滨海城市水资源保护与管理

Water Conservation and Management in Coastal Areas

主编 王 琳

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Preface

The marine environment is a precious asset. The oceans and seas provide 99% of the available living space on the planet; they cover 71% of the Earth's surface and contain 90% of the biosphere and consequently contain more biological diversity than terrestrial and freshwater ecosystems. Marine ecosystems play a key role in climate and weather patterns. Indispensable to life itself, the marine environment is also a great contributor to economic prosperity, social well-being and quality of life.

However, the marine environment is under significant pressure at present. The coastal ecosystems are at risk on every continent, with land-based pollution sources causing over 80 percent of the global pollution of marine water. Concentrated population in coastal zones have brought about uncontrolled urban wastewater discharges, industrial water pollution, and soil contamination as a result of intensified agricultural activities, causing widespread degradation of coastal surface water resources, aquatic eco-systems and aquifers. Water conservation and management in coastal areas are therefore critical and pressing issues for local communities and governments.

How to link the effects of upstream freshwater resources and river basin management to coastal ecosystems, efficiently treat sewage and industrial wastewater, and better protect aquatic ecosystems and meet basic water requirements for human use, are, therefore, serious challenges to our future. Governments at all levels as well as local communities bear an ultimate obligation to make water conservation the highest priority by adopting long-term strategic plans and formulating adequate public policy. The scientific community and other professionals involved in water issues along with industries have responsibility to develop feasible methods and innovative technologies for water resources conservation and water pollution control. It is essential to boost water use efficiency, increase the fraction of wastewater to be recycled and reused, and improve water and wastewater treatment processes through research and developments in science and technology.

The papers presented in book are the outcome of a conference held in Qingdao in November 2005, during which the authors addressed these key issues and presented their research and experience in relevant fields. We believed that the essence of the papers will not only provide readers with an understanding of innovation and excellence in water conservation technology and management practices but also serve as an excellent tool for scientists, engineers, managers and decision makers around the world to acknowledge information and share their creative ideas and valuable experience in achieving water resource sustainability on the planet, especially in coastal regions.

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Part 1

Sustainable Exploitation and Utilization of Water Resource

A Genetic Fuzzy Analytical Hierarchy Process Based Projection Pursuit Method for Selecting Schemes of Water Transportation Projects

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Abstract The optimal selection of schemes of water transportation projects is a process of choosing a relatively optimal scheme from a number of schemes of water transportation programming and management projects, and this is of importance in both theory and practice in water resource systems engineering. In order to achieve consistency and eliminate the dimensions of fuzzy qualitative and fuzzy quantitative evaluation indexes, to determine the weights of the indexes objectively, and to increase the differences among the comprehensive evaluation index values of water transportation project schemes, a projection pursuit method, named FPRM-PP for short, was developed in this work for selecting the optimal water transportation project scheme based on the fuzzy preference relation matrix. The research results show that FPRM-PP is intuitive and practical, the correction range of the fuzzy preference relation matrix $\boldsymbol{A}$ it produces is relatively small, and the result obtained is both stable and accurate; therefore FPRM-PP can be widely used in the optimal selection of different multi-factor decision-making schemes.

Key words water transportation project; optimal selection of schemes; fuzzy analytical hierarchy process; projection pursuit; genetic algorithm

1 Introduction

Optimal selection of schemes of water transportation projects is a process of choosing a relatively optimal scheme from a number of schemes of water transportation programming and management projects, on the basis of the principle such that both the evaluation index system and the economic and environmental benefit from it are optimal, and this is of importance in both theory and practice of water resource systems engineering. In order to classify and rank all schemes in a one-dimensional real number space, the essence of the process is how to transform rationally a multiple-index evaluation problem into single comprehensive evaluation index (Mayer *et al.*, 2002; Ren and Wang, 1998; Yin *et al.*, 2001; Wu *et al.*, 2001; Zhang, 2002). In recent years the fuzzy comprehensive optimal-selection model (Yin *et al.*, 2001), grey comprehensive preferential model, artificial neural network comprehensive preference model (Wu *et al.*, 2001), analytic hierarchy process comprehensive optimal-selection model (Yin *et al.*, 2001; Zhang *et al.*, 2002) and other models (Cordon *et al.*, 2001) proposed by many researchers, have played important roles in project scheme selection and decision-making. But there still exist many complex problems: too many evaluation indexes are involved; the dimensions of the indexes may be different; it is difficult to determine the weights of the indexes, which lead to difficulties in the application of the models. Especially in water transportation project scheme selection, which has both fuzzy qualitative and fuzzy quantitative evaluation indexes, the difficulties are more obvious (Feng and Zhou, 1998; Huang, 1999). They are mainly manifested in the difficulty of ensuring consistency among the indexes and making them non-dimensional (Hu and He, 2000; Guo, 2002), the problem of how to determine the weights, the marginal differences among the comprehensive evaluation index values, the liability of the results to subjective factors, *etc.* Therefore, Yao and Zhang (1998) proposed the Fuzzy Preference Relation Matrix (named FPRM for short), transformed it into a fuzzy consistency judgment matrix by mathematic manipulation, and then used the preference values of this matrix as the consistent and dimensionless values of the evaluation indexes of each scheme. However, because the consistency of the original fuzzy preference matrix has not been considered, the differences between the fuzzy consistency matrix and fuzzy preference relation matrix can be very large, which may imply that the expert information contained in the FPRM may be lost, leading to a reduction of the

