Balance Between Construction and Conservation

Research on Rational Design Approach in Waterfront Ecological Sensitive Area

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Abstract: Waterfront ecology sensitive area is a specific urban space should be focused and discussed. Many urban ecologists, designers, and planner describe key research questions and frontiers for urban ecology, design and planning. They usually focus on the relationship between urban ecology and urban construction. However, through analysis the consequences of previous research, we can find a barrier which insulate the urban construction and ecology conservation of many previous researches. Therefore, how to design cities where people, urban development and ecology can both flourish? How to make balance between urban construction and ecology conservation? Does there exist any potential design or planning approach or concept can be used to achieve this balance?

Based on above questions, this research aims to provide a rational urban design approach and framework based on a comprehensive digital ecology analysis sandbox which combine the multi-source urban big data and digital techniques, such as water quality, health and ecological security data and MIKE 21model. Xianghu lake waterfront area was selected as case study to verify the approach and research consequences. Through the research, urban designer and planner can understand the reason and influence mechanism behind these issues more scientifically and clearly. Meanwhile, main methods and design approaches which demonstrate by the research may contribute for further ecological sensitive and sustainable urban design.

1. Introduction

During the urbanization process, there is an inherent tension between urban construction and ecological environment conservation. (Lin and Li, 2019) On the one hand, due to ecological vulnerability and potential ecological security risk, urban development and construction is usually restricted in ecological high-sensitive area. On the other hand, specific and graceful scenery of ecological sensitive area usually attract more urban development and activity. (DeFries, Hansen, Turner, Reid, & Liu, 2007; Jing, Liu, Cai, Liu, & Zhang, 2018; Li *et al.*, 2013) However, as Lin and Li (2019) indicated that generally many local governments pay more attention to immediate economic benefits from urban development than other factors. This situation is prominent in China. Economic benefits leaded urban development pattern usually breaks the

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balance between ecology and urban construction, and result many environment issues, such as pollution, urban waterlogging and biodiversity loss (Kiss and Kiss, 2018). Simultaneously, protection-leaded ecological sensitive area development pattern builds a 'wall' between urban development and environment ecology (He, Tian, Gao, & Zhao, 2014). The contradiction between urban construction and ecological conservation is intensified by this negative relationship. Therefore, how to make a balance between urban construction and conservation? How to balance the economic benefits and ecological quality? Does there exists any methods can be used to balance the development and protection during the design and planning process?

For above questions, many urban ecologists, designers and planners demonstrate the frontiers for urban ecology, design and planning field. These previous researches can be divided into three main types based on their research questions and objects. The first type of research is focus on the urban ecology only. This kind of research consider the urban ecological environment as a complete system. For example, Douglas (2012) in his research indicated that the urban ecology is to examines how the characteristics of the urban landscape mosaic, a various part of it. These researches have contributed to the recent development of landscape ecology (Yu *et al.*, 2019). These researches mention to analysis the ecology part of whole urban system, and they attempt to understand both internal and external mechanism between ecological factors and whole urban system (Kiss and Kiss, 2018). Unfortunately, these researches set urban ecology factors as a priority and might ignore the bidirectional influence between urban development and urban ecology. Another type of researches admitted urban ecology as a transdisciplinary science. These researches criticize current conventional urban planning which often focuses more on development demands, economic growth than on ecological sustainability (Nassauer *et al.*, 2014). These researches illustrated a remarkable improvement in urban ecology research field, because they attempt to build a bridge between urban planning and ecology. However, based on the consequences of these researches, we can find a common point in here is that the ecological theories and landscape ecology are still in prior position. Therefore, urban construction and ecological environment conservation is still considered unequally during the urban development process (Wu, Xiang and Zhao, 2014). Recently, based on the progress of technology and methodology in urban design, development and research field. A new kind of research appearing in the relationship between urban construction and urban ecology filed. These researches mention to understand the deep interrelationship between urban development and urban ecology through adopt the advanced techniques and methods, such as GIS (Geographic Information System) (Lin and Li, 2019). These researches focus on the advanced technology and methodology, and the influence of these new technology in relevant research filed. These researches provide an opportunity to understand the deep interaction between urban construction and ecology conservation, and thinking how to make balance between construction and conservation during urban development process.

