The Index System Construction of Province Initial Water Rights Allocation System Based on the Algorithm of Attribute Reduction

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Abstract

On the basis of the pre-research of index system of province initial water rights allocation system, as well as the complexity and differences of the allocation system, the index system of province initial water rights allocation system in this paper is comprehensively designed first, and the index framework divided into three layers of target, criteria and index angles is established. Taking advantages of the algorithm of attribute reduction based on Rough Sets theory in data processing and data screening, this paper constructs the index selection model of province initial water rights allocation system. Then the primary index is screened to determine the key evaluation index, with the algorithm of attribute reduction based on Rough Sets, finally forming the index system of province initial water rights allocation system.

Keywords: *Index System, Algorithm of Attribute Reduction, Rough Sets, Province Water Rights Allocation.*

1. Introduction

In recent decades, along with the increasing deficiency of water resources, much attention has been focused on water rights allocation systems for solving the water conflicts among different regions in China [1,2,3]. An initial allocation of water rights to determine annual water use caps for different users in a reasonable and transparent way underpins better water resources management [4]. The design of index system of province initial water rights allocation system is the key step to determine annual water use caps for different provinces in a transparent way [5,6]. Hence, it is necessary to construct a scientific index system for achieving the rational and efficient method of utilization of water resources.

The commonly used methods of constructing index system mainly include Analytic Hierarchy Process [7], Fuzzy Comprehensive Evaluation [8,9,10], Principal Component Analysis [4] and Delphi Method. Although these methods have been applied successfully to construct index system, there are limitations when they are applied in the practical situation. By most of the above methods, the index system is always constructed subjectively, or based on much more data. In fact, a good deal of data is not easy to get.

As an important concept of Rough Sets theory, the objective of reduction construction is to reduce the number of attributes, and at the same time, to preserve the certain properties that we want [11]. Under the condition of unchanged classification and decision abilities, the algorithm of attribute reduction based on Rough Sets method is to delete irrelative or insignificant attribute, has been applied in many domains of index selection practice. In 2009, the algorithm of attribute reduction based on Rough Sets method was proposed, and the feasibility and validity of the method was verified by its application on deleting irrelative or insignificant evaluation index of the Enterprise product innovation capability [12]. The algorithm of attribute reduction based on Rough Sets method was used to screen the evaluation indexes of PPP project, and a suitable evaluation index system for PPP project was set up at last [13]. The theory of Rough Sets and Information Entropy were introduced to build the index system of evaluation of urban development level, and the practicality and effectiveness of this model was illustrated by an example [14].

In view of the limitations of the general methods and the advantage of the algorithm of attribute reduction based on Rough Sets in data processing and data screening, combining with the connotation and character of the province initial water rights allocation system, this paper applies the algorithm of attribute reduction based on Rough Sets method to establish the index system of province initial water rights allocation system.

2. The Establishment of Index System Frame

The principles of establishing index system are important to ensure this method and conclusion accepted by administration and public [4]. In China, some experts have

put forward different water rights allocation principles [15,16,17]. According to the characteristic of province initial water rights and the views of domestic and overseas scholars and experts, we finally select the principles of current situation, fairness, efficiency, sustainable development and macro-control as the fundamental principles of establishing index system for province initial water rights allocation.

(1) Current situation. The province initial water rights allocation is a high social sensitivity work, which has great impact on the water rights of vested interests groups. The present water-using state is the result of long-term interaction by various historical factors, which could reflect the balance of all kinds of power at some extent.

(2) Fairness. The allocation of province initial water rights is a redistribution of benefit for the stakeholders. Under the background of the overall building of a harmonious society, the allocation of province initial water rights should follow the principle of fairness, which guarantees the justice of water resources among different regions and users.

(3) Efficiency. Efficiency requires that those stakeholders with higher water use efficiency and greatest "income or revenue per drop" should get more water. While the phenomenon of water shortage and water waste is increasingly serious, it is one of the important goals of allocation plan of province initial water rights to improve the efficiency of water utilization.

(4) Sustainable development. Sustainable principle is to keep water resources perpetually exploited, namely to realize the identical rights of the use of water resources for both contemporary and future generations.

(5) Macro-control. Since the ownership of water resources belongs to the state, the allocation plan of province initial water rights is a policy-related behavior. Furthermore, the utilization of water resources possesses the characteristic of externalities naturally, which will result in market failure. Hence, the administrative allocation of province initial water rights and the market allocation are inseparable from the macroeconomic regulation and control of government.

In light of the fundamental principles of establishing index system for province initial water rights allocation, we build the index system frame of province initial water rights allocation. As shown in Table 1.

