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Urban Optimum Population Size and Development Pattern Based on Ecological Footprint Model: Case of Zhoushan, China

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ABSTRACT

The agglomeration of population in the city can reflect the prosperity in the economy, society and culture. However, it has also brought a series of problems like environmental pollution, traffic congestion, housing shortage and jobs crisis. The results can be shown as the failure of urban comprehensive function, the decline of city benefits, and the contradiction between socioeconomic circumstance and ecosystem. Therefore, a reasonable population capacity, which is influenced by ecological resources, urban environment, geographical elements, social and economic factors, etc., is objectively needed. How to deal with the relationship between the utilization of natural capital and development of the city is extremely essential. This paper takes Zhoushan Island as an example, which is the fourth largest island off the coast of China. Firstly, the interactively influencing factors of urban optimal population are illustrated. And method is chosen to study the optimal population size. Secondly, based on the model of ecological footprint (EP), the paper calculates and analyzes the ecological footprint and ecological capacity of the Zhoushan Island, in order to explore the optimal population size of the city. Thirdly, analysis and evaluation of the resources and urban environment carrying capacity is made. Finally, the solution of the existing population problems and the suggestion for the future development pattern of the city are proposed in the urban eco-planning of Zhoushan Island. The main strategies can be summarized in two aspects: one is to reduce the ecological footprint, the other is to increase the ecological supply. The conclusion is that the current population of Zhoushan Island is far beyond the optimum population size calculated by the ecological footprint model. Therefore, sustainable development should be the guidance for urban planning in Zhoushan Island, and a low-carbon development pattern for the city is advocated.

1. Introduction

In the early phase of urbanization, big cities usually have suitable location conditions, reasonable spatial structures and good development conditions with high efficiency while compared to the small ones, which means better service facilities, higher living standards and more job opportunities for the city inhabitants. At the same time, the agglomeration effect of population can bring high socioeconomic efficiency and rapid expansion for the city development.

However, as increasing population gathering in the city, some negative effects appear constantly. When the population is beyond the maximum capacity ecological environment can carry, disorders of the urban system will be caused by the impact of ecological environment deterioration. In numerous large cities in Asia, traffic congestion, environmental pollution, resource shortage and other negative issues occur in varying degrees. The population concentration with the rapid urbanization process, which leads to the population exceeding the supporting capacity of the urban ecological environment, is one of the primary reasons for the contradictions in the process of urban development. Therefore, researches on the optimal population size of the city are of great importance, and must be an indispensable part in the study of urban development.

On the other hand, scientific measurement of the urban population size and understanding of the resources carrying capacity of the city can be helpful to control the influence which urban activities have on the environment within the adjustment ability of ecological system. In addition, they would be important reference indexes of urban planning, and of great significance to the sustainable development of the city.

As the population size is one of the important factors for the urban sustainable development, in this paper, the ultimate goal of the research is to explore urban optimum population with the ecological footprint model. And the solution of the existing population problems and the suggestion for the future development pattern of the city are supposed to be proposed according to the analysis of the model.

2. Urban Optimum Population Size

2.1 Theory of Optimum Population

Optimum population is a concept of population theory, which means an moderate quantity of population for the development of a country or a region. It refers to a stable population which can bring the maximum economic benefit under a certain level of productivity.

The concept was firstly proposed by Edwin Cannan (1888). He emphasized the maximizing revenue of the industry, which is the standard of the economic moderate population. The concept refers to a stable population which can bring the maximum economic benefit under a certain level of productivity. And Cannan (1964) proposed that population should keep proper relationship with the capacity of industrial and agricultural production, in order to achieve the maximum benefit for nation economy. Later the theory was developed by Sauvy (1970), who studied the relationship between population growth and economic growth and proposed the dynamic optimum population theory. The theory not only developed from a static state to a dynamic one, but it also focused on other elements like welfare, population quality and employment besides the economic benefit. With the issues of ecological environment becoming increasingly important, more researchers, such as Forrester (1971), Meadows (1972), and Vitousek (1986), started to focus on the limit to the population, which has a strong relationship with environment carrying capacity. In the phase after 1990s, more studies on the Theory of Optimum Population occurred in China. Many scholars began to study the moderate population size with the perspective of sustainable development, which has been an highlight. The theories are mainly about the population development strategy, balance of population and ecosystem, population system with different elements (Gao, 2010).

