Article

A new Environmental Performance Index using analytic hierarchy process: A case of ASEAN countries

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Received 23 July 2012; *Accepted 5 August 2012*; *Published online 1 September 2012*
IAEES

Abstract
Rapid development and increasing number of population may indicate a good sign for nation's development. However, development sometimes brings negative side effect particularly from environment performance perspective. Environmental Performance Index (EPI) had been introduced since 2006 to depict the environment 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. One of the weaknesses in the arithmetic mean is the mathematics operation might neglects some extreme values in data. This paper proposed a new EPI using a decision making tool of Analytic Hierarchy Process (AHP). Pair wise comparison scales in AHP were utilized to set new EPI for nine ASEAN countries. A new ranking EPI among ASEAN countries showed that Brunei was the highest EPI followed by Singapore. The new ranking may offer an alternative measure in evaluating environmental performance particularly for ASEAN countries.

Keywords environmental sustainability; Environmental Performance Index; analytic hierarchy process; decision making.

1 Introduction

Sustainable development is the situation when development and preservation on environment get balance. However, other issues like economy sustainability and socio-political sustainability are not neglected. In facts, sustainable development is a development where the concepts of essential needs until to those poor people and limitations imposed on environment to meets present and future needs are satisfied (United Nation World Commission on Environment and Development, 2009). One of the major types of sustainable development is environmental sustainability. It is a process to make sure that the daily life activities and any usage of environment is friendly environmental and preserved our environment. An unsustainable environment is a contra-situation which 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 which are used to assess the environmental sustainability are Emergy Evaluation and Ecological Footprint Analysis. The outcomes evaluate more on resources depletion, consumption patterns, waste production and absorption (Marchettini et al., 2007). 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 (Odum, 1998). 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 (Eco Greenwares, 2009). Per capita ecological footprint is comparing consumption and lifestyles and checking this against nature's ability to provide for this consumption (Cui and Yu, 2009).

Another way used to assess the environment sustainability is the 2012 Environmental Performance Index which ranks 132 countries on ten policy categories covering both environmental public health and ecosystem vitality. This index had been conducted by The Yale Center for Environmental Law and Policy and the Center for Earth Information Science Information Network of Columbia University (2012). These indicators provide a gauge at a national government scale on how close countries are to established environmental policy goals (Yale Center for Environmental and Policy et al., 2012). 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 indicator calculation in the context of the global EPI is in Eq. 1,

$$((\text{international range}) - (\text{distance to target}))/ (\text{international range}) \times 100 \quad (1)$$

The EPI is based on a proximity-to-target methodology whereby 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. The illustration of methodology shows in Fig. 1. "Better" and "worse" are relative term only and refer to the distance to the target.

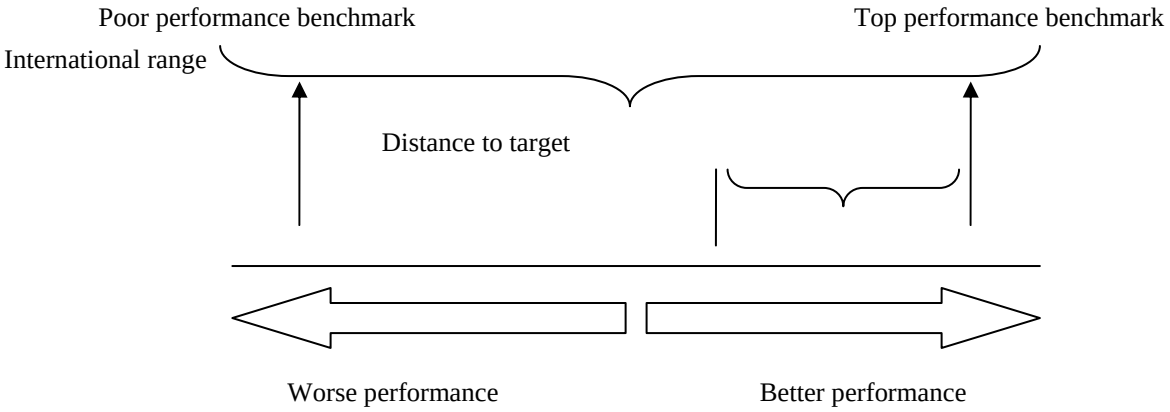

Fig. 1 Diagram illustrating the proximity-to-target methodology (Emerson et al., 2012).

Then all the values were sum up and averaged. The data was retrieved from official statistics reported by governments, spatial data compiled by research, observing from monitoring stations and from modelled data (Emerson et al., 2012). So it can be seen that the EPI only depends on a simple mean arithmetic in the computation.

