

Grey Correlation Analysis of Industrialization, Urbanization and Water Environment Carrying Capacity in Wuhan

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Abstract: Promoting water environment management and sustainable development in Wuhan, and profoundly grasping the relationship between its industrialization, urbanization development level and water environment carrying capacity, are of great significance improving Wuhan's water environment carrying capacity and coordinating industrialization and urbanization. This paper selects the data of water-environment-related indicators of Wuhan City from 2011 to 2017, constructs the water environment carrying capacity evaluation index system from the aspects of water resources and water environment, water pollution control and socio-economic bearing, and calculates the comprehensive value of water environment carrying capacity. Using correlation analysis, we conducted a quantitative study of the relationship between industrialization, urbanization and Wuhan's water environment carrying capacity. Results showed that the level of industrialization and urbanization has an important impact on the water environment carrying capacity of Wuhan. In particular, it is more closely related to the development of urbanization than industrialization. The intensity of population urbanization and the per capita urban area are the two most relevant. The comprehensive energy consumption per 10,000 yuan of output value, which is also one of the industrial indicators, has relatively minimal impact. Upgrading of Wuhan's industrial structure should be actively promoted, new industrialization and urbanization roads should be taken, and urban development model should be optimized to achieve sustainable development.

1. Introduction

With the development of economy and society, many water environment pollution problems have been triggered and the water environment carrying capacity has been further affected. Water environment management has become a hot spot of academic circles at home and abroad, which is also an inevitable requirement for achieving sustainable development and building a community of human destiny. Wuhan is an important core city in the Yangtze River Economic Belt. The water area of the whole territory is 2217.6km², which is more than 1/4 of the national land area. There are more than 140 lakes in large and small areas, of which at least 42 are in urban areas. The water resources has obvious special characteristics. During 2011-2017, the resident population of Wuhan increased from more than 10,200 to 10.89 million, the urban built-up area increased from 507 km² to 585 km², and the urbanization level has exceeded 80%. The annual GDP increased from 675.6 billion yuan to 1,341 billion yuan. As an indicator to measure the degree of coordination between social economic development and water environment, water environmental carrying capacity has gradually become the basis for measuring the degree of coordination between human society and the water environment. Water environmental carrying capacity is the link and intermediary between human activities and water environment. It reflects the degree of coordination between human activities and the functional structure of water systems, as well as the state or ability of sustainable development of water systems [2].

In China, due to the large scale of social economy, unreasonable production layout and ineffective environmental protection measures, water environmental problems have become increasingly prominent and become the limiting factor for regional sustainable development. Industrialization and urbanization, as two extremely important human activities, have a bearing on the impact of water environment carrying capacity during their development and advancement. The “Yangtze River Economic Belt Strategy” is one of the major strategies of the “One Belt, One Road” national strategy. This strategy redefines China’s spatial development strategy. It emphasizes the regional integrated development model with deep integration of watershed perspectives, while pursuing regional coordinated development. More emphasis on the carrying and support of the resource environment. The development of the Yangtze River Economic Belt is essentially a process of accelerating industrialization and urbanization, but its industrialization and urbanization should take the road of new industrialization and new urbanization [3]. The rapid industrialization and urbanization process in the past decade has intensified the contradiction between industrial and urban development and the water environment. Wuhan responds to the strategic requirements of the Yangtze River Economic Belt, effectively protects and utilizes water resources, strictly controls water pollution, properly handle the relationship between rivers and lakes, strengthen the comprehensive management of river basin environment, strengthen ecological protection and restoration along the river, and coordinate industrialization and urbanization. Grasping the internal relationship between industrialization and urbanization, and fully promoting the development of new industrialization and new urbanization are particularly important for optimizing water environment management and achieving sustainable development.