As a conclusion, the studies of early optimum population theory paid more attention to economic factors, while later the environment carrying capacity began to be involved in the measurement of population size. And now the theory has been furthered with sustainable development strategy.

2.2 Effect Factors

The carrying capacity of urban population is limited with certain condition. And the population size is determined by numerous factors which interact with each other and have combined effect on the population. The factors mainly includes environment and resources, location, urban evolution, economic and social conditions.

2.2.1 Environment and Resources

The natural ecosystem is the physical material basis for human to live. If the pressure of the human is not beyond the bearing capacity, the urban ecosystem will be under a safe condition, which can be the foundation of a sustainable development for economy and society. On the contrary, the ecological resources and environment will suffer from unrecoverable damage, and city development will be influenced. Therefore, the optimum population is under the restrictions of resources and environment, which is the indispensable part determining the population size. This basic factor applied in the study of ecological footprint and ecological capacity to calculate the optimum population size of a city or a region.

2.2.2 Location

The location of a city represents the basic difference, which is determined by geographical conditions, transportation conditions and the role of the city within the whole urban region. The geographical location represent the natural condition, which has a great influence on the development of a city. For example, the coastal cities usually have better chances and rapid development speed than other cities. And transportation conditions also affect the development of a city. For instance, a city with inconvenient accessibility usually has a relatively smaller size. In addition, the regional specialization will have impact on the city function. In general, different locations will cause the adjustment of city function and land use, which will stimulate the change of spatial form and population capacity.

2.2.3 Urban Evolution

According to the model proposed by Peter Hall in 1984, the development phases of urban evolution mainly include urbanization (population concentration in the city center), suburbanization (population spread to the suburbs) and counter-urbanization (the increasing of the population spread). During the different phases, the distribution of the population changes between the center and edge of the city, which presents the dynamic change of the population capacity of the city as well. In conclusion, the evolution of the population experiences the phase of urbanization with population concentrating in the city center, and the phase of suburbanization with migration to the suburbs.

2.2.4 Economic and Social Factor

Firstly, the economic and social factor is related to the level of economic development, which is a comprehensive indicator. The influence of the economic development level on the urban population capacity can be reflected through the living standard and the number of jobs provided. The job opportunities supplied are the primary factor affecting the population capacity.

Secondly, change of economic and social activities is influenced by city function, which has a deep relationship with the industry structure. In the different phases of economic development, the adjustment of the urban industry structure can promote the replacement and upgrade of the industry, which would lead to the transformation of urban land utilization and urban spatial form. At last, it will cause the labor migration and the fluctuations of population.

Thirdly, the carrying capacity of urban facilities is an important factor, which contains the aspects of goods supply and waste disposal. The population capacity cannot be enlarged if the living standards are improved without good urban facilities. And the carrying capacity is affected by city economy. If the economic strength is powerful enough, the population capacity can be increased.

Based on the different factors, there are numerous kinds of mathematical model for calculation and research on urban optimum population size. For example, there are multi-objective decision making approach (Jin et al, 2010) for multi-factor evaluation, short board principle of minimum volume factors(Xu, et al, 2003), concept model based on the urban ecology (Ren, 2006), etc. However, the above methods with complicated factors which contain more or less subjective factors, and among which there is no acknowledged quantitative method. In this paper, the study mainly takes the ecological environment and resources as the main factor. Through the analysis of ecological footprint, the article calculates the urban optimum population size and explores how to achieve sustainable development.

3. Method

3.1 Concept of Ecological Footprint

The concept of ecological footprint was proposed by Willian E.Rees (1992). Further it was improved by Wackernagel (1996), which is an innovative development of quantitative measurement in the field of sustainable development. Ecological footprint is mainly used for the calculation of biological production area, which could maintain the resource consumption and waste elimination under the certain population and economic size. Ecological carrying capacity means the sum of biologically productive land area provided by a district. After comparing the resources and energy consumption of a country or a region to the ecological capacity it has, we can estimate the development of the country's or the region's ecological safety. If ecological footprint is less than ecological carrying capacity, ecological remainder appears, which indicates that human influence is within the scope of ecological carrying capacity provided by the region. Then the ecosystem is safe. Otherwise there will be an ecological deficit, which indicates that the human needs for products and services have exceeded the supply of the ecosystem.

