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Fuzzy Analytic Network Process for Evaluating Quality of Life: A Case of Coastal Population

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A B S T R A C T

Background: Evaluation of Quality of life (QOL) has been explored using various approaches ranging from typical statistical analysis to advanced integrated intelligent approaches. However, there have been very little discussions about the application of hierarchical network based decision analysis to evaluate QOL. Furthermore, evaluation of QOL mostly conducted to general population of a country or a group of people. **Objective:** This paper aims to apply fuzzy analytic network process (fuzzy ANP) for evaluating QOL of a coastal population in a new gazetted wetlands area. Coastal population in Setiu Wetlands of Terengganu, Malaysia was sampled for evaluating their level of QOL. An expert in coastal population studies was interviewed to provide linguistic evaluation with respect to three factors and ten sub-factors of QOL. The six-step fuzzy ANP method was successfully employed in obtaining the total percentage of QOL. **Results:** It is found that the sub-factor of income was identified as the highest contributor to the QOL. The least contributor was the sub-factor of environment. The total QOL was fifty four per cents, which indicate that the level of QOL of the population is medium. **Conclusion:** The results reflect the mediocre level of QOL among the coastal population, thereby more initiatives need to be facilitated to improve their QOL.

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INTRODUCTION

Quality of life (QOL) is becoming an integral part of social measurement or indicator of a country or a group of people. It is commonly associated with well-being of a group of people or people residing in a country. QOL is different with the standard of livings where standard of livings is measured using the sole factor of household income. Factors used to measure QOL can be multi-dimensional and typically categorized into different groups, such as economics, social and physical. In Malaysia, the Economic Planning Unit (2011) defines the QOL as personal developments, a healthy life style, freedom to obtain knowledge and managing a standard of living which satisfied the simple needs of persons. Income and distributions, education, health, transports and communications are the components that are included in measuring QOL index. In other words, QOL in Malaysia has been investigated from socio-economic status of the people. QOL has been investigated not only for a particular country (Kapuria, 2013) but also focused to relatively small community such kidney patients (Abdullah and Jamal, 2011), city dwellers (Lotfi and Solaimani, 2009), adolescent (Chipuer *et al*., (2003) and coastal populations (Kadarpeta and Kostenzer, 2011; Creel, 2003).

QOL has been investigated with multiple approaches and methods. Khamis (2000), for example, adopted linear structural method for a fifteen-variable questionnaire representing three factors of QOL. The three factors were socio-economic, structural demographic and family. Chen and Yao (2014) examined QOL using a fuzzy measure. Three-step computation and fuzzy scoring method were designed for the study. The results show that, fuzzy-scales weighted-by-membership is the most suitable fuzzy scoring method for measuring the QOL. Abdullah (2014) validates an instrument for measuring QOL among Malaysian youth using multi-variate analysis of principle component analysis. Abdullah and Farhana (2013) propose index of QOL for Malaysian using fuzzy inference systems. However, attempts to evaluate QOL using fuzzy multi-criteria decision making

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approaches have been given little attention. Multi-criteria analysis approaches seem appropriate with QOL thanks to its multi-dimensional concept. Indicators or dimensions of QOL such as income, safety, education, and freedom are naturally subjective and uncertain. Therefore, QOL is more appropriately addressed with fuzzy multi-criteria approaches and one of the fuzzy multi-criteria decision making methods that purposely measure the interdependency among criteria is fuzzy analytic network process (fuzzy ANP). In this paper, QOL of a coastal population in Setiu Wetlands of Terengganu, Malaysia is evaluated using fuzzy ANP.

Review And Preliminary:

The analytic network process (ANP) is one of the many methods in the family of multi-criteria decision making. It was introduced by Saaty (1996) as another method in decision analysis with the purpose to simplify the popular method of analytic hierarchy process (AHP). The main difference between AHP and ANP can be spotted on the type of hierarchical structure of the problem. The AHP represents a framework with a uni-directional hierarchical relationship, but the ANP allows for complex interrelationships among hierarchical structures or decision level. Apart from that, the ANP provides feedback that can be represented by network and it replaced the hierarchy which is used by the AHP. There are basically two types of ANP, which is conventional and integrated with fuzzy set. Due to the vagueness and uncertainty in decision making with conventional ANP, the concept of fuzzy ANP was proposed. The fuzzy ANP replaces the hierarchies into network structure.

