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PUTRAJAYA RIVER SYSTEM RANKING USING FUZZY COMPOSITE PROGRAMMING

Supiah Shamsudin[1,*], Noor Baharim Hashim[1], Azmi Ab Rahman[2]
[1]*Faculty of Civil Engineering, Universiti Teknologi Malaysia 81310, Skudai, Johor, Malaysia*
[2] *Faculty of Management and Human Resource Development, Universiti Teknologi Malaysia 81310, Skudai, Johor, Malaysia*

*Corresponding Author: *supiah@fka.utm.my*

Abstract: Putrajaya river systems which consist of Sg. Chuau, Sg. Limau Manis and Sg. Bisa were ranked under multi criteria environment for future management. The rivers were ranked using multicriteria decision making approach, specifically applying Fuzzy Composite Programming (FCP). There are three main objectives of ranking; i) improving water quality, ii) enhancing water quantity and iii) minimising cost. The FCP structure contained 15 first-level indicators, six second level indicators, three third level indicators and one final indicator. Sensitivity analysis using four different set of weights were carried out to ensure the robustness of the options. Sungai Chuau was ranked the first with the highest ordered sequence value of 0.494. The highest ranking was determined based on the shortest distance between the fuzzy box and an ideal point. Sungai Chuau should be given the highest priority in the management and conservation of resources than the other river systems

Keywords: *Fuzzy Composite Programming; Ranking; Multicriteria Decision Making; River Management.*

Abstrak: Sistem sungai Putrajaya yang terdiri dari Sg. Chuau, Sg. Limau Manis dan Sg. Bisa telah dipangkatkan menggunakan persekitaran multikriteria untuk pengurusan pada masa hadapan. Sungai–sungai ini telah dipangkatkan menggunakan pendekatan membuat keputusan multikriteria iaitu menggunakan Pengaturan Komposit Fuzzi (PKF). Tiga objektif utama pemangkatan telah ditentukan; i) meningkatkan kualiti air, ii) menambah kuantiti air dan iii)mengurangkan kos. Struktur PKF yang dibina mengandungi 15 petunjuk tahap pertama, enam petunjuk tahap kedua, tiga petunjuk tahap ketiga dan satu petunjuk akhir. Analisis kepekaan menggunakan empat set pemberat yang berbeza telah dijalankan untuk memastikan ketegapan pilihan itu. Pemangkatan sistem sungai yang tertinggi adalah Sungai Chuau dengan nilai susunan jujukan tertinggi 0.494. Selain itu, penentuan pangkat tertinggi adalah berdasarkan jarak terdekat di antara kotak fuzzi dan titik unggul. Sungai Chuau perlu diberi keutamaan di dalam pengurusan dan pemeliharaan sumber berbanding sistem sungai yang lain.

Katakunci: *Pengaturcaraan Komposit Fuzzi; Pemangkatan; Membuat Keputusan Multikriteria; Pengurusan Sungai.*

1.0 Introduction

Effective water management assumes assessment of both the amounts of water needed to meet diverse demands, and quality of water that enables its proper use and recycle (Azevedo et al., 2000). The overall water systems including quantitative and qualitative aspects should be emphasized for the purpose of sustainable development, meeting socio-economic demands and political needs. In recent years, the planning and management of water resources system emphasize on a holistic development in all possible aspects of objectives which includes i)improving water quality, ii) enhancing water quantity and iii) minimizing cost. Management of river systems previously focused on a single goal mainly for water quality improvement. Thus, it is timely to implement integrated river basin management, which takes into consideration multiple aims in decision making of water resources projects. Ranking of river systems could facilitate decision making process and identifying priority river basin issues.

Evaluating and ranking of existing river basin through proper algorithms is important for determining the most reasonable and efficient use of water system. A structured approach for multiobjective ranking called Fuzzy Composite Programming (FCP) was applied for this purpose. This fuzzy river basin assessment tool was used to rank several river basins based on their relative degree of potential. As more information becomes available the structure can be modified to include additional information (Hagemeister et al., 1996).

