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A Fuzzy Decision Making Model for Assessing Quality of Life: A Case of a Coastal Wetlands Community

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Abstract: This study highlights a fuzzy decision making method for assessing Quality Of Life (QOL) of a wetlands community. The assessment of QOL is a complex problem since many uncertain criteria are available and many sub-criteria are involved in the decision-making process. To deal with this challenge, the fuzzy Analytic Network Process (fuzzy ANP) is applied to proposed total weights of ten sub-criteria of QOL for a coastal community of Setiu Wetlands Terengganu. A major advantage of the fuzzy ANP is that it incorporates interdependent relationships between criteria and sub-criteria. Five experts that familiar with the QOL of coastal community were invited to provide linguistic evaluation based on the sub-criteria. Three experts suggest that the total QOL of the community is >0.5 out of one. The results also unveiled that the sub-criteria, namely politic, health care, public safety, and power and water provision are the main contributors to the QOL. The main contribution of this paper is the introduction of a fuzzy multi-criteria decision approach for assessing QOL specifically for the wetlands community.

Key words: Analytic network process, quality of life, linguistic variable, fuzzy number, Malaysia

INTRODUCTION

A number of decision making tools have been developed over the last four decades to deal with either qualitative or quantitative information of Multi-Criteria Decision Making (MCDM) problems. Saaty (1980) was pioneered in proposing, the decision tool, Analytic Hierarchy process (AHP) to handle the multiplicity of choices of the decision problems. The AHP is a mathematical device of MCDM in which the decision problem is structured hierarchically. However, in decision analysis, there are many decision problems that cannot be analyzed hierarchically due to their interaction and dependencies of higher-level elements in a hierarchy on lower-level elements. In order to overcome this issue, Saaty (1996) proposed the method of Analytic Network Process (ANP) where dependencies and interactions among criteria are taken care of. Unlike the AHP, the ANP is rather represented by a network. Furthermore, the ANP is constructed based on feedback in clusters. Many researchers have shown their interest over applications of this method.

The ANP has been widely applied in energy policy planning (Ulutas, 2005), marketing and logistics (Agarwal *et al*., 2006), economics and finance (Niemira and Saaty, 2004) and civil engineering (Neaupane and Piantanakulchai, 2006). There was also research on selection of wastewater treatment technology in small communities (Senante *et al*., 2015) and territorial and environmental assessment (Promentilla *et al*., 2006; Bottero and Mondini, 2008; Wolfslehner and Vacik, 2008). Similar to the AHP, the ANP also uses the pair-wise comparison matrix to calculate the uncertainty in multi-criteria decision making problem.

In light of uncertainty in decision problems and also in judgment process, fuzzy ANP was introduced. In the fuzzy ANP, crisp numbers of linguistic evaluation are replaced with triangular fuzzy numbers. With the introduction of triangular fuzzy numbers into the fuzzy ANP, the optimal solution in crisp number is becoming more complicated to attain. To ease this problem, Chang (1996) proposed extent analysis method to transform fuzzy numbers to crisp numbers. The extent analysis deals this transformation using the knowledge of intersection between two fuzzy numbers and degree of possibility. Despite its complexity, the fuzzy ANP has been applied in a handful of research. Dagdeviren and Yuksel (2010), for example, introduced the uses of fuzzy ANP for Balanced Score Card (BSC). The BSC approach was integrated with the fuzzy ANP technique to determine the level of performance of a business on the basis of its vision and strategies. The same researcher, Yuksel and Dagdeviren

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(2010) also conducted a research on fuzzy fuzzy ANP for measurement of the sectorial competition level. Vinodh *et al.* (2011) have proposed a study on applications of the fuzzy ANP for supplier selection in manufacturing organizations.

MATERIALS AND METHODS

Preliminaries: Background of the fuzzy ANP is presented in this section. It includes fuzzy sets, triangular fuzzy number, and linguistic variables.

Definition 1; fuzzy sets (Zadeh, 1965): A fuzzy set $\bar{A}$ in the universe of discourse $X = \{x_1, x_2, ..., x_n\}$ is defined by:

$$\bar{A} = \{\langle x, \mu_{\bar{A}}(x)\rangle | x \in X\}$$

which is characterized by membership function $\mu_{\bar{A}} : X \rightarrow [0,1]$ where $\mu_{\bar{A}}(x) \in [0,1]$ indicates the membership degree of the element x to the set $\bar{A}$.