The fuzzy ANP is one of the fuzzy multi-criteria decision making methods and it is a useful method to solve the difficult decisions with multiple dimensions and hierarchies. The fuzzy ANP is the later version of ANP where fuzzy number is integrated to the conventional ANP instead of crisp number. The problem of defuzzification of fuzzy numbers is solved using Chang's (1992, 1996) extent analysis method. The fuzzy ANP with extent analysis method is easier than other approaches that used fuzzy ANP (Yuksel and Dagdeviren, 2010). In 2010, Yuksel and Dagdeviren (2010) introduced fuzzy ANP for Balanced Scorecard (BSC). The BSC approach was integrated with fuzzy ANP technique to determine the level of performance of a business on the basis of its vision and strategies. Dagdeviren and Yuksel (2010) have conducted a research on fuzzy ANP method for measurement of the sectorial competition level. The fuzzy ANP method was composed by factors and sub-factors hierarchically. Local weight of factors and sub-factors were calculated and pairwise comparison matrices were constructed by expert team using the scale value. Vinodh *et al*., (2011) have proposed a study on applications of fuzzy ANP for supplier selection in manufacturing organization. The fuzzy ANP process was regarded as a feasible and compatible method in industrial scenario for effective supplier selection. In short, the fuzzy ANP was built from the integration of conventional ANP with the uncertain theory of fuzzy sets. Linguistic variables and membership functions are the main components in the fuzzy ANP. As to make this paper self-contained, the following definitions are presented.

Definition 1 Zadeh (1965):

A fuzzy set $\bar{A}$ in the universe of discourse $X = \{x_1, x_2, ..., x_n\}$ is defined by

$$\bar{A} = \{\langle x, \mu_{\bar{A}}(x)\rangle | x \in X\} \quad (1)$$

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

Definition 2 (Kauffman & Gupta, 1985):

A triangular fuzzy number, $\bar{A}$ can be denoted as $\bar{A} = (a,b,c)$ and the membership function is given by

$$\mu_{\bar{A}}(x) = \begin{cases} x-a/b-a, & a \le x \le b \\ c-x/c-b, & b \le x \le c \\ 0 & \text{, otherwise} \end{cases}$$

Figure 1 illustrates the membership function of triangular fuzzy number. If $a = b = c$ then the triangular fuzzy number become crisp or real number.

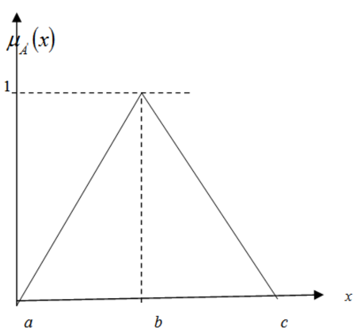

Fig. 1: Membership function of triangular fuzzy number.

Definition 3 (Zimmerman, 1991):

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 u.

$T(x)$ - denotes the term set of x, that is the set of name for linguistic value of x. Each value being fuzzy variable that is generically by x and ranging over U.

G - is 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 - is a semantic rule for associating with each X its meaning, $M(x)$, is a fuzzy subset U.

Research Framework:

This research investigates QOL of the specific group of population that residing along coastal area of Setiu Wetlands in Terengganu.

3.1 Description of Location:

Setiu Wetlands are sited in the north part of Terengganu and it belongs to the districts of Setiu which is placed at the east coast of Peninsular Malaysia. It is situated at the coordinate (N05^{0}40'38.6''E102^{0}43'03.2''). It consists of Setiu River and lagoon with various islands. Also, it is a place which surrounded by estuary, wetland and mangroves. In addition, it has a big ecosystem that having cluster of biological diversity and riches in natural resources. Populations around the wetland produce the well-known Terengganu anchovies, fish, fish-crackers and shrimp paste. For the coastal population in Setiu Wetlands, most of the villagers in the Wetlands worked as fishermen. Based on Head of Household and Poor Household Profile Registry from Ministry of Rural and Regional Development's Poverty Eradication Unit, Setiu is one of the districts with the highest rate of poverty with a third of the fisherman household are recognized as poor. The Terengganu state government proposes to gazette the Setiu Wetlands as a national park with the purpose to preserve the ecosystem of Setiu Wetlands.