Based on above, this research aim to find a rational urban design approach which can be involved in urban planning process to make balance between urban construction and ecological environment conservation during urban development. For achieve this aim, multi-source urban big data was adopted to construct a digital ecological analysis sandbox in here. Afterwards, waterfront area of Xianghu lake was selected to conduct case study, due to the ecological environment is more sensitive in waterfront area and the issues is the area is more representative. During the research, water quality, health, ecological security, etc. was examined. Meanwhile, MIKE 21 model was used to simulate water network flow field. According to the analysis consequences, rational approaches were researched and adopted during the urban design process to make balance between urban construction and ecology conservation in the ecological sensitive area.

2. Methodology

Through adopted the digital methodology, multi-source big data of urban ecology filed is combined and calculated in here to build a digital ecological analysis sandbox. (Figure 1) The main methods during this process is demonstrated in below.

Micro-climate analysis: This method mentions to analysis the interaction between urban form and urban micro-climate. Different urban form might result different micro-climate condition. Thus, through adopted the micro-climate analysis method in urban design process can improve the comfort level of urban physical environment in a place. Micro-climate analysis is divided into two aspects in here. (1) The thermal environment of research area is measured through two steps. Firstly, satellite remote sensing data of 1984, 1991, 2003 and 2015 was acquired through LANDSAT of United States Geological Survey (USGS). Then, Computer simulation technology was adopted to establish urban spatial model, and software such as ENVI-met, ECOTECT and RayMan were used to simulate and evaluate the thermal environment (Stewart, 2011). By analyzing the simulation results and comparing the differences of thermal environment under different urban spatial morphological indexes and spatial morphological types, the coupling correlation between urban spatial morphology and urban thermal environment is concluded (Coseo and Larsen, 2014). Afterwards, site investigation method is adopted to collect Surface temperature, air temperature, relative humidity and other meteorological data, and through combine the land function of the research area and various spatial morphological indicators to analysis the interactive mechanism between urban 3D morphology and urban micro climate. (2) The method for measurement the wind environment is includes three steps. The first step is use field research method to calculate the spatial morphology indexes in research area as the basis factors of wind environment case study. Afterwards, computer numerical simulation method was also used to establish the space model of the central area and conduct numerical simulation for the wind environment (Bruse and Fleer, 1998). Then, CFD software scSTREAM was adopted to generate the simulation results and comprehensively analyze the space distribution characteristics of the wind speed at the pedestrian height (Murakami *et al.*, 1999). Afterwards, conduct multivariate linear regression analysis on the wind speed parameters and space form parameters of blocks with data analysis software SPSS, and discuss the correlation between each space form index and the wind speed level at the pedestrian height, further evaluate the characteristics and causes by comparing the differences of wind environment in different types of space units.

Surrounding Surface Runoff Analysis: The surface runoff can be considered as the main aspect of non-point source pollution in an area. Urban non-point sources are the main sources of water pollution, which have the characteristics of sudden, high flow and heavy pollution. During the urban construction process, the surface will be changed from nature to hard. Therefore, through analysis the surface runoff situation can reduce the urban non-point source pollution. In this research, GIS (Geography Information System) was adopted to conduct the surface runoff analysis (Singh *et al.*, 2010). Firstly, the basic site information which include altitude, topography and current river system is imported to the GIS platform. In addition, the local hydrologic data and rainfall data was also adopted to analysis the site surface runoff. Then, Arc Hydro Tools was used to analysis the direction and catchment line of the site.

MIKE 21model: is a computer program that simulates flows, waves, sediments and ecology in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions. It was developed by DHI. MIKE 21 contains a series of modules, which in combination cover nearly the full range of possible water quality and ecological applications. Therefore, MIKE 21 can be used for design data assessment for coastal and offshore structures, optimization of port layout and coastal protection measures, cooling water, desalination and recirculation analysis, environmental impact assessment of marine infrastructures, water forecast for safe marine operations and navigation, coastal flooding and storm surge warnings, inland flooding and overland flow modeling. Through MIKE 21 software package, the concentration field, water level, water depth and X&Y velocity field of main pollutants in Xianghu were simulated, and the comprehensive evaluation of water status was obtained to guide the optimization of shore shape and shoreline and site selection of wetlands during the design process. In this research, MIKE 21 model was used to conduct the comprehensive simulation of water ecological environment through following steps. Firstly, MIKE 21 model was adopted to conduct the simulation of concentration field of major pollutants, water levels, water depth and flow velocity in X&Y direction. Afterwards, multi-factor superposition analysis was conducted to integrate the simulation of above aspects. Then, the key optimization and protection ecological sensitive areas were determined through comprehensive evaluation of multi-factors. Finally, the reverse simulation verification was conducted to justify the analysis consequences. Through adopt the MIKE 21 model, the water ecological environment in research site can be comprehensive evaluated. The evaluation and simulation consequences of MIKE 21 model provide a meaningful and scientific foundation to support the rational urban design approach in ecological sensitive area.