Definition 2; triangular fuzzy number (Kauffman and Gupta, 1985): A Triangular Fuzzy Number (TFN) can be denoted as and the membership function is given by:

$$\mu_A(x) = \begin{cases} x - l/m - l, & l \le x \le m \\ u - x/u - m, & m \le x \le u \\ 0 & \text{otherwise} \end{cases}$$

Definition 3; Linguistic variable (Zimmermann, 2001). A linguistic variable characterized by the quintuples (X, T(X, U, G, M), where X = The name of the variable, U = The universe of discourse that associated with the base variable , T (X) = the term set of that is the set of x name for linguistic value of x. Each value being fuzzy variable that is generically by x and ranging over U, G = a syntactic rule for generating the name X, of the values of x. A particular X, that is name generated by G, is called a term, M = a semantic rule for associating with each linguistic term.

Chang's extent analysis is utilized to calculate the fuzzy pairwise comparison weight matrix. Output of this extent analysis is weights of criteria or sub-criteria (Goztepe *et al*., 2013). The local weights are transformed to crisp numbers in order to simplify the computation of the fuzzy ANP. The framework of this research is explained in the next section.

Research framework: This section describes the site or location of the Setiu Wetlands, Criteria and sub-criteria of QOL.

Table 1 Criteria and sub-criteria of the QOL

Criteria	Sub-criteria
Social	Politics
	Public transport and communication
	Health care
	Public Safety
	Power and water provision
Economic	Income
	Education
Physical	Environment
	Housing quality
	Social participation

Location: Setiu Wetlands are sited in the north part of Terengganu, Malaysia and it belongs to the districts of Setiu which is placed along the east coast of Peninsular Malaysia and facing the South China Sea.

Criteria and sub-criteria: The criteria and sub-criteria for the assessment are defined. Table 1 shows the sub-criteria for each criteria.

Data collection: Linguistic data were collected from five decision makers who are expert in QOL among coastal community via personal communication.

Assessment model: The fuzzy ANP that purposely used to assess the QOL of coastal wetland community is summarized in the following steps.

Step 1: The criteria and sub-criteria used to determine the QOL are identified.

Step 2: Local weight of criteria and sub-criteria are calculated. Pairwise comparison matrices are constructed by an expert team using the linguistic scales.

Step 3: Interdependent weights of the criteria are calculated and the dependencies among the criteria are assumed.

Step 4: Global weight of the sub-criteria are calculated using interdependent weights of the criteria and local weights of sub-criteria.

Step 5: Total QOL can be determined by multiplying the global weight of sub-criteria with scale values. The five-step computation is implemented in the case of coastal community in Setiu Wetlands Terengganu.

RESULTS AND DISCUSSION

The implementation of the fuzzy ANP to the linguistic data provided by the experts are summarized in this study. Table 2 shows the scale used in the questionnaire which represents the linguistic scale for difficulty and importance.

Table 3-6 show the pairwise comparison matrix of criteria and sub-criteria using the data provided by one of the experts and the result is transformed into TFN.

The interdependent weights of criteria are calculated and the dependencies among the criteria are considered. Table 7-9 show the inner dependence matrix of perspectives and the relative importance of the criteria with respects to the criteria. A matrix for degree of relative impacts for criteria is constructed based on the information from Table 7-9:

$$\begin{array}{c} \\ \text{Economic} \\ \text{Social} \\ \text{Physical} \end{array} \begin{array}{c} \text{Economic Social Physical} \\ \begin{pmatrix} 1.0 & 0 & 0.5 \\ 1.0 & 1.0 & 0.5 \\ 0 & 1.0 & 1.0 \end{pmatrix} \end{array}$$

Weight factors are calculated to show the interdependency of weights of criteria:

W_{factor} = Interdependence weights of criteria

$$W_{factor} = \frac{1}{2}(\text{Degree of relative impact for criteria} \times \text{Local weights of criteria})$$

$$= \frac{1}{2}\left[\begin{pmatrix} 1.0 & 0 & 0.5 \\ 1.0 & 1.0 & 0.5 \\ 0 & 1.0 & 1.0 \end{pmatrix} \times \begin{pmatrix} 0.3333 \\ 0.3333 \\ 0.3333 \end{pmatrix}\right]$$

$$= \begin{pmatrix} 0.25 \\ 0.4167 \\ 0.33333 \end{pmatrix}$$

Next, global weights of the sub-criteria are calculated using interdependent weights of the criteria and local weights of sub-criteria. Table 10 shows the global weights of all sub-criteria. Table 11 presents weights of sub-criteria and total weights obtained from five experts.