3.2 Data collection:

In this study, the data were collected via guided interview based questions that developed by the authors. An expert with vast experienced in behavior of coastal population was sought to be interviewed and providing linguistic evaluation. The questions were developed to determine the relationship between the factors and sub-factors that will affect the QOL among coastal population in Setiu Wetlands. The factors and sub-factors that defined in this study are presented in Table 1.

Table 1: Factors and sub-factors of QOL.

Factors	Sub-factors
Economic	Income
	Education
Social	Politic
	Public Transport and communication
	Health care
	Public safety
	Power and water provision
Physical	Environment
	Housing quality
	Social participation

3.3 Linguistic variable:

The expert was asked to make pair-wise comparison between two factors and make a decision on the difficulty and importance of factor in the scale of 1 to 6. Each scale is defined by a specific triangular fuzzy number and linguistic variable. The scale was adopted based on the linguistic scale for difficulty and importance of Boran and Goztepe (2010) and Yuksel and Dagdeviren (2010). Table 2 shows the detailed linguistic variables and triangular fuzzy numbers (TFN).

Table 2: Linguistic variables and triangular fuzzy numbers.

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

3.4 Computation method:

The fuzzy ANP is applied to calculate the local and global weights of factors and sub-factors of QOL. The computations can be described according to the following steps.

Step 1:

Identify factors and sub-factors of MCDM problems.

Step 2:

Structure the fuzzy ANP method into three stages where objectives, factors and sub-factors are interactively linked.

Step 3:

Compute local weight of factors and sub-factors.

Step 4:

Compute interdependent weights of the factors.

Step 5:

Compute the global weight for the sub-factors using interdependent weights of the factors (Step4) and local weights of sub-factors (Step 3).

Step 6: Compute weight for sub-factor:

Detailed computations are described in the case of evaluating QOL among coast population in Setiu Wetland.

Computation And Results:

The fuzzy ANP extent analysis method proposed by Chang's (1992, 1996) is primarily employed in this case study. The computations are implemented according to the following steps.

Step 1: Identify factors and sub-factors:

Three main factors are identified in which each factor has two or more sub-factors (see Table 1).

Step 2: Construct a hierarchical structure of the problem:

A hierarchical structure of the problem is constructed within the framework of the fuzzy ANP method. Figure 2 depicts the three-stage of hierarchical structure.

Step 3: Compute local weight:

Local weights of factors and sub-factors are computed using pairwise comparison matrix based on linguistic scale evaluation provided by the expert. All linguistic scales are represented by triangular fuzzy numbers (see Table 2). An assumption of no dependency among the factors is made as to fulfill the prerequisite condition in the fuzzy ANP. Table 3 shows the pairwise comparison matrix of factors where TFNs are used to represent linguistic variables.

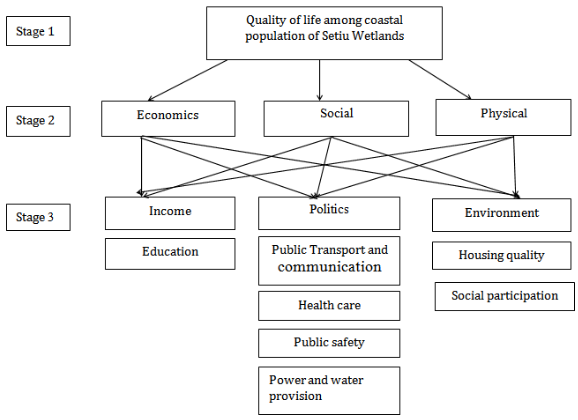

Fig. 2: Hierarchical structure of the QOL.

Table 3: Pairwise comparison matrix of factors.