COD method: In environmental chemistry, the chemical oxygen demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution. (Clair *et al.*, 2003) It is commonly expressed in mass of oxygen consumed over volume of solution which in SI units is milligrams per litre (mg/L). A COD test can be used to easily quantify the amount of organics in water. The most common application of COD is in quantifying the amount of oxidizable pollutants found in surface water (e.g. lakes and rivers) or wastewater. COD is useful in terms of water quality by providing a metric to determine the effect an effluent will have on the receiving body, much like biochemical oxygen demand (BOD). COD method was used to evaluate the water quality of the research area. During the research, 16 water quality sampling points was selected to acquire the water sample. Based on a standard method which is described by International Organization for Standardization (ISO) for measuring chemical oxygen demand in ISO 6060. In this research, potassium dichromate was used to test the water sample. Potassium dichromate is a strong oxidizing agent under acidic conditions. Acidity is usually achieved by the addition of sulfuric acid. The reaction of potassium dichromate with organic compounds is given by:

$$C_nH_aO_bN_c + dCr_2O_7^{2-} + (8d + c)H^+ \longrightarrow nCO_2 + \frac{a+8d-3c}{2}H_2O + cNH_4^+ + 2dCr^{3+}$$

where $d=2n/3+a/6-b/3-c/2$. Most commonly, a 0.25 N solution of potassium dichromate is used for COD determination, although for samples with COD below 50 mg/L, a lower concentration of potassium dichromate is preferred. In the process of oxidizing the organic substances found in the water sample, potassium dichromate is reduced (since in all redox reactions, one reagent is oxidized and the other is reduced), forming Cr3+. The amount of Cr3+ is determined after oxidization is complete, and is used as an indirect measure of the organic contents of the water sample. Based on the COD method, the water quality of the research area was tested. The measurement results of water quality will be used to justify the design scheme and compare with the simulation results of research area after urban construction.

Pollution load index: is the total amount of pollutants that enter a water body from point and surface sources within a certain period of time. Pollution load is an important index for water quality evaluation, prediction and water pollution control. The Pollution Load Index (PLI) is obtained as concentration Factors (CF). This CF is the quotient obtained by dividing the concentration of each metals. The PLI of the place are calculated by obtaining the n-root from the nCFs that were obtained for all the metals. With the PLI obtained from each place. During this research, pollution load index method was adopted to calculate the pollution load of the site through the formula in below.

$$V(t)\frac{dc}{dt} = Q_{in}(t) \bullet C_{in}(t) - Q_{out}(t) \bullet C(t) + S_c + kV(t)C$$

V(t) – The amount of water at time *t*(m3); dc/dt – Rate of change of COD, ammonia nitrogen and other parameters; Qin(t) – Streamflow at time *t*(m3/a); Qout(t) – The outflow at time *t*(m3/a); Cin(t) – The inflow concentration at time *t*(mg/L); Cout(t) – The outflow concentration at time *t*(mg/L); C(t) – Lake concentration at time *t*(mg/L); Cs – Pollution from external sources; k – The comprehensive degradation coefficients of COD and ammonia nitrogen.

Through calculate the pollution load index, the pollution load ability of the research area can be acquired to provide a reference for discover rational urban design approach in ecological sensitive area.

Case selection and study: Based on above measurement methods, Xianghu Lake area was selected to conduct the urban ecological research for discover the rational urban design method and justify the research consequences and possible ecological sensitivity design method. Xianghu Lake research area locate in the East of China. The site is near Qiantang river and Hangzhou city (Figure 2). In 2018, Hangzhou local government launched an urban development project around Xianghu Lake. According to this development project, the surrounding waterfront area will be constructed to a national tourism resort. However, Xianghu Lake is a part of whole Qiantang river system, and the ecological environment is sensitive in Xianghu Lake area. If the ecological environment of Xianghu Lake is negative impacted during the construction process, it will result a ecological chain reaction for whole Qiantang river system. How to balance the interest between economic and ecological dimension can be considered as an urgent issue during the development process. Therefore, based on this practical problem, we select Xianghu Lake as the case study in here to integrated analysis the ecological environment of the site through digital methods and techniques. Then, based on the evaluation consequence to discover the rational urban design approach in the waterfront ecological sensitive area.