The result suggests that three experts give assessment of total QOL with >0.5 out of one. The other two experts suggest total QOL with <0.5. It is interesting to note that all experts agree that there are four common sub-criteria contributed to the total QOL. The four sub-criteria are politic, health care, public safety and power and water provision.

Table 2: Linguistic scales of difficulty and importance and scale value

Linguistic scale for difficulty	Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale	Scale in questionnaire
Just equal	Just equal	(1, 1, 1)	(1, 1, 1)	2
Equally Difficult (ED)	Equally important (EI)	(1/2, 1, 3/2)	(2/3, 1, 2)	1
Weakly More Difficult (WMD)	Weakly more important (WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)	3
Strongly More Difficult (SMD)	Strongly more important (SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)	4
Very strongly More Difficult (VSMD)	Very strongly more important (VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	5
Absolutely More Difficult (AMD)	Absolutely more important (AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)	6

Table 3: Local weights and pairwise comparison matrix of criteria

Criterias	Economics	Social	Physical	Local weights
Economics	(1, 1, 1)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	0.3333
Social	(1/3, 2/5, 1/2)	(1, 1, 1)	(2, 5/2, 3)	0.3333
Physical	(2, 5/2, 3)	(1./3, 2/5, 1/2)	(1, 1, 1)	0.3333

Table 4: Local weights and pairwise comparison matrix of sub-criteria (economics)

Economics	Income	Education	Local weights
Income	(1, 1, 1)	(2/5, 1/2, 2/3)	0.0000
Education	(3/2, 2, 5/2)	(1, 1, 1)	1.0000

Table 5: Local weights and pairwise comparison matrix of sub-criteria (social)

Social	P	PTC	HC	PS	PWP	Local weights
P	(1, 1, 1)	(2, 5/2, 3)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2, 5/2, 3)	0.2302
PTC	(1/3, 2/5, 1/2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(2/7, 1/3, 2/5)	0
HC	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	0.2598
PS	(2, 5/2, 3)	(3/2, 2, 5/2)	(1/3, 2/5, 1/2)	(1, 1, 1)	(2, 5/2, 3)	0.2651
PWP	(1/3, 2/5, 1/2)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(1, 1, 1)	0.2449

Politics-P, Public Transport and Communication-PTC, Health Care-HC, Public Safety-PS, Power and Water Provision-PWP

Table 6: Local weights and pairwise comparison matrix of sub-criteria (physical)

Physical weights	E	HQ	SP	Local
E	(1, 1, 1)	(2, 5/2, 3)	(2/5, 1/2, 2/3)	0.4324
HQ	(1/3, 2/5, 1/2)	(1, 1, 1)	(1/3, 2/5, 1/2)	0
SP	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 1, 1)	0.5676

Environment-E, Housing Quality-HQ, Social Participation- SP

Table 7: The inner dependence matrix of the perspectives with respect to "economics"

Economics	Social	Physical	Relative importance weights
Social	(1, 1, 1)	(5/2, 3, 7/2)	1.0
Physical	(2/7, 1/3, 2/5)	(1, 1, 1)	0.0

Table 8: The inner dependence matrix of the perspectives with respect to "social"

Social	Economic	Physical	Relative importance weights
Economic	(1, 1, 1)	(2/5, 1/2, 2/3)	0.0
Physical	(3/2, 2, 5/2)	(1, 1, 1)	1.0

Table 9: The inner dependence matrix of the perspectives with respect to "physical"

Physical	Social	Economic	Relative importance weights
Social	(1, 1, 1)	(1/3, 2/5, 1/2)	0.5
Economic	(2, 5/2, 3)	(1, 1, 1)	0.5

Table 10: Global weights of sub-criteria

Criteria	Interdependent weights of criteria	Local weight of sub-criteria	Global weights
Economic	0.25	Income-0	0
		Education-1.0	0.25
Social	0.4167	Politic-0.2302	0.09592
		Public Transport and communication-0	0
		Health care-0.2598	0.10825
		Public safety-0.2651	0.11046
		Power and water provision-0.2449	0.10204
Physical	0.3333	Environment-0.4324	0.14413
		Housing quality-0	0
		Social participation-0.5676	0.1892