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credibility of the preference values (Song and Yang, 2003). On the basis of the above-mentioned achievements, in this paper a new method for water transportation project scheme optimization, named Fuzzy Preference Relation Matrix-Projection Pursuit (FPRM-PP), is presented. In this method, we first use the Accelerating Genetic Algorithm (AGA) (Jin and Ding, 2002) to check and correct the consistency of the fuzzy preference relation matrix directly and at the same time to compute the preference values, then we use the Projection Pursuit (PP) method to synthesize the preference values of each scheme under each index, and use the obtained projection value as the comprehensive evaluation value for each scheme. Some preliminary theoretical analysis and a case study are also presented.

2 Projection Pursuit Method for Optimizing Schemes of Water Transportation Projects

Suppose in a water transportation project problem the kth evaluation index value of the ith scheme is x_{ik}, $i=1, 2, \cdots, n$, $k=1, 2, \cdots, m$, n and m being the numbers of the schemes and evaluation indexes respectively. The FPRM-PP method includes the following five steps:

Step 1: Compare the schemes two by two under the evaluation indexes, and then construct a fuzzy preference relation matrix $\boldsymbol{A}^k=(a_{ij}^k)_{n\times n}$, $k=1,2,\cdots,m$. Here a_{ij}^k is the preference relation coefficient of scheme i against scheme j, defined specifically as follows (Huang, 1999; Yao and Zhang, 1998): if the decision-maker assumes scheme i is better than scheme j, then $a_{ij}^k=1$; if scheme i is equally good as scheme j, then $a_{ij}^k=0.5$; and if scheme i is worse than scheme j, then $a_{ij}^k=0$. It is obvious that $a_{ij}^k+a_{ji}^k=1$, so the fuzzy preference relation matrix is a kind of fuzzy complementary judgment matrix.

Step 2: Check and correct the consistency of the fuzzy preference relation matrix $\boldsymbol{A}^k$ and calculate the preference values. If $\boldsymbol{A}^k$ satisfies the additive transitivity

$$(a_{il}^k-0.5)+(a_{lj}^k-0.5)=(a_{ij}^k-0.5),\quad (\forall i,l,j\in\{1,2,\cdots,n\}) \tag{1}$$

then it is called the fuzzy consistency judgment matrix (Yao and Zhang, 1998; Song and Yang, 2003), where $k=1, 2, \cdots, m$. $(a_{ij}^k-0.5)$ can be perceived as the degree to which scheme i is superior to scheme j under index k, and the fuzzy consistency judgment matrix shows that this degree can be transited. The fuzzy consistency judgment matrix has the feature of center-division transitivity, and this accords with the consistency of the human decision-making thinking, thus it can be used widely (Yao and Zhang, 1998). According to Eq. (1), Song and Yang (2003) proposed the consistency index of fuzzy complementary judgement matrix $\boldsymbol{A}$

$$\rho^k=\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{\substack{l=1\\ j\neq i l\neq i,j}}^{n}|(a_{il}^k+a_{lj}^k-0.5)-a_{ij}^k|/[n(n-1)(n-2)], \tag{2}$$

and suggested that $\boldsymbol{A}^k$ has satisfactory consistency when the consistency index is not greater than 0.2.

Suppose the preference value of the ith scheme of the fuzzy preference relation matrix $\boldsymbol{A}^k$ is s_i^k, which satisfies $s_i^k>0$ and $\sum_{i=1}^{n}s_i^k=1$, and $\boldsymbol{W}^k=(w_{ij}^k)_{n\times n}$ is called the weight matrix of $\boldsymbol{A}^k$, where $w_{ij}^k=\alpha(s_i^k-s_j^k)+0.5$ $(\forall i,j\in\{1,2,\cdots,n\})$; parameter $\alpha\geqslant0.5(n-1)$. The smaller α is, the more importance the decision-maker attaches to the differences of preference values among schemes (Lu, 2002). In practice generally $\alpha=0.5(n-1)$. It can be proved that (Song and Yang, 2003; Lu, 2002) the necessary and sufficient condition that the fuzzy preference relation matrix $\boldsymbol{A}^k$ possesses complete consistency is $\boldsymbol{A}^k=\boldsymbol{W}^k$.