The calculation of ecological footprint is based on two facts: (1) for the vast majority of resources consumption and waste generated, people can determine the quantity (2) the resources and waste can be converted into a corresponding biologically productive area. Therefore, ecological footprint of any known population (an individual, a city or a country) is the total biologically productive area (including land and water area) that produce all the resources consumed by these population and absorb the waste generated.

3.2 Calculation Model

Ecological footprint can be used to compile population, resource consumption and resource efficiency into a simple and convenient means, which makes the comparison between different cities easier as well. In the concept of ecological footprint, there are 6 types of biological productive land, including cropland (providing food crops and economic crops), grazing land (suitable for the animal husbandry), forests (including plantation and natural forest), carbon uptake land (absorbing the waste generated by fuel) built-up land (including residential area and roads) and fishing grounds (mainly providing aquatic products).

According to the model of Wackernagel (1996), The following one is the formula for the calculation of ecological footprint:

$$EF = N \times ef = \sum_{i=1}^{n} aa_i = N \sum_{i=1}^{n} \left({c_i}/{p_i}\right) r_j$$

Where:

EF is the total ecological footprint.
N is the population size.
ef means the per capita footprint - by summing all the ecosystem areas appropriated.
i is the type of consumption item.
aa_i is the per capita land area of the type i.
c_i is per capita consumption of type i.
p_i is the average annual productivity or yield of type i.
r_j is the equivalence factor.

For the ecological capacity, the formula is:

$$EC = N \sum ec = N \sum (a_j r_j y_j)$$

Where:

EC is the total ecological capacity.
N is the population size.
ec means the per capita ecological capacity.
j is the type of land.
a_j is the per capita land area of the type j.
r_j is the equivalence factor.
y_j is the yield factor.

***Figure 1**: Location of Zhoushan Island*
(Source: base map is available from http://chiangbt.github.io/webcontent/Mapboxmap.html)

For the calculation formula above, the ecological footprint (EF) essentially measures the human demand for basic subsistence from ecological service. While the ecological capacity (EC) is the service which can be provided by the natural ecosystem. By comparing the gap between Ecological footprint (EF) and ecological capacity (EC), it can quantitatively reveals the impact human beings have on the ecosystem. The index is a quantitative analysis about the influence of human social activities on the natural ecological environment.

4. Urban Optimum Population Size of Zhoushan Island

4.1 Introduction of Zhoushan Island

Zhoushan Island is the main island of Zhoushan Archipelago. It is located in the southeast of Hangzhou Bay and in the northeast area of Zhejiang province. The whole island is oriented northwest-southeast. Zhoushan Island is the largest island in Zhejiang province, and the fourth largest island off the coast of China (Figure 1). The closest point of the island to the mainland is about 8.1km. The island is surrounded by sea, which forms an independent ecosystem. The scenery is beautiful with mountainous terrain, which is a combination of mountains, city and sea. The total area of the island is 502.65 km2. According to the Sixth National Population Census (2010) in China, the total population of Zhoushan Archipelago is 1,221,261, and the population of Zhoushan Island is 660,900. With the special natural conditions, Zhoushan Island can be regarded as an independent ecosystem model, which is suitable for the calculation of ecological footprint.

4.2 Ecological Footprint of Zhoushan Island

Based on the concept of the ecological footprint, the method mentioned above, and the data information mainly extracted from Zhoushan City Statistical Yearbook (2011), the calculation of the

Table 1: Ecological footprint of Biological Resources in 2010

Biological resources	Global average annual production (p_i) (kg/gha)	Consumption per person* (c_i) (kg/person)	Per-capita ecological footprint (aa_i) (gha/person)	Type of ecologically productive land
Grain	2,744	60.90	0.022194	Cropland
Vegetable	18,000	85.80	0.004767	Cropland
Oil	1,856	7.70	0.004149	Cropland
Pork	285	12.00	0.042105	Grazing land
Beef and mutton	33	1.00	0.030303	Grazing land
Poultry	940	5.10	0.005426	Grazing land
Dairy products	502	11.40	0.022709	Grazing land
Poultry and Eggs	400	7.90	0.019750	Grazing land
Fruit	18,000	44.20	0.002456	Forest land
Tea	566	0.06	0.000106	Forest land
Aquatic products	29	29.9	1.031034	Fishing grounds

*Source: *Zhoushan City Statistical Yearbook (2011),* pp: 11-27.

ecological footprint in Zhoushan Island is mainly composed of two parts: biological resources consumption and energy consumption.

