A method to evaluate coordination between regional economic, social development and water resources

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Abstract. Coordination between regional economic, social development and water resources is the key factor for the sustainable development of regions. Scientific evaluation of the coordination and analysis of similar reasons will improve the management level of decision-makers. The Coupling Coordination Degree model (CCD) developed on synergistic theory is now considered as a better method to evaluate coordination between systems. But, there are still some deficiencies. This paper attempts to improve the method in two aspects,: (1) introduce Full Permutation Polygon Synthesis Illustration method (FPPSI) to replace the two key steps of the present CCD model. To realize the data standardization and the comprehensive evaluation of system state, and to achieve the analysis of corresponding reasons. And (2) calculate the coupling coordination degrees of systems’ evolution speeds instead of comprehensive evaluation indexes, which will fully reflect the dynamic interaction between systems. To verify the feasibility of the method, Taihu Basin is taken as a case study. Results demonstrate that the improved CCD model is not only able to reflect the dynamic interaction between systems adequately, but also visually presents the specific reasons through geometrical illustration.

1. Introduction
Nowadays, with the rapid industrialization and urbanization in developing countries, the problems of environmental pollution and resource depletion exacerbate. How to coordinate social, economic development, and environmental resources protection becomes a thorny issue for decision-makers in local governance. Among various natural resources, water resource is considered as particularly important. Whether the survival of organisms or the industrial production, they are inseparable from the water. Therefore, the coordination
between social, economic development and water resource becomes the priority for governments.

Water resources system is a subsystem of the environmental resources system, so we can look for methods from the relevant theories or approaches which are adopted in the economic and ecological resources relationship studies to explore the coordination between economic development and water resources. For such kind of study, the traditional theory is Environmental Kuznets Curve (EKC) first proposed by Grossman and Krueger in 1992. The EKC argues that the relationship between the economic development and environment quality shows improvement after deterioration like the inverted letter “U.” Based on this hypothesis, many scholars carry out numerous empirical research [3, 12, 18] and various improvements are made on research methods [1, 17]. Some apply EKC in the relationship between the economic development and water resources [2, 21]

Meanwhile, with the elaboration of the synergy theory [6, 8], more and more scholars try to adopt this approach in the economic and environmental resources relationship studies. In the synergy theory, Hermann Haken believes there are many different systems in natural [7]. Although they are different in the attributes, in the whole environment, the systems interact and promote, and may change between steadiness and unsteadiness. This view offers new ways to study the relationship between the economic development and environmental resources. Based on the synergy theory, some scholars draw on the capacitive coupling concept and model in physics. Developing the coupling degree template, evaluating the interactive relationship of systems or elements and apply, to the study of relationship between economic, social development and resource environment changes in different areas [4, 10, 24]. The relevant results show the coupling degree model not only can explain the interactive relationship but also can indicate the tendency of the system, which is of great significance for the regulatory of systems [20]. At the same time, some scholars point out the coupling degree is necessary for judgment on the weakness or strength of the interactions, but dependence on coupling degree may lead to the fault evaluation [15, 23]. For example, when the integrated order parameter values are close and both low in the two subsystems, the coupling degree index may regard wrongly that this state is better than others. To avoid this problem, they import the comprehensive coordinating index to improve this model, called Coupling Coordination Degree model (CCD).

Compared with the EKC and its related econometric methods, the CCD model more fits in this study. However, there are still some deficiencies in the model. For example, the model takes the geometric mean method or linear weighted sum method [14, 23], or the principle component analysis method [9, 25] in the system comprehensive evaluation index calculation. To reflect the whole states of systems, but they cannot intuitively and precisely indicate the similar reasons why the system has become the state, which makes the model stay in the shallow evaluation.

