Researches of Water Bloom Emergency Management Decision-making Method and System Based on Fuzzy Multiple Attribute Decision Making

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Abstract

The prevention and management of water blooms is an important measure of environment protection. At present, although there is a variety of research achievement in water bloom management methods, the related reports in water blooms emergency management decision are hardly ever. Because the forming mechanism of water bloom is still unknown, it is difficult to come up with optimal water bloom management decision-making methods. Based on the deep research of mechanism characteristic and emergency management decision model of water bloom, this paper puts forward a Multiple Attribute Decision Making (MADM) based on water bloom emergency management decision-making methods, and applying to the lake reservoir water bloom emergency management program's selection, making model validation according to the lake reservoir as well, and then providing effective informational decision basis for environmental protection department to prevent and manage the water bloom.

Keywords: *formation mechanism of water bloom, emergency management decision, Multiple Attribute Decision Making methods*

1. Introduction

Water bloom phenomenon is a worldwide water pollution hazards, it's a manifestation of water eutrophication, morever, it intensifies the water pollution.. Considering the huge harmfulness caused by water bloom, the water bloom management has been one of the emphases on water pollution management [1].

In recent years, there have been researches on emergency decision-making methods in many fields, such as Huixing Guan, Mao Liu, etc. they put forward an expert's opinion decision-making method according to the ammonia leakage accident. Such method asks for multi-experts provide corresponding utility function and the attribute weights interval number to different attributes respectively, making quantitative analysis and synthesis by Monte Carlo simulation method, and for emergency decision-making method of ammonia leakage accident in some factory [2-3]. Zhixin Xu etc. established emergency decision-making model based on multi-attribute utility analysis method according to the characteristics of nuclear accident emergency decision, which can help decision makers consider the related factors during the emergency decision making process and express the contribution of each attribute to schemes by utility ways [4]. Yunjian, Nayagam etc. apply the ant clustering algorithm to national emergency decision analysis, showing numerical information and generic information in national emergency by mixed attribute data sets; we can work out the occurrence of national emergency by using such arithmetic, and such arithmetic can apply to the emergency intelligent decision support of national emergency [5-6]. From the above, we can see that emergency decision-making method has been used in many fields, but water bloom emergency decision-making method hasn't been formed.

At present, there have been many schemes to manage the water bloom, but when, where and which type of governance scheme to adopt, and can not only protect the water environment, but also improve the economic, the water bloom management decision-making scheme is the key point. Accordingly we conduct the research from three aspects respectively:

1) the influenced qualification of water bloom's outbreak;

2) the management method of water bloom;

3) the emergency decision-making method.

This paper firstly established the multi-index system, build water bloom multi-objective decision-making model for emergency management based on Multiple Attribute Decision Making theory, analyze all kinds of schemes to manage water bloom, and then put forward the influence factors of water bloom management and the target constraint conditions. After obtaining the entire attribute sets of the influence of water bloom management, each attribute makes different influences to water bloom management according to actual circumstances. So we should build a kind of attribute weight distribution model to optimize theory, and determine the inter-physical volume between each attributes and decision-making conclusion, and then get the optimal management decision-making ranking [7]. Thus, make the best scheme selection of water bloom management, and provide optimal decision basis for water environmental protection department to manage the water bloom. In addition, such management is of great significance to the protection and restoration of laker eservoir environment, and the promotion has considerable social and economic benefits.

2. Water Bloom Emergency Management Methods Based on Fuzzy Multiple Attribute Decision Making

2.1 Multiple Attribute Decision Making (MADM) Theory

MADM chooses the optimal solution or sorts the limited and selected scheme of decision problem in considering of multiple attribute (or index). MADM refers to a choice process after some management of the attribute and scheme information. The basic data used in such process is mainly the decision matrix, attribute function or the preference information of the scheme.

MADM problem evaluates the scheme based on attributes, and the attributes represent the characteristics and properties of scheme. MADM is in essence a sort while compared to comprehensive property of the scheme. According to the standardization of the decision-making matrix $R=[r_{ij}]_{n\times m}$ and attribute weight vectors $\omega=(\omega_1,\omega_2,\cdots,\omega_m)^T$, the scheme x_i relation between comprehensive attribute value and the attribute weights is

$$z_i = \sum_{j=1}^{m} r_{ij}\,\omega_j \qquad (1)$$

When the attribute weight and the attribute value are both known, we can determine the character of the scheme according to the comprehensive attribute value of each scheme.

