strip park
	Wuyuanwan bay Thanksgiving Square	5.2km^2	2016	Municipal comprehensive park
Xinglin bay waterfront park systerm	Xinglin bay green road park	20.6Kilometer	2015	Strip park
	Garden Expo Court	1082km^2	2007	Exhibition park、National park

3.2.2 Orderly planning and ecological restoration of Wuyuan Bay waters during development of new urban area

Wuyuan Bay area is located in the northeast of Xiamen Island and covers an area of 12.56 km^2 (including a water area of 3.98 km^2). It is the only urban new area in the eastern part of the island which is subject to the overall planning（Figure 2）. Due to the construction of the seawall in the bay in the late 1950s and the late 1970s, the exchange capacity between the water body in the bay and the outer seawater approached zero, and the ecosystem was seriously damaged(Huang Haiping et al., 2015). Based on the experience of remediation of YUNDANG Lake waters and the enormous economic and social benefits value brought about by the improvement of urban landscape, the premise of planning and development in Wuyuan Bay Area is the regional ecological restoration and the improvement of urban landscape image. After the overall planning and development from 2005 to 2009, the landscape ecological pattern of Wuyuan Bay has undergone tremendous changes : The original outer bay reclamation area has become a construction land, the

salty field within the bay has been restored into landscape waters, the bay area is connected by a banded waterfront walkway or trail system, which continuously integrates a series of waterfront public spaces such as Wuyuan Bay Wetland Park, Wuyuan Bay Thanksgiving Park and Huanwu Lake Bay Trail（Table 4）, thereby promoting the urbanization development process in the northeastern part of Xiamen Island, attracting a large number of people to enter, and reducing the development pressure of the old urban area and the central urban area of YUNDANG Lake in the southwest.

3.2.3 Advance layout of Xinglin Bay waters and new urban area expansion during cross-island development

Located in Jimei District outside the island（Figure 2）, Xinglin Bay has a freshwater area of 6.9km2. In 1956, it became a closed reservoir due to the construction of seawall. Continuously adopting the ecological restoration concept of Wuyuan Bay waters development, the Xiamen Municipal Government took the opportunity of hosting the 6th International Garden Expo to determine that the city parks carry out the large-scale exhibitions to enhance the public's attention to the newly developed area and provide an endless driving force for development of the new area. After nearly ten years of development, the development orientation of Xinglin Bay New Area mainly includes the recreation, residence and mixed functions with the shoreline retreat line set for the building and the hydrophilic buffer zone reserved. The integration from the inner bay to the outer bay involves in Xinglin Bay Green Way and Garden Expo Site to a large-scale ecological park system with Xinglin Bay as the core. The construction of the urban park system of Xinglin Bay has played a

Figure 7 The photos of the waterfront park system : Yundang、Wuyuanwan and Xinglin Bay.

huge role in promoting the construction of Xiamen Bay New Urban Area greatly promoting the urban integration process inside and outside Xiamen Island.

4. Spatial form and efficiency of large-scale waterfront park system in Xiamen

4.1 Spatial form of three major waterfront park systems

It can be seen from Figure 7 that the three major waterfront park systems make full use of the abundant coastal and lake-shore resources of Xiamen Bay, connect and organize the overall planar composition of the waterfront area with linear walkway space. Point-like and planar islands & terraces in the middle of the water body are fully utilized to organize the construction of the park system. Due to the differences in development time sequence and the surrounding environment as well as the development concept, the scale of the planar layout is different.

4.2 Spatial efficiency of three major waterfront park systems

4.2.1 Spatial domain of three major waterfront park systems - connectivity efficiency

A coastline can provide significant development potential in new urban functional organization and environmental planning Through the land use, urban organization and waterside-related activities (Hoyle, 2002) and can also improve the competitiveness of the city by providing the large-scale attractive leisure, office and residential projects (Fainstein, 2008). （Figure 8）Before 2000, the parks around the YUNDANG Lake water system were completed and put into use. However,