Concerning about the method in calculating the environmental performance index, the new ideas comes out by introducing the weight as the priority on index measurement. Hence, the objective of this paper is to

rank a new EPI 2012 for ASEAN countries using the Analytic Hierarchy Process (AHP) as the alternative way in calculating the environmental index. The paper unfolds as follows. The next section briefly introduces some definitions about suggested method which is AHP and application using the software Expert Choice. In the subsequent section, a new ranking in EPI 2012 are proposed and comparison between original EPI 2012 are made. Conclusions appear in the last section.

2 Analytical Hierarchy Process (AHP)

The analytic hierarchy process is a mathematical device in multi-criteria decision making which designing the decision factors in a hierarchic problem structure (Saaty, 1990). The main target of the AHP is to decide and help decision makers in making resolutions for the complex problems by structuring the criterion hierarchy of multi-criteria decision making. The first element in AHP procedures is determining the focus or aim of the problem identified. It is considered as the first level for the AHP hierarchy. Next would be multiple criterion that define alternatives and the last level is the contributing alternatives (causes/factors) for the focus. The standard scale with absolute numbers used as a measurement in order to manage the weight of each alternative. The scale measurement from 1 to 9 in a fundamental scale of measurement listed in Table 1.

Table 1 Pair-wise comparison scale for AHP preference (Saaty and Windi, 1980; Saaty, 2008)

Preference on pair wise comparison	Preference number	Explanation
Equally important	1	Two activities contribute equally to the objective
Weak importance of one over another	3	Experience and judgment slightly favor one activity over another
Essential or strong importance	5	Experience and judgment strongly favor one activity over another
Demonstrated importance	7	An activity is strongly favored and its dominance is demonstrated in practice
Absolute importance	9	The evidence favoring one activity over another is the highest possible order of affirmation
Intermediate values between the two adjacent judgments	2, 4, 6, 8	When compromise is needed
If activity *i* has one of the above nonzero numbers assigned to it when compared with the activity *j*, then *j* has the reciprocal value when compared with *i*	Reciprocals of above nonzero	A logical assumption

It is assumed that an element with weight zero is eliminated from comparison because zero can be applied to the whole universe of factors not included in the discussion. Reciprocals of all scaled ratios that are ≥ 1 are entered in the transpose positions. The procedure of AHP can be summarized as

1) Model the problem as a hierarchy containing the decision goal, the alternatives and the criteria that evaluating the alternatives.
2) Establish priorities among the elements of the hierarchy by making a series of judgments based on pair-wise comparisons of the elements.
3) Synthesize these judgments to yield a set of overall priorities for the hierarchy.
4) Check the consistency of the judgments.
5) Come to a final decision based on the results of the process.

Besides manual calculation, the decision can be made using the Expert Choice. This software works with few steps. The basic steps in executing AHP are:

Step 1: Construct on hierarchy structure for the problems in order to have a clearer view on criteria and alternatives.

Step 2: Identify all the criteria and alternatives in model view pane.

Step 3: Fill the scale of relative measurement of the criteria in pair-wise comparison matrix.

Step 4: Fill the scale of relative measurement of each alternatives in pair-wise comparison matrix.

Step 5: Compute the overall index in the entire hierarchy.

3 New Environmental Performance Index (EPI): A Case of ASEAN Countries

Environmental Performance Index 2012 is retrieved from Yale Center for Environmental and Policy et al., (2012). The indexes of nine ASEAN countries are given in Table 2.

Table 2 Environmental Performance Index (EPI) 2012 score

ASEAN Countries	EPI Score
Malaysia	62.5
Brunei	62.5
Thailand	60.0
Philippines	57.4
Singapore	56.4
Cambodia	55.3
Myanmar	52.7
Indonesia	52.3
Vietnam	50.6

The ten policies 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. The original data are given in Table 3(a) and 3(b).

Table 3(a) Index each policy categories

ASEAN Countries	Environmental Burden of Disease	Air Pollution (impact on humans)	Water Pollution (impact on humans)	Air Pollution (impact on ecosystem)	Water Pollution (impact on ecosystem)
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 3(b) Index each policy categories (continue)

ASEAN Countries	Biodiversity	Forestry	Fisheries	Agriculture	Climate Change
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 country is computed according to the following steps:

Step 1: Construct on hierarchy structure for the problems. It is given in Fig. 2.