This multiobjective analysis of river basin ranking incorporates uncertainties in terms of fuzzy membership function and interval numbers (the lowest and highest likely range). Fuzziness represents situations where membership in the sets cannot be defined on a yes/no basis because the boundaries of the sets are vague. The membership degree for an imprecise value can be determined using “expert judgement” based on experience and observed measurement (Stanbury et al., 1991). Chameau and Santamaria (1987) described four methods for developing membership functions (i.e. shape and range) of fuzzy numbers, i.e. point estimation, interval estimation, exemplification and pairwise comparison. Interval estimation was applied in this study for its simplicity and requires less computation. Uncertainty analysis or fuzziness in river basin management was included to take into account the vagueness in the data range.

2.0 Material and Methods

2.1 Site Description

Putrajaya wetlands straddle over 400-hectare watercourses of Sungai Chuau, Sungai Bisa and Sungai Limau Manis (Figure 1). This man-made lake was created by inundating the valleys of the three major rivers. Sungai Chuau watershed is located in the north of Putrajaya wetlands, covering Universiti Putra Malaysia, MARDI, Sedgeley Farm, Madingley Farm and Palm Garden Resort. Sungai Bisa, which originates from Ghia Tai Teng Farm joins Sungai Chuau near Raja Alang Farm. Sungai Limau Manis originates from Tengah Village in Merab and flows through Limau Manis Village and

Perang Besar Farm. The dominant land uses in the three catchments are oil palm and rubber trees. The river quality in the Putrajaya watershed is characterized by moderately high concentrations of phosphorus, nitrogen, BOD and some heavy metals (Khor et al., 1999).

The primary function of these wetland systems is to ensure that the water entering the lake meets the standard set by the Perbadanan Putrajaya. Besides functioning as a water cleansing and filtration system, the wetland systems also help in flood mitigation, nature conservation, eco-tourism, recreation, research, education and protection against soil erosion. The wetlands have been planted with a variety of aquatic plants that act as a natural filtration system, removing nutrients and pollutants from the catchment (Khor et al., 1999).

2.2 *Fuzzy Composite Programming*

FCP which is an extension of compromise programming (Zeleny, 1982) was developed by Bardossy and Duckstein (1992). FCP organizes a problem into the following steps:

i) Define alternatives
ii) Define basic indicators
iii) Group basic indicators into progressively smaller, more general groups.
iv) Define weights, balancing factors and the worst and best values for the indicator
v) Evaluate and rank the alternatives

This distance based method incorporates uncertainty and group indicators into multi level composite structures. The hierarchical structure aggregates the first level fuzzy indicators into more complex second level fuzzy indicators. This process of aggregation continues until the final-level fuzzy indicator is achieved. Bardossy and Duckstein (1992) noted that the best and worst values may be crisp (unfuzzy) or fuzzy in nature. The largest and most likely intervals have a membership level of 0 and 1. The normalization process is described by the following equation (Bogardi, 1992):

$$Si = \frac{Z_i - Z_{i-}}{Z_{i+} - Z_{i-}} \tag{1}$$

where Si is normalized *i*th fuzzy indicator; Z_i is value of *i*th fuzzy indicator; Z_{i+} is maximum possible value of *i*th indicator and Z_{i-} is minimum possible value of *i*th indicator. The FCP structure can be established such that the first-level indicators will utilize known or relatively easily obtained information, which will lead to ranking or assessment of a very complex system (Hagemaster et al., 1996). The units and magnitude of the first level fuzzy indicators are not critical because the distances are normalized.

The composite distance was computated by the following equation (Bogardi, 1992):

$$L_j = \left(\sum_{i=1}^{nj} \alpha_{ij} S_{ij}^{pj} \right)^{1/pj} \tag{2}$$

where L_j is fuzzy composite distance in group *j* , S_{ij}^{pj} is the normalized fuzzy value of indicator *i* group *j*, *nj* is the number of indicators in group *j*, α_{ij} is weight expressing the relative importance of indicators in group *j* such that their sum is 1, and *pj* is the balancing factors among indicators for group *j*.