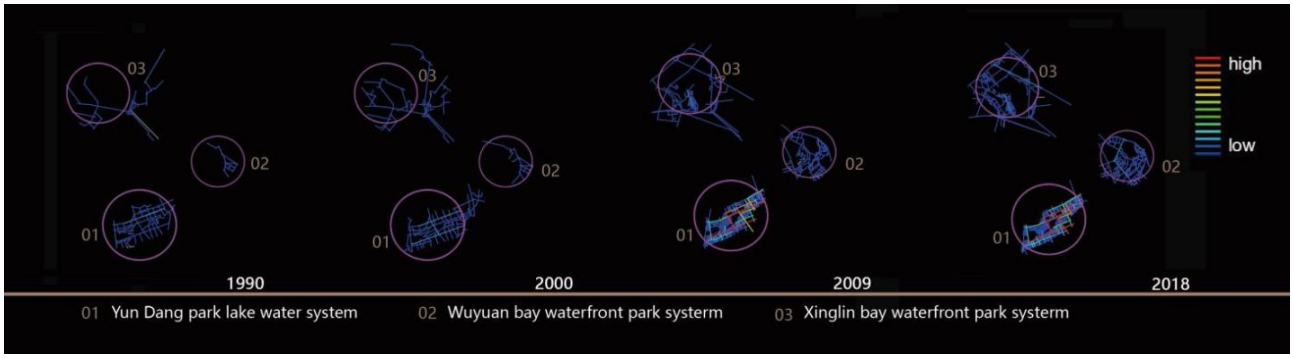


Figure 8: Spatial distribution of ChoiceR3 in Xiamen, 1990, 2000, 2009, 2018 (integrated by red to blue)

the early built parks were scattered around the lake with poor connectivity: urban green space being scattered, broken and unconnected; urban traffic road network making the layout and organization of park land scattered and fragmented; and the trail or walkway system around the bay being not effectively connected to each park at the spatial level. Therefore, the selection value in which the

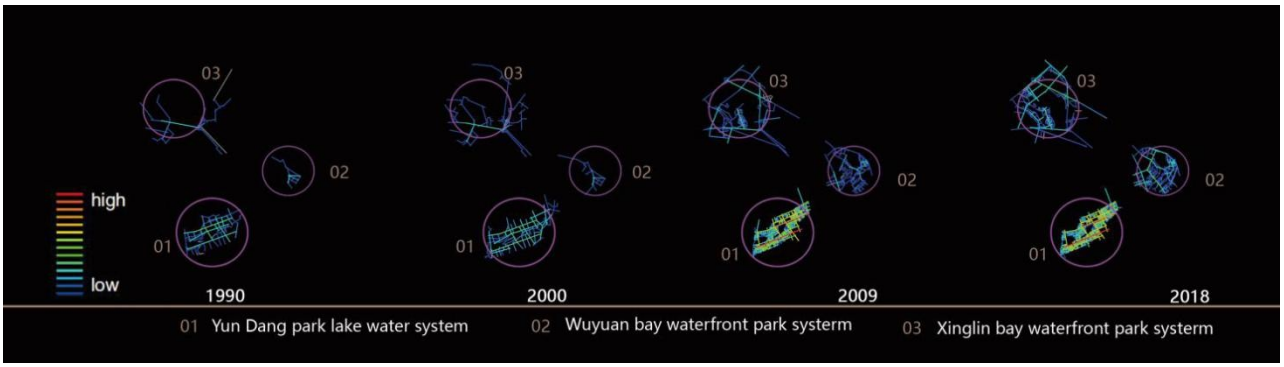


Figure 9: Spatial distribution of integrationHHR3 in Xiamen, 1990, 2000, 2009, 2018 (integrated by red to blue)

path travel potential is a measurement indicator is low, a situation like developed areas such as Wuyuan Bay and Xinglin Bay. After 2000, the trail around the lake effectively integrated the greening landscape resources of all levels of the city by integrating the green roads, parks, plazas and green residential areas that scattered on the lakeside, thereby making the selection degree of regional syntax obviously increased and reflecting the core position of the areas around YUNDANG Lake in the downtown area of Xiamen Island. By 2018, the construction of YUNDANG Lake waterfront park system had taken shape with the park construction being mainly based on small-scale spatial transformation or local area function improvement and the overall degree of selection not changing changed much. Furthermore, it can be observed that since 1990, the selection value of waterfront park systems in Wuyuan Bay and Xinglin Bay has not changed significantly. The analysis shows that Xiamen Island has successfully carried out a transition featuring One Core and Multiple Centers. However, for the waterfront park system in the urban development new area, it needs time for the development and improvement in the population, economy, and industry so forth in the surrounding area. Obviously, two waterfront park systems in Wuyuan Bay and Xinglin Bay are not really integrated into the urban development process with the space efficiency of connectivity being not yet obtained.