2.1. *Results*

Based on the consequences of comprehensive analysis of ecological environment in the research site through digital ecological analysis sandbox. This research verified that the ecological environment will be impacted during urban construction process again. Through simulate the different design proposals of the site, we find that some proposal might negative influence the local ecological environment in different extent. This result is discussed by many previous researchers, and this finding can be considered as common knowledge at same time. Based on this concept, the ecological protection is always set as a priority during urban design, planning and construction process. However, according to the evaluation process, this research found something different. During the designing proposal simulation process, we find that some proposals not only without any negative impact on local ecological environment, but also improve the ecological quality in some extent. Based on this finding, we attempt to make a link between urban design and ecology and find a rational urban design approach in ecological sensitive area.

2.2. *Result of water surface runoff*

Based on GIS platform, firstly, the internal morphology of Xianghu lake surface runoff system was summarized in detail. Through consequence visualization process, we can find that Xianghu waterfront ecological area is located at the intersection of Qiantang river, Puyang river and Fuchun river. Thus, the surface runoff in Xinghu waterfront area us a complex network. Meanwhile, through site investigation, we find that the surface water and groundwater are abundant in the region. The ecological environment of Xianghu waterfront area is mainly composed of rivers, lakes, rivers, canals and ponds. In addition, based on the analysis results of basic geography factors, such as altitude, terrain and mountain distribution, we also find that the mountain has multiple catchment lines to provide an effective water supplement in whole Xianghu area.

As the methodology part indicated that surface runoff is the main route of non-point source pollution in an ecological sensitive area. Therefore, some purification measures are needed to prevent the non-point source pollution in the area. In addition, the multiple catchment lines should be considered during the urban design and construction process to prevent the water from shrinking. Based on that, the urban construction should avoid interdict the main surface runoff.

2.3. *Result of water quality*

Water quality is the major ecological factor to reflect the situation of whole waterfront ecological environment. Through MIKE 21 software package, the concentration field, water level, water depth and XY dimension velocity field of main pollutants in Xianghu were simulated. The results indicated that the water velocity in the south of the lake and along the narrow coast of the lake is mostly 0.04m/s, which is prone to eutrophication and algal bloom. Furthermore, based on the calculation results of COD, the single factor evaluation method was further adopted to evaluate the water quality of the lake. The results reflected that Xianghu water quality is classified as grade IV or V in national standard (GB 3838-2002), and the main exceeding factor is TN compared with grade III water quality. (Table 1) The water quality of the southern river is of class IV and V, and the main pollutant factors are CODMn and nh3-n. The water quality of the farmland section near qiantang river is better than that of the urban section.

Based on above results, we find that increasing the dikes and islands in the lake is conducive to enhancing the variability of water flow field and cultivating the diversified ecosystem of Xianghu lake, and the comprehensive evaluation of water status was obtained to guide the optimization of shore shape and shoreline and site selection of wetlands during the urban design process.

2.4. *Result of Pollution load ability*

Based on the methods which was demonstrated in methodology part, the direct catchment area of Xianghu lake covers an area of 19.25km squared, of which the planned urban land area is 12.81km squared and the mountainous and hilly area is 6.44km squared. After weighting the

Table 1. *Water quality measurement results. Source: Made by Author.*

Sample Point	CODMn	TP	TN	NH_3-N	COD
1	1.85	0.0103	1.52	0.54	5.6
2	2.44	0.0079	1.55	0.46	4.7
3	3.08	0.0251	3.11	1.22	2.6
4	2.28	0.0091	1.71	0.33	5.5
5	2.32	0.0085	1.60	0.42	5.5
6	2.36	0.0079	1.63	0.44	5.1
7	2.20	0.0090	1.44	0.4	5.8
8	2.96	0.0062	0.86	0.45	5.4
9	1.75	0.0123	1.48	0.41	6.6
10	1.40	0.0054	1.27	0.35	5.6
11	2.36	0.0094	1.28	0.31	5.7
12	2.36	0.0079	1.63	0.44	5.1