Therefore, this paper tries to make some improvements on the present CCD model. And it aims to provide a more comprehensive and scientific method for the decision-makers to evaluate the coordination between regional economic, social development and water resources and analyze the similar reasons, so that they can make appropriate policy adjustments and ultimately promote local sustainable development.
2. Improvement of Coupling Coordination Degree Model

2.1. Present Coupling Coordination Degree Model

For decades, with the development of system science and the synergy theory, the academic field has seen many studies on interaction relationship among two or more systems, with the development of network coupling theory and related models being representative. Coupling, originally a concept in physics, refers to the phenomenon that two or more systems or movements influence each other and may get together through the interaction, in which a dynamic and mutually reinforcing relationship would form under the benign interaction among the subsystems [22]. After that system coupling is introduced into the ecological environment, regional economic, social development and other fields [11]. Models to evaluate the interaction relationship between systems are also established and improved continuously in a wide application [9, 14, 23, 25]. So far, the CCD model can be regarded as a suitable method in the study of interaction relationship between systems, which comprises the following steps:

- Construct indicator system- to construct the relationship evaluation indicator system, the indicators are required to reflect the running states of the systems and the relationship among the systems, so as to effectively evaluate the coordination relationship.
- Set up efficacy function- set that system \( S_i \) has got the parameter \( e_i=(e_{i1}, e_{i2}, \ldots, e_{in}) \), \( n \geq 1 \) and the value of the \( e_{ij} \) is no less than \( \alpha_{ij} \) and no more than \( \beta_{ij} \), the efficacy function \( u_i(e_{ij}) \) is no less than 0 and no more than 1. Due to its ambiguity, it can determine the specific form of the function according to the method of membership degree in fuzzy mathematics. Efficacy function is divided into three types as follows according to the contribution of the parameter to the system:

  Positive efficacy type:
  \[
  u_i(e_{ij}) = \begin{cases} 
  1, & x_{ij} < \alpha_{ij} \\
  (x_{ij} - \beta_{ij})/(\beta_{ij} - \alpha_{ij}), & \alpha_{ij} \leq x_{ij} \leq \beta_{ij} \\
  0, & x_{ij} > \beta_{ij} 
  \end{cases}
  \]

  Negative efficacy type:
  \[
  u_i(e_{ij}) = \begin{cases} 
  1, & x_{ij} < \alpha_{ij} \\
  (\beta_{ij} - x_{ij})/(\beta_{ij} - \alpha_{ij}), & \alpha_{ij} \leq x_{ij} \leq \beta_{ij} \\
  0, & x_{ij} > \beta_{ij} 
  \end{cases}
  \]

  Moderate efficacy type:
  \[
  u_i(e_{ij}) = \begin{cases} 
  1, & x_{ij} < \alpha_{ij} \\
  (x_{ij} - \alpha_{ij})/(c_{ij} - \alpha_{ij}), & \alpha_{ij} \leq x_{ij} \leq c_{ij} \\
  (\beta_{ij} - x_{ij})/(\beta_{ij} - \alpha_{ij}), & d_{ij} \leq x_{ij} \leq \beta_{ij} \\
  0, & x_{ij} \geq \beta_{ij} 
  \end{cases}
  \]

In the above functions, \( e_{ij} \) represents N.O.\( j \) indicator in the system \( S_i \), and \( x_{ij} \) represents the value of N.O.\( j \) indicator in the system \( S_i \).
- Calculate comprehensive evaluation index. Comprehensive evaluation index calculates the system parameters’ "total contribution" to the system development. It can be achieved by the integrated method, which adopts the geometric mean method and weighted linear method in practical application.
In (1), \( U_i(u_i) \) is the comprehensive evaluation index of the system \( S_i \), and \( \lambda_{ij} \) is the weight of N.O. parameter in the system \( S_i \).

- Construct coupling coordination function. By the use of the capacitive coupling concept and the coupling coefficient model in physics for reference, the mutual system interaction coupling model could be set as following.

\[
C_m = \left( \frac{(U_1(u_1) \cdot U_2(u_2) \cdots U_m(u_m))}{\prod (U_i(u_i) + U_j(u_j))} \right)^{1/m},
\]

\( i = 1,2,\cdots,m, j = 1,2,\cdots,m, i \neq j \)

Based on (2), it imports the comprehensive coordination index \( T \), to found the CCD model.

\[
T = \sum_{i=1}^{m} \delta_i U_i(u_i)
\]

\( \delta_i \) represents the weight of the system \( S_i \), and \( D \) represents the coupling coordination degree.

