A New Fuzzy Weighted Based Computation for Environmental Performance: A Case of ASEAN Countries

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Abstract: Environmental Performance Index (EPI) has been introduced since 2006 to depict the environmental performance for most of the countries in the world. The index considers ten policy categories associated with environmental public health and ecosystem sustainability. The main mathematics operation in establishing EPI is arithmetic mean of all ten policy categories. However, this operation carries a potential disadvantage as it may neglects some extreme values in policy categories data and also employs equal weight for policy categories in obtaining EPI scores. To illustrate the issue of weight in computing environmental performance, this paper proposes intuitionistic fuzzy entropy weight method in calculating environmental performance to determine the weight of country and compares the weight of EPI as computed by the proposed weighted-based fuzzy entropy with the proximity to target formula and a decision making method. The original data of EPI among nine ASEAN countries are selected to illustrate the computation. The entropy weight of country and dual memberships of intuitionistic fuzzy sets are considered as the important properties in this computation. A new weight of EPI among ASEAN countries show that Singapore is the best country in environmental performance followed by Brunei. The proposed method may offer an alternative measure in evaluating environmental performance particularly for ASEAN countries.

Key-Words: - Environmental sustainability, Environmental Performance Index, weight entropy, ASEAN countries, intuitionistic fuzzy entropy.

1 Introduction

Sustainable development can be defined generally as the situation when development and preservation on environment get balance. Other issues in development and preservation such as economics, ecology, culture and socio-politics are also included in defining sustainable development. In other words, the definition of sustainable development comes in many variations. The most quoted definition of sustainable development is from Our Common Future also known as the Brundtland Report [2]. The report states the sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It comprises two key concepts; the concept of needs, in particular, the essential needs of the world's poor to which overriding priority should be given; and the idea of limitations imposed by state of technology and social organization on the environment's ability meet the present and future needs. There are many types of sustainable development such as environmental sustainability, economical sustainability, socio-political sustainability, ecological sustainability and cultural sustainability. Environmental stability is one of the much talked topics under the comprehensive concept of sustainable development. Environmental sustainability is a process to make sure that the daily life activities and any usage of environment is friendly environmental and preserved environment. An unsustainable environment is the situation where the usage and development does not preserve the environment and the nature's source had been used is more than the replenished.

The widely method used to assess the environmental sustainability are Emergy Evaluation (EME) and Ecological Footprint Analysis (EFA). The outcomes of the assessment are focused on resources depletion, consumption patterns, waste production and absorption [3]. Environmental impact is measured by the emergy investment ratio defined as the ratio of the emergy purchased from the economy divided by the emergy from the local environment [4]. Ecological footprint analysis compares human demand on nature with the biosphere's ability to regenerate resources and provide services. It is done by assessing the biologically productive land and marine area required to produce the resources a population consumes and absorb the corresponding waste using prevailing technology [5]. Per capita ecological footprint (EF) is comparing consumption and lifestyles and checking this against nature's ability to provide for this consumption [6].

Performance in handling environmental policy categories is another perspective in environmental assessment. Environmental Performance Index (EPI) which ranks 132 countries over ten policy categories covering both environmental public health and ecosystem vitality is one of the popular measures in assessing environmental performance of a country. This index had been conducted by The Yale Center for Environmental Law and Policy (YCELP) and the Center for Earth Information Science Information Network (CIESIN) at Columbia University. These indices provide a gauge at a national government scale on how close countries are to established environmental policy goals [7]. Each policy categories is made up of one or more environmental indicators. For each country and indicator, a proximity-to-target value is calculated based on the gap between a country's current result and the policy target. The generic formula for the proximity-to-target in the context of the global EPI is calculated using the following distance to target formula.

$$\frac{\text{(international range)} - \text{(distance to target)}}{\text{(international range)}} \times 100$$

The EPI is based on a proximity-to-target methodology where each country's performance on any given indicator is measured based on its position within a range established by the lowest performing country, equivalent to 0 on a 0-100 scale and the target, equivalent to 100.

All values of proximity-to-target indicators were summed and averaged. Data selection was made from official statistics reported by governments, spatial data, observing from monitoring stations and from modelled data [8]. It can be seen that EPI use a simple average calculation thereby may neglect some extreme values in the data.