urban non-point source pollution load, the comprehensive output coefficients of COD, TN and TP were 320kg/(ha.a), 40kg /(ha.a) and 7.0kg /(ha.a), respectively. According to the water area of Xianghu lake is about 10.6km^2. The comprehensive degradation coefficient of COD, TN, ammonia nitrogen and other pollutants is 0.05d^{-1}, and the safety coefficient is 0.75. Therefore, under the condition of surface class III water quality as the target, the sewage carrying capacity of the lake is: COD: 3789t/a; TN: 157 t/a; TP: 32 t/a. The load of non-point source pollution in Xianghu catchment area is: COD: 1068t/a; TN: 133 t/a; TP: 23.3 t/a. Based on above measurement results, the current pollution carrying capacity is slightly larger than the non-point source pollution load in the catchment area around Xianghu lake.

Therefore, the above numerical value of pollution load ability of Xianghu Lake can be considered as the critical value and deadline during the urban design and construction process.

2.5. *Result of waterfront ecological health*

Waterfront ecological health can be considered as a multi-level complex index system which involve basic water quality characteristic, water network from, hydrological characteristics, ecological system and ecological landscape. Thus, based on the functional zoning and systematic structure analysis of Xianghu lake as a tourist resort, the ecological health risk evaluation index system of Xianghu lake is constructed. The established health evaluation factors include 17 evaluation indexes of hydrology and water resources, water system structure, ecological function, ecosystem health and tourism landscape value. (Table 2)

The health score of Xianghu Lake was 2.95, and the health evaluation level was good. These indexes also can be used to guide the urban design and construction.

Table 2. *Weight and assignment of waterfront ecological health measurement index. Source: Made by Author*

Standard	Weight	Index	Weight	Assignment
Water quality Characteristic B1	0.43	Nemerow multi-factor index (C11)	0.64	3
		Nutrition index (C12)	0.26	2
		DO (Dissolved Oxygen) (C13)	0.10	1.55
Hydrological characteristics B2	0.16	The lowest ecological water satisfied level (C21) Runoff into the lake (C21)	0.75	4
		Water renewal cycle (C22)	0.25	3
Water network from B3	0.07	Lake basin stability (C31)	0.25	3
		Lakeshore stabilit (C32)	0.25	3
		Vegetation integrity (C33)	0.25	3
		Form of shoreline and revetment (C34)	0.25	4
Ecological System Index B4	0.26	Green belt plant coverage (C41)	0.09	4
		Phytoplankton diversity (C42)	0.06	3
		Native plant retention rate (C43)	0.07	4
		Natural water proportion (C44)	0.39	2
		Habitat quality index (C45)	0.39	3
Landscape Ecological Index B5	0.08	Aesthetic measure (C51)	0.33	4
		Landscape accessibility (C52)	0.33	3
		Lakeside green belt width (C53)	0.34	4

2.6. *Result of urban micro-climate*

Temperature is an index which may also influence physical feeling of people, especially during the summer. Thus, the thermal environment is also measured in the waterfront area to ensure a comfortable waterfront physical environment in the pedestrian level. Through measurement of both thermal and wind environment, we find in the lake area there is a cold island zone running from northeast to southwest in the site and surrounding areas, and the heat island area is concentrated in the northwest and northeast areas. In addition, the wind speed in the area along the river is concentrated in the range of 2~5m/s, and the wind comfort presents the characteristics of subsection change. Meanwhile, there also exist many hot island zone and quiet wind, weak wind zone in the surrounding area of Xianghu Lake, due to the wind corridors are blocked by surrounding mountains. Furthermore, the air pollution is closely related with the wind environment and impact on urban physical environment. Thus, based on the measurement results, the southwest side of Xianghu lake is easily affected by air pollution.

Based on above analysis results, we can believe that the wind is the best solution for issues of both thermal environment and air pollution. Thus, wind corridors should be reasonably constructed to adjust wind direction and reduce the site's heat island effect during the urban design and construction process.

