第 48 卷第 12 期
2021 年 12 月

湖南大学学报（自然科学版）
Journal of Hunan University（Natural Sciences）

Vol. 48. No. 12.
December 2021

Open Access Article

A MULTI-CRITERIA DECISION-MAKING IDEAL INTERVAL METHOD FOR COMPREHENSIVE EVALUATION OF WATER ENVIRONMENT QUALITY

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Abstract
The classic multi-criteria decision-making by ideal point approach is studied, since the water environment quality evaluation standard is regarded to be an interval concept rather than a point concept. The evaluation standard processing into ideal points has some flaws. A multi-criteria decision-making ideal interval technique (MCDMIIT) is developed to overcome this flaw. The MCDMIIT principle is introduced, along with its composition method and application to complete water environment evaluation. MCDMIIT is more efficient than projection pursuit model and neural network technique. MCDMIIT is more applicable than multi-criteria decision-making ideal point technique. MCDMIIT is commonly utilized in environmental quality assessment.
Keywords: Water environment quality; comprehensive evaluation; multi- criteria decision-making; ideal point method; ideal interval method
抽象的
由于水环境质量评价标准被视为区间概念而非点概念，因此研究了经典的理想点法多准则决策。 将评价标准加工成理想点存在一定的缺陷。 开发了一种多标准决策理想区间技术（MCDMIIT）来克服这一缺陷。 介绍了MCDMIIT原理及其组成方法及在完成水环境评价中的应用。 MCDMIIT 比投影追踪模型和神经网络技术更有效。 MCDMIIT 比多准则决策理想点技术更适用。 MCDMIIT 常用于环境质量评估。
关键词：水环境质量； 综合评价； 多标准决策； 理想点法； 理想区间法

1. Introduction

Water quality classification standards are used to assess the comprehensive quality of water environment in a given area throughout time. The closest grade standard is used to determine the comprehensive quality of water environment in a given area. There are numerous ways for evaluating water quality now, including fuzzy comprehensive assessment, unascertained measurement model, grey relational analysis, neural network, PP model, and multi-criteria decision-making 2 ideal point method [1-3]. Each approach has distinct features. Among these, the multi-criteria decision-making 2 ideal point technique is not only straightforward to use and grasp, but also can depict the complex link between water quality and multiple pollution or nutrient indicators. The point approach [2,3]

Received: October 05, 2021 / Revised: October 31, 2021 / Accepted: November 30, 2021 / Published: December 31, 2021
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converts the assessment criterion into points incorrectly. This research presents a Multiple Criteria Decision Making 2 Ideal Interval technique (MCDMIIT) to tackle this flaw.

2. The basic steps of MCDMIIT

It is essential to include n indicators that impact water quality as n criteria functions in multi-criteria decision-making $f_j(x), j = 1,2, \dots, n$ in order to use the ideal point approach [2,3] for thorough assessment of water quality. Its best value is $f_j^*, (j = 1,2, \dots, n)$where f_j^* refers to the j-th standard index value for each level of the criteria function. It is important to note that if the best possible solution for all of these indicators (the best possible solution Xj here refers to the level corresponding to the $j-th$ standard indicator value) is the same, then set it to X^*. Then all the criteria functions at X^* reach their respective optimal values at the same time, and Xj is the level of comprehensive water environment quality in a certain area over a given period of time. Though it's improbable that this will come to pass, Decision-making based on several criteria. If $f_j^*, (j = 1,2, \dots, n)$, is the ideal point in the ideal point technique, then f_j^* is the best value It is used to compare the water environment indicators in the region with the standard water environment indicators at a certain spot. Nearest-to-target distance and grade are determined and used to estimate overall water environment quality. The grade corresponds to the ideal point in terms of distance, and it is roughly considered as such.

The multi-criteria decision-making 2 ideal point method considers the indicator values of the monitoring sample and the indicator values of each level as points, and the distribution of the indicators of the monitoring sample is regarded as a curve, and the quality of the water environment is assessed. Decisions are made using a collection of curves that represent each level of the standard. Although the original approach should be enhanced in light of the specifics of the study topic, it should not be used as is. Of course, each index value represents an interval in the quality standard. To illustrate, Table 1 displays the lake water quality standard [4]. Between 0.0 to 1.0 micrograms per liter, the level I standard value of total phosphorus is within this range, while the level III standard value of oxygen consumption is within this range. "Interval" refers to a concentration range of between 0.36 and 1.80 micrograms per liter. When it comes to multi-criteria decision-making, the classic 2 ideal point technique is not reliable enough. Monitored sample values are referred to as "points," whereas standard values for each level are referred to as intervals. Methods for integrating the notion of processing points and intervals have been presented for water environment quality evaluation.