2.2 The Improved Fuzzy MADM Method.

In view of the shortcomings of MADM, we adopt the improved fuzzy MADM method for the further research. Multiple attribute interval numbers can be regarded as a special kind of fuzzy numbers, so we choose the fuzzy sorting method and technology to the further research [8]. During the interval MADM, the main problems are how to express the interval number judgment and export the sort of the scheme from interval numbers decision matrix. The matrix in the interval number for element is called interval number matrix, filed as $A=[a_{ij}]_{n\times m}$, the operation can be defined as common digital matrix.

The following are the definition of standardized interval number.

Define 1 $R=[r_{ij}]_{n\times m}$ as the standardized interval number decision matrix.

If $i=1,2,\cdots,n,\ j=1,2,\cdots m,$,
Then $r_{ij}=[r_{ij}^L,r_{ij}^U]$, and $r_{ij}^L,r_{ij}^U\in[0,1]$.

$$\begin{cases} r_{ij}^L = a_{ij}^L \Big/ \sqrt{\sum_{i=1}^{n}(a_{ij}^U)^2}, \\ r_{ij}^U = a_{ij}^U \Big/ \sqrt{\sum_{i=1}^{n}(a_{ij}^L)^2}, i\in N,\ j\in T_1 \end{cases} \qquad (2)$$

2.3 Optimization right recovered model

In MADM problems, there are many objective methods of attributes. This paper adopts reference [9,10] attribute weight method, and gaining the model through the provided attribute weight optimization by the form of interval numbers. The following are the definition of interval number's closed value and ideal value.

Dedinition2 establishes standardized interval number matrix $A=[r_{ij}]_{n\times m}$, and $A=[r_{ij}]_{n\times m}$. Making two random matrix of the interval norm $\|r_{ij}-r_{kj}\|=|r_{ij}^L-r_{kj}^L|+|r_{ij}^U-r_{kj}^U|$, name $d(r_{ij},r_{kj})=\|r_{ij}-r_{kj}\|$ as the closed valve between decision matrix elements r_{ij} and r_{kj}.

Dedinition3 establishes standard interval numbers decision matrix $A=[r_{ij}]_{n\times m}$ each ideal attribute value is $r_i^+=\left[r_i^L+\ ,\ r_i^U+\right]$,

and $r_j^L+ = \max\{r_{ij}^L + / i = 1,2,\cdots,n\}$,
$r_j^L+ = \max\{r_{ij}^U + / i = 1,2,\cdots,n\} \quad (j = 1,2,\cdots,m)$,
as for the attribute, the deviation between the value of each scheme and scheme ideal value is (expressed by square)

$$D_i(\omega) = \sum_{j=1}^{m} d^2(r_j^+, r_{ij})\omega_j^2, i \in N, j \in M$$

The selection of weight vectors should make the total departure between values of the entire scheme and ideal scheme value minimum, which should meet the following constraint optimal problem.

$$MinF(\omega) = \sum_{j=1}^{m}\sum_{i=1}^{n} D^2(r_{ij}, r_i')\omega_j^2$$
$$s.t. \quad \omega_j \geq 0,\ j = 1,2,\cdots m \quad \sum_{j=1}^{m}\omega_j = 1 \qquad (3)$$

2.4 Interval numbers decision matrix

In view of the shortcomings of MADM, we adopt the improved fuzzy MADM method for the further research. Take the multiple attribute interval numbers as fuzzy numbers, choose the fuzzy sorting method and technology to make the further research. During the fuzzy MADM, the problems need to be solved are the expression of interval numbers and how to sort the scheme from the fuzzy (interval number) decision matrix. The matrix based interval numbers for element is called interval number matrix, represented by $A = [a_{ij}]_{n\times m}$, its operation can be defined by common digital matrix operation.

Set $A = [a_{ij}]_{n\times m}$ as interval number matrix, that is $a_{ij} = [a_{ij}^L, a_{ij}^U]$.

Record $A^L = [a_{ij}^L]_{n\times m}, A^U = [a_{ij}^U]_{n\times m}$, and $A = [A^L, A^U]$.