2. Literature review

With the increasingly prominent problem of water pollution, the academic community has made in-depth research on water environment management and evaluation. Foreign studies on river regulation started earlier, and some developed countries have accumulated rich experience in river governance. In 1938, Seifert of Germany put forward the concept of “pro-healing river governance”; in the 1950s, Germany officially established the engineering management of near-natural Rivers, and proposed that the rectification of rivers should conform to the principle of life. Since the 1990s, the US water resources development and management work will take into account the ecological restoration of rivers as a must-have project, and propose a new model of river management that integrates ecological, economic and cultural sustainability. At the beginning of 2005, the German multi-sector jointly proposed “Emscher Master Plan: Looking to the Future”, aiming at ecological management of rivers. URS Company of the United States studied the Keys watershed carrying capacity in Florida, covering the concept of bearing capacity, research methods and research models [3]; Munther [4] studied the urban water resources carrying capacity from the perspective of water supply; Rijiberman [5] listed water resources carrying capacity as a measure of urban water resources security; Harris [6] studied the water resources agricultural capacity of agricultural production areas as a measure of regional development potential.

Li Jiao [7] selected a comprehensive evaluation method based on gray matter element analysis, comprehensive entropy method and analytic hierarchy process to comprehensively evaluate the water environment carrying capacity of Hunan Province and Dongting Lake area; Huang Lixin adopted system dynamics The law sets up nine different schemes, and evaluates the water resources carrying capacity of Jiangsu Province based on the evaluation of water supply and demand tension coefficient. Jiang Dachuan [9] used the unit GDP comprehensive water consumption assessment method combined with the index conversion method to calculate Wuhan city. The bearing capacity of water resources; Jiang Xiaohui et al. starting with the relationship between environment, population and economic development, the large-scale system decomposition method-coordinated thinking was used to decompose the whole system into several subsystems according to its function to study the Guanzhong area in Shaanxi. The coordination relationship between industrialization and urbanization has been extensively studied by scholars, and its impact on the environment and

resources has been thoroughly explored. Jing Xueqing according to the concept of urbanization Define the urbanization level evaluation index system from four aspects, use the quantitative method to comprehensively measure the urbanization level of 11 provinces and cities in the Yangtze River Economic Belt, and use the panel data model weighting method to empirically test the impact of urbanization on the wastewater discharge of the Yangtze River Economic Belt and the further influence on the water environment.

3. The gray correlation analysis method

Grey system theory has become the trend of today's system science system and the development of uncertainty system theory [8]. Grey relational analysis is a measure of the degree of correlation between discrete sequences in grey system theory and is an important part of the grey system theory. Grey correlation refers to the uncertain relationship between things, or the relationship between factors and the main behavior between system factors. Grey relational analysis is the premise of grey prediction, clustering and decision-making. The basic idea is to judge the degree of correlation between factors according to the degree of similarity between curves. The grey relational analysis model is to serialize and model the gray relation lacking specific or concrete operating mechanism and physical prototype, and then establish a gray relational analysis model to quantify, order, and manifest the gray relation, thus becoming a complex system, providing an important means of technical analysis.

3.1 Gray correlation analysis

3.1.1. Non-dimensional processing of data

X is the gray correlation factor set, $X_0 \in X$ is the reference sequence, $X_i \in X$ is the comparison sequence, $X_0(k)$, $X_i(k)$ ($k=1, 2, 3, \dots, m$) are X and X respectively. ($i = 1, 2, 3, \dots, n$) The number of points k can construct the original evaluation matrix $X = (X_0, X_1, X_2, \dots, X_n)$. Since the data units of the reference sequence and the comparison sequence are different, the original sequence needs to be dimensionlessly processed.

Commonly used methods are initial value method, mean value method and interval value method. In this study, the initial value method is used, that is, the first data of the same series is used to remove all subsequent data, and a multiple sequence of each data relative to the first data is obtained, that is, the initial valued series. In general, the initial value method is applicable to the non-dimensionalization of more stable socio-economic phenomena, because most of such series show a steady growth trend, and the initial trend can make the growth trend more obvious [9]. Its formula is:

$$x'_i(k) = \frac{x_i(k)}{x_i(1)} \quad \text{formula} \quad (1)$$

Where $k = 1, 2, \dots, m$; $i = 1, 2, \dots, n$. After the dimensionless processing, the processed matrix can be obtained as a basis for further calculation.