To obtain the optimal solution or to compare between alternatives, the decision-maker must provide a complete set of weights as required by Equation (2). These weight parameters are established based on the degree of importance for each indicator possesses relative to other indicators of the same group. The tentative weight used in Equation. 2 range between 0 and 1.0. The preferences were identified from the highest ordered sequence value, *N* which was computed from:

$$N_j = \frac{\beta_j - \alpha_j}{2} + \alpha_j \tag{3}$$

where β and α were obtained from the interaction line of maximizing and minimizing membership functions (Chen, 1985).

The balancing factor, *p* reflects the maximal deviations between indicators of the same group. The normal values used for balancing factors in Equation (2) are 1.0 and 2.0. By increasing the *p* value in Equation (2) the influence of the maximum deviations from the ideal point on the value of L_j is increased. In other words, when the decision-maker uses a high value of *p*, those alternatives that have a poor performance will be penalized severely. This allows the decision-maker to impose different values of *p* to different groups of objectives. The uncertainty in the determination of the distance from the ideal is the consequence of the uncertainty inherent in the information that fed the multi-objective decision process.

The calculated fuzzy distances for all alternatives were then used to determine the closest distance to the ideal solution. The alternative that minimizes Equation (2) will be the optimal solution to the problem. If the problem involves only a few alternatives, it is possible to achieve an order of preference in the alternatives by visual inspection.

The study assigned number of relative priority or rank number to each of the basic indicator with insufficient data especially for economic aspects. The rank number was also related to potential degree of advantage or merit the basic indicator could contribute (Bogardi, 1992). The data for the basic indicators were obtained from the Selangor Department of Irrigation and Drainage, the Selangor Department of Environment, and the Perbadanan Putrajaya.