Zaharia [9] used the global pollution index to evaluate the environmental impact produced by economic activities. The status of the environment, specifically in air, water resources, soil and noise are analysed with respect to discharges such as gaseous discharges in the air, final effluents discharged in natural receiving basins or sewerage systems and discharge onto the soil. For each environmental component, a quality index and an evaluation score that quantifies the pollution state of the environmental component are determine using an evaluation scale. The evaluation score range is 1 for minimum value (expressing an irreversible and major degradation state of the environment component) and 10 for maximum value (expressing a non-affected natural state of the environment). Then for each environmental component, the cumulative effects of the pollutants into each environmental component are expressed by the average arithmetic value for all specific quality indexes. Those evaluation score values are used to be adapted into global pollution index formula. The larger value of index indicates the worst environment had been affected by economic activities.

With the advent of computing based technology, Liqian and Jianming [10] conducted an eco-environmental quality assessment of Xining city based on geographic information system (GIS) and analytic hierarchy process (AHP). The assessment result marks with colours using GIS, which show the qualities; red for stop and green for pass. Also, the assessment conducted ranked the factors influenced the eco-environment in Xining area using weight obtained using AHP. Social cycle is a dominant factor eco-environment in Xining area followed by hydrosphere, atmosphere, lithosphere and biosphere.

Assessment of environmental issues was also gained attention by intelligent methods based on fuzzy sets theory. Silvert [11], for example, found that fuzzy logic can be used to classify and quantify environmental effects of a subjective nature, such as bad odours and it even provides formalism for dealing with missing data. The fuzzy memberships not only can be used as environmental indices but it is also possible to obtain a more traditional type of index through defuzzification. The fuzzy methodology also used to evaluate of the dual assessment concept intuitionistic fuzzy sets were hybridized with AHP. This integrated approach which later known as IF-AHP was meant to handle both vagueness and ambiguity related uncertainties in the environment decision-making process.

Sadiq and Tesfamariam [12] used IF-AHP methodology to select best drilling fluid (mud) for drilling operations under multiple environmental-based criteria like air emissions, spills, water column, bioaccumulation, benthic effects, air emission and ground water contamination.

In another attempt to further proliferate the AHP in environmental assessment, Wan Ismail & Abdullah [1] proposed a new environmental index. The method used pair wise comparison scale in analytic hierarchy process to set a new EPI for ASEAN countries. A comparison scale was given using a pair-wise comparison scale for AHP preference introduced by Saaty and Windy [13]. A weight of each policy category was considered as an important element prior to proposing overall index. Despite this success, the AHP has its own weaknesses. While using AHP, the decision problem is decomposed into a number of subsystems in which substantial number of pair wise comparisons need to be completed. Number of pair wise comparisons to be made may become very large depending on the size of matrix. The relation (n (n−1)/2) where n is size of decision matrix clearly lead to a lengthy task [14]. Another disadvantage of the AHP method is the artificial limitation of the use of the 9-point scale. Sometimes the decision maker might find difficult to distinguish among them. Also, the AHP method cannot cope with the fact that an alternative is 25 times more important than another alternative [15, 16].

As an effort to overcome these weaknesses, a new approach in calculating environmental performance index is proposed. The proposed method for measuring environmental performance is taken into account weight of each policy category. The method was originally proposed by Ye [17] as a method in fuzzy decision-making method based on the weighted correlation coefficient. Intuitionistic fuzzy weight entropy proposed by Vlachos and Sergiadis [18] is used to determine weight of environmental performance for each country. The entropy of country and dual membership in intuitionistic fuzzy sets (IFSs) is considered as an important priority in this calculation. In contrast to the simple arithmetic in EPI computation, this paper applies dual evaluation of intuitionistic fuzzy entropy where no aggregations of policy categories data are involved. Unlike the AHP that handle uncertainty with crisp numbers, the intuitionistic fuzzy numbers provides more flexible approach and are capable of making comprehensive evaluation even under uncertainties thanks to dual membership of intuitionistic fuzzy sets.

To the best of authors' knowledge, this dual assessment method has not been tested to environmental performance. The weight of each policy category and two-sided memberships of intuitionistic fuzzy sets (IFSs) is considered as an important characteristic in this calculation.