3.1.2. Calculate the grey correlation coefficient

From a geometric point of view, the degree of association is essentially the degree of similarity between the reference series and the shape of the comparison series curve. If the comparison series is close to the shape of the curve of the reference sequence, the degree of correlation between the two is large. Conversely, if the shapes of the curves are different, the degree of correlation between the two is small. Therefore, the magnitude of the difference between the available curves is used as a measure of the degree of association. First, the absolute values of the elements corresponding to each of the comparison sequence and the reference sequence are calculated one by one, that is, $|x'_0(k) - x'_i(k)|$. Then calculate the correlation coefficient of each comparison sequence and the corresponding element of the reference sequence, and the formula is:

$$\zeta_i(k) = \frac{\min_i \min_k |x'_0(k) - x'_i(k)| + \rho \min_i \min_k |x'_0(k) - x'_i(k)|}{|x'_0(k) - x'_i(k)| + \rho \min_i \min_k |x'_0(k) - x'_i(k)|} \quad \text{formula} \quad (2)$$

In the formula, ρ is the resolution coefficient, which is used to weaken the influence of the distortion of the correlation coefficient by the excessive $\Delta(\max)$. This coefficient was artificially introduced to increase the significance of the difference between the correlation coefficients. The value is in (0,1); the smaller the ρ is, the larger the difference between the correlation coefficients is, the larger the ρ is, the smaller the difference between the correlation coefficients is; $\rho=0.5$ is usually taken.

3.1.3. Calculate the degree of relevance

Since the degree of association between each comparison sequence and the reference sequence is reflected by n correlation coefficients, the associated information is scattered and it is not convenient to compare them as a whole. Therefore, it is necessary to centrally process related information. And averaging is a way of focusing information. That is, the average of the correlation coefficients of the comparison series and the reference series for each period is used to quantitatively reflect the degree of association between the two series, and the calculation formula is:

$$r_{ok} = \frac{1}{n} \sum_{i=1}^n \zeta_{ok}(t) \quad \text{formula} \quad (3)$$

3.1.4. Comprehensive evaluation (correlation)

According to the above formula, by substituting relevant data, the degree of comprehensive correlation between the comparison sequence and each reference sequence can be obtained. The greater the correlation degree, the larger the value, and the smaller the correlation degree, the smaller the value. Correlation degree is a measure of the correlation between factors. It can only measure the relative size of the degree of closeness between factors. The absolute value of the value is often of little significance. The key is to reflect the relationship between the correlation degree of each comparison series and the same reference series. When there are p comparison columns, there are p corresponding degrees. Arranged in order of their numerical values to form an associative sequence. It reflects the relationship between the “primary and secondary” and “good and bad” of the comparison series for the same reference series.

4. Empirical analysis

4.1. Calculating the water environment carrying capacity of Wuhan city

Before calculating the water environment carrying capacity, constructing a scientific and reasonable water environment carrying capacity index system is the key to the rational development and management of urban water environment resources. In the specific research, the factors affecting the carrying capacity of the water environment are complex and diverse, and it is necessary to provide not only the necessary material basis and conditions for population and economic development, but also the treatment of sewage discharge. It is especially important to determine a scientific and rational evaluation subsystem. Specific indicators should be extracted from the water and water environment indicators related to society and economy, and the continuity and availability of data should be considered.