3. Discussion: Rational Design Approach in Ecological Sensitive Area

As the introduction part of this paper demonstrated, during the rapid urbanization process, there exist a serious contradiction between urban construction and ecological environment. In the past decades, many urban researchers, designers and planners are all believes ecological conservation have priority during the urban planning and construction process. In China, the "protected areas" are also known by the term "ecological rea line" (ERL), which mainly focuses on green spaces in urban areas. (Lin and Li, 2019) The ERL means that the ecological deadline for urban development and design. This concept results the "conservation" become the "over-lords" during the design and development process. However, through above analysis, we have to better understand the ecology and sustainability of cities. Based on the digital measurement method and techniques, we can understand the interrelationship between urban ecology and urban construction deeply. Therefore, we argue that relationship between urban construction and ecological environment conservation is not antagonistic. A win-win relationship can be achieved between construction and conservation. Therefore, take Xianghu Lake waterfront ecological sensitive area as an example, we discussed a rational design approach framework to make balance between construction and conservation.

Water purification process: is a comprehensive system, it includes purification microunits, corridor and interarea three steps. These three parts will refine water and rain step by step to reduce the potential pollution threat. Water purification methods by land block treatment, underlying surface treatment, and ecological water system treatment: the green roof, sunken green space and rainwater garden; underlying surface treatment includes road retention canals, permeable paving and municipal drainage pipelines; and ecological water system treatment includes ecological purification group, waterfront wetland and rainwater storage pond.

Block and Building Water purification Strategy: there three main aspects are including in here: (1) multiple greening combinations can minimize surface runoff and improve water quality; (2) increase green roof, reduce hard pavement, reduce urban rainwater runoff, and reduce urban rain flood risk. It is recommended that the green roof rate reaches 50%. (3) It is suggested that the rainwater collection and treatment rate can reach 80%.

Urban green space and permeable floor design approach: there two strategies including in here: (1) Three-dimensional greening includes vertical greening, roof lawn, roof garden, balcony greening, etc. (2) Pervious floor can quickly infiltrate into the surface, effectively replenish groundwater, mitigate the urban heat island effect, and protect the urban natural water system from damage.

Optimization embankment and waterfront: Based on the simulation results of MIKE model package, the existing embankment types are optimized accord to different water height. In addition, all embankment optimization method will also enhance the waterfront vitality and ecological environment.

4. Conclusion

Urban ecology in China started in the early 1980s, China's urban ecology has focused on environmental pollution and eco-cities. It means that the ecological conservation still has a priority