Factors	Economics	Social	Physical
Economics	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)
Social	(2/5,1/2,2/3)	(1,1,1)	(1,3/2,2)
Physical	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)

A pairwise comparison matrix is constructed using the information obtained from Table 3. The pairwise comparison matrix of factors is written as,

$$= \begin{pmatrix} (1,1,1) & \left(\frac{3}{2},2,\frac{5}{2}\right) & \left(\frac{3}{2},2,\frac{5}{2}\right) \\ \left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right) & (1,1,1) & \left(1,\frac{3}{2},2\right) \\ \left(\frac{2}{5},\frac{1}{2},\frac{2}{3}\right) & \left(\frac{1}{2},\frac{2}{3},1\right) & (1,1,1) \end{pmatrix}$$

With the purpose to find the weight of factors, inverse matrix and multiplication between reciprocal

TFN and TFN are made. An example of the calculation for the factor of economics is given as follows.

Step 3.1 Value of fuzzy synthetic extent :

Sum of reciprocal fuzzy numbers are computed as,

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

$$=\left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

$$=\left[\begin{array}{c}\frac{1}{1+\frac{5}{2}+\frac{5}{2}+\frac{2}{3}+1+2+\frac{2}{3}+1+1}, \\ \frac{1}{1+2+2+\frac{1}{2}+1+\frac{3}{2}+\frac{1}{2}+\frac{2}{3}+1}, \\ \frac{1}{1+\frac{3}{2}+\frac{3}{2}+\frac{2}{5}+1+1+\frac{2}{5}+\frac{1}{2}+1}\end{array}\right]$$

$$=\left[\frac{1}{\frac{37}{3}}, \frac{1}{\frac{61}{6}}, \frac{1}{\frac{83}{10}}\right]$$

$$=\left[\frac{3}{37}, \frac{6}{61}, \frac{10}{83}\right]$$

S_1 = Economics

$$S_1 = \sum_{j=1}^{m} M_{g1}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

$$=\left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \otimes \left[\frac{3}{37}, \frac{6}{61}, \frac{10}{83}\right]$$

$$=\left[\begin{array}{c}1+\frac{3}{2}+\frac{3}{2}, 1+2+2, \\ 1+\frac{5}{2}+\frac{5}{2}\end{array}\right] \otimes \left[\frac{3}{37}, \frac{6}{61}, \frac{10}{83}\right]$$

$$= [4,5,6] \otimes \left[\frac{3}{37}, \frac{6}{61}, \frac{10}{83}\right]$$

$$= [l_1, m_1, u_1]$$

$$= [0.3243, 0.4918, 0.7229]$$

Therefore, the value of fuzzy synthetic extent for the factor of economic is given as

S_1=economics $= [0.3243, 0.4918, 0.7229]$

Value of the fuzzy synthetic extent for the other two factors is computed using the similar steps. It is given as,

$S2$ =Social $= [0.1946, 0.2951, 0.4418]$

S_3 =Physical= $[0.1541, 0.2131, 0.3213]$

Step 3.2 Compute degree of possibility:

Degree of possibility for S_1, S_2, S_3 are computed using

$$V(S_2 \geq S_1) = \begin{cases} 1, \text{if } m_2 \geq m_1 \\ 0, \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{otherwise,} \end{cases}$$

$$V(S_1 \geq S_2) = 1.0 (\text{as } m_1 \geq m_2)$$

$$V(S_1 \geq S_3) = 1.0 (\text{as } m_1 \geq m_3)$$

$$V(S_2 \geq S_1) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} = \frac{0.3243 - 0.4418}{(0.2951 - 0.4418) - (0.4918 - 0.3243)} = \frac{-0.1175}{-0.1467 - 0.1675} = \frac{-0.1175}{-0.3142} = 0.374$$

$$V(S_2 \geq S_3) = 1.0 (\text{as } m_2 \geq m_3)$$

$$V(S_3 \geq S_1) = 0 (\text{as } l_1 \geq u_3)$$

$$V(S_3 \geq S_2) = \frac{l_2 - u_3}{(m_3 - u_3) - (m_2 - l_2)} = \frac{0.1946 - 0.3213}{(0.2131 - 0.3213) - (0.2951 - 0.1946)} = \frac{-0.1267}{-0.1082 - 0.1005} = \frac{-0.1267}{-0.2087} = 0.6071$$