2.2. Improved Coupling Coordination Degree Model

As described in the introduction part, there are still some shortcomings in the present CCD model. This study attempts to improve the method in two aspects, (1) introduce the Full Permutation Polygon Synthesis Illustration method (FPPSI) to replace the two key steps of the present CCD model, realizing the data standardization, the comprehensive evaluation of system state, also and the analysis of similar reasons. And (2) calculate the coupling coordination degrees of systems’ evolution speeds instead of comprehensive evaluation indexes, which will adequately reflect the dynamic interaction between systems.

The FPPSI method has been proposed by Wu et al. when he studies the indices and the evaluation process of eco-city [22]. When used in evaluation, the FPPSI method has the following advantages over other methods, (1) it provides not only precise algebraic values, but also a geometrically intuitive visualization of the status of each indicator. And (2) it alters the traditional additive approach to combining indicators by using a multidimensional approach that more appropriately reflects the integrative system principle, that the whole is more than the sum of its parts [11]. So, it is now widely used in the comprehensive evaluation of systems, especially in the social, economic system and environmental resources system [5, 19]. Although the method needs the experts to determine the critical value of indicators at first, it does not completely get rid of personal intervention, and it has been under continuous improvement in the following promotion and application [13, 11].

The basic idea of FPPSI is to first to set up standardized indicators, and then constitute a central n-gon with the upper limit of the indicator as its radius and an irregular n-gon with the value of each index which is a full array of the indicators by the end to end. The total can form \((n-1)!/2\) different irregular polygons and the comprehensive index defined as the ratio of the mean area of all these irregular polygons and the area of the n-gon.
The indicator value is standardized by (5).

\[ F(x) = \frac{d(x + b)}{x + c}, a \neq 0, x \geq 0 \]  

(5)

\[ F(x) \text{ Satisfy: } F(L) = -1, F(T) = 0, F(U) = 1 \]

In (5), L, U, and T represent the lower limit, the upper limit, and the threshold for parameter \( x \) respectively. Thus:

\[ F(x) = \frac{(U - L)(x - T)}{(U + L - 2T)x + (U + L)T - 2UL} \]  

From (6), standardized function \( F(x) \) value is no less than -1 and no more than 1 when reflecting the value of the indicators from L to U. And the reflection of the increasing speed changes along the indicator value. When the indicator value is less/more than the threshold value, the growth rate of the standardized indicator will decrease/increase gradually. And the threshold value is the turning point of the growth rate of the indicator value.

Therefore, as for the indicator \( x_i \), the standardization is:

\[ S_i = \frac{(U_j - L_j)(x_j - T_j)}{(U_j + L_j - 2T_j)x_j + (U_j + L_j)T_j - 2UL_j} \]  

In (7), \( L_i, U_i, \) and \( T_i \) represent the minimum value, maximal value and threshold value for parameter \( x_i \) respectively.

A regular \( n \)-sided polygon can form by \( n \) indicators where the vertices represent \( S_i = 1 \), the central point represents \( Si = -1 \), and the radius from each vertex to the central point represents the value of the corresponding standardized indicator. An inner polygon, lying midway between the outer polygon and the center of the polygon, accounts for the threshold of the indicators, where \( S_i = 0 \) (\( x_i = T \)). When inside the inner polygon, the values of the standardized indicators are negative and less than their thresholds. And when outside the inner polygon, the values are positive and greater than their threshold values [11, 19].

The number of triangles which form by the polygon center and \( n \) indicators is:

\[ n(n - 1)/2 \]

The sum of the square is:

\[ 0.5 \sin\left(\frac{2\pi}{n}\right) \sum_{i \neq j} (S_i + 1)(S_j + 1) \]

Where \( S_i \) is the standardized value of indicator \( x_i \), and \( Si+1 \) represents the distance from the normalized value of indicator \( x_i \) to the polygon center.