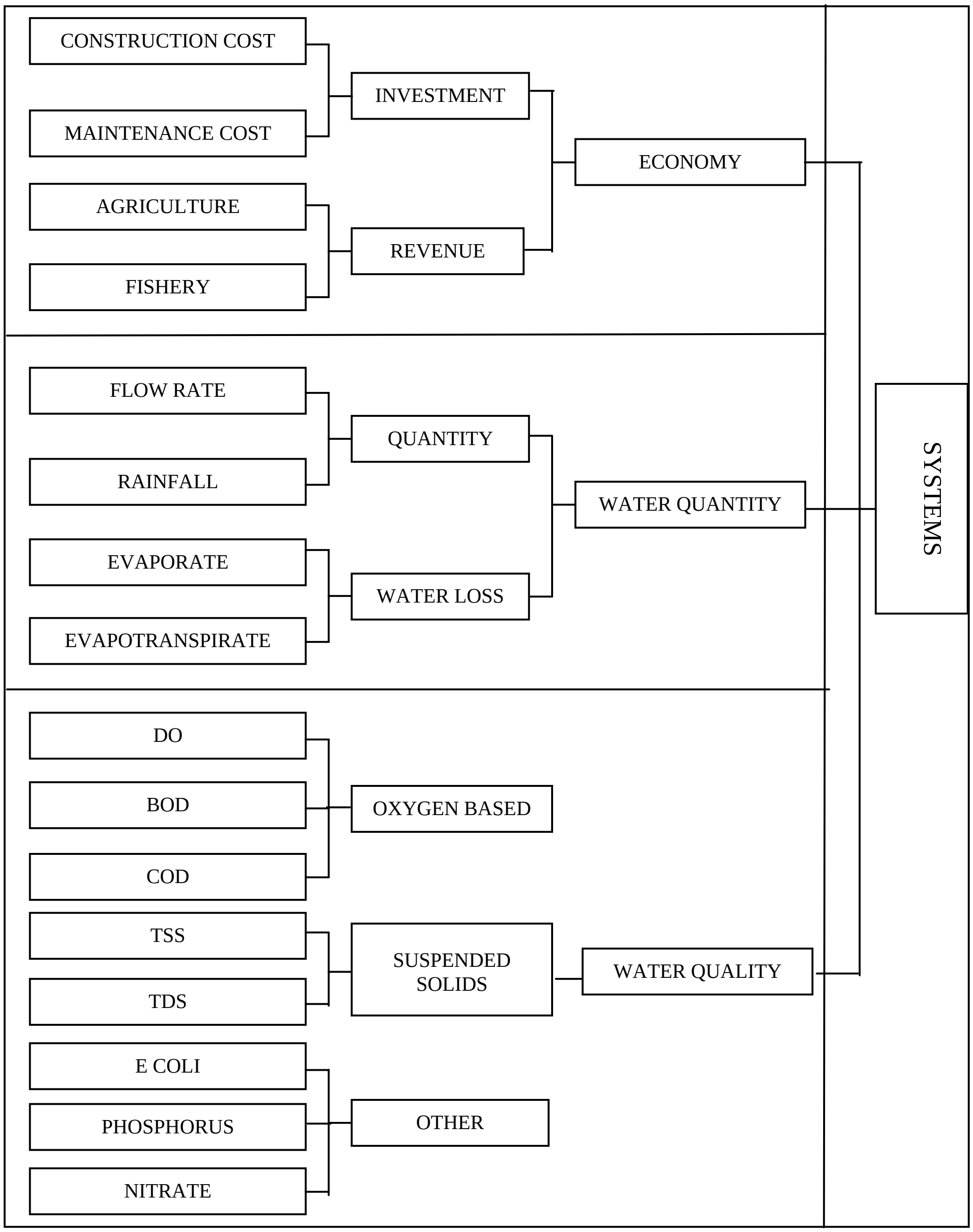

Figure 2: Fuzzy Composite Programming structure for Putrajaya River Systems

3.0 Results and Discussion

The FCP structure developed for Putajaya river basin assessment contained 15 first-level indicators, six second level indicators, three third level indicators and one final indicator (Figure 2). This structure was developed specifically for Putrajaya River Systems. Water quantity and quality are the major criteria in watershed management practice to ensure sustainable use of river and wetlands systems. The basic indicators are associated with the criteria of river systems which include the flow rate, rainfall, evaporation, DO, BOD and COD. The Investment, Water Loss, Suspended Solids and others were second level indicators. The Economy, Water Quality and Water Quantity were the third level indicators.

The results of ranking Putrajaya river basins are presented graphically and numerically. The graphical results in the form of boxes are shown in Figures 3 to 5. The boxes were plotted based on the trade-off between the management objectives. The width of the boxes represents the uncertainty and fuzziness in the trade-off. The shortest distance between the fuzzy box and the ideal point gives the highest ranking river. The highest ranking river was also evaluated by selecting the highest ordered sequence value (Bogardi, 1992). Sungai Chuau is ranked top with the highest ordered sequence value of 0.494 (Table 1). This seems reasonable because Sungai Chuau has sufficient water discharge for lake use and reasonable water quality status. It also has economic potentials from the watershed activities which include oil palm, rubber, cocoa and papaya plantations.

The evaluation of alternatives was carried out by assigning weight and balancing factors to each of the criteria. Four sets of different weight and balancing factors are described in Cases I, II, III and IV (Tables 2, 3, 4 and 5). This sensitivity analysis (Tables 2 to 5) indicated that changes in weights did not affect the overall result significantly. The sensitivity analysis showed the robustness of the option with Sungai Chuau frequently became the best-ranked river. Sungai Chuau remains the highest ranking river which means that future management and conservation should concentrate on this river. The ranking process revealed that Sungai Chuau is a better river system in terms of the water quality, water quantity and economy. This approach could be extended to river systems at other locations.

Table 1: Ordered sequence values for Putrajaya rivers

River	Ordered Sequence Values
Sg. Chuau	0.494
Sg. Bisa	0.464
Sg. Limau Manis	0.416