The aim of this paper is to propose weights for policy categories and subsequently propose a new rank of EPI. Nine ASEAN countries are tested to the weighted correlation coefficient method as an alternative method in calculating new EPI. The paper unfolds as follows. The next section briefly introduces some definitions related to the method. Section 3 describes the weighted correlation coefficient in IFSs proposed by Ye [17]. Section 4 presents weights for policy categories and a new ranking of EPI. Discussions section presents a new ranking of EPI. A comparison between original EPI and related study is made in this section. Conclusions appear in the last section.

2 Preliminaries

This section introduces the basic definitions relating to fuzzy set theory, intuitionistic fuzzy sets (IFSs) and the intuitionistic fuzzy entropy that will use in the entire paper.The theory of fuzzy sets proposed by Zadeh [19] has successfully applied in numerous fields such as engineering, finance, biology and etc.

Definition 1 Fuzzy set theory [19].

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

$$A = \{< x, \mu_A(x) > | \, x \in X\}, \qquad (1)$$

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

Out of several higher order fuzzy sets, intuitionistic fuzzy sets [20] and interval-valued intuitionistic fuzzy sets [21] are two primary extensions of the conventional fuzzy sets theory. Both are alleviate some drawbacks of Zadeh's fuzzy sets and have been found to be highly useful to deal with vagueness. An IFSs allocates both membership and non membership to each element of the universe. The concept of vague set [22] is another extension of ordinary fuzzy set which has been proved to be equivalent to IFSs [23]. The IFSs make descriptions of the objective world become more realistic, practical, and accurate, making it very promising. Instead of using fuzzy approach, past researchers have studied IFSs to be applied in variety area such as decision making problems [24], medical diagnostics [25] and pattern recognition [25] and seem to be more popular than fuzzy sets in recent years.

Definition 2 Intuitionistic fuzzy sets [20].
An IFS in X is an expression A is defined by

$$A = \{< x, \mu_A(x), \nu_A(x) > | x \in X\}, \quad (2)$$

where $\mu_A(x): X \to [0,1]$ and $\nu_A(x): X \to [0,1]$, with the condition $0 \le \mu_A(x) + \nu_A(x) \le 1$. The numbers $\mu_A(x)$ and $\nu_A(x)$ represent respectively the membership degree and non-membership degree of the element x to the set A. For each IFSs in X:

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x), \quad (3)$$

for all $x \in X$. Then $\pi_A(x)$ is called the intuitionistic index or hesitancy degree of the element x in the set A. It can be seen that $0 \le \pi_A(x) \le 1, x \in X$.

For two IFS $A = \{< x, \mu_A(x), \nu_A(x) > | x \in X\}$ and $B = \{< x, \mu_B(x), \nu_B(x) > | x \in X\}$ the two relations are follows:

(1) $A \subseteq B$ if and only if $\mu_A(x) \le \mu_B(x)$ and $\nu_A(x) \le \nu_B(x)$ for any $x \in X$;
(2) $A = B$ if and only if $\mu_A(x) = \mu_B(x)$ and $\nu_A(x) = \nu_B(x)$ for any $x \in X$.

Definition 3 Entropy measure of IFSs [27].
Let A be an IFS in the universe of discourse $X = \{x_1, x_2, ..., x_n\}$. The entropy measure of IFSs is defined as follows:

$$E_{LT}(A) = -\frac{1}{n \ln 2} \times \sum_{i=1}^{n} \left[\begin{array}{l} \mu_i \ln\left(\dfrac{\mu_i}{\mu_i + \nu_i}\right) + \\ \nu_i \ln\left(\dfrac{\nu_i}{\mu_i + \nu_i}\right) - \pi_i \ln 2 \end{array} \right]. \quad (4)$$

3 Method and Material

This section elucidates more about the intuitionistic fuzzy weight entropy as an alternative method in calculating the environmental performance and the EPI 2012 data as a material in the proposed method.