When there are \( (n-1)!/2 \) indicators, there are \( n(n-1)!/2=n!/2 \) triangles, and the sum of the square is:

\[ 0.5 \sin\left(\frac{2\pi}{n}\right) \sum_{i \neq j} (S_i + 1)(S_j + 1) \cdot \frac{n!}{2} \cdot \frac{2}{n(n-1)} \]
Correspondingly, the sum square of \( \frac{(n-1)!}{2} \) regular center polygons (side length=2) is:

\[
0.5 \sin\left(\frac{2\pi}{n}\right) \cdot 4 \cdot n \cdot \frac{(n-1)!}{2}
\]

The ratio of the two value is the full permutation polygon comprehensive index

\[
S = \sum \frac{(S_i + 1)(S_j + 1)}{2 \cdot n \cdot (n - 1)}
\]

(8)

Where \( S \) represents the comprehensive index.

From the above description, it can be seen that the data standardization method in FPPSI has the same function with the efficacy function in the present CCD model; the comprehensive index may also realize the overall evaluation of the development status of the system. Thus it can adequately replace two key steps (efficacy function construction and comprehensive evaluation index calculation) in the present CCD model. Moreover, FPPSI not only has algebraic analytics, but also can make a geometrical representation. Researchers can simply find the specific indicators promoting or hindering the system development through the geometrical illustration, and that is why the system shows the present status. Therefore, compared with the current methods, the introduction of FPPSI can overcome the problems of the present methods which just stays on the surface of system evaluation, having no way to do a deeper analysis.

Also, perhaps affected by the present related research, the thinking of most scholars is limited. When they are to measure the relationship between the systems, comprehensive development level always first comes to their mind. Most scholars rarely focus on the system evolution speed. It is thought that the relationship of the systems’ evolution rates may more effectively reflect the actual dynamic interaction between systems than the overall development level. Therefore, this paper puts forward another improvement to the CCD model, which is to study the system coordinated relationship based on the system evolution speed rather than the system comprehensive development level. Of course, the system development speed may be negative; then the relationship can be divided into three categories: a positive growth of both, negative growth of both and anisotropic growth (one is in negative growth; the other is in positive growth). Thus it will help researchers study the coordinated development relationship of systems more comprehensively.

3. Case Study

To verify the feasibility of the method, Taihu Basin is taken as a case study. As one of the most developed areas in China, Taihu Basin produces 21.0% national GDP with only 2.2% square and 11.65% population in 2012. With the increasing population, the rapid development of economic, industrialization and urbanization, the pressure on the water resource and environment is increasing. Thus environmental water issues have become so prominent that it has even affected the safety of the drinking water around the basin. So it is significant to coordinate the economic-social development and water-resource development for the healthy and sustainable development of the basin.
3.1. Construction of Indicator System

The construction of an appropriate evaluation indicator system is necessary for the reasonable evaluation of the coordination relationship between social, economic development and water resource. Under the principals of science, comprehensiveness, objectivity, independence, representation, and data availability, is combined with the specific circumstances of Taihu Basin and the purpose of this research. Taking the related research results for reference [13, 16, 20] , it constructs two aspects of the indicator system to reflect the state of social, economic development and water resources development in Taihu Basin (Table 1).

Table 1. Indicator system of the social, economic system and the water resources system.