$R = [r_{ij}]_{n\times m}$ is standardized decision matrix.
If $i = 1,2,\cdots,n \quad j = 1,2,\cdots m$,
Then $r_{ij} = [r_{ij}^L, r_{ij}^U]$, and $r_{ij}^L, r_{ij}^U \in [0,1]$.

$$r_{ij} = a_{ij} / \|a_i\| \qquad j \in T_1, i \in N$$
$$r_{ij} = (1/a_{ij}) / (\|1/a_i\|) \quad j \in T_2, i \in N \qquad (4)$$

$$\|a_i\| = \sqrt{\sum_{j=1}^{m} a^2{}_{ij}}, \|1/a_i\| = \sqrt{\sum_{j=1}^{m}(1/a_{ij})^2} \qquad (5)$$

Extend the standardized methods to interval number and according to the interval algorithms, (4) are written as:

$$\begin{cases} r_{ij}^L = a_{ij}^L \Big/ \sqrt{\sum_{i=1}^{n}(a_{ij}^U)^2} \\ r_{ij}^U = a_{ij}^U \Big/ \sqrt{\sum_{i=1}^{n}(a_{ij}^L)^2} \quad i \in N, j \in T_1 \end{cases} \qquad (6)$$

$$\begin{cases} r_{ij}^L = (1/a_{ij}^U) \Big/ \sqrt{\sum_{i=1}^{n}(1/a_{ij}^L)^2} \\ r_{ij}^U = (1/a_{ij}^L) \Big/ \sqrt{\sum_{i=1}^{n}(1/a_{ij}^U)^2} \quad i \in N, j \in T_2 \end{cases}$$

2.5 Algorithm steps

1) Select the related attributes in evaluation scheme;

2) Make fuzzy management to attributes, constitute a decision matrix $A = [a_{ij}^L, a_{ij}^U]_{n\times m}$, $(j = 1,2,\cdots,m \quad i = 1,2,\cdots,n)$; a_{ij}^L Take the minimum value at the j attribute of the i location, and a_{ij}^U take the maximum value at the j attribute of the i location;

3) According to the standardized management of decision matrix in formula (2), obtain $R = [r_{ij}]_{n\times m}$;

4) According to the optimization model, obtain the optimal attribute weight vector $\omega_j^L, \omega_j^U \quad (j = 1,2,\cdots,m)$;

5) According to formula (1), calculate the comprehensive attribute value of each scheme $[z_i^L, z_i^U]$;

6) Use formula $z_i = (z_i^L + z_i^U)/2$ to manage the comprehensive attribute value, and sorting according to the result.

3 The Verification of MADM

3.1 Obtain the attribute weight

Because there are many factors influence the management of water bloom, including objective factors and the subjective factors by manager. These factors possess different importance degrees in the selection of management decision-making scheme, and need to establish reasonable weight distribution model. In order to highlight the real importance of each factors; adopting the optimization theory, through establishing target function and combining the physical situation of algae water bloom management and expertise together, building weight optimization allocation model of algae water bloom management combine with subjective and objective values:

$$MinF(\omega) = \sum_{j=1}^{m}\sum_{i=1}^{n} D^2(r_{ij}, d_i)\omega_j^2 \quad (7)$$

r_{ij} is the objective attribute value, d_i is the subjective preference attribute value; $D(r_{ij}, d_i) = \|r_{ij} - d_i\|$ means decision maker's deviation between the j attribute's subjective preference attribute value at the i scheme with the corresponding objective attribute value; ω_j is the j scheme optimal weight.

3.2 The water bloom emergency management decision-making based on multiple attribute theory comes true.

According to the characteristics of the lake reservoir in our country, select the measured data of the main lake reservoir in recent years, and verify the model on the basis of the algorithm steps.

Choose the main index factors of water bloom management method: total nitrogen, total phosphorus, PH value, dissolved oxygen, conductivity, chlorophyll, water temperature, illumination time, peripheral natural environment, geographical location, water utilization, population liquidity, water treatment investment, life wastewater, algae biomass, plankton, etc.

Choose the main methods of water bloom management: nutrient biological control technology in lake endogenous, microbial algal inhibiting, water erosion (dilution), artificial aeration, mechanical remove algae, disinfection method, ultraviolet ray method, electrolytic process, ultrasonic method, etc.

Take quantitative treatment to qualitative attribute (such as peripheral natural environment, geographic location, etc.), and constitute a standardized matrix $R=[r_{ij}]_{n\times m}$ with quantitative attribute, the matrix data is shown in table1. Because there is a good deal of experimental data, we just give part of the standardization decision matrix after standardized treatment.

Table1 standardized matrix

index / Management methods	total nitrogen	total phosphorus	PH value	dissolved oxygen
Method 1	0.595	0.059	0.889	0.612
Method 2	0.587	0.051	0.855	0.698
Method 3	0.512	0.052	0.812	0.603
index / Management methods	**conductivity**	**chlorophyll**	**water temperature**	
Method 1	0.894	0.021	0.253	
Method 2	0.843	0.024	0.298	
Method 3	0.812	0.025	0.219	

Notes: Method 1: microbial algal inhibiting. Method 2: water erosion. Method3: artificial aeration.