4.2.1 Biological Resources Consumption

Biological resources consumption can be divided into several categories like agricultural products, animal products, forest products, fruit, wood etc. And there are further classifications. The main types of production and the results of calculation are shown in Table 1.

4.2.2 Energy Consumption

The part of the energy consumption mainly deals with the data of coal, gas, electricity and other energy source. And the energy consumption will be converted to land area when calculating the ecological footprint. Main energy sources in Zhoushan Island are coal, gasoline, diesel oil and electric power. The conversion factor is according to the average calorific value of fossil energy production land in the world. And the results in Table 2 shows the conversion result from energy to the area of ecologically productive land.

4.2.3 Calculation of Ecological Footprint

The above process has illustrated the calculation of different consumption separately. Big difference exits in the production capacity of different land. Therefore, it is essential to multiply the area of each category of land by the equivalence factor, which can convert the result to a unified and comparable standard. Thus, various productive areas are summed up, and the results are multiply by the corresponding equivalence factors. The following table 3 shows that the ecological footprint of Zhoushan Island in 2010 is 1.006 gha per person.

4.3 Ecological Capacity of Zhoushan Island

4.3.1 Equivalence Factor and Yield Factor

Generally, the qualities of resources are totally distinct in different countries and districts. Therefore, the area of the same land type cannot be compared directly, which needs to be adjusted. And the distinction could be expressed by yield factor. Specifically, yield factor refers to the difference between the local production of a certain biological production area within a country or a region, and the average one of the world. The yield factor in the paper is from the average number of

Table 2: Ecological footprint of energy Consumption in 2010

Type of energy	Global average annual production (GJ/ha)	Conversion factor (GJ/ton)	Net Consumption[a] (ton)	Per-capita eco-footprint (gha per person)	Type of ecologically productive land
Coal	55[b]	20.934	1,668,916	0.520134	Carbon uptake Land
Gasoline	93[b]	43.124	4,386	0.001665	Carbon uptake Land
Diesel oil	93[b]	42.705	54,315	0.020422	Carbon uptake Land
Electric power	1000[c]	11.840	213,838	0.002073	Built-up land

[a] Source: *Zhoushan City Statistical Yearbook (2011),* pp: 1-10.
[b] The unit is GJ/ha
[c] The unit is kilowatt-hour./ha

Table 3: *Ecological footprint of Zhoushan Island in 2010*

Land use type	Demand area (gha per person)	Equivalence Factor[a]	Equivalence area (gha per person)
Cropland	0.031110	2.82	0.087730
Grazing land	0.120293	0.54	0.064958
Forest land	0.002562	1.14	0.002921
Fishing grounds	1.031034	0.22	0.226827
Built-up land	0.002073	2.82	0.005846
Carbon uptake Land	0.542220	1.14	0.618131
Ecological Footprint			1.006413

[a] *Equivalence factor used in the table is from the calculation of FAO in 1993 (The common standard is used to make the results comparable with other countries and regions).*

China used by Zhang, Xu, and Cheng (2001). While the equivalence factor, which has the function to convert the land area of different type to a comparable standard, is chosen from the world average production of biological resources calculated by FAQ in 1993.

4.3.2 Calculation of Ecological Capacity

In order to get the ecological capacity, the first step is to have the statistics of biological productive land area, which including the different type of the land use (cropland, grazing land, forest land, fishing grounds, built-up land and carbon uptake land). The following steps are to multiply each type of land area by the equivalence factor and yield factor, sum up the results, and then divide the total one by the population. The result is the ecological capacity, which means the per-capita ecological space for urban development Zhoushan Island provide. Table 4 shows the biological productive land area of the island is 672866.84 gha. With the subtraction of biodiversity protection, the ecological capacity is 0. 451521 gha per person.