| Type               | Item                  | Sub-item                                      |
|--------------------|-----------------------|----------------------------------------------|
| Social economic    | Economic development  | Per capita GDP                                |
| system             |                       | Per capita fiscal revenue                      |
| Social development |                       | Proportion of tertiary industry               |
|                    |                       | Engel coefficient                             |
|                    |                       | Level of education                             |
|                    |                       | Population density                            |
|                    |                       | Per capita fiscal expenditure                 |
|                    |                       | Level of urbanization                          |
|                    |                       | Urban-rural gap                                |
|                    |                       | Urban greening construction level              |
|                    |                       | Urban greening facility level                  |
| Water resources    | Water resources       | Total amount of water resources               |
| system             | endowments            |                                             |
|                    |                       | Lake water quality                            |
|                    |                       | River water quality                           |
| Water supply       | Total water supply    | Total urban water supply                       |
| Water resources    | Rate of water         | Rate of water resources development and        |
| protection         | resources development| utilization                                   |
|                    |                       | Proportion of investment in soil conservation |
|                    |                       | and ecological restoration                    |
|                    |                       | Ratio of the eco-water usage                  |
|                    |                       | Investment in the treatment of industrial     |
|                    |                       | waste water                                   |
|                    |                       | Total industrial waste water discharged       |
|                    |                       | Qualified rate of the industrial waste water  |
|                    |                       | discharged                                    |
|                    |                       | Length of the city sewage pipes               |
|                    |                       | Daily disposal capacity of city sewage         |
|                    |                       | Non-production and non-living water proportion |
|                    |                       | in cities                                     |

Note: The above indicator system mainly takes city related indicators for the comprehensive considerations of national urbanization construction background, transference from farmland water construction to city water construction, urbanization in Taihu Basin,
current high-level industrialization, future development demand, and statistical indicator settings in relevant statistical yearbooks, etc.

3.2. Data Sources
The original data mostly comes from the 2001-2013 yearbooks, such as "Chinese Statistical Yearbook", "Chinese Environment Statistic", "China water resources Yearbook" and "Water resources bulletin of the Taihu Basin and southeastern rivers. Also from "Jiangsu Statistical Yearbook", "Zhejiang Statistical Yearbook", "Shanghai Statistical Yearbook", "China City Statistical Yearbook", "China Environmental Statistics Yearbook" and so on. Calculation indirectly gets some statistics and some individual years’ data gets from the result of the adjacent year with the value interpolation function.

Note: geographically, Taihu Basin scatters 53% in Jiangsu province, 33.4% in Zhejiang province, 13.5% in Shanghai City, 0.1% in Anhui province. And it has been jointly governed by the governments and relevant departments of Jiangsu, Zhejiang and Shanghai. Province in China performs as the local governance unit. And data availability, statistical consistency, and data of water quality index, etc. Are taken from the lakes and rivers of Taihu Basin, while the other index data are integrated from Jiangsu, Zhejiang and Shanghai. Therefore, the Taihu Basin in this paper refers to the pan Taihu Basin.

3.3. Coupling Coordination Degree Calculation
To calculate the coupling coordination degree, the first step is to apply FPPSI to realize the data standardization and the comprehensive development index calculation.

It should be noted that, as introduced earlier, efficacy function can be divided into three types: positive efficacy, adverse efficiency, and moderate efficacy. The standardization of positive efficacy and adverse efficiency indicators are fairly straightforward, which only requires the setting of the upper limit, lower limit, and threshold of each indicator, while that of moderate efficacy indicators are relatively complex which sees appropriate interval as the premise. As a result, many indicators are not merely positive or negative in the long run, but in the short term or according to the development present, the demand, the particular numerical situation, they can be seen as indicators of only positive or negative efficacy. Take Taihu nutrition indicator as an example. By the relevant standards, if the nutrition indicator is less than 20, then the water is poor nutrient and not conducive to the development of water resources system. If between 20 and 50, the water is moderate nutrient and supportive to the elaboration of the water resources system; if between 50 and 60, the water is mild eutrophication and not conducive to the development of water resources system. Obviously, the indicator is a moderate indicator. However, the actual data of 2001-2012 shows that the values of this indicator are all higher than 50, which indicates a negative efficacy indicator.