On the basis of grasping the bearing capacity of Wuhan urban water environment as a whole, the structural entropy weight method and the mean square error decision-making method are used to jointly combine the subjective and objective decision-making, and the three subsystems (water resources environment, water pollution control and socio-economic bearing) are constructed to calculate the urban water environment carrying capacity of Wuhan [10]. Combined with the actual situation in Wuhan, the calculation system of three criterion layers, six target layers and a total of 21 indicators was determined. The three criteria are water resources and environment, water pollution

control, and socio-economic bearing. Target levels include water quality, pollution emissions and water supply and demand, technology management, domestic sewage control, population and social development levels. The calculation results are as follows:

Table.1. Comprehensive value of urban water environment carrying capacity in Wuhan

	2011	2012	2013	2014	2015	2016	2017
Water resources environment	0.202	0.24	0.235	0.242	0.251	0.263	0.266
Water pollution control	0.282	0.291	0.314	0.323	0.346	0.358	0.367
Socioeconomic carrying	0.173	0.198	0.22	0.234	0.255	0.276	0.288
Comprehensive value	0.657	0.729	0.769	0.799	0.852	0.897	0.921

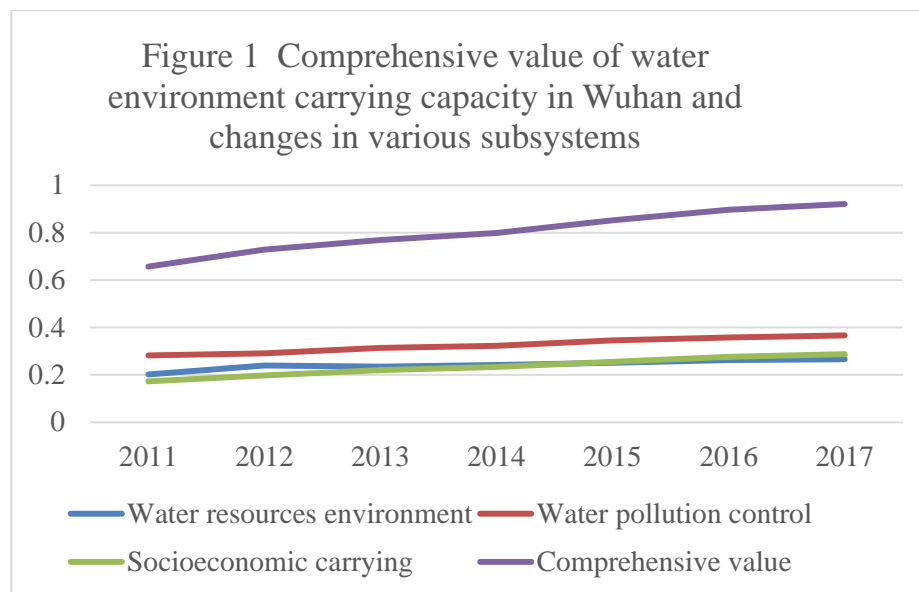


Figure 1. Comprehensive value of water environment carrying capacity in Wuhan and changes in various subsystems

It can be seen from Table 1 and Figure 1 that the comprehensive value of Wuhan water environment carrying capacity has shown a steady upward trend in 2011-2017, and its score has increased from 0.657 to 0.921. The three subsystems have increased to varying degrees, among which the water pollution control subsystem is in Wuhan. The water environment carrying capacity has the greatest impact, and its level has been significantly higher than the water resources environment and socio-economic bearing subsystem. In addition, the socio-economic bearing subsystem has the fastest growth rate and exceeded the contribution of the water resources environment subsystem in 2014, but there is still a certain gap from the contribution of water pollution control. Since 2011, Wuhan's pollution control and treatment capacity for urban lakes and rivers has continued to improve, and the city's comprehensive water environment carrying capacity has been enhanced. With the further development of industrialization and urbanization in Wuhan, the pressure on water resources and domestic sewage discharge will only continue to increase, so it is extremely important to strive to improve water pollution control.