Now the preference values $\{s_i^k|i=1, 2,\cdots, n\}$ of each scheme can be calculated from the known fuzzy preference relation matrix $\boldsymbol{A}^k$. If $\boldsymbol{A}^k$ possesses complete consistency, then

$$\sum_{i=1}^{n}\sum_{j=1}^{n}|0.5(n-1)(s_i^k-s_j^k)+0.5-a_{ij}^k|/n^2=0, \tag{3}$$

where the symbol $|x|$ means the absolute value of x. Because of the fuzziness and complexity of practical systems, and the diversity, localization and instability in human recognition, it is unavoidable that the fuzzy preference relation matrix the decision-maker constructs in practice can not satisfy the consistency condition, and this problem can not be solved thoroughly. In practical decision-making, to suit many kinds of practical complex systems, it is only required that the fuzzy preference relation matrix has satisfactory consistency. The term on the left hand side of Eq. (3) is defined as the consistency index of $\boldsymbol{A}^k$ by Xu (2002), and if its value is not larger than 0.1, $\boldsymbol{A}^k$ is then thought to have satisfactory consistency.

If the fuzzy preference relation matrix $\boldsymbol{A}^k$ does not possess satisfactory consistency, it needs to be corrected. Suppose the corrected judgment matrix of $\boldsymbol{A}^k$ is $\boldsymbol{B}^k=(b_{ij}^k)_{n\times n}$, the preference values of each scheme of $\boldsymbol{B}^k$ are also written as $\{s_i^k|i=1, 2,\cdots, n\}$, then the $\boldsymbol{B}^k$ which makes the following form the least is called the optimal fuzzy consistency judgment matrix:

$$\min CIC(k,n)=\sum_{i=1}^{n}\sum_{j=1}^{n}|b_{ij}^k-a_{ij}^k|/n^2+$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} | 0.5(n-1)(s_i^k - s_j^k) + 0.5 - b_{ij}^k | / n^2, \quad (4)$$

$$\text{s. t. } b_{ii}^k = 0.5 \quad (i=1,2,\cdots,n),$$

$$1 - b_{ji}^k = b_{ij}^k \in [a_{ij}^k - d, a_{ij}^k + d] \cap [0,1],$$

$$(i=1,2,\cdots,n, j=i+1,i+2,\cdots,n)$$

$$s_i^k > 0 \quad (i = 1,2\cdots,n), \sum_{i=1}^{n} s_i^k = 1,$$

where the objective function $CIC(k, n)$ is called the consistency index coefficient of the fuzzy preference relation matrix $\boldsymbol{A}^k$; d is a nonnegative parameter, which can be chosen in [0, 0.5] according to the experience of the authors; the other notations are the same as before. Eq. (4) is a nonlinear optimal problem which is difficult to deal with by traditional optimal methods, where the optimized variables are the preference values $\{s_i^k | i=1, 2,\cdots,n\}(k=1, 2,\cdots, m)$ and the upper triangular matrix elements of the corrected judgment matrix $\boldsymbol{B}^k = \{b_{ij}^k\}_{n\times n}$. To a rank n fuzzy preference relation matrix $\boldsymbol{A}^k$, the number of independent optimized variables is $n(n+1)/2$. Obviously, the smaller $CIC(k, n)$ is, the higher the consistency degree is, and when the global minimum value $CIC(k, n)=0$, $\boldsymbol{B}^k=\boldsymbol{A}^k$. At this time, $\boldsymbol{A}^k$ has complete consistency. And from the restriction

$$\sum_{i=1}^{n} s_i^k = 1,$$

we can be certain that this global minimum value is unique. As a kind of general optimization methods based on the mechanisms of natural selection and natural genetics, AGA can be applied to deal with the optimization problem easily and effectively (Jin *et al.*, 2001; Jin and Ding, 2002). When $CIC(k, n)$ is less than a critical value, it can be assumed to have satisfactory consistency, and each preference value based on this computation is acceptable; otherwise it is necessary to adjust d or $\boldsymbol{A}^k$ until it has satisfactory consistency. Based on a large number of numerical experiments and making reference to the consistency index critical values (0.1 or 0.2) proposed by Xu (2002) and Song and Yang (2003), we preliminarily consider that it can be assumed to have complete consistency when the consistency index coefficient of the fuzzy preference relation matrix $CIC(k, n)$ is not greater than 0.2.