Table 1: The index system frame of province initial water rights allocation

Object Layer	Standard Layer	Index Layer
The allocation of province initial water rights	Current situation	Current water consumption **(a)**
		Water consumption per capita **(b)**
		Water consumption per plowland **(c)**
		Regional satisfaction of water distribution **(d)**
		Project scale of existing water supply **(e)**
	Fairness	Average runoff of years **(f)**
		Population size **(g)**
		Water distribution per capita **(h)**
		Effective irrigation area **(i)**
	Efficiency	GDP per capita **(j)**
		Industrial output per capita **(k)**
		Agricultural output per capita **(l)**
		Water consumption per ten thousand yuan of GDP **(m)**
		Water consumption per ten thousand yuan of agricultural output **(n)**
		Water consumption per ten thousand yuan of industrial output **(o)**
		Utilization coefficient of agricultural water **(p)**
		Utilization coefficient of industrial water **(q)**
	Sustainable development	Economic growth rate **(r)**
		Population growth rate **(s)**
		Water with Green unit **(t)**
		Percentage of Sewage Disposed **(u)**
		Attainment rate of wastewater discharge **(v)**
		Satisfaction of water with ecological environment **(w)**
	Macro-control	Policy inclination **(x)**
		Protection of vulnerable groups **(y)**

3. The Index System Construction Based on the Attribute Reduction

3.1 The method of Attribute Reduction

As an important concept of Rough Sets theory, an attribute reduction is a subset of attributes that are jointly sufficient and individually necessary for preserving a particular property of the given information table [18,19,20]. Let $S=\{U,A,V,F\}$ be an information system, where $U=\{x_1,x_2,\cdots,x_n\}$ is a non-empty set of finite objects (the universe of discourse); $A=\{a_1,a_2,\cdots,a_m\}$ is a non-empty finite set of attributes, and $A=C\bigcup D$ where C is the set of conditional attributes and D is the set of decision attributes.

Let $V=\bigcup_{p\in A}V_p$, V_p be the value range of the attribute $p\in A$ (V is the range of any attribute p). If for any $q\in A$ and $x\in U$, it holds that $f(x_i,q)\in V_q$, then we call $f:U\times A\to V$ is the information function. For any $B\subseteq A$, $R(B)$ is called indiscernibility relation (equivalence class) if it satisfies $R(B)=\{(x_i,x_j)\in U\times U\mid \forall a\in B, f(x_i,a)=f(x_j,a)\}$.

Let $a(X)$ be the value of X, the dimension of discernibility matrix M is $n\times n$, Where n is the number of the basic objects. If both conditional attribute and decision attribute is not identical, then the element value is different; if decision attribute is identical, then the element value is $\varnothing$; if the decision attributes are different but condition attributes are exactly identical, which means that data is incorrect or the condition attributes are insufficient, then the attribute reduction will not be considered. The calculation formula of discernibility matrix M is shown as formal (1).

$$C=\begin{cases} a\in A, & a(x_i)\neq a(x_j)\ \ D(x_i)\neq D(x_j); \\ \varnothing, & \text{eles.} \end{cases} \quad (1)$$

3.2 The Steps of Screening Indexes system

On the basis of the established index system frame of province initial water rights allocation, we apply the algorithm of attribute reduction based on Rough Sets theory to screen the initial evaluation index system. The calculation procedure of the algorithm of attribute reduction based on Rough Sets theory in data processing and data screening is as follows:

Step 1 Determine the attribute set A. Let A be $A=C\bigcup D$, where the condition attribute set C is the set of all indexes of index layer, and suppose it as $C=\{a,b,\cdots,y\}$; the decision attribute set D is the reasonable results of province initial water rights allocation, and suppose it as $D=\{R\}$.

Step 2 Assign the attribute sets. Apply five levels of 0, 1, 2, 3, 4 to assign the attribute sets according to the requirement of province initial water rights allocation practices. The grading of levels is analyzed by the actual situation of the different indexes.

Step 3 Determine the attribute decision table. According to the above attribute sets, collect 9 teams of the finished public project as a sample set. Corresponding to the attribute of every index, we can form the attribute decision table. As shown in Table 2.

Step 4 Establish the discernibility matrix M. According to the principle of discernibility matrix, when both the condition attributes and the decision attributes are not equal, we will take different attribute combination for the element value for different samples of the identical attribute. Otherwise, the element value takes empty set.