Step 3.3 Compute local weights:
Assume that:

$d'(A_i) = \min V(S_i \geq S_k)$ where $k = 1,2,3$; $k \neq i$

$A_i (i = 1,2,3)$ are three elements and $d'(A_1)$ = local weights of Economics, $d'(A_2)$ = local weights of Social and $d'(A_1)$=local weights of Physical

$$d'(A_1) = \min V(S_1 \geq S_2, S_1 \geq S_3) = \min V(1.0, 1.0) = \frac{1.0 + 1.0}{1.0 + 1.0 + 0.374 + 1.0 + 0 + 0.6071} = \frac{2.0}{3.9811} = 0.5024$$

$$d'(A_2) = 0.3451$$

$d'(A_3)$
0.1525

Then, the local weight vector is given by $W' = (d'(A_1), d'(A_2), \cdots, d'(A_n))^T$

$$W' = (d(A_1), d(A_2), d(A_3))^T = (0.5024, 0.3451, 0.1525)^T = \begin{pmatrix} 0.5024 \\ 0.3451 \\ 0.1525 \end{pmatrix}$$

Summarily, local weights of the factor are shown in Table 4.

Local weights for sub-factors are computed with the similar fashion. Table 5, Table 6 and Table 7 show the local weights for sub-factors.

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Table 4: Local weights of factors.

Factors	Local Weights
Economics	0.5024
Social	0.3451
Physical	0.1525

Table 5: Local weights of sub-factors (economics).

Economics	Local Weights
Income	0.6842
Education	0.3158

Table 6: Local weights of sub-factors (social).

Social	Local Weights
Politics	0.0716
Public transport and communication	0.1663
Health care	0.2641
Public safety	0.2355
Power and water provision	0.2626

Table 7: Local weights of sub-factors (physical).

Physical	Local Weights
Environment	0.0172
Housing quality	0.5441
Social participation	0.4387

Step 4: Compute interdependent weight:

The degrees of relative impact of factors are multiplied by the local weight of factors (results in Step 3) to compute the interdependent weights. Table 8, Table 9 and Table 10 show the inner dependent matrix and the relative importance of factors with respects to the factor that considered constant. The calculations of the relative importance weights are similar to the calculation for the local weights of factors.

Table 8: The inner dependent matrix of factors with respect to "economics".

Economics	Social	Physical	Relative importance weights
Social	(1,1,1)	(1,3/2,2)	0.6842
Physical	(1/2,2/3,1)	(1,1,1)	0.3158

Table 9: The inner dependent matrix of factor with respect to "social".

Social	Economic	Physical	Relative importance weights
Economic	(1,1,1)	(3/2,2,5/2)	1.0
Physical	(2/5,1/2,2/3)	(1,1,1)	0

Table 10: The inner dependent matrix of factors with respect to "physical".

Physical	Social	Economic	Relative importance weights
Social	(1,1,1)	(2/5,1/2,2/3)	0
Economic	(3/2,2,5/2)	(1,1,1)	1.0

With the information in Table 8 ,Table 9 and Table 10, a matrix for degree of relative impacts for factors is constructed as :

$$\begin{array}{c} \\ Economic \\ Social \\ Physical \end{array} \begin{array}{c} \begin{array}{ccc} Economic & Social & Physical \end{array} \\ \begin{pmatrix} 1.0 & 1.0 & 1.0 \\ 0.6842 & 1.0 & 0 \\ 0.3158 & 0 & 1.0 \end{pmatrix} \end{array}$$

W_{factor}

Interdependent weights are computed as = degree of relative impact for factors × local weights of factors

$$= \frac{1}{2}\begin{pmatrix} 1.0 & 1.0 & 1.0 \\ 0.6842 & 1.0 & 0 \\ 0.3158 & 0 & 1.0 \end{pmatrix} \times \begin{pmatrix} 0.5024 \\ 0.3451 \\ 0.1525 \end{pmatrix}$$

$$= \frac{1}{2}\begin{pmatrix} 1.0 \\ 0.6872 \\ 0.3104 \end{pmatrix} = \begin{pmatrix} 0.5 \\ 0.3436 \\ 0.1552 \end{pmatrix}$$

Step 5:

Global weight for the sub-factors are computed using interdependent weights of the factors (Results from Step 4) and local weights of sub-factors (Results from Step 3).