4.2.2 Accessibility of three major waterfront park systems - service efficiency

The degree of integration reflects and measures the specific space as the potential and advantage of the behavioral destination. The service efficiency of the waterfront park system can be analyzed by site accessibility. As shown in Figure 9, this is consistent with the process of urban transformation in Xiamen Island. In 1990, the regional core integration of YUNDANG Lake Waterfront Park system was not obvious, while waters of Wuyuan Bay and Xinglin Bay were in an undeveloped state. From 2000 to 2009, the regional integration of YUNDANG Waterfront Park system increased significantly and the integrated area was further expanded, reflecting the composite, diversified and spatial advantages of urban functions. The open layout and surrounding urban space permeability were good enough to satisfy the emotional needs of people in high-density cities to alleviate the feeling of depression, and the service efficiency was relatively high. During this period, Wuyuan Bay

Waterfront Park system was initially formed, but the timeliness of project development needed to be strengthened with its attractiveness being still significantly different from that of YUNDANG Lake Waterfront Park. The construction of Horticulture Expo Garden in Xinglin Bay led to the basic formation of the site transportation network and the island-like waterfront landscape pattern, attracting a large number of people in a certain time and greatly increasing the regional integration degree. By 2018, with the further refinement and implementation of policies (Cross-island Development & Coordinated Urbanization Inside and Outside Island) in Xiamen, the functions of YUNDANG Lake Waterfront Park System had basically been patched with the integration value being not obvious, but there had been a more obvious increase in the integration of Wuyuan Bay Waterfront Park System and Xinglin Bay Waterfront Park System outside the island, with the appearance of the more obvious integration center, reflecting the implementation effect of the cross-island development strategic plan.

5. Analysis and discussion

5.1 Examining the construction process of Xiamen waterfront park system from perspective of urban integration evolution

Large-scale waterfront system urban park, as a huge organic component of urban spatial organization, is a link medium between built artificial environment and natural environment. Its landscape effect, social effect, economic effect and ecological effect can have an impact on the integration degree of urban spatial organization, thereby leading to cross-regional and cross-sea development of island-type cities. The change in the spatial structure integration degree of Xiamen from 1990 to 2018 indicates that during the urbanization process of the cross-bay construction from the island to its exterior, the “lock-in” effect of the single center of the island is still higher than the attraction of multiple centers for evacuation. The space integrative core of the main urban area with the largest attractiveness, the highest commercial potential and the best convenience still expands around the surrounding area of YUNDANG Lake, but it shows the development result of the integration sub-center migration toward island exterior and differentiation with time. In three bay area cases, YUNDANG Lake area has the earliest development and is most affected by urban construction pressure and social factors, but its integrated park types are rich and diverse, and range from large municipal comprehensive parks to small community parks with varied scales thereby being closest to the needs of urban residents. Therefore, the regional integration has always maintained the highest value in urban transformation and development. After the completion of the Wuyuan Bay Waterfront Park System and Xinglin Bay Waterfront Park System, the ecological environment has greatly enhanced the attractiveness of the new urban area, and the service efficiency has improved significantly, indicating that the construction of Xiamen as a bay city is gradually moving towards a positive and good development direction. However, from the

perspective of regional connectivity, the construction of the waterfront park systems in Wuyuan Bay and Xinglin Bay areas has yet to be tested by the pressure of further development of the city, and the positive effects on the integration, synergy and competitiveness of urban development are still needed to be further verified.

5.2 Improvement of form and space efficiency in waterfront parks from perspective of regional development

Since 2000, YUNDANG Lake Area always as the core of the city's integration has a high connection value with other urban spaces, a strong influence on the surrounding urban space, good accessibility and spatial permeability, thereby providing a waterfront public space which is close to nature and diverse in style for the urban area of Xiamen subject to the the high-density & high-intensity construction, meeting the needs of citizens' daily life and leisure, and enhancing the image of urban landscape. The construction of the waterfront park system as a urban leisure and tourism destination in Xiamen, has achieved good economic benefits, brought about a huge tourism increment effect, and promoted the leap-forward development of Xiamen's urbanization process in the late 20th century. Wuyuan Bay Area is an emerging strategic center in the northeastern part of Xiamen Island. Xinglin Bay, located in the core site of Jimei New Area development outside the island, is an important pioneering project in Xiamen's cross-island development strategy. In Wuyuan Bay Area, Horticulture Expo Garden has become a core component of the public green space system in Jimei-Xinglin New Area, which is the improvement and supplement of the urban park system featuring One Area, One Ring, Two Belts, and Multiple Corridors in Xiamen (Lin Ying, Fan Jiangmei, & Pan Wei, 2008). It is still in a low state when examined from the connection value parameters of the four time periods, but we can see that the walkway around the bay in the three large waterfront park systems has a strong effect of connection and integration with public resources from the surrounding urban areas thereby weakening the strait boundary effect and reflecting the phased-type results of historical development in Xiamen as a bay-type city.

It is worth noting that the development of Xinglin Bay Waterfront Park System is different from the other two cases. It adopts the advanced strategy of driving the urban development Horticulture Expo Garden Scenic Spot with subsequently a series of leisure green space with different levels and functions which is integrated with the surrounding waterfront line so retaining the boundary part of the natural habitat to a greater extent and the better openness. In other words, it makes the new urban system more quickly integrate into the cycle of the original natural system, greatly promoting the urbanization process to integrate areas inside and outside Xiamen Island.