Step 3: Construct the projective index function. Here the aim of the projection pursuit method is to synthesize the m dimensional data $\{s_i^k | k=1,2,\cdots, m\}$ to one dimensional $z(i)$, which is named the projective value in the projective direction $a = (a(1), a(2),\cdots, a(p))$, by the following equation:

$$z(i) = \sum_{k=1}^{m} a(k) s_i^k \quad (i = 1,2,\cdots,n), \quad (5)$$

and then to conduct scheme optimization based on the one dimensional scattering figure of $\{z(i)\}$. Here $\boldsymbol{a}$ is a unit length vector in Eq. (5). Obviously, different projective directions reflect different structural characters, different synthesis forms and different data mining approaches. In the synthesis process, the obtained $z(i)$ are required to have the following distribution characteristics: the local projective dots should be as dense as possible, and it is best for them to condense into dot groups that are separated as much as possible. Based on these requirements, a projective index function can be designed as follows (Friedman and Turkey, 1974)

$$Q(\boldsymbol{a}) = S_z D_z, \quad (6)$$

where S_z is the standard variance of $z(i)$, and D_z is the local density

$$S_z = [\sum_{i=1}^{n} (z(i) - \bar{z})^2/(n-1)]^{0.5}, \quad (7)$$

$$D_z = \sum_{i=1}^{n}\sum_{j=1}^{n} (R - r_{ij}) u(R - r_{ij}), \quad (8)$$

where $\bar{z}$ is the mean of the series $\{z(i) | i=1,2,\cdots,n\}$; R is the window radius of the local density, and the value of R can generally be chosen (Friedman and Turkey, 1974) as $0.1 S_z$; the distance $r_{ij} = |z(i) - z(j)|$; and $u(t)$ is the unit pulse function, whose value is 1 if $t \geqslant 0$ and 0 otherwise.

Step 4: Optimize the projective index function. The value of the projective index function $Q(\boldsymbol{a})$ changes only according to the variety of the projective direction $\boldsymbol{a}$ when the scheme set has been determined. The optimal projective direction is the direction which best reveals some structure characters of the high dimensional sample data, and which can be estimated by solving the following optimal problem

$$\max Q(\boldsymbol{a}) = S_z D_z, \quad (9)$$

$$\text{s. t. } \sum_{k=1}^{m} \boldsymbol{a}^2(k) = 1. \quad (10)$$

Obviously, this is a complex nonlinear optimal problem that is not easy to deal with by traditional methods, where the optimized variables are $\{a(k) | k=1,2,\cdots,m\}$ (Friedman and Turkey, 1974). However, the AGA can be used to solve it both conveniently and effectively. When AGA is used to solve the above optimal problem, before calculating the individual fitness function expressed by Eq. (9), the projective direction $\boldsymbol{a}$ has to be transformed according to Eq. (10), then the restriction problem presented by Eq. (10) can be treated.

Step 5: Select the optimal scheme. The projective values $z^*(i)$ of the schemes can be obtained by substitution of the optimal projective direction $\boldsymbol{a}^*$ obtained in Step 4 into Eq. (5). The larger the value of $z^*(i)$ is, the more preferable the ith scheme is. The scheme with the largest $z^*(i)$ value is regarded as the optimal scheme.

3 Case Study

In order to further illustrate the application of the FPRM-PP method, now take the selection of schemes for a water transportation investment project as an example: there are seven schemes for this project which is of great social benefit. On analysis, the following social evaluation indexes are proposed (Feng and Zhou, 1998): 1) Impact on the regional water transportation of the project = (mileage of main channel that the project increases/original mileage) × 100%, C_1; 2) The network efficiency of water transportation raised by the project = [(turnover volume of goods transportation after the completion of the project − the original turnover volume)]/the original turnover volume of goods transportation × 100%, C_2; 3) The demand made by the project area, i.e. the demand for the project according to the area's development in terms of regional productivity and overall planning, C_3; 4) The comprehensive capability for water resource application of the project in terms of water transportation, urban construction, tourism, etc., C_4; 5) Type of the project according to its attribute and importance level, a project being classified as a key project, a general project or a maintenance project, C_5; 6) The scale of land requisition, house dismantling and resettling expressed by the percentage of the total investment of the project spent in this aspect, C_6; 7) The role the project plays in improving the comprehensive traffic, i.e. the improvement it brings to the port and land route traffic after its completion, C_7. These indexes are shown in Table 1 (Feng and Zhou, 1998).