The application process of FPPSI is as follows:
- Calculate the parameters in equation (7) according to the processed data. And the min value, max value and average value of \( x_i \) are used to replace \( L_i, U_i, \) and \( T_i \) respectively, which can not only simplify the calculation method but also cut down the subjectivity to some extent.
- Standardize the parameters in equation (7). If the indicator is positive, use (7); if the indicator is negative, use the opposite of (7), that is -\( S_i \).
Calculate the system comprehensive evaluation index $U_{ij}$ of the different period in equation (8) with the standardized parameters. After calculating $U_{ij}$, calculate the evolution speed $V_{ij}$ with relative link method as (9).

$$V_{ij} = \frac{U_{i(j-1)} - U_{i(j-1)}}{U_{i(j-1)}}$$

(9)

Evaluate the coordination relationship of the evolution speed $V_{ij}$.

$$C_j = (-1)^k \sqrt{\left(\|V_{ij}\|\cdot\left|\|V_{ij}\| + \|V_{ij}\|\right)\prod_{j}^{\|V_{ij}\|}}$$

(10)

$$T_j = \delta_1 V_{ij} + \delta_2 V_{ij}$$

(11)

$$D_j = (-1)^k \sqrt{|C_j| \cdot T_j}$$

(12)

In (10) and (12), $k$ represents the judgment parameter of the system coordination direction. If the two systems have the same developing direction, $k=2$; If the two systems have different direction developing direction, $k=1$. In (11), it is regarded that social, economic system development is as equally important as the water resources system development, thus $\delta_1=\delta_2=0.5$. $D_j$ represents the coupling coordination degree of the social system evolution speed and the water resources system evolution speed in $j$ period.

3.4. Results and Analysis

With the calculation method described in the previous section, the development rates of the social, economic system and water resources system in Taihu Basin from 2001 to 2014 are calculated and shown in Figure 1.

![Figure 1. Evolution speed of the social, economic system (SES) and the water resources system (WRS) in Taihu Basin.](image)

Figure 1 shows the fluctuation of evolution speed of water resources system in Taihu Basin in the 2001-2014 period, and some individual years are even with negative growth, (2002, 2009, 2011, 2012). Economic, social system fluctuates more gently since 2002 and keeps in growth. During most years, evolution speed and direction of the two systems are consistent, but in some individual years, they are inconsistent (2005, 2009, 2010); in 2001, 2002, 2005, 2007, 2009, 2010, 2011, 2012, 2014. Growth rate of the economic social system
are greater than water resources system, and in 2003, 2004, 2006, 2008, 2013, growth rate of water resources system is higher than the economic social system. After an outbreak of blue-green algae in Taihu Lake in 2007, the water resource system growth begins to decline and appears negative growth in 2009 which shows the malpractice treatment after pollution.

Generally speaking, the change trend of the social, economic system is more stable than that of water resource system, because the adjustments effect of government on the economic, social system is more visible, while water resources system reacts slower to government adjustments.

With the improved CCD model, the coupling coordination degrees of the economic, social system and water resources system in Taihu Basin in the 2001-2014 period are calculated and shown in Figure 2.

**Figure 2.** Coordination between the social, economic system and the water resources system in Taihu Basin.

According to Figure 2, in the 2001-2014 period, the coordination relations between the social, economic system and water resources system in Taihu Basin fluctuates. In most years, the two systems maintain a good state of positive development, but positive relationship reduces in the overall downward trend from 0.718 in 2001 to 0.142 in 2014. The two systems’ coupling coordination degree is negative in 2002, 2009, 2011, 2012, but the absolute value is about 0.2 (not very serious), which means the two systems deviate from each other in the corresponding periods. Overall economic, social development has not promoted water resource system, and on the contrary, it has created a particular restriction.

Secondly, the coupling coordination degree has a slight fluctuation, and the fluctuation is not in an ideal range. The main reason is that the development of water resource system is not good, and fails to synchronize with that of the economic, social system.

Thirdly, from the perspective of annual sequence, in water resources system, the score items of the social side, such as daily sewage treatment capacity of cities, the total length of city's waterways, urban water supply, and industrial wastewater treatment success rate etc., are superior to those of the natural side. Such as the proportion of ecological water use, water conservation, ecological investment proportion, and industrial wastewater emissions, etc. Comparatively, the score items in the economic, social system seem more balanced.