Table 11: Total quality of life

Sub-criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Income	0.1875	0	0.17618	0	0.375
Education	0.125	0	0.11745	0.125	0
Politic	0.01134	0.0145	0.01456	0.02398	0.02321
Public transport and communication	0.00025	0.0018	0.00668	0	0.01763
Health care	0.08314	0.1165	0.11078	0.08119	0.05516
Public safety	0.04048	0.0412	0.03953	0.02762	0.00055
Power and water provision	0.0907	0.0605	0.0613	0.05102	0.05015
Environment	0	0	0.00869	0.07207	0.03265
Housing quality	0	0.0834	0.00321	0	0.01633
Social participation	0	0.0417	0	0.0473	0.01633
Total weight	0.5484	0.3576	0.5384	0.4282	0.5871

CONCLUSION

Assessment of QOL is not a straight process as too many criteria need to be considered. There is no direct way to measure what is of value for the QOL as different people has different opinion on the QOL (Cobb, 2015). In this study, fuzzy ANP has been employed as an assessment model in describing the QOL of a coastal community in Setiu Wetlands, Terengganu, Peninsular Malaysia. Linguistic assessments provided by five experts were used as input data to the fuzzy ANP. The sub-criteria of politic, health care, public safety and power and water provision are identified as the main contributors to the QOL of Setiu Wetlands community. The fuzzy ANP process is found to be practically feasible and compatible not only in the industrial scenario but also can be extended to social economics studies. However, in the present study, it can be seen that the five experts provide a minor inconsistency in their assessments, there by one reliable aggregation method such as ordered weighted averaging aggregation operators could be proposed in future research.

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REFERENCES

Agarwal, A., R. Shankar and M.K. Tiwari, 2006. Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach. Eur. J. Oper. Res., 173: 211-225.

Bottero, M. and G. Mondini, 2008. An appraisal of analytic network process and its role in sustainability assessment in Northern Italy. Manage. Environ. Qual. Int. J., 19: 642-660.

Chang, D.Y., 1996. Applications of the extent analysis method on fuzzy AHP. Eur. J. Oper. Res., 95: 649-655.

Dagdeviren, M. and I. Yuksel, 2010. A fuzzy Analytic Network Process (ANP) model for measurement of the Sectoral Competititon Level (SCL). Expert Syst. Appl., 37: 1005-1014.

Goztepe, K., S. Boran and H.R. Yazgan, 2013. Estimating Fuzzy Analytic Network Process (FANP) comparison matrix weights using artificial neural network. Int. J. Adv. Sci. Technol., 6: 1-14.

Kauffman, A. and M.M. Gupta, 1985. Introduction of Fuzzy Arithmetic: Theory and Applications. Van Nostrand Publisher, New York, USA.

Neaupane, K.M. and M. Piantanakulchai, 2006. Analytic network process model for landslide hazard zonation. Eng. Geol., 85: 281-294.

Niemira, M.P. and T.L. Saaty, 2004. An analytic network process model for financial-crisis forecasting. Int. J. Forecast., 20: 573-587.

Promentilla, M.A.B., T. Furuichi, K. Ishii and N. Tanikawa, 2006. Evaluation of remedial countermeasures using the analytic network process. Waste Manage., 26: 1410-1421.

Saaty, T.L., 1980. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. 2nd Edn., McGraw-Hill International Book Co., New York, USA., ISBN: 9780070543713, Pages: 287.

Saaty, T.L., 1996. Decision Making with Dependence and Feedback: The Analytic Hierarchy Process. RWS Publications, Pittsburgh, PA., USA.

Senante, M.M., T. Gomez, R. Caballero, H.F. Sancho and S.R. Garrido, 2015. Assessment of wastewater treatment alternatives for small communities: An analytic network process approach. Sci. Total Environ., 532: 676-687.

Ulutas, B.H., 2005. Determination of the appropriate energy policy for Turkey. Energy, 30: 1146-1161.

Vinodh, S., R.A. Ramiya and S.G. Gautham, 2011. Application of fuzzy analytic network process for supplier selection in a manufacturing organisation. Exp. Syst. Appl., 38: 272-280.

Wolfslehner, B. and H. Vacik, 2008. Evaluating sustainable forest management strategies with the analytic network process in a pressure-state-response framework. J. Environ. Manage., 88: 1-10.

Yuksel, I. and M. Dagdeviren, 2010. Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm. Expert Syst. Appl., 37: 1270-1278.

Zadeh, L.A., 1965. Fuzzy sets. Inform. Control, 8: 338-353.

Zimmermann, H.J., 2001. Fuzzy Set Theory and its Applications. 4th Edn., Springer, Boston, ISBN-13:978-0792374350 , Pages: 544.