Table 1 Social evaluation index values and their projection values for a water transportation project

Scheme number	Social evaluation index values							Projection value
	C_1 (%)	C_2 (%)	C_3	C_4	C_5	C_6 (%)	C_7	
1	14.4	36.7	extraordinarily great	ordinary	key	6.1	bigger	0.492
2	9.8	56.6	ordinary	higher	general	10.3	ordinary	0.272
3	7.6	55.4	great	ordinary	general	12.4	ordinary	0.266
4	11.3	44.2	extraordinarily great	much higher	key	3.5	more much bigger	0.564
5	3.0	29.7	comparatively great	ordinary	general	5.1	ordinary	0.263
6	5.4	14.5	extraordinarily great	lower	maintenance	10.4	bigger	0.267
7	1.4	4.2	ordinary	ordinary	general	5.2	bigger	0.269
Contribution ratio of index	18.01%	6.31%	20.94%	3.22%	19.77%	20.27%	11.49%	

Through Table 1 we can obtain the fuzzy preference relation matrix for each scheme as follows under those seven social evaluation index values:

$$
\boldsymbol{A}^1=\begin{bmatrix}
0.5 & 1.0 & 1.0 & 1.0 & 1.0 & 1.0 & 0.1 \\
0.0 & 0.5 & 1.0 & 0.0 & 1.0 & 1.0 & 1.0 \\
0.0 & 0.0 & 0.5 & 0.0 & 1.0 & 1.0 & 1.0 \\
0.0 & 1.0 & 1.0 & 0.5 & 1.0 & 1.0 & 1.0 \\
0.0 & 0.0 & 0.0 & 0.0 & 0.5 & 0.0 & 1.0 \\
0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.5 & 1.0 \\
0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5
\end{bmatrix},\quad
\boldsymbol{A}^3=\begin{bmatrix}
0.5 & 1.0 & 1.0 & 0.5 & 1.0 & 0.5 & 1.0 \\
0.0 & 0.5 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5 \\
0.0 & 1.0 & 0.5 & 0.0 & 1.0 & 0.0 & 1.0 \\
0.5 & 1.0 & 1.0 & 0.5 & 1.0 & 0.5 & 1.0 \\
0.0 & 1.0 & 0.0 & 0.0 & 0.5 & 0.0 & 1.0 \\
0.5 & 1.0 & 1.0 & 0.5 & 1.0 & 0.5 & 1.0 \\
0.0 & 0.5 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5
\end{bmatrix},
$$

$$
\boldsymbol{A}^2=\begin{bmatrix}
0.5 & 0.0 & 0.0 & 0.0 & 1.0 & 1.0 & 1.0 \\
1.0 & 0.5 & 0.5 & 1.0 & 1.0 & 1.0 & 1.0 \\
1.0 & 0.5 & 0.5 & 1.0 & 1.0 & 1.0 & 1.0 \\
1.0 & 0.0 & 0.0 & 0.5 & 1.0 & 1.0 & 1.0 \\
0.0 & 0.0 & 0.0 & 0.0 & 0.5 & 1.0 & 1.0 \\
0.0 & 0.5 & 0.0 & 0.0 & 1.0 & 0.5 & 1.0 \\
0.0 & 0.5 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5
\end{bmatrix},\quad
\boldsymbol{A}^4=\begin{bmatrix}
0.5 & 0.0 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5 \\
1.0 & 0.5 & 1.0 & 0.0 & 1.0 & 1.0 & 1.0 \\
0.5 & 0.0 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5 \\
1.0 & 1.0 & 1.0 & 0.5 & 1.0 & 1.0 & 1.0 \\
0.5 & 0.0 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5 \\
0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5 & 0.0 \\
0.5 & 0.0 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5
\end{bmatrix},
$$

$$\boldsymbol{A}^5=\begin{bmatrix}0.5 & 1.0 & 1.0 & 0.5 & 1.0 & 1.0 & 1.0\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5\\0.5 & 1.0 & 1.0 & 0.5 & 1.0 & 1.0 & 1.0\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5\\0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.5 & 0.0\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 1.0 & 0.5\end{bmatrix},$$

$$\boldsymbol{A}^6=\begin{bmatrix}0.5 & 1.0 & 1.0 & 0.0 & 0.0 & 1.0 & 0.0\\0.0 & 0.5 & 1.0 & 0.0 & 0.0 & 0.5 & 0.0\\0.0 & 0.0 & 0.5 & 0.0 & 0.0 & 0.0 & 0.0\\1.0 & 1.0 & 1.0 & 0.5 & 1.0 & 1.0 & 1.0\\1.0 & 1.0 & 1.0 & 0.0 & 0.5 & 1.0 & 0.5\\0.0 & 0.5 & 1.0 & 0.0 & 0.0 & 0.5 & 0.0\\1.0 & 1.0 & 1.0 & 0.0 & 0.5 & 1.0 & 0.5\end{bmatrix},$$

$$\boldsymbol{A}^7=\begin{bmatrix}0.5 & 1.0 & 1.0 & 0.0 & 1.0 & 0.0 & 0.5\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 0.0 & 0.0\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 0.0 & 0.0\\1.0 & 1.0 & 1.0 & 0.5 & 1.0 & 0.5 & 1.0\\0.0 & 0.5 & 0.5 & 0.0 & 0.5 & 0.0 & 0.0\\1.0 & 1.0 & 1.0 & 0.5 & 1.0 & 0.5 & 1.0\\0.5 & 1.0 & 1.0 & 0.0 & 1.0 & 0.0 & 0.5\end{bmatrix}.$$

The computed preference values of the fuzzy preference relation matrices by using FPRM-PP (parameter $d=0.15$) are shown in Table 2, where the consistency index coefficient value of each of the seven matrices is not greater than 0.2, so they are thought to have satisfactory consistency, and the computed preference values of each scheme are acceptable.