In years of 2002, 2009, 2011, 2012, coupling coordination degree of the economic, social system and water resources system in Taihu Basin is negative mainly because of the negative growth of economic social system in the corresponding period. Why does water resources
system appear negative growth? This study would find the relevant reasons by applying FPPSI.

![Figure 3](image)

**Figure 3.** Comprehensive assessment of the water resources system in the water resources system negative development year.

According to Figure 3, in 2002, 2009, 2011, 2012 the main reasons for water resource system’s negative development in Taihu Basin is the reduction of the efficiency value of the total amount of water resource. Lake water quality, total industrial wastewater discharged, proportion of investment in soil conservation and ecological restoration, and ratio of the eco-water usage, which have hindered the water resources system positive development (the corresponding indicator efficiency values shrink from the periphery to the center point). At the same time, it could be found that, the efficiency values of river water quality, total water supply, rate of water resources development and utilization, total urban water supply, investment in the treatment of industrial waste water, qualified rate of the industrial waste water discharged, length of the city sewage pipes, daily disposal capacity of city sewage, non-production and non-living water proportion in cities show growth trend (the corresponding indicator efficiency values expand from the center point to the periphery), which means these indicators do not hinder the development of water resources system. It indicates that relevant departments in Taihu Basin have not ignored the protection of water resource under the development, industrialization and city construction, but the overall planning of the protection, development and utilization of water resources are still inadequate, especially in soil and water conservation and ecological construction investment.
Figure 4. Comprehensive assessment of the social, economic system in the water resources system negative development year.

Figure 4 shows, in 2002, 2009, 2011, 2012, the economic social system in Taihu Basin keeps on positive growth. Efficiency values of most indicators increase (the corresponding indicator efficiency values expand from the center point to the periphery), promoting the positive development of social, economic system. However, there are also some factors hindering the development such as the gap between urban and rural areas, and Engel coefficient effect on the system (the corresponding indicator efficiency values shrink from the periphery to the center point).

From the analysis above, it is not difficult to find that there is a particular relationship between the negative growth of the water resource system and the development of the social, economic system in Taihu Basin. For example, in the corresponding periods, the efficiency value of the rate of water resources development and utilization is lower, which is the main hindering factor to the development of water supply system. And the efficiency value of the population density is low too, indicating that the increase in the population density in the economic and social system makes the rate of water resource development and utilization increase, and restricts the positive development of water resources system to some extent.

According to the results and analysis above, relevant departments can have a particular understanding of the situation. The tendency and the reasons of coordination between the regional economic, social development and water resources in Taihu Basin taking corresponding measures, increasing the proportion of ecological investment and ecological water using. Reducing the rate of water resource development and utilization through the introduction to advanced water-saving technologies, and redesigning the overall plan of water conservancy construction investment.

4. Conclusions
This paper integrates Full Permutation Polygon Synthesis Illustration method (FPPSI) and the presents coupling degree coordination model (CCD). Evaluating the coordination between systems, effectively improving the current methods of shallow evaluation to an in-depth
outlook of the interaction, and uniquely illustrating the assessment results more intuitive. In addition, another improvement in this paper, calculating the coupling coordination degrees of systems’ evolution speeds instead of comprehensive evaluation indexes, can adequately reflect the dynamic interaction between systems. 

To verify the feasibility of the method, we apply the improved CCD model to evaluate the coordination between social, economic system and water resource system in Taihu Basin. From the evolution speed tendency analysis, it can find that whether the development direction and development speed of the two systems are consistent or not. From the coupling coordination degree calculation of the two systems’ evolution speeds, it can find whether the coordination between the two systems is positive or not. From the influencing factor analysis by FPPSI, it can see the reasons why the coordination between the two systems presents above state. According to the evaluation results, decision-makers will have a clear and precise understanding of the situation, tendency and reasons of coordination between the regional economic, social development and water resources and take corresponding measures.

Therefore, the improved CCD model introduced in this paper provides a better method for the decision-makers to evaluate the coordination between regional economic, social development and water resources and to analyze the similar reasons, which will help them make appropriate policy adjustments to promote the local efficient and sustainable development.

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