3.1 Intuitionistic Fuzzy Weight Entropy

Based on the entropy measure of IFSs proposed by De-Luca Termini [27], intuitionistic fuzzy entropy for alternative A_i obtained using IFSs entropy measure by Vlachos and Sergiadis [18]:

$$E(A_i) = -\frac{1}{n \ln 2} \sum_{i=1}^{n} \left[\begin{array}{l} \mu_A(C_j) \ln \mu_A(C_j) + \nu_A(C_j) \ln \nu_A(C_j) \\ - (1 - \pi_A(C_j)) \ln(1 - \pi_A(C_j)) \end{array} \right] \quad (5)$$

Here if, $\mu_A = 0, \nu_A = 0, \pi_A = 1$, then $\mu_A \ln \mu_A = 0$, $\nu_A \ln \nu_A = 0, (1 - \pi_A)\ln(1 - \pi_A) = 0$ and if $\mu_A = 1$, $\nu_A = 0, \pi_A = 0$, then $\mu_A \ln \mu_A = 0, \nu_A \ln \nu_A = 0$, $(1 - \pi_A)\ln(1 - \pi_A) = 0$ respectively.

Thus, the final weight entropy for each alternative A_i can be defined using the model of entropy weights:

$$w_i = \frac{1 - E(A_i)}{m - \sum_{i=1}^{m} E(A_i)} \quad (6)$$

where $w_i \in [0,1]$ and $\sum_{i=1}^{m} w_i = 1$ for $(i = 1, 2, ..., m)$.

3.2 Environmental Performance Index 2012

Environmental Performance Index 2012 issued by Yale Center for Environmental Law and Policy and Center for International Earth Science Information Network (2012) among nine ASEAN countries are given in Table 1. Nine ASEAN countries are indicates Ai (i=1, 2, 3, 4, 5, 6, 7, 8, 9).

Table 1: Environmental Performance Index 2012

Ranking	Countries (A_i)	EPI Score
1	Malaysia (A_1)	62.5
2	Brunei (A_2)	62.5
3	Thailand (A_3)	60.0
4	Philippines (A_4)	57.4
5	Singapore (A_5)	56.4
6	Cambodia (A_6)	55.3
7	Myanmar (A_7)	52.7
8	Indonesia (A_8)	52.3
9	Vietnam (A_9)	50.6

The ten policies, c_i (i=1, 2, 3, 4, 5, 6, 7, 8, 9, 10) retrieved are environmental burden of disease, air pollution (impact on humans), water (impact on humans), air pollution (impact on ecosystem), water (impact on ecosystem), biodiversity, forestry, fisheries, agriculture and climate change. Table 2(a) and 2(b) shows the data for ASEAN countries extracted from Yale Center for Environmental Law and Policy and Center for International Earth Science Information Network [7].

Table 2(a): Index each policy categories

ASEAN Countries	Environmental Burden of Disease, c_1	Air Pollution (impact on humans), c_2	Water Pollution (impact on humans), c_3	Air Pollution (impact on ecosystem), c_4	Water Pollution (impact on ecosystem), c_5
Malaysia	80.6	97.3	82.6	41.5	48.4
Brunei	86.4	100.0	38.2	37.1	99.6
Thailand	87.6	40.3	70.0	42.9	18.2
Philippines	58.0	55.4	38.9	39.1	36.4
Singapore	100.0	100.0	100.0	31.2	14.5
Cambodia	35.7	42.0	11.6	64.4	45.3
Myanmar	40.7	33.8	28.7	70.2	50.9
Indonesia	57.7	54.3	23.1	38.9	46.7
Vietnam	42.5	31.0	42.5	43.8	37.8

Table 2(b): Index each policy categories (continue)

ASEAN Countries	Biodiversity, c_6	Forestry, c_7	Fisheries, c_8	Agriculture, c_9	Climate Change, c_{10}
Malaysia	90.1	17.4	31.0	95.5	28.0
Brunei	90.7	66.7	67.6	44.2	5.2
Thailand	78.9	87.0	34.2	93.9	39.2
Philippines	66.0	90.1	25.8	92.4	64.7
Singapore	34.1	79.4	18.4	98.5	28.3
Cambodia	94.8	28.3	21.6	66.7	73.9
Myanmar	53.6	26.3	33.3	84.8	77.3
Indonesia	75.3	54.7	38.1	54.6	48.9
Vietnam	54.1	81.4	19.4	47.8	56.5

The index for each policy category is converted into intuitionistic fuzzy sets (IFS) notation to fit with the fuzzy entropy weight formula.