According to formula (3), obtain the optimal attribute weight vector:

$$\omega_j = \begin{pmatrix} 0.133919, & 0.035733, & 0.018756, & 0.065893, \\ 0.019577, & 0.030092, & 0.156449, & 0.061438, \\ 0.074871, & 0.052536, & 0.056248, & 0.079579, \\ 0.049724, & 0.071971, & 0.030058, & 0.063157 \end{pmatrix}$$

According to formula (1), the comprehensive property values of each scheme after calculation are obtained:

$$z_i = \begin{pmatrix} 0.387248\ , 0.410984\ , 0.479478\ , 0.501826\ , \\ 0.541181\ , 0.294642\ , 0.346780\ , 0.475989, \\ 0.263948 \end{pmatrix}$$

And according to the comprehensive property values of each scheme, make a sort of schemes from the optimal to worst by adopting MADM method, as shown in table2:

Table2. The sort of each scheme by MADM

The name of hydration treatment project	**Decision value**
1、mechanical remove algae	1.850887
2、artificial aeration	1.676820
3、water erosion (dilution)	1.641286
4、electrolytic process	1.260366
5 、 nutrient biological control technology in lake endogenous	0.984530
6、ultraviolet ray method	0.971781
7、microbial algal inhibiting	0.869570
8、disinfection method	0.646359
9、ultrasonic method	0.488358

The analyzed results of the lake reservoir water bloom emergency decision by fuzzy MADM method, as shown in table3:

Table3. The sort of each scheme by fuzzy MADM

The name of hydration treatment project	**Decision value**
1、mechanical remove algae	0.541181
2、artificial aeration	0.501826
3、water erosion (dilution)	0.479478
4、electrolytic process	0.475989
5 、 nutrient biological control technology in lake endogenous	0.410984
6、ultraviolet ray method	0.387248
7、microbial algal inhibiting	0.346780
8、disinfection method	0.294642
9、ultrasonic method	0.263948

Compare table2 and table3, we can see that by using the MADM method and fuzzy MADM method, the first four schemes are consistent, which means the core idea of the two methods is consistent. In the meanwhile, it reflects that the fuzzy MADM method is more objective and close to practical.

4 The realization of system and decision method

The realization of system is shown as fig2, the system uses multi-water quality parameter remote real-time monitor: used for display the real-time water quality parameters and geographic coordinate's information; historical data inquires of multi-water quality parameter: used for inquiring the historical data inquires of multi-water quality parameter and geographic coordinate's information; the receiving of GPRS teletransmission data: used for the real-time receiving of multi-water quality parameter information by hypogyny intelligent instruments; water bloom emergency management decision-making model: the embedded algorithm based on the calculation of input data works out the sort of output water bloom management scheme , providing effective decision-making basis for the management of water bloom.

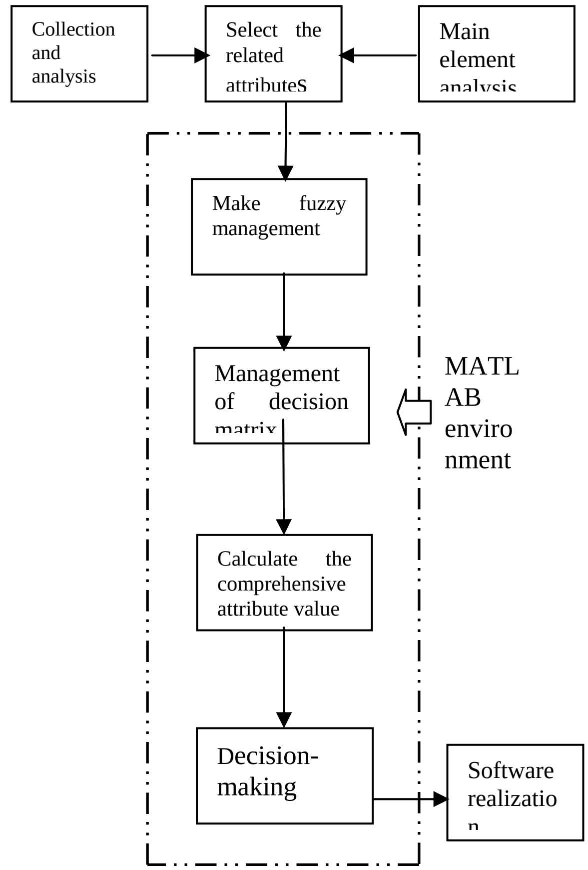

Fig1. The realization of system

The realization of emergency decision-making method is shown as fig3; such method applies MADM method and sorts through the compare of each scheme's comprehensive attribute value. According to the attribute characteristics of different wave, select the optimal water bloom management scheme, so as to realize the function of water bloom emergency decision-making.