4.2 Results and analysis of grey correlation analysis

The gray correlation analysis of Wuhan water environment carrying capacity, industrialization and urbanization was carried out, and the reference sequence and comparative sequence index were determined. From the perspective of the factors affecting the carrying capacity of the water environment, the development of industrialization and urbanization has improved the level of social productivity, the level of science and technology, and the living standards of the people, thereby improving the carrying capacity of the water environment; but on the other hand, due to industrialization and townships. The objective development needs will inevitably affect the water

environment capacity, the water environment self-purification capacity, and the regional water resources, thus reducing the regional water environment carrying capacity. The reference sequence in the study specifically selects the comprehensive value of water environment carrying capacity (X0), and the comparison sequence selects the proportion of the added value of the secondary industry to GDP (X1), the intensity of population urbanization (X2), and the area of per capita urban area (X3). Per capita GDP (X4), the proportion of employees in the tertiary industry (X5) and the comprehensive energy consumption per 10,000 yuan of output value (X6). Among them, the comprehensive value of water environment carrying capacity has been calculated, the population urbanization intensity (X2) is equal to the ratio of the urban population to the rural population; the per capita urban area (X3) is equal to the ratio of the urban built-up area to the total population, and the rest The indicator values can be obtained by direct query.

Table.2. Original values of Wuhan index series from 2011 to 2017

Year	X0	X1	X2	X3	X4	X5	X6
2011	0.657	0.481	1.997	0.613	68315	0.497	1.02
2012	0.729	0.483	2.094	0.633	79482	0.495	0.79
2013	0.769	0.486	2.087	0.65	89000	0.518	0.76
2014	0.799	0.475	2.087	0.668	98000	0.523	0.738
2015	0.852	0.457	2.405	0.684	104132	0.525	0.694
2016	0.897	0.439	2.538	0.702	111469	0.53	0.662
2017	0.921	0.437	2.643	0.848	123831	0.541	0.63

In the first step, the data is subjected to dimensionless processing according to equation (1) using the initial value method; the second step is to calculate the absolute difference between the comparison series and the reference sequence in the same period; the third step is to calculate using equation (2) The gray correlation coefficient, the minimum and maximum values of the absolute difference are substituted into the calculation, and the resolution coefficient $\rho=0.5$; in the fourth step, the gray correlation degree is calculated according to the formula (3) and sorted in descending sort (Table 4).

Table.3. Correlation degree calculation table

Year	r1	r2	r3	r4	r5	r6
Correlation degree	0.652	0.824	0.807	0.712	0.711	0.505
Sort	5	1	2	3	4	6

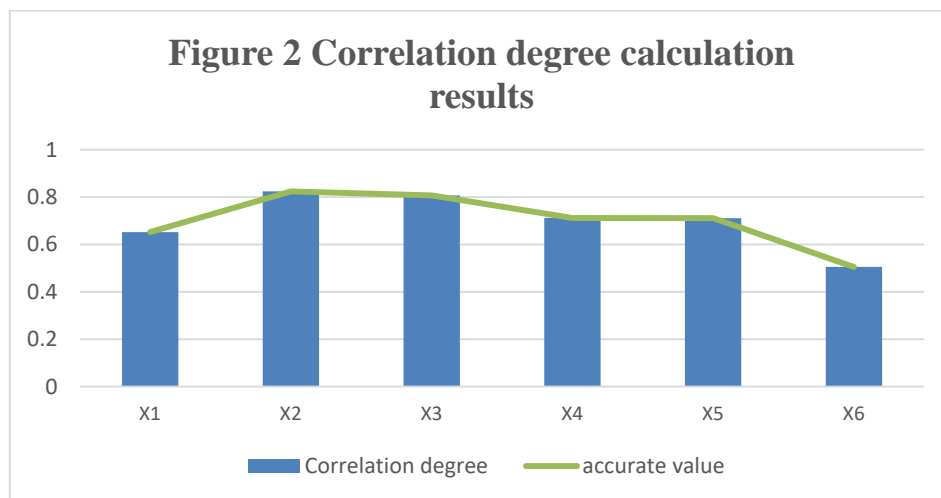


Figure 2. Correlation degree calculation results

The comprehensive ranking and evaluation are shown in Table 3 and Figure 2. Combined with the above analysis, the correlation between the development of urbanization and the carrying