Table 2 Computed values of fuzzy preferential relation matrices by using FPRM-PP

Judgement matrix	Preference values of each scheme							Coefficient value of consistency index
	w_1	w_2	w_3	w_4	w_5	w_6	w_7	
$\boldsymbol{A}^1$	0.268	0.188	0.141	0.220	0.054	0.098	0.030	0.20
$\boldsymbol{A}^2$	0.138	0.240	0.241	0.194	0.088	0.064	0.035	0.18
$\boldsymbol{A}^3$	0.220	0.062	0.137	0.222	0.081	0.219	0.060	0.13
$\boldsymbol{A}^4$	0.114	0.248	0.116	0.261	0.113	0.033	0.115	0.11
$\boldsymbol{A}^5$	0.254	0.116	0.116	0.259	0.116	0.022	0.115	0.09
$\boldsymbol{A}^6$	0.134	0.069	0.041	0.257	0.217	0.066	0.216	0.16
$\boldsymbol{A}^7$	0.1860	0.057	0.061	0.222	0.061	0.221	0.191	0.11

The projective index function for this case is obtained by substitution of the preference values of each scheme in Table 2 into Eqs. (5), (7), (8), and (6) in turn, and we use AGA to solve the selection problem determined by Eqs. (9) and (10). Then we obtain the maximum projective index function value, 0.034, and the optimal projective direction $\boldsymbol{a}^*=(0.431, 0.151, 0.501, 0.077, 0.473, 0.485, 0.275)$. Substituting $\boldsymbol{a}^*$ into Eq. (5), we obtain the projective values $z^*(i)$ for each scheme, which are also shown in Table 1.

Table 1 shows that: a) According to the projective values of the schemes, the seven schemes can be divided into three groups as follows: scheme 4 is the optimal scheme, scheme 1 is the second optimal scheme, and schemes 2, 3, 5, 6 and 7 are inferior schemes. This result accords with both the practical conditions and the results of fuzzy comprehensive evaluation (Feng and Zhou, 1998) and multi-factor decision-making optimization method based on fuzzy consistency matrix (Huang, 1999). But the differences among the comprehensive evaluation index values of the schemes by using FPRM-PP are remarkable, and the results are less affected by subjective factors; b) The use of FPRM-PP for selecting schemes of water transportation projects is feasible and effective, and compared to other methods it has the obvious advantages that there is no need to establish membership functions, and no need to set a weight to each evaluation index beforehand, so it can be widely used in practical application conveniently. According to the optimal projective direction, we can determine the contribution ratios of the evaluation indexes to the projection values as shown in Table 1. The larger the contribution ratio of an evaluation index is, the more it affects the selection result, which can provide important in-formation for evaluation index screening and scheme improvement.

4 Conclusions

In the process of solving the optimal selection of schemes of water transportation projects, in order to achieve consistency and eliminate the dimensions of fuzzy qualitative and quantitative evaluation indexes, to determine the weights of the index without influence from subjective factors, and to increase the differences among the comprehensive evaluation index values of the schemes, a projection pursuit method, named FPRM-PP for short, is proposed based on fuzzy preference relation matrix. The result shows that: a) the correction range for matrix **A** by FPRM-PP is smaller than by the commonly used consistency transform methods; b) as a kind of general optimization method based on the mechanisms of natural selection and natural genetics, AGA can be applied to deal with the optimal problem easily and effectively, and its result on preference values accords with the result of selection consistency transform method, the stability being the same and the precision even higher; c) the FPRM-PP is a global direct correction method, which uses the information of each element in the original fuzzy preference relation matrix to correct the matrix by using the projection pursuit method to synthesize the preference values of each scheme under each index. The FPRM-PP fully utilizes the information of preference values of each scheme and both scattering and the clustering of the comprehensive evaluation index values are distinct, and the result of selection is less affected by subjective factors, so the FPRM-PP can be widely used in selecting different multi-factor decision-making schemes.

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Integrity of Local Ecosystems and Storm Water Management in Residential Areas

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Abstract The authors designed an ecological storm water system in a residential area to replace the conventional underground channels for the collection of storm water so as to reduce the nutrients and sediments discharged. This system contains natural sub-creeks as drainage channels discharging overflow to nearby creeks, an open green trench, a storage pond, and natural sub-creeks. The sub-creeks were designed to be integrated into community landscape, which not only increases the efficiency of water usage, but also improves the aesthetic qualities of the community residence area as required by Agenda 21. This research proved the feasibility of an open storm water collection and utilization system for the design of a community water system.