The basic steps of MCDMIIT for comprehensive assessment of water environment quality are as follows:

Step : 1 The first step is to build the criteria vector function. To develop the goal vector function, choose the n indicators governed by the water quality standard and do a full evaluation of water quality.

$$F(x) = [f_1(x), f_2(x), \dots, f_j(x), \dots, f_n(x)]^{\mathrm{T}} \quad (1)$$

Where $f_j(x)$ is the jth index, $j = 1, 2, \dots, n$.

Step : 2 Create the monitoring point's indication vector. Assume that F_k is the index vector of the kth monitoring point:

$$F_k = [f_{1,k}, f_{2,k}, \dots, f_{j,k}, \dots, f_{n,k}]^{\mathrm{T}} \quad (2)$$

Where $k = 1, 2, \dots, L$. L is the number of monitoring points, f_j and k are the $j-th$ index value of the $k-th$ monitoring point.

Step : 3 Construct a vector of perfect intervals. Each grade standard index in the standard for the quality of the aquatic environment is an ideal interval vector $F_i{}^*$:

$$F_i^* = [f_{1,i}^*, \quad f_{2,i}^*, \quad \dots, f_{j,i}^*, \dots, f_{n,i}^*]^{\mathrm{T}} \qquad f_{j,i}^* = [a_{j,i}, b_{j,i}] \quad (3)$$

Where $i = 1, 2, \dots, m$ and, $a_{j,i}, b_{j,i}$. are the left and right ends of the interval corresponding to the $i-th$ level's $j-th$ standard index, respectively. Assume that the values of each index from I to V are sorted in ascending order; otherwise, the index must be inverted and replaced. For example, following inversion processing, the values for the transparency indicators in Table 1 are 0.027, 0.083, 0.417, 1.818, and 5.882, and the indicators for each monitoring point should be handled similarly.

To determine how far away each ideal interval vector is from the monitoring point, use this calculation: The distance $d(i,k)$ between the monitoring value of the kth monitoring point and the ideal interval vector i is used to enhance the assessment outcomes.

$$d(i,k) = \sum_{j=1}^{n} \lambda_j \Delta(i,k,j) \quad (4)$$

Where $\Delta(i,k,j)$ is calculated as follows:

(1) When the evaluation factor is at level 1, that is, when $i = 1$

$$\Delta(i,k,j) = \begin{cases} (f_{j,k} - a_{j,1})/(b_{j,1} - a_{j,1}) & f_{j,k} \in [a_{j,1}, b_{j,1}] \\ 1 + (f_{j,k} - a_{j,2})/(b_{j,2} - a_{j,2}) & f_{j,k} \in [a_{j,2} b_{j,2}] \\ 3 & f_{j,k} > b_{j,2} \end{cases} \quad (5)$$

(2) When the evaluation factor is at level 2 to 4, i.e. $i = 2, 3, 4$

$$\Delta(i,k,j) = \begin{cases} \dfrac{(f_{j,k} - a_{j,i})}{(b_{j,i} - a_{j,i})} & f_{j,i} \in [a_{j,i}, b_{j,i}] \\ 1 + \dfrac{(f_{j,k} - b_{j,i-1})}{(a_{j,i-1} - b_{j,i-1})} & f_{j,i} \in [a_{j,i-1} b_{j,i-1}] \\ 1 + \dfrac{(f_{j,k} - a_{j,i+1})}{(b_{j,i+1} - a_{j,i+1}} & f_{j,i} \in [a_{j,i+1}, b_{j,i+1}] \\ 3 & f_{j,i} < a_{j,i-1}, f_{j,i} > b_{j,i+1} \end{cases} \quad (6)$$

(3) When the evaluation factor is at level 5, that is, when $i = 5$

$$\Delta(i,k,j) = \begin{cases} \frac{(f_{j,k} - a_{j,5})}{(b_{j,5} - a_{j,5})} & f_{j,k} \in [a_{j,5}, b_{j,5}] \\ 1 + \frac{(f_{j,k} - b_{j,4})}{(a_{j,4} - b_{j,4})} & f_{j,k} \in [a_{j,4} b_{j,4}] \\ 3 & f_{j,k} < a_{j,4} \end{cases} \quad (7)$$

λj is the weight. $i = 1, 2, \dots, m$; k = 1, 2, …, L, L is the number of monitoring sites that have been established .

Step : 4 Calculate the shortest possible distance. To find out the overall quality of the aquatic environment at the $k-th$ monitoring point, divide the number of monitoring points (k) by the number of levels i corresponding to $\min_{i} d(i,k)$, then divide the result by the number of monitoring points (k).