4.4 Optimum Population Size of Zhoushan Island

In the model, ecological capacity can represent the condition of resources and environment provided by a country or a region. While the ecological footprint refers to the consumption level of the population. When it comes to the calculation of optimum population size, population based on the calculation of per-capita ecological footprint can be a ecological modest population, and a sustainable population capacity for the region within the ecological capacity.

The population can be calculated by the formula below, which is the optimum population size based on the ecological footprint.

$$\mathbf{P} = \mathbf{N} \times \left({}^{ec}/_{ef} \right)$$

Where:

N is the population size.
ec is the per capita ecological capacity.
ef means the per capita ecological footprint.

After generating the status into the formula (N=660,900, ec=0.451522 gha per person, ef = 1.006416 gha person), the optimum population size of Zhoushan Island is 296,508, which is only half of the current population size.

5. Evaluation of the resources and environment carrying capacity

5.1 Ecological Deficit and Remainder

The ecological deficit or remainder, means the result of the difference between ecological footprint and ecological capacity. If can reflect the utilization condition of the natural resources in one region. Ecological

Table 4: *Ecological capacity of Zhoushan Island in 2010*

Land use type	Supply area (gha)	Equivalence factor	Yield factor[a]	Adjust area[b] (gha per person)
Cropland	11,939.19	2.82	2.61	0.132962
Grazing land	505.54	0.54	0.19	0.000078
Forest land	21,657.18	1.14	1.28	0.047817
Fishing grounds	717,325.71	0.22	1.00	0.238783
Built-up land	13,193.79	2.82	1.66	0.093453
Carbon uptake Land:				
Total	764,621.41	-	-	0.513092
Biodiversity protection[c]	91,754.57	-	-	0.061571
Ecological capacity	**672,866.84**	-	-	**0. 451521**

[a] *Yield factor is the difference between local production of a certain country (or area) and the average output of the worldThe yield factor here is acording to the average data of China.*
[b] *The population of Zhoushan Island is 660,900.*
[c] *Source: Minus 12% of the total, which is suggested by Our Common Future (1987), pp: 27.*

Table 5: *Ecological deficit/remainder of Zhoushan Island in 2010*

	Ecological demand footprint[a] (gha per person)	Ecological supply footprint[b] (gha per person)	Ecological deficit/remainder (gha per person)
Biological resources	0.382439	0.419640	0.037201
Cropland	0.087730	0.132962	0.045232
Grazing land	0.064958	0.000078	**-0.064880**
Forest land	0.002921	0.047817	0.044896
Fishing grounds	0.226830	0.238783	0.011953
Energy resources	0.623977	0.093453	**-0.530524**
Built-up land	0.005846	0.093453	0.087607
Carbon uptake Land	0.618131	0	-0.618131
	Minus 12% biodiversity		
Total	**1.006416**	**0.451522**	**-0.554894**

[a, b] Statistics of ecological demand and supply are from the results in Table 4 and Table 5.

footprint can measure the biological production area required with a certain level of consumption. When compared with the ecological carrying capacity, which reflects the productive area that can be provided by a country or a region, the result can supply the quantitative basis for the judgment: whether the productive and consumptive activities are within the range of ecosystem carrying capacity. Ecological deficit can reflect that the human influence has exceeded the ecological capacity. Then with the intention to satisfy the requirements, the region has the requirement to import resources or consume of the insufficient natural capital to balance the ecological needs. In both cases can reflect the unsustainable pattern of regional development. And the unsustainable level are measured by ecological deficit. On the country, the ecological remainder demonstrates that ecological capacity is enough to support the population pressure. The natural capital has the chance to be accumulated and the consumption pattern in the region is relatively sustainable.

The above table 5 shows the ecological deficit/remainder of Zhoushan Island in 2010. According to the table, the per-capita ecological deficit is 0.55 gha, and the total ecological deficit has reached 366729.6 gha. Ecological supply footprint takes 44.86% of the ecological demand footprint. And the compound ecosystem of the island are in the situation of "ecological overload", which means the ecological footprint is far beyond the ecological capacity.