Table 2: The attribute decision table

C	1	2	3	4	5	6	7	8	9	C	1	2	3	4	5	6	7	8	9
a	3	3	2	4	2	2	2	3	2	**n**	2	3	3	2	2	3	2	1	3
b	4	2	1	3	2	3	3	2	1	**o**	2	3	1	2	4	3	2	1	0
c	3	4	2	3	3	3	4	2	3	**p**	3	3	2	4	3	2	2	4	3
d	4	4	4	3	2	2	3	4	2	**q**	3	2	4	1	3	1	2	2	4
e	3	3	3	2	2	3	4	3	2	**r**	2	3	4	3	2	2	2	3	2
f	3	2	3	2	1	1	2	3	3	**s**	3	3	3	2	3	2	4	2	3
g	2	3	3	1	2	3	4	2	3	**t**	1	3	2	3	2	1	1	2	2
h	2	3	3	1	2	2	2	3	3	**u**	1	2	0	1	2	3	2	3	2
i	2	3	4	3	3	3	4	4	4	**v**	4	3	2	3	3	4	3	3	3
j	3	2	4	4	3	3	3	4	2	**w**	4	3	3	3	4	2	4	3	3
k	2	3	3	4	2	3	2	3	3	**x**	4	4	3	4	3	3	3	3	2
l	2	3	3	3	3	3	4	3	3	**y**	3	2	4	1	2	3	3	2	2
m	2	1	3	2	2	2	3	3	4	**R**	3	3	2	3	2	2	3	3	2

Then, the discernibility matrix table is shown in Table 3 by the formal (1).

Table 3:The discernibility matrix table

	1	2	3	4	5	6	7	8	9
1	∅								
2	∅	∅							
3	abcghijklmnopqrtuvwxy	abcfjkmopqrtuvxy	∅						
4	∅	∅	abcdefghikmnopqrstuvxy	∅					
5	abdefilotuvxy	acdefgijmnoqrtwx	∅	abdfghjkopqrstuwxy	∅				
6	abdfgiklnopqsuwx	abcdfhjmpqrstuvwxy	∅	adegfhjknoprtuvwxy	∅	∅			
7	∅	∅	bcdefghjklnoqrstuvwy	∅	bcdefgilmopqsty	cdefgiklmnoqsuvw	∅		
8	∅	∅	abgnpqrsuvy	∅	acdefhijkmnopqrsuw	abcdfghijmnopqrtvwy	∅	∅	
9	abdeghijklmnoqtuvwxy	abcdefimoqrtx	∅	abdfghijkmnopqrstuxy	∅	∅	bcdefghjklmnopqstwxy	abcdegjmnopqrsuxy	∅

Step 5 Calculate the importance of the index and the cumulative percentage. Calculate the importance of the index and the cumulative percentage based on discernibility matrix M . Calculating formula of the importance of the index is shown as formal (2).

$$f(x)=\sum_{i=1}^{r}\sum_{j=1}^{r}\frac{\lambda_{ij}}{|m_{ij}|} \quad (2)$$

where $\lambda_{ij}=\begin{cases}0 & x\notin m_{ij}\\ 1 & x\in m_{ij}\end{cases}$, $|m_{ij}|$ mean the number of indexes that m_{ij} contains.

The computed results of the importance of the index and the cumulative percentage are shown in Table 4.

Table 4: The importance of the index and the cumulative percentage

Index	I	FI	CP (%)	Index	I	FI	CP (%)
q	1.058	0.054	5.35	**m**	0.797	0.040	63.14
o	1.044	0.053	10.63	**c**	0.749	0.038	66.93
b	0.955	0.048	15.46	**i**	0.709	0.036	70.52
f	0.944	0.048	20.23	**s**	0.709	0.036	74.10
a	0.900	0.046	24.78	**j**	0.709	0.036	77.69
u	0.882	0.045	29.24	**w**	0.708	0.036	81.27
d	0.872	0.044	33.65	**n**	0.706	0.036	84.83
y	0.871	0.044	38.05	**e**	0.658	0.033	88.16
g	0.863	0.044	42.42	**v**	0.652	0.033	91.46
t	0.861	0.042	46.77	**k**	0.650	0.033	94.74
r	0.822	0.042	50.92	**h**	0.571	0.029	97.63
x	0.810	0.041	55.02	**l**	0.469	0.024	100.00
p	0.809	0.040	59.11				

Note: Importance is abbreviated as I; Fixed Importance is abbreviated as FI; Cumulative Percentage is abbreviated as CP.

According to the above calculation steps and the related data in Table 4, combining with the expert experiences, we select some indexes that meet the condition of its accumulative total importance reach more than 85%. Hence, we will screen five indexes e, v, k, h and l which respectively represents project scale of existing water supply, attainment rate of wastewater discharge, industrial output per capita, water distribution per capita and agricultural output per capita. We select the rest of the 20 indicators as the indexes of province initial water rights allocation.

4. Conclusion

According to the connotation and characteristics of province initial water rights allocation system, in the light of the fundamental principles of establishing index system for province initial water rights allocation, we build the index system frame of province initial water rights allocation. Then taking advantages of the algorithm of attribute reduction based on Rough Sets theory in data processing and data screening, this paper constructs the index selection model of province initial water rights allocation system. This paper owns particular practical reference for the construction of a scientific index system to achieve the rational and efficient use of water resources.

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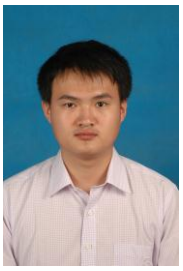

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