The above five steps constitute the MCDMIIT for comprehensive assessment of water environment quality.

3. Experimental results

For the purpose of demonstrating the viability of MCDMIIT, this research relies on data from the literature [4] to conduct a detailed evaluation of the eutrophication of lake water quality [5, 6]. The parameters for evaluating the quality of lake water are listed in Table 1. The data from water samples taken from the Five Great Lakes may be seen in Table 2. For the purposes of this work, the values j = 0125, j = 1, 2, 3, and 4 are employed. In the present state of affairs, the MCDMIIT formula (4) is employed to determine the comprehensive distance between each monitoring point index and the IV level standard. Table 2 shows the findings of the study. According to the findings in Table 2, the shortest distance between each monitoring site is picked from among the five possible distances:

$$d = min\{d(1,k), d(2,k), d(3,k), d(4,k), d(5,k)\} \quad (8)$$

Table 1 Normative parameters for evaluating the water quality of lakes [4]

	Index	Total phosphorus/ (μg·L-1)	Oxygen consumption(μg·L-1)	Transparency/m	Total nitrogen
water	Extremely poor nutrition I	<1	<0.09	> 37	<0.02
quality	Poor nutrition II	<4	<0.36	> 12	<0.06
	Middle nutrition III	<23	<1.80	> 2 . 4	<0.31
class	Eutrophication IV	<110	<7.10	> 0 . 55	<1.20
do not	Very nutritious V	<660	<27.10	> 0 .17	<4.6

Table 3 displays the shortest distance between each monitoring location, as well as the level of each monitoring point. Following the MCDMIIT minimum distance criteria, it has been determined that the water quality is highly nutrient-rich (V), the water quality is meso-nutrient (III), and the water quality is eutrophic (V) (IV).

Table 2 combined, the data and indications from the monitoring stations of the Five Great Lakes achieve a complete distance of grade I to grade V.

	Index	Distance

Monitoring points	Total phosphorus/ (μg·L-1)	Oxygen consumption(μg·L-1)	Transparency/m	Total nitrogen	d(1, k)	d(2, k)	d(3, k)	d(4, k)	d(5, k)
Lake (1)	130.003	10.303	0.353	2.763	2.267	2.272	2.311	1.359	0.917
Lake (2)	105.003	10.703	0.403	2.003	2.265	2.270	2.039	1.292	1.121
Lake (3)	20.003	1.403	4.503	0.223	2.254	1.305	0.557	1.449	3.003
Lake (4)	30.003	6.263	0.253	1.673	2.273	2.280	1.566	0.936	1.557
Lake (5)	20.003	10.133	0.503	0.233	2.263	1.647	1.174	1.110	1.841

Table 3 An assessment methodology and standards comparison, as well as findings of three different techniques of estimating minimum distances between the Great Lakes, are presented.

Monitoring points	shortest distance	Belonging to	method		
			MCDMIIT	Neural Network Method	PP
Lake (1)	0.914	V	V	V	V
Lake (2)	1.118	V	V	IV	V
Lake (3)	0.554	III	III	III	III
Lake (4)	0.933	IV	IV	IV	IV
Lake (5)	1.107	IV	IV	IV	IV

There are PP models and neural network methods that compare the assessment findings of the five great lakes described above with those of MODMIIM. Results from [4] are estimated values that have been rounded off. [4] Table 3 lists the comparative findings. MCDMIIT 's evaluation result is identical to that of the PP model [4], as shown in Table 3, and MCDMIIT 's calculating technique is considerably easier than the PP model [4].

Conclusion

Quality is regarded as a point in water environment impact assessments because of the problems with multi-criteria decision-making and the ideal point approach. A multi-criteria decision-making-ideal point approach is used to analyze the standard, and the key findings are as follows:

1. In conducting a comprehensive assessment of the Great Lakes water quality using the multi-criteria decision-making -ideal interval method, researchers were able to obtain results that were scientifically sound, reasonable, and comparable to those of the PP model [4]

and only one of the neural network methods [5]. There are a variety of monitoring points.

2. It is better than the PP model [4] and the neural network technique [5] to use a multi-criteria decision-making 2 ideal interval approach, since the formula (4) can be directly used and the computation can be done with a basic calculator. It's simple and straightforward.

3. While the ideal point approach has a narrower application scope, the ideal interval method has a more concrete physical significance. The weight j in equation (4) may be modified to suit the specific features and requirements of the situation at hand. As a result, the optimal interval approach for multi-criteria decision-making 2 is applicable and versatile enough to be applied in a variety of different sectors for evaluating environmental quality.

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