Key words storm water management; ecological community; water management; open trench; greenway; pond system

1 Introduction

Population growth has created escalating pressures on our resources (natural, human and social) on local, regional, and global scales. These pressures negatively impact the natural environment, our communities and the quality of our lives. In the face of these global challenges, people have more and more concerns for environment and sustainability.

The concept of sustainable development emerged as an effective solution to this thorny problem. Rather than pitting economic growth against environmental protection, proponents of sustainability have shifted the terms of debate by focusing on development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987).

Based on the above definition, the authors believe that sustainable community development involves the ability of a local community to utilize its natural, human and technological resources to ensure that all members of present and future generations can attain a high degree of health and well-being, economic security, and maintenance of the integrity of the ecological systems.

The concept of integrity in ecosystems traces its roots to the land ethic defined by Leopold (2004). A rich, though mostly conceptual, literature exists on ecological integrity, which can be summarized as 'integrity can only be defined clearly (in terms of evaluative criteria) for specific ecosystems, in the context of man being an integral part of the ecosystem.' Since water is a key factor in our ecosystem, the explicit relationship between ecosystem integrity and water management is our objective. Effective and sustainable water usage is not just water-saving, but also its safe return to our ecosystem. Our case analysis will present an idea how to use an ecological instrument to design a community for the maximization of its function and also for the fulfillment of requirement of ecological integrity.

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2 Relationship between Runoff and Ecology

Runoff is an essential element of our ecosystem. Adaptation for water balance and conservation helps determining a species habitat range. Typically, the peak-flow change of pre/post development is dramatic; for example, in many intact forest areas, it is only 1% annual runoff under a natural forested condition, but it can be 70% annual runoff for an intensive community area. A further impact of deforestation and denudement due to over-exploitation and shifting cultivation, biotic and abiotic interferences has caused considerable degradation to natural resources such as that shown in Fig. 1.

We depend on a healthy ecosystem, including clean water, to survive on this planet. Therefore, effective and sustainable water use should be emphasized and based on an ecological approach and water management should be coupled with ecological environment-community development.

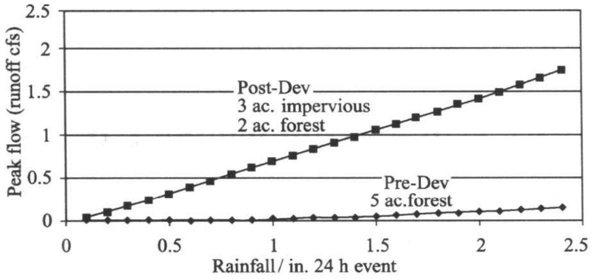

Fig. 1 Pre/Post development comparison (Source: SBUH method, perv. Cn 70/imp. Cn 99, 5 acre site.).

3 Current Situation of Storm Water Management in Community

3.1 Increasing Runoff

Runoff is created to a certain extent when human activities alter the natural water balance. As trees, vegetation and soils are replaced with roads and buildings, less rainfall infiltrates into the ground, less gets taken up by vegetation and more becomes storm water runoff. The follow equations show runoff increase with impervious cover area in an urban area.

Annual runoff is calculated by:

- $R = P \times P1 \times Rv$,
- R = annual runoff (in.),
- P = annual rainfall (in.),
- P1 = fraction of annual rainfall events that produce runoff (usually 0.9),
- Rv = runoff coefficient.

The runoff coefficient is calculated by:

- $Rv = 0.5 + 0.9Ia$,
- Ia = impervious fraction.

This coefficient is based on the percentage of impervious cover of the watershed area. Impervious surfaces are limited to two main features of human development: building rooftops and transportation systems. Impervious surfaces are man-made areas that do not readily absorb or retain water, including, but not limited to, building roofs, parking and driveway areas, graveled areas, sidewalks, and paved recreation areas. To satisfy population needs, we have more and more paved areas – for example, new housing or industrial developments, urban infills, driveways, patios, new roads, *etc.* So the amount of runoff increases rapidly. It has been estimated that the amount of urban runoff from paved areas in Qingdao, China has increased about ten folds over the last 100 years due to development. In addition, the level and range of pollutants in runoff have increased.