By using the MADM method and fuzzy MADM method, the first four schemes are consistent. But the sort of 5, 6, 7 schemes change, according to the expertise, we can make sure that the fuzzy MADM method is more objective and close to the practice. The effect is shown as fig2:

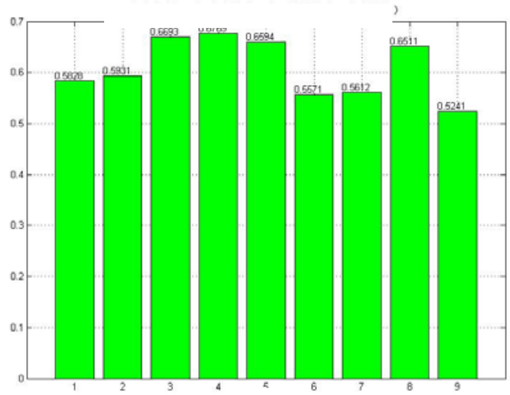

Fig2 the compare of decision-making method

5. Conclusion

This paper introduces the problem of multiple attribute decision making and does researches according to the application in water bloom emergency decision-making. First of all, make a comprehensive narration of MAMD theory's definition, standardized method, characteristic and sorting method, and then establish the MADM model with completely unknown attribute weight and fuzzy interval number. According to the lake reservoir wave in Beijing, making simulation experiment of water bloom emergency decision-making with fuzzy MADM method, and apply the emergency decision-making method to practice,which provides effective basis for the management of water environment.

Acknowledgment

Supported by Beijing Natural Science Foundation（8101003）, National Natural Science Foundation of China（51179002）, and the Beijing Municipal Commission of Education (PHR201007123,PHR201008238) and the Beijing Municipal Commission of Education Science and Technology Foundation Project.

References:

[1] Zaiwen LIU,Lifeng CUI,and Xiaoyi WANG, "Research and Application of Artificial Intelligence for Water Environment Protection", 2006 International Conference on AI, 2006,pp:362-366.

[2] Guan Huixing Liu Mao Zhao Qingxiang, "The Emergency Decision of Ammonia Leak Based on Group，Decision Making Method"， Acta Scientiarum Naturalium Universitatis Nankaiensis, 2007, 40(6),pp:28-33

[3] Jamehbozorg, A. and S. M. Shahrtash. "A Decision Tree-Based Method for Fault Classification in Double-Circuit Transmission Lines". IEEE Transactions on Power Delivery ,2010,25(4),pp:2184-2189.

[4] XU Zhixin; XI Shuren; QU Jingyuan, " Multi-attribute analysis of nuclear reactor accident emergency decision making", Journal of Tsinghua University(Science and Technology), 2008,48（3）,pp:248-251

[5] LIU Bing-hui, " The Application and Method on MADM-based Fuzzy Synthetic Evaluation", Journal of Shanxi University(Philosophy and Social Science Edition), 2010, 33 (1),pp:101 - 104.

[6] YUN Jian, LIU Yong-kui, HE Li-jun, CHEN Hua, WANG Shuang-cheng, "Application of ant colony clustering algorithm in aided intelligent decision-making for emergency related to ethnic groups"， Application Research of Computers, 2009,26(2),pp: 509-512

[7] Nayagam, V. L. G., S. Muralikrishnan, et al. "Multi-criteria decision-making method based on interval-valued intuitionistic fuzzy sets", Expert Systems with Applications .2011,8(3),pp: 1464-1467.

[8] MA Qi-dong, FANG Li-gong, IANG Yan-lin, WANG Bin, "Method of Comprehensive Evaluation of Operational Effectiveness Based on Intuitionistic Fuzzy Sets Multi-attributes Decision Making", Command Control & Simulation,2011,33(2),pp:45-48.

[9] ZHANG Lei, FANG Yang-wang, WU Zong-yi,ZHOU Xiao-bin, "Research of Comprehensive Ability of Pilot Based on FMADM", Fire Control and Command Control, 2011，36(2),pp:85-88.

[10] Alipour, M. H., A. Shamsai, et al. "A new fuzzy multicriteria decision making method and its application in diversion of water." Expert Systems with Applic 2011,37(12),pp: 8809-8813.

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