4 Implementation

The process of calculating the intuitionistic fuzzy entropy weight for ASEAN countries can be divided into two phases. The first phase is converting the entire index for policy categories into IFSs form. Then, in the second phase, the intuitionistic fuzzy entropy weights of ASEAN countries are calculated. A new weight based on environmental performance can be obtained using the following steps:

Step 1 Convert to interpretation score, $\mu''(x)$.

Let's take data of Malaysia as an example in this calculation. The original data of environmental burden of disease policy category are converted to IFSs. Since the maximum value of is 100%, then the interpretation score is 80.6% (see Table 2(a)).

Step 2 Determine the value of hesitation, $\pi(x)$.

Levels of consistency and membership grades in Table 3 are used to determine value of hesitation.

Table 3: Conversion of consistency expressions to membership grades [28]

Consistency	$\mu''(x)$	$\pi(x)$
No or very low consistency	0.0-0.2	0.8 – 1.0
Low consistency	0.2-0.4	0.6 – 0.8
Moderate consistency	0.4-0.6	0.4 – 0.6
High consistency	0.6-0.8	0.2 – 0.4
Very high or total consistency	0.8-1.0	0.0 – 0.2

If the value of $\mu''(x) = 1$ then $\pi(x) = 0$ and if $\mu''(x) = 0.9$ then $\pi(x) = 0.1$. From Step 1, $\mu''(x) =$ 0.806, then hesitation value is 0.2, in the level of very high consistency.

Step 3 Calculate the value of membership, $\mu(x)$.

The value of membership, $\mu(x)$. is calculated using the equation

$$\mu(x) = \mu''(x)[1 - \pi(x)] = 0.806[1 - 0.2] = 0.6448.$$

Step 4 Calculate the value of non membership, $v(x)$.

The value of non membership, $v(x)$ is calculated using equation (3),
$v(x) = 1 - \mu(x) - \pi(x) = 1 - 0.6448 - 0.2 = 0.1552.$

Step 5 Arrange the memberships in the IFSs notation.

$$C_1 = (\mu(x), v(x), \pi(x)) \\ = (0.6448, 0.1552, 0.2)$$

Memberships for other policy categories of ASEAN countries are calculated with the similar fashion. It is listed in Table 4(a), Table 4(b) and Table 4(c).

Table 4(a): IFS of policies for ASEAN countries

Countries	Environmental Burden of Disease (DALYs), c_1	Air Pollution (impact on humans), c_2	Water (impact on humans), c_3	Air Pollution (impact on ecosystem), c_4
Malaysia	(0.6448, 0.1552, 0.2)	(0.9730, 0.0270, 0.0)	(0.6608, 0.1392, 0.2)	(0.1660, 0.2340, 0.6)
Brunei	(0.7776, 0.1224, 0.1)	(1.0000, 0.0000, 0.0)	(0.1528, 0.2472, 0.6)	(0.1484, 0.2516, 0.6)
Thailand	(0.7884, 0.1116, 0.1)	(0.1612, 0.2388, 0.6)	(0.4900, 0.2100, 0.3)	(0.1716, 0.2284, 0.6)
Philippines	(0.3480, 0.2520, 0.4)	(0.3324, 0.2676, 0.4)	(0.1556, 0.2444, 0.6)	(0.1564, 0.2436, 0.6)
Singapore	(1.0000, 0.0000, 0.0)	(1.0000, 0.0000, 0.0)	(1.0000, 0.0000, 0.0)	(0.0936, 0.2964, 0.7)
Cambodia	(0.1428, 0.2572, 0.6)	(0.1680, 0.2320, 0.6)	(0.0116, 0.0884, 0.9)	(0.3864, 0.2136, 0.4)
Myanmar	(0.1628, 0.2372, 0.6)	(0.1014, 0.1986, 0.7)	(0.0861, 0.2139, 0.7)	(0.4914, 0.2086, 0.3)
Indonesia	(0.3462, 0.2538, 0.4)	(0.2715, 0.2285, 0.5)	(0.0462, 0.1538, 0.8)	(0.1556, 0.2444, 0.6)
Vietnam	(0.1700, 0.2300, 0.6)	(0.0930, 0.2070, 0.7)	(0.1700, 0.2300, 0.6)	(0.1752, 0.2248, 0.6)

Table 4(b): IFS of policies for ASEAN countries (continuation from Table 4(a))