6. Conclusions and recommendations:

6.1. Conclusions

(1) From the perspective of material space and social behavior, Xiamen has achieved a successful transition from an island city to a bay city in the past 30 years. Urban parks acting as a special city development gene have participated in important activities such as the renovation of the old urban area of YUNDANG, the transfer of the center of Wuyuan Bay New Area, the cross-island development of Xinglin Bay Area, and even played a pioneering role in the implementation of the cross-island strategy. With the feature of the integrated center emerging in the spatial structure, urban parks have promoted the implementation of the Xiamen cross-island development strategy and accelerated the urbanization process.

(2) Due to the limitation of natural form, the development of the bay waterfront park system has a high degree of spatial identity, but it has great differences due to different geographical locations, time nodes and development conditions. All three park systems adopt the linear space to connect bay waters and integrate shoreline resources, and adopt point-like or face-like islands and terraces in waters as the main land for park construction to accommodate a variety of common or individual group-type activities. The length and width of the linear space around the bay and the difference in the integration with the surrounding urban texture can affect the order and spatial experience of the waterfront space, thus affecting human behavior.

(3) Limited geographical capacity and landscape topographical constraints are the most important limiting factors for the expansion and development of island cities. Constructing a large-scale waterfront park system is one of the important and effective methods for the development of waterfront space in island cities. The connectivity of waterfront space and the accessibility of activity space are affected by factors such as the development time, type configuration, and construction intensity of the park. The waterfront park system can repair the missing ecological functions of the old urban area, catalyze and promote the development of the new urban area [29], more accurately reflecting the essential characteristics of urban waterfront space as a kind of public space.

(4) The heterogeneity of the waterfront space provides a buffer zone for high-density urban space, which can integrate the waterfront coastline that has been damaged by disorderly development, rationally allocate natural resources and human resources, strengthen the image of the public space provided by waterfront space, support the generation of public leisure behaviors and activities of commonality or individuality, provide citizens with a better vision and perspective for viewing, understanding and feeling the island cities, and reconcile the inconsistent texture space of the city, in which the spatial performance is more active, open and efficient.

6.2. Strategies and recommendations for sustainable development

Sustainable urbanization has been positioned as a method of responding to the uncertainties of the future development of different types of cities, which has been widely accepted and recognized worldwide（Roggema, R. 2016). From the development process of Xiamen City in China, we can see a microcosm of urban progress in developing countries. For most cities in China, the strategic decision-making and policy orientation at different stages of development are extremely important . Li Xinhu et al (2011) pointed out that the potential determinants of Xiamen Island's spatial expansion include labor policy, urban master plan, population growth and industrial development so forth. Island-type cities should use planning and design techniques to make clever use of natural bay and mountain & water resources to eliminate the obstacles to space development brought by the bay, increase and optimize the urban regeneration function, use the urban park's environmental network and site facilities to enhance the comprehensive carrying capacity of urban infrastructure, create more flexible space to adapt to dynamic social behavior needs, and develop empirical models applicable to the sustainable development of island-type cities.

The combined use of the two concepts i.e. new urban metabolism and elastic development can make an important contribution to the formulation and implementation of sustainable development strategies(Magoni, & Marcello. 2017). The development and reconstruction of the waterfront area of the island city reflects the historical changes in the use of land and water resources at the edge of the city. The governance process in the waters of YUNDANG Lake means that the various administrative departments of Xiamen Municipal Government actively learn from the advanced experience and carry out the correction and innovation, with their attitude towards environmental pollution experiencing a transition from passive acceptance to active governance, from negative treatment to active prevention. Furthermore, the urban park construction is used to adjust and correct the urban ecological resilience and spatial structure, providing a sample for reference for each new district in their development practices. Despite the different historical backgrounds of construction, these practices are a good experimental model, which solves many practical problems through collaborative planning and design integration, and accumulates relevant experience in urban development.

7. Research limitations and research recommendations

This paper attempts to explore the urban development of Xiamen Island by combining the dual perspectives of material space and social space, focusing on the positive development of the development of island-type cities. Since the 1990s, the Chinese government has noticed that the development of the waterfront area is a positive measure to enhance the urban landscape and strengthen the city's attractiveness and competitiveness. This is of great significance to island-type cities. In fact, due to the grim nature of global climate change and ecological environment, the

impact of the waterfront park system on modern urban development may be long-term, complex, dynamic and uncertain, and there will be a series of potential catalytic effects. The research in this paper is inevitably limited by research perspectives and research conditions. Therefore, I hope that the subsequent research can further explain this with a more rigorous and comprehensive analysis.

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