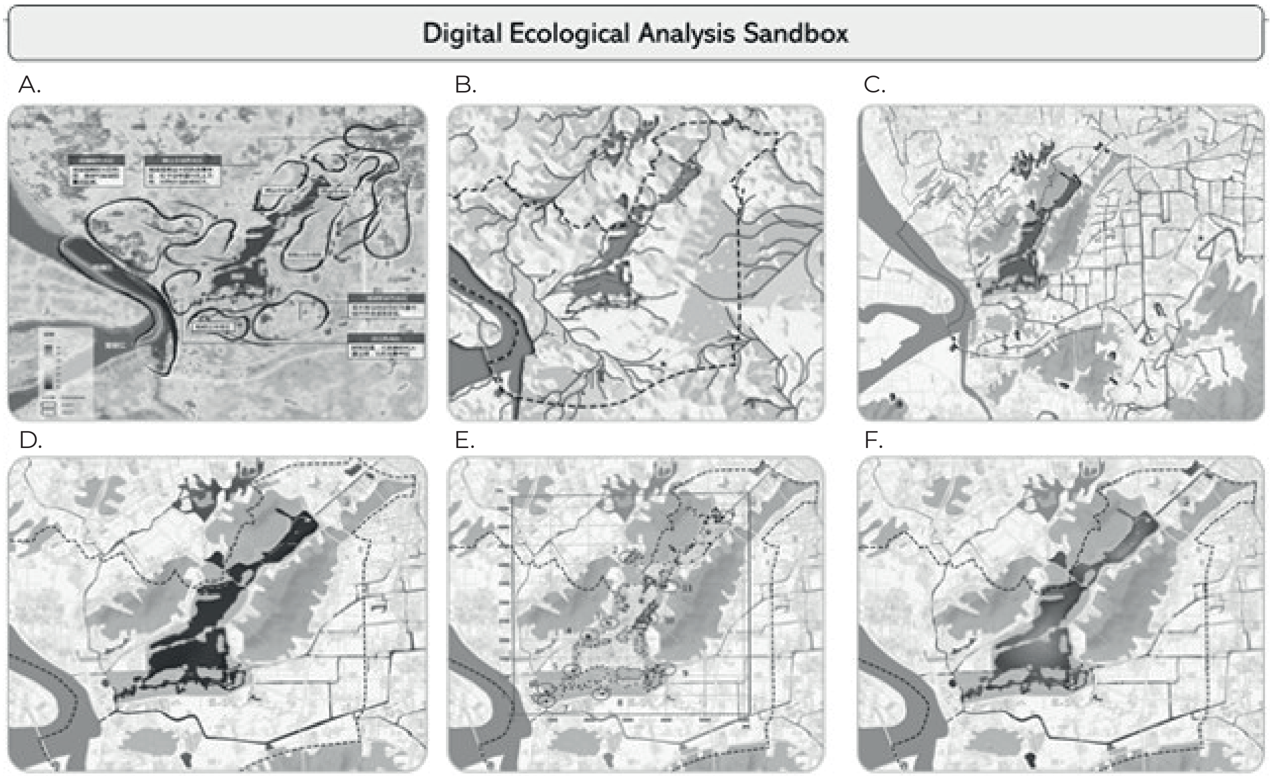

Figure 1. *Digital Ecological Analysis Sandbox. Source: Author Make (a. Micro-climate analysis method; b. Sorrounding Surgace Runoff Analysis; c. Water quality evaluation; d. Pollution load analysis; e. MIKE 21 model; f. Water ecology health evaluation).*

during the urban construction process. If we related with the urban development background in China, this situation might be correct, due to the ecological system still under the risk of destruction during the urban construction process. However, due to the speed of urbanization is slow down, the relationship between urban construction and ecological conservation should be rethought under new background. Therefore, this research through build a digital ecological analysis sandbox to conduct an integrated evaluation of a waterfront ecological sensitive area. Afterwards, based on the evaluation consequence, we demonstrate a possible rational design approach in ecological high-sensitive area to balance the urban construction and conservation. However, these approaches can be considered as an ideal concept, more verification and exploration should be conducted in the future.

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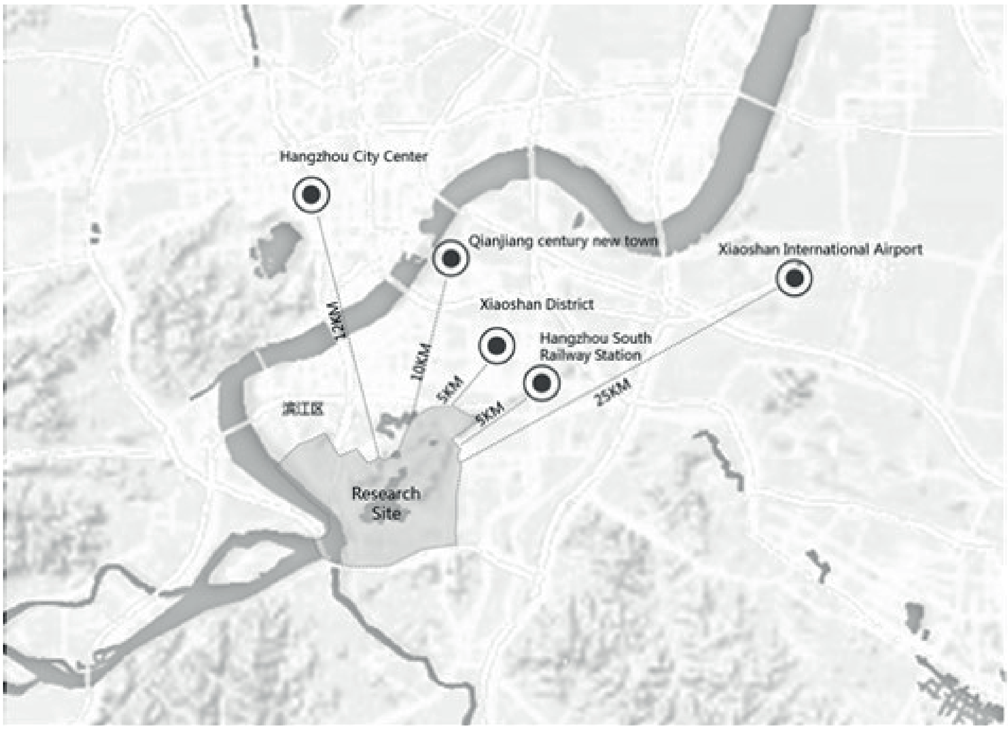

Figure 2. *Location of the research site. Source: Author Make.*

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