capacity of Wuhan's water environment is the highest (the indicators X2, X3 and X1 are highly correlated with the level of urbanization development, and the corresponding degree of relevance is ranked 1st, 2nd and 5. Among them, the correlation between population urbanization intensity and per capita urban regional area is relatively close, which is significantly higher than other indicators); while the correlation between industrial development and Wuhan water environment carrying capacity is relatively low (higher with industrial development level) The relevant indicators X4, X5, X1 and X6, the corresponding degree of relevance are ranked 3 to 6, respectively, wherein the per capita GDP and the proportion of the tertiary industry employees are almost the same, and the comprehensive energy consumption r_6 of the output value per 10,000 yuan is much lower than other. Index). In general, the water environmental carrying capacity of Wuhan is closely related to the industrialization and urbanization development. The use of water resources by industrialization and urbanization and the control of water pollution all affect the support capacity of the water environment for human activities. Specifically, the urbanization intensity reflecting "population" and "geographical landscape" has a far-reaching impact on the water environment, while industrialization-related wastewater discharge, industrial water use and water pollution have been accompanied by industrial wastewater in Wuhan in recent years. The utilization rate is increased, the COD and nitrogen and oxygen emissions in the wastewater are gradually reduced, and the impact of the industrialized water supply environment has achieved obvious control effects. Promoting the urbanization process and improving the water environment carrying capacity of Wuhan is the next step. At the same time, with the further development of industrialization and urbanization in Wuhan, the pressure on water resources and domestic sewage discharge will only continue to increase, and it is extremely important to improve water pollution control.

5. Conclusions and recommendations

The main conclusion of this study is that the comprehensive value of urban water environment carrying capacity in Wuhan increased steadily from 2011 to 2017, and its score increased from 0.657 to 0.921, indicating that the water environment carrying capacity of Wuhan city has been continuously enhanced in recent years, water resources and environment. Coordinated with the development of social economy. Wuhan's pollution control and treatment capacity for urban lakes and rivers continued to improve, and the city's comprehensive water environment carrying capacity was enhanced. In addition, Wuhan has laid a good foundation for water environment by participating in and promoting the construction of the Yangtze River Economic Belt and establishing a national central city. Wuhan water environment carrying capacity is more related to the development level of urbanization. Measuring the urbanization intensity of population and the per capita urban area in urbanization level actually affect the carrying capacity of Wuhan water environment. With the increasing utilization rate of industrial wastewater in Wuhan and the gradual reduction of COD and nitrogen and oxygen emissions in wastewater in recent years, the impact of industrialized water supply environment has achieved significant control effects and improved in the process of promoting urbanization. And improving the water environment carrying capacity of Wuhan is the focus of the next step.

Based on the above, we propose the following: On the one hand, Wuhan's future development should strive to promote the transformation and upgrading of economic development, on the other hand, it is necessary to continuously promote the construction of environmental infrastructure, the innovation of environmental management technology, and the pioneering test of the environmental protection system. The construction of ecological civilization should be dimensionally practiced, thereby promoting the realization of the economic development of the Yangtze River Economic Belt and the coordinated development of the ecological environment. Adhere to the path of new industrialization and urbanization, the urbanization in population and geographical landscape is of great significance, which is worthy of more policy guidance. At the same time, Wuhan should further promote the coordinated development of industrialization and urbanization, adding new power to the further improvement of the carrying capacity of Wuhan's water environment. Power.

Wuhan should also strengthen the construction of environmentally-friendly infrastructure such as urban drainage systems, improve the capacity of domestic sewage treatment, promote industrial technology innovation and upgrade to reduce energy consumption, further introduce laws and regulations, guide the status quo of water environment management, improve water resources and environmental foundation, effectively promote urban water environmental pollution, continue the improvement of the control and governance level, and finally achieve the goal of ecological civilization construction. These are Wuhan's strategic opportunities and city missions, but also the most powerful response and support to the “Belt and Road” strategy.

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