5.2 Analysis of the Ecological Overload Issue

According to Figure 2, Cropland, forest land, built-up land and waters have the remainders, while Carbon uptake land and the grazing land are with the ecological deficit. It can be found that Zhoushan Island has no supply for carbon dioxide absorption, and the proportion of grazing land is only 1%. The excessive consumption of the fossil energy is a main reason of the overload Issue. Therefore, the ecological footprint of the energy consumption is the component which has the potential to be changed. As a result, low carbon development could be the direction for improving the situation. The promotion of low-carbon mode for the supply and consumption of energy is essential. The result also shows that these two kinds of resources are mainly provided by external cities. At the same time,

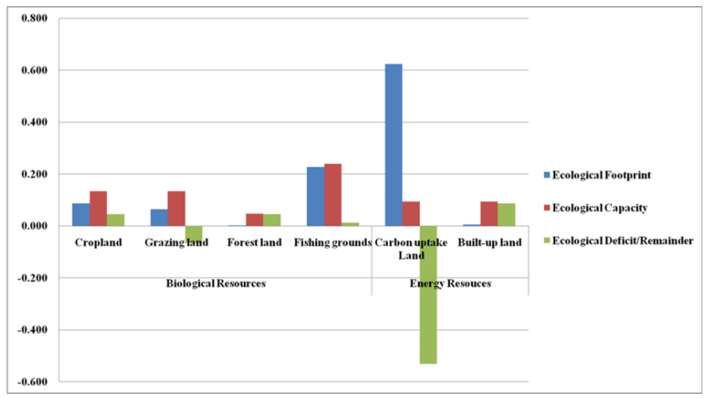

Figure 2: *Ecological footprint, capacity, deficit/remainder of Zhoushan Island (unit: gha per person)*

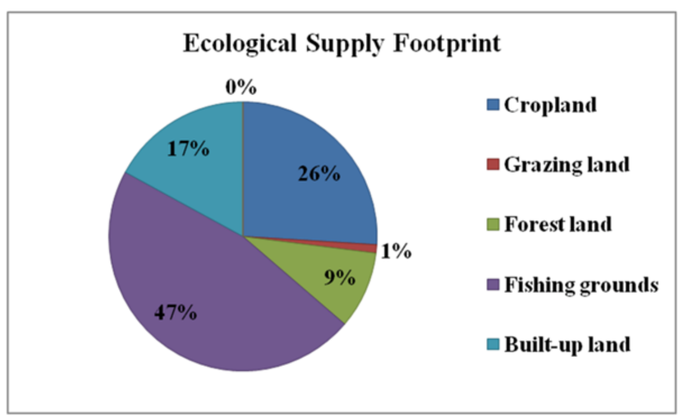

Figure 3: *Ecological Supply Footprint of different type of land*

the supply of water area accounting for 47% of the total, while other ecological supply footprints only take the percentage of 53% totally. The imbalance between supply and demand is obvious (Figure 3).

When comparing the ecological footprint of Zhoushan Island(1.0) with the average data of world(2.7), China (2.1) and Zhejiang province(2.5) (Figure 4), the result shows that the consumption of the resource and

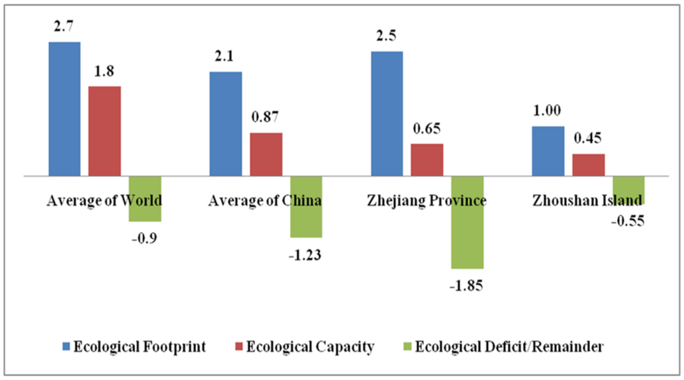

Figure 4: *Comparison with the average of World, China and Zhejiang province (unit: gha per person)*
Data Source: China Ecological Footprint Report 2010, pp.12.

energy is relatively lower than the average, which indicates the lower level of economic development in Zhoushan Island. Therefore, more emphasis should be put on the new mode of development in the future. As to the ecological capacity, which is also lower than the average ones, it reflects the less ecological resources and energy sources supplied, as well as the fragility of the ecosystem. However, the ecological deficit of Zhoushan Island (-0.55) separately takes 61.1%, 44.7%，29.7% of the average ecological deficit of World, China and Zhejiang Province, which is much smaller than the average ones and shows a big potential of the development in the future.