3.2 Management of Stormwater

Stormwater from the roof is piped down to the ground, and discharged into the drain, then into a big pipe, and eventually into the sea. Sometimes the water is discharged directly into a stormwater pipe. Other times the water is sent into a stream, or a large concrete channel. Traditional stormwater design is aimed at letting the stormwater flow as fast as possible to the sea – through big pipes or big channels. Figs. 2 and 3 indicate a layout of runoff collection and discharge pipeline system in Shinan District, Qingdao, China, which explicitly illustrates a conventional way to discharge runoff and a network using large-sized runoff collection pipeline with a diameter of 2 m is under construction. The higher the impervious area is, the larger the discharge pipeline and the higher the discharge speed are. Fig. 4 shows the runoff pollutants impacting on the seawater quality of Qingdao Bay. The detail of pollutants contained in the runoff is shown in Table 1, which presents pollution assessment of the stormwater collection system at Loushan outlet in Qingdao (Wang *et al.*, 2004). As shown in Table 1, the pollutants tend to increase with time. The increased pollutants in runoff seriously impact the receiving water body quality and its ecology.

Therefore, conventional approaches to flooding control obviously results in frequent flooding and draught in the drainage area and the quality of the storm water will be influenced. And, no doubt, non-point pollution is related to stormwater. The unsustainability of these approaches is evident in

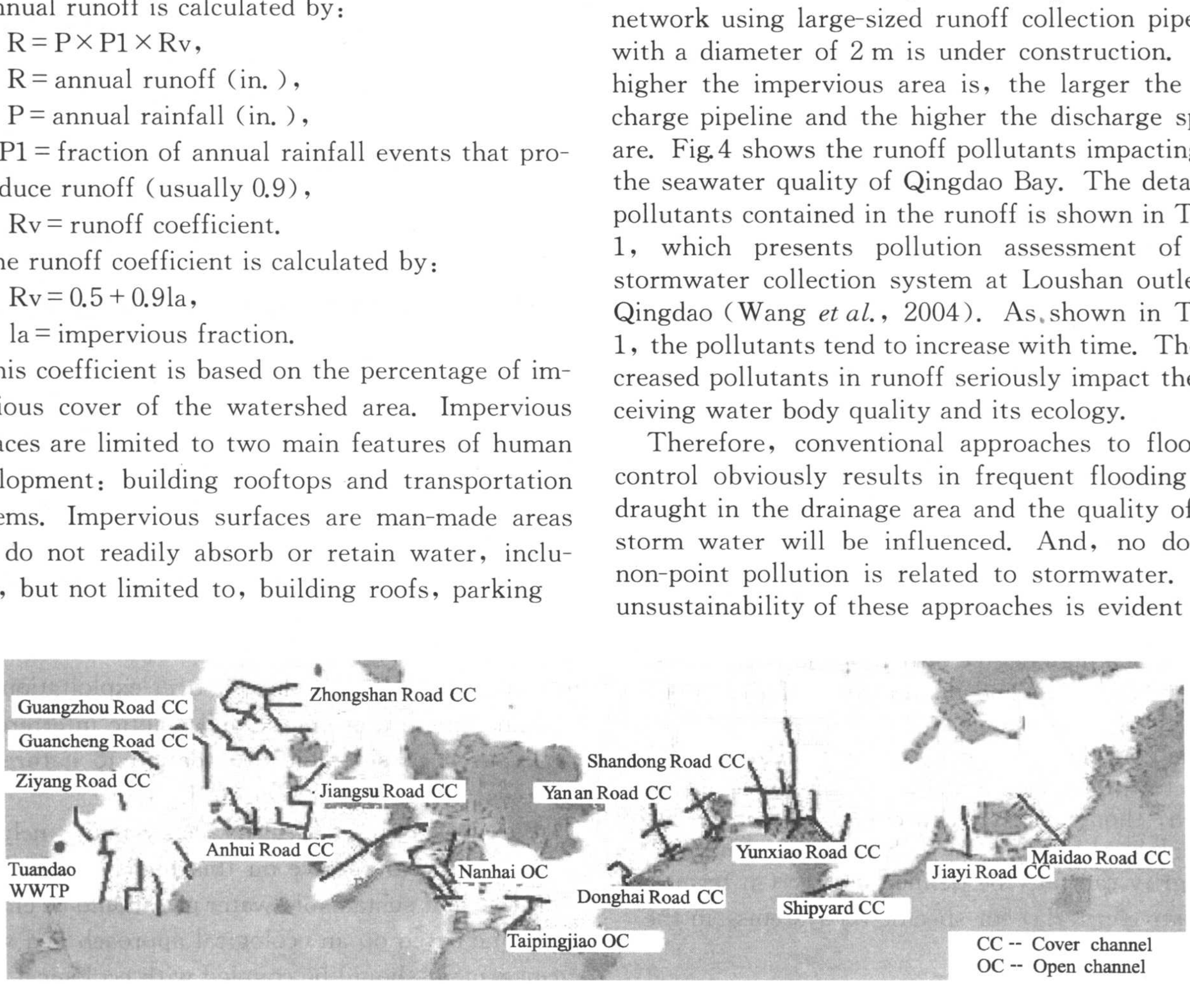

Fig. 2 Location of storm water outlets to coastal waters of Shinan District, Qingdao, China.