Application of Fuzzy Decision-making Technology in the Regional Water Supply-demand Satisfaction Analysis

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Abstract

This paper has taken Shandong Peninsula as an example and constructed theoretic model of fuzzy clustering to analyze supply-demand satisfaction of water resources based on the fuzzy decision-making technology proposed by Professor Chen shouyu. It shows that the method is strict in theory and the final result is classified excellently for the actual situation. It provides a new way to analyze supply-demand satisfaction degree of regional water resources and further perfects evaluation system of water supply and demand.

Keywords: Application; Regional water resources; Supply-demand satisfaction; Fuzzy clustering model; Sample rank

1. Introduction

Water resource is essential for human to survive and develop. However, the contradiction between supply and demand of water resources has become increasingly outstanding, which has been one of strategic problems throughout the world [1-2]. In recent years, due to an increasing demand for water between economic development and people's lives, serious water waste and water environmental degradation, supply and demand of water resources have been unbalanced [2]. Supply-demand balance problem of regional water has caused widespread concern, and the related research mainly focuses on forecast analysis, dynamic simulation and coordination analysis of water supply and demand now. KOU Li-min has predicted the water demand and available water supply from 2015 to 2030 in Baoding and made supply and demand analysis on water resources of different level years [3]. Wang Li-zhi has given prediction on water demand and supply of Guantao county in 2015 (from the level in 2005), then

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compared results of predictive analysis of demand and supply of water resources between each township and the whole county [4]. YUAN Ru-hua established system dynamics model of regional water resources supply and demand on the basis of interactive relationship between each element of water supply and demand system and population, economy, society and ecological environment. Then Dynamic simulation was developed [5]. ZHAO Zhen-guo built simulation model of supply and demand of water resources through drawing up the rule of water resources disposition. Based on total water shortage rate, unit water shortage rate and water supply guarantee rate in simulation results, water resources allocation results in different schemes were gotten by optimizing distribution relations [6]. ZENG Ling-gang established the mathematical simulation model for computing supply and demand equilibrium of water resources by system engineering thought. A new way was given in the paper for the supply and demand equilibrium in a district [7]. LU Ju-chun applied the theory of the gray systems, combined the gray connectedness and gray entropy and developed a supply and demand coordination analyzing model. It provided the analysis of the coordination between the supply and demand of water resources with a new method [8]. Zhang Lingxian applied system theory and linear objective programming to develop a reliable mathematical optimization model for supply and demand balance of water resources for small towns. The contradiction of supply and demand of water resources was analyzed, and an optimization measure of water utilization was put forward [9]. ZHAO Yong studied the balanced situation between water resources demand and supply of Ningxia region on different levels based on overall balance analysis [10]. Supply-demand balance of water resources has been discussed more and more, but supply-demand satisfaction analysis is less. Water supply-demand balance schemes in different regions will initiate different satisfaction degree. The result has a very important influence on regional economic and social development. However, supply-demand satisfaction is a kind of comprehensive cognition and subjective criteria, so it is a fuzzy concept by itself and needs decision-making and optimization.

2. Theoretic model of fuzzy decision-making technology

2.1. Fuzzy clustering model

Assume that a sample set be composed of samples to be clustered for fuzzy concept or subset [11], and there exists characteristic value of indexes to show feature of each sample. Thus, the sample set can be clustered by the characteristic value matrix:

$$X = \{ x_i \} \quad i=1,2,\cdots,m; \quad j=1,2,\cdots,n. \quad (1)$$

With different physical dimensions, the characteristic value of indexes first need normalized to cluster. The matrix X can be transformed into normalization matrix:

$$R = \{ r_i \} \quad i=1,2,\cdots,m; \quad j=1,2,\cdots,n. \quad (2)$$

Assume that n samples be clustered based on standard values of m indexes and c classes, the fuzzy clustering matrix is expressed by U.

$$U = \{ u_{jh} \} \quad h=1,2,\cdots,c; \quad j=1,2,\cdots,n. \quad (3)$$

Assume that characteristic value of m indexes for class h be called cluster center, so index characteristic value of c classes can be expressed by fuzzy clustering center matrix S.

$$S = \{ s_{ih} \} \quad i=1,2,\cdots,m; \quad h=1,2,\cdots,c. \quad (4)$$

Fuzzy clustering iterated formulas are as follows:

Optimal fuzzy clustering matrix:

$$\mu_{ih} = \left[ \sum_{i=1}^{m} \left( \frac{\sum_{h=1}^{c} \omega_h (r_{ih} - s_{ih})^2}{\sum_{i=1}^{m} \sum_{h=1}^{c} \omega_h (r_{ih} - s_{ih})^2} \right)^{-1} \right]^{1/2} \quad (5)$$

Optimal fuzzy clustering center matrix:
2.2. Sample rank based on fuzzy clustering

The rank of cluster samples can be obtained from H. Relative rank feature value formula:

\[ H = (1, 2, \ldots, c) \mu_{ij} \]  

### 3. Case Study—Supply-demand Satisfaction Analysis of Water Resources in Shandong Peninsula

Shandong peninsula urban agglomerations are composed of 8 cities: Dongying, Jinan, Qingdao, Rizhao, Weihai, Weifang, Yantai and Zibo. They are the most concentrated areas and have active productivity in cities and towns of Shandong Province. However, with the development of society and economy, the contradiction between supply and demand of water resources has been increasingly prominent. This paper will discuss water supply-demand situation and analyze satisfaction degree in Shandong Peninsula cities. It is of great significance for the water resources sustainable development.

According to actual water supply, water consumption and socio-economic indicator of Shandong peninsula in 2000 [12], supply-demand satisfaction degree of water resources in each city of Shandong Peninsula in 2000 can be calculated in table 1.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Total water supply (100 million m³)</th>
<th>Living water (m³/ per person)</th>
<th>Industrial water (m³/ ten thousand yuan)</th>
<th>Field irrigation water (m³/ha)</th>
<th>Forestry, Animal Husbandry and Fishery water (m³/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Town</td>
<td>Country</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dongying</td>
<td>15.91</td>
<td>39.08</td>
<td>27.67</td>
<td>72.87</td>
<td>6588.99</td>
</tr>
<tr>
<td>Jinan</td>
<td>17.47</td>
<td>47.74</td>
<td>33.53</td>
<td>33.72</td>
<td>4530.00</td>
</tr>
<tr>
<td>Qingdao</td>
<td>10.91</td>
<td>29.27</td>
<td>25.48</td>
<td>12.31</td>
<td>1927.57</td>
</tr>
<tr>
<td>Rizhao</td>
<td>6.44</td>
<td>25.09</td>
<td>25.66</td>
<td>39.84</td>
<td>3637.16</td>
</tr>
<tr>
<td>Weihai</td>
<td>3.28</td>
<td>21.58</td>
<td>22.68</td>
<td>6.54</td>
<td>1359.81</td>
</tr>
<tr>
<td>Weifang</td>
<td>21.74</td>
<td>19.91</td>
<td>24.48</td>
<td>26.21</td>
<td>2999.83</td>
</tr>
<tr>
<td>Yantai</td>
<td>11.05</td>
<td>22.28</td>
<td>23.88</td>
<td>14.97</td>
<td>2174.38</td>
</tr>
<tr>
<td>Zibo</td>
<td>13.64</td>
<td>44.56</td>
<td>27.98</td>
<td>28.72</td>
<td>5268.46</td>
</tr>
</tbody>
</table>

According to the principle of equal weight, eight cities are classed (c=4). Optimal fuzzy clustering matrix U is obtained by using iterative formula (5) and (6). Then use formula (7) and compute relative rank feature value H of each sample.

\[ H = (1.6160, 1.8271, 3.5888, 3.0000, 3.5582, 2.0088, 3.7832, 1.3779) \]

From relative rank feature value H, the order of supply-demand satisfaction degree is: Yantai, Qingdao, Weihai, Rizhao, Weifang, Jinan, Dongying, Zibo.

Based on different levels of water shortages among the cities, the related departments have set various water resources allocation schemes. Therefore supply-demand satisfaction degree in each city is also different. Although water supply is not enough in Yantai City, supply-demand satisfaction degree is higher as water quantity in industry, life, agriculture and forestry, animal husbandry and fishery is well coordinated.
4. Conclusion

Fuzzy clustering iterative model is applied to the analysis of water supply-demand satisfaction degree in Shandong Peninsula. Results show that the classification generally corresponds with the actual situation. So the method is effective. However, the rapid development of economy will greatly intensify the contradiction between supply and demand of regional water resources and affect the satisfaction degree. It is important to optimize the allocation of water resources by advanced science and technology in order to ensure favorable development. Only in this way can we solve the supply and demand of regional water resources really.

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