Countries	Water (impact on ecosystem), c_5	Biodiversity, c_6	Forestry, c_7
Malaysia	(0.2420, 0.2580, 0.5)	(0.8109, 0.0891, 0.1)	(0.0348, 0.1652, 0.8)
Brunei	(0.9960, 0.0040, 0.0)	(0.8163, 0.0837, 0.1)	(0.4669, 0.2331, 0.3)
Thailand	(0.0364, 0.1636, 0.8)	(0.6312, 0.1688, 0.2)	(0.7830, 0.1170, 0.1)
Philippines	(0.1456, 0.2544, 0.6)	(0.4620, 0.2380, 0.3)	(0.8109, 0.0891, 0.1)
Singapore	(0.0145, 0.0855, 0.9)	(0.1023, 0.1977, 0.7)	(0.6352, 0.1684, 0.2)
Cambodia	(0.2265, 0.2735, 0.5)	(0.8532, 0.0468, 0.1)	(0.0849, 0.2151, 0.7)
Myanmar	(0.2545, 0.2455, 0.5)	(0.2680, 0.2320, 0.5)	(0.0789, 0.2211, 0.7)
Indonesia	(0.2335, 0.2665, 0.5)	(0.6024, 0.1976, 0.2)	(0.2735, 0.2265, 0.5)
Vietnam	(0.1512, 0.2488, 0.6)	(0.2705, 0.2295, 0.5)	(0.6512, 0.1488, 0.2)

Table 4(c): IFS of policies for ASEAN countries (continuation from Table 4(b))

Countries	Fisheries, c_8	Agriculture, c_9	Climate Change, c_{10}
Malaysia	(0.0930, 0.2070, 0.7)	(0.9550, 0.0450, 0.0)	(0.0840, 0.2160, 0.7)
Brunei	(0.4732, 0.2268, 0.3)	(0.1768, 0.2232, 0.6)	(0.0052, 0.0948, 0.9)
Thailand	(0.1026, 0.1974, 0.7)	(0.8451, 0.0549, 0.1)	(0.1568, 0.2432, 0.6)
Philippines	(0.0774, 0.2226, 0.7)	(0.8316, 0.0684, 0.1)	(0.3882, 0.2118, 0.4)
Singapore	(0.0368, 0.1632, 0.8)	(0.9850, 0.0150, 0.0)	(0.0849. 0.2151, 0.7)
Cambodia	(0.0432, 0.1568, 0.8)	(0.4669, 0.2331, 0.3)	(0.5173, 0.1827, 0.3)
Myanmar	(0.0999, 0.2001, 0.7)	(0.6784, 0.1216, 0.2)	(0.6184, 0.1816, 0.2)
Indonesia	(0.1524, 0.2476, 0.6)	(0.2730, 0.2270, 0.5)	(0.2445, 0.2555, 0.5)
Vietnam	(0.0388, 0.1612, 0.8)	(0.2390, 0.2610, 0.5)	(0.3390, 0.2610, 0.4)

Step 6 Calculate the intuitionistic fuzzy entropy.
The intuitionistic fuzzy entropy is calculated using Eq. (5).

$$E(A_1) = -\frac{1}{10\ln 2}\left[\begin{bmatrix}0.6448(\ln 0.6448)+\\0.1552(\ln 0.1552)-\\(1-0.2)\ln(1-0.2)\end{bmatrix}+\begin{bmatrix}0.9730(\ln 0.9730)+\\0.0270(\ln 0.0270)-\\(1-0)\ln(1-0)\end{bmatrix}+\ldots+\begin{bmatrix}0.0840(\ln 0.0840)+\\0.2160(\ln 0.2160)-\\(1-0.7)\ln(1-0.7)\end{bmatrix}\right]$$
$$= 0.3514$$

Step 7 Calculate the intuitionistic fuzzy entropy weight.
The intuitionistic fuzzy entropy weight for Malaysia, for example, is measured using Eq. (6).

$$w(A_1) = \frac{1-0.3514}{9-3.3991} = 0.1158$$

where $\sum_{i-1}^{9} E(A_i) = 0.1158 + 0.1174 + 0.1056 + 0.0971 + 0.1482 + 0.1111 + 0.1040 + 0.0957 + 0.1050 = 3.3991.$

The calculation is executed to other eight countries and the entropy weights are listed in Table 5:

Table 5: Weight entropy of ASEAN countries

Countries (A_i)	$W(A^*, A_i)$
Malaysia (A_1)	0.1158
Brunei (A_2)	0.1174
Thailand (A_3)	0.1056
Philippines (A_4)	0.0971
Singapore (A_5)	0.1482
Cambodia (A_6)	0.1111
Myanmar (A_7)	0.1040
Indonesia (A_8)	0.0957
Vietnam (A_9)	0.1050

The larger value of weight indicates the best country in environmental performance. So we can see that Singapore is the best performer in environmental performance followed by Brunei and Malaysia.