6. Suggestions for the Urban Planning and Development Strategy

Based on the ecological footprint model, the optimum population scale is only half of the current population. The population has already beyond the ecosystem carrying capacity. Currently, economic development of Zhoushan Island rely mainly on the external resources. Although the life of people has not been affected by now, the ecological environment might face resources shortage in the future. Without the water area, deficit would sharply occur in other types of land. Therefore, the solution to the ecological overload issue is of great significance. The main strategies can be summarized in two aspects. One is to reduce the ecological footprint, the other is to increase the ecological supply, which means to improve the ecological carrying capacity. As an island city, the experience of Zhoushan a great reference significance for cities of similar type.

6.1 Reduction of the Ecological Footprint

6.1.1 Sustainable Use of Resources

The development of circular economy can realize high efficiency and recycling of the resources, which means to improve of utilization efficiency and reduce of the consumption. The other way is to advocate energy conservation and emission reduction. Low carbon target can be used, with less land of waste and pollution to reduce the ecological requirements.

6.1.2 Utilization of New Energy

There is a big scarcity of the energy resources in Zhoushan Island, leading to a large dependence of economic development on other regions. The best way to change the situation is to develop new energy to save the consumption of the traditional energy resources. For instance, with the adequate wind resources and sea resources, development of wind power and hydropower can be a good way to reduce the consumption of the traditional energy. The result can be the improvement of the overall efficiency, and reduction of the carbon dioxide emission, which can directly reduce the ecological deficit brought by energy consumption.

6.2 Improvement of the Ecological Capacity

6.2.1 Rational Use of Cropland

The land of Zhoushan Island is limited. As the increase of population on the island, the pressure of the space for survival will increase, especially the requirement of cropland. Thus, the protection of the cropland is essential, which should be emphasized in the urban planning. The methods can be strict control of land use, as well as relevant examination and approval procedures. At the same time, situations like cropland occupied by buildings and roads should be avoided. In addition, methods can be used to enlarge the ecological capacity of the land. Specifically, increasing investment in the area of science and technology would increase the production of per unit area.

6.2.2 Proper Urban Planning

Comprehensive and integrated research and strategy planning are required to be emphasized in the urban development. The urban construction land should be planned reasonable with the farmland with good productive quality. The natural features about the mountains and marine resources are essential to be considered in the comprehensive study and strategic planning. Eco-planning is also essentially needed to guide the construction of the ecological space, as well as the protection of the resources and ecosystem. Not only the planning of urban construction land, but also detailed ecological construction planning should be made to guide the rehabilitation and construction of the ecological space. For example, there is protection and control plan of ecological zone with urban growth boundary and ecological corridor.

6.2.3 Optimization of the Industrial Structure

In the constituents of the ecological capacity, the sea capacity accounted for nearly 50%, makes a large contribution to the ecosystem. The primary industry in Zhoushan Island has a large percentage. However, the Marine biological resources has been under great pressure with overfishing and pollution. As an island, the better pattern of the industry might be taking good use of the local feature to develop the high technology industry based on the sea environment, and coastal tourism. These new types of industry have the characteristics of low ecological cost and high added value, when compared to the industry with high energy consumption.

7. Conclusion

According to the theory of ecological footprint and the related calculation model, the current population of Zhoushan Island is far beyond the optimum population scale calculated by the ecological footprint model, more attention should be paid to the sustainable development with a harmonious relationship with the environment and resource. Although there are some shortages in the concept and model of ecological footprint, it can provide a direction of thinking and planning the city as a whole system. With the intention to find the balance between economic consumption and ecological capacity, the optimum population is also a good tool that can be used to measure the development phases of the city.

The goal of urban planning is to improve the living standards of people and promote the social, economic and ecological aspects in the sustainable process of the city. Planning the population scale which is appropriate to the urban development conditions is the key element to the protection of urban sustainable development. According to the constraint of the resource and environment carrying capacity, in order to solve the problem of " ecological overload", sustainable development should be the guidance for urban planning in Zhoushan Island, and a low-carbon development pattern for the city is needed.

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