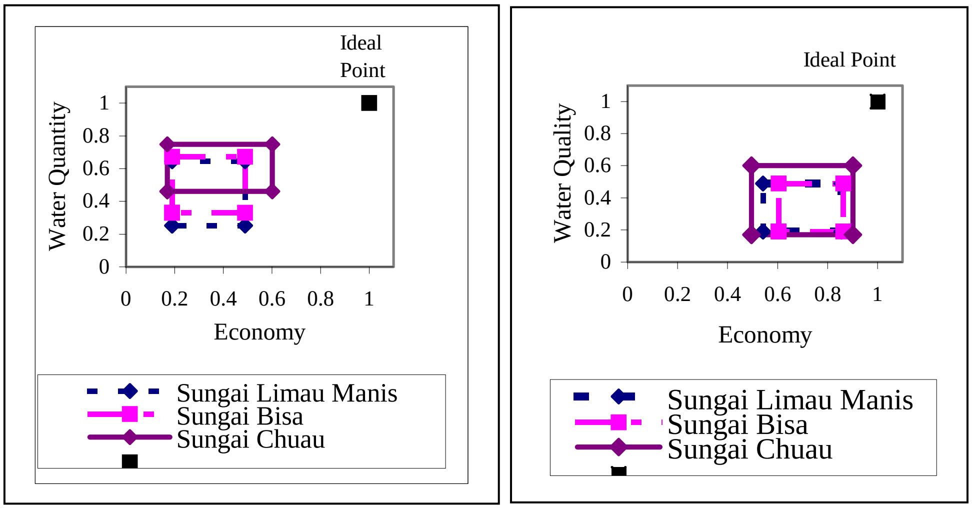

Figure 3 : Water quantity verses economy Figure 4: Water quality verses economy

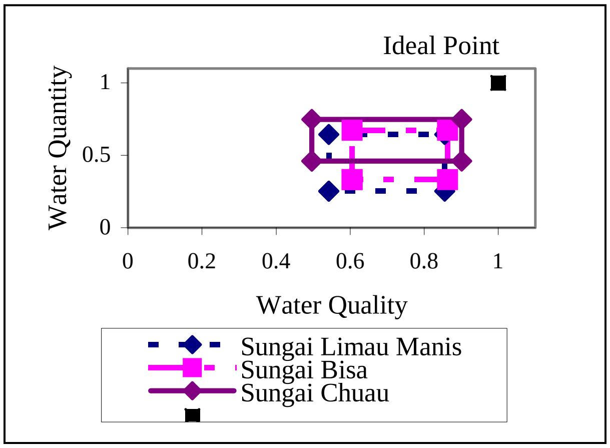

Figure 5: Water quantity verses water quality

Table 2a : Set of weight and balancing factors for Case I

Composite Indicators	Weight	Balancing Factor
Economy	0.33	P=2
Water Quality	0.33	P=2
Water Quantity	0.33	P=2

Table 2b : Sensitivity analysis using set of weights for Case I

Composite Indicator	The best alternatives
Water Quality vs Economy	Sungai Chuau
Water Quantity vs Economy	Sungai Chuau
Water Quantity vs Water Quality	Sungai Chuau

Note: Best Alternative- based on the shortest distance in Figures 3 to 5 and ordered sequence value, Table 1

Table 3 : Sensitivity analysis using set of weights for Case II

Composite Indicators	Weight	Balancing Factor	The Best Alternatives
Economy	0.60	P=2	Sg Chuau
Water Quality	0.20	P=2	Sg. Limau Manis
Water Quantity	0.20	P=2	Sg. Bisa

Table 4 : Sensitivity analysis using set of weights for Case III

Composite Indicators	Weight	Balancing Factor	The Best Alternatives
Economy	0.20	P=2	Sg Chuau
Water Quality	0.60	P=2	Sg. Bisa
Water Quantity	0.20	P=2	Sg Limau Manis

Table 5 : Sensitivity analysis using set of weights for Case IV

Composite Indicators	Weight	Balancing Factor	The Best Alternatives
Economy	0.20	P=2	Sg Chuau
Water Quality	0.20	P=2	Sg. Bisa
Water Quantity	0.60	P=2	Sg Limau Manis

4.0 Conclusions

MultiCriteria Decision Making approach specifically Fuzzy Composite Programming was applied to rank Putrajaya river systems which include Sungai Chuau, Sungai Limau Manis and Sungai Bisa. The highest ranking was associated with the highest ordered sequence value and shortest distance between the fuzzy box and the ideal point. The analysis showed that Sungai Chuau has the highest ranking. Sungai Chuau was ranked the first with the highest ordered sequence value of 0.494. In managing the Putrajaya lake, it is suggested that Sungai Chuau be given higher priority in the management and conservation of resources than the other river systems..

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