Global sub-factor weight = interdependent weight of the factor to which it belongs × local weight of sub-factors.

For example, global weights for income = 0.5 × 0.6842 = 0.3421. The computations for other sub-factors are computed with the similar fashion. Table 11 shows the global weights of all sub-factors.

Step 6: Compute percentage of QOL:

At this step, percentage of QOL can be determined by multiplying the global weight of sub-factors with the scale value. The scale value represents the degree of contribution of sub-factor to QOL. Scale values proposed by Cheng *et al.*, (1999) are adopted. Table 12 shows the scale value for each linguistic.

Therefore, the percentage of each sub-factor is computed as, Percentage of factor = Global weights × scale value For example, the percentage of income = 0.3421× 0.75 = 0.2566

The percentages for others sub-factors are computed in the similar fashion. Ultimately, the total percentages of QOL of the case study are established by adding all the percentages of sub-factors. Table 13 summarizes the percentages of the sub-factors and the percentages of QOL of coastal population at Setiu Wetlands.

Table 11: Global weights of sub-factors.

Factors	Interdependent weights of factors	Local weight of sub-factors	Global weights
Economic	0.5	Income – 0.6842	0.3421
		Education - 0.3158	0.1579
Social	0.3436	Politic – 0.0716	0.0246
		Public Transport and communication – 0.1663	0.0571
		Health care – 0.2641	0.0907
		Public safety – 0.2355	0.0809
		Power and water provision – 0.2626	0.0902
Physical	0.1552	Environment – 0.0172	0.0027
		Housing quality – 0.5441	0.0844
		Social participation – 0.4387	0.0681

Table 12: Linguistic variable and scale value.

Linguistics variable	Scale value
Very high (VH)	1
High(H)	0.75
Medium(M)	0.5
Low(L)	0.25
Very low(VL)	0

Table 13: Percentage of sub-factors and the total percentage of QOL.

Sub-factors	Global weights	Linguistic evaluations	Scale value	Quality of life
Income	0.3421	High	0.75	0.2566
Education	0.1579	Medium	0.5	0.0790
Politic	0.0246	Low	0.25	0.0062
Public Transport and Communication	0.0571	Medium	0.5	0.0286
Health care	0.0907	High	0.75	0.0680
Public safety	0.0809	Low	0.25	0.0202
Power and water provision	0.0902	Medium	0.5	0.0451
Environment	0.0027	Medium	0.5	0.0014
Housing quality	0.0844	Low	0.25	0.0211
Social participation	0.0681	Low	0.25	0.0170
Total QOL (%)				54.32

It can be seen that the sub-factor of income carried the highest percentage. This finding supports the earlier hypothesis that income is the factor which brings the largest impact to QOL among coastal population in Setiu wetlands. The other sub-factors are marginally contributed to QOL with smaller percentages. An interesting finding is that the sub-factor of environment which is scored below one percent is the lowest contributor. It is consistent with the general assumption that the people residing at wetlands are not very concerned about their environment as they already enjoyed a comfortable living environment. In other words, this can be explained that from the view of experts, environmental issues are not so important to coastal population compared to other sub-factors. The total percentage of QOL is merely 50 percent, reflecting the medium level of QOL of coastal population in Setiu Wetlands.

Conclusions:

This paper has shown the superiority of fuzzy ANP in establishing a percentage that can reflect the status of QOL specifically for coastal population in Setiu Wetlands. The Interdependencies among sub-factors of QOL were taking into consideration in the computation. The expert opinion in providing linguistic evaluation was the primary source of data that eventually led to the total QOL. The six-step computation substantiated with triangular fuzzy numbers has shown the veracity of the results. However, the finding at some extents has several limitations. The proposed QOL evaluation is only correct within the framework of fuzzy ANP. Other similar methods may end with different results. The finding also mainly depends on the data provided by a single expert. A group of expert and other approaches of multi-criteria decision making are among the several options that can be left for future research.

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