5 Discussion

A new EPI for ASEAN countries has been obtained using intuitionistic fuzzy entropy weight. The weight of each country obtained after considering the entropy of country and the dual-sided measurements of IFSs. Those weights then used to evaluate the best country on environmental performance. From Table 5, Singapore leads in the first place followed by Brunei and Malaysia while the last three countries are Myanmar, Vietnam and Indonesia. The weights of environmental performance from original EPI 2012, the AHP and proposed method are tabulated in Table 6. An EPI 2012 score had been normalized using fuzzy normalization method for fuzzy weights [29].

Table 6: EPI for ASEAN countries: weight analysis

Countries	EPI 2012	AHP method	Proposed Method
Malaysia	0.1226	0.1420	0.1158
Brunei	0.1226	0.1720	0.1174
Thailand	0.1177	0.1220	0.1056
Philippines	0.1126	0.0790	0.0971
Singapore	0.1107	0.1580	0.1482
Cambodia	0.1085	0.1090	0.1111
Myanmar	0.1034	0.1130	0.1040
Indonesia	0.1026	0.0590	0.0957
Vietnam	0.0993	0.0460	0.1050
$\sum w$	1	1	1

Then, the new weights and weights from the other methods are depicted in Figure 1.

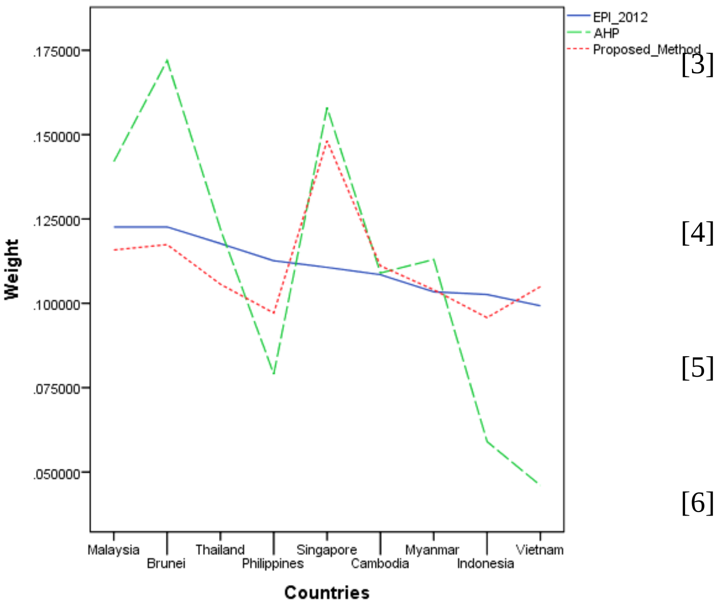

Fig. 1 EPI for ASEAN countries: weight analysis

It can be seen that the weight obtained using intuitionistic fuzzy entropy weight is differs from original EPI 2012 and EPI using AHP. The difference can be related due to membership and non membership of IFSs and entropy used in intuitionistic fuzzy entropy weight.

6 Conclusion

This paper has shown the capability of fuzzy weight and IFSs in proposing the new way of calculating environmental performance. The original version of EPI is only included arithmetic mean for all ten policy categories in the main calculation. The weakness of this simple mathematical operation is it might neglects some extreme values in the data. Thus, this paper uses intuitionistic fuzzy entropy weight as a better mathematical solution which considers the entropy of each of country and the IFSs considers two-sided of measurement, the membership and non membership value. A new weight of EPI among ASEAN countries show that Singapore is the highest followed by Brunei and Malaysia. The new weight may offer an alternative measure in evaluating environmental performance among ASEAN countries.

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