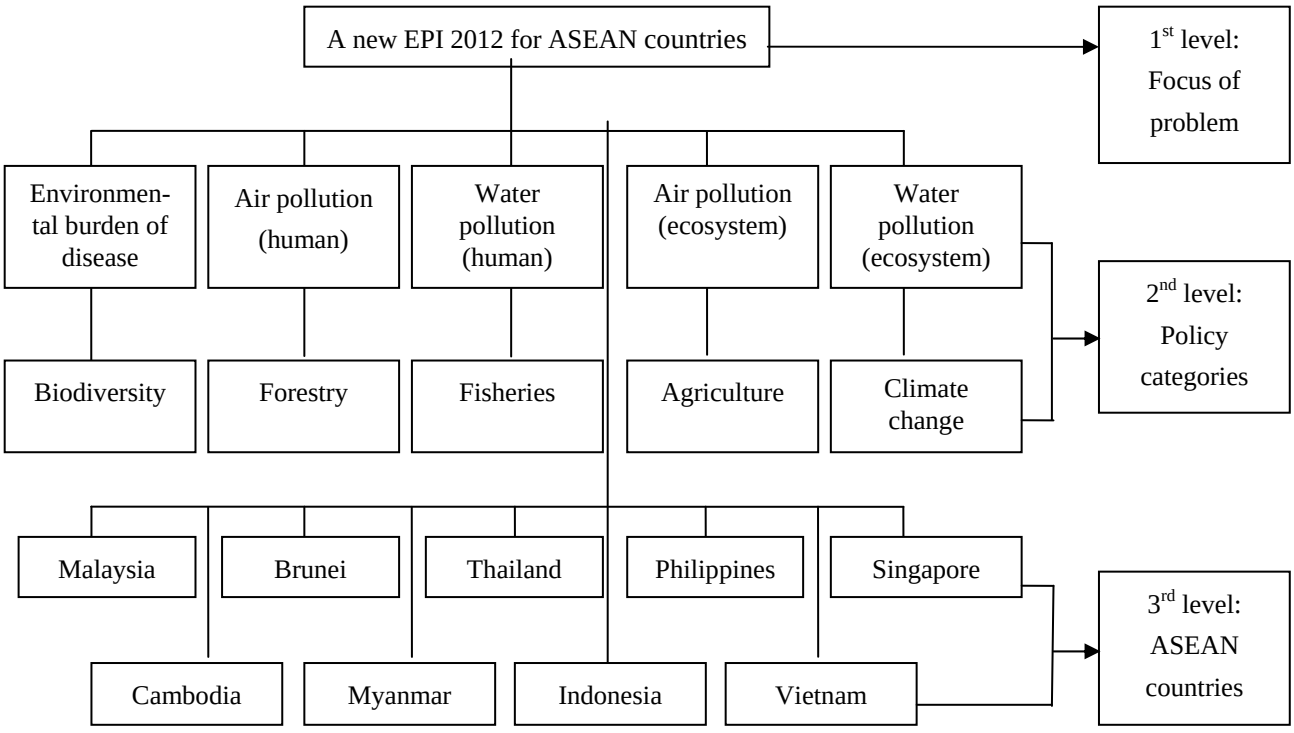

Fig. 2 Hierarchy structure for the new EPI 2012.

Step 2: Identify criterions and alternatives that are listed in model view pane.

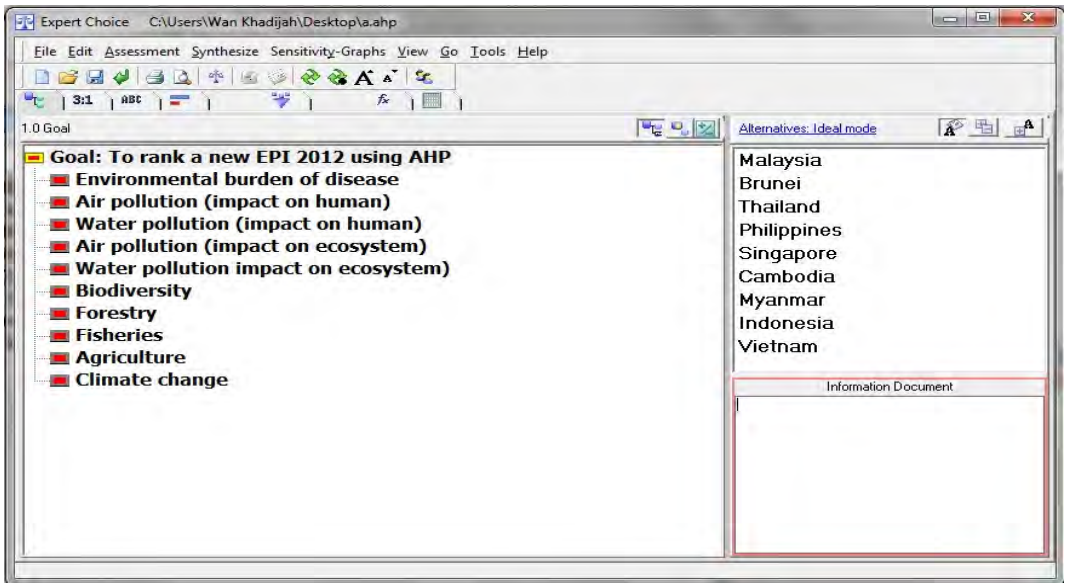

Fig. 3 Model view pane in Expert Choice.

Step 3: Using Table 1, the scale of relative measurement of the criteria in pair-wise comparison decided by the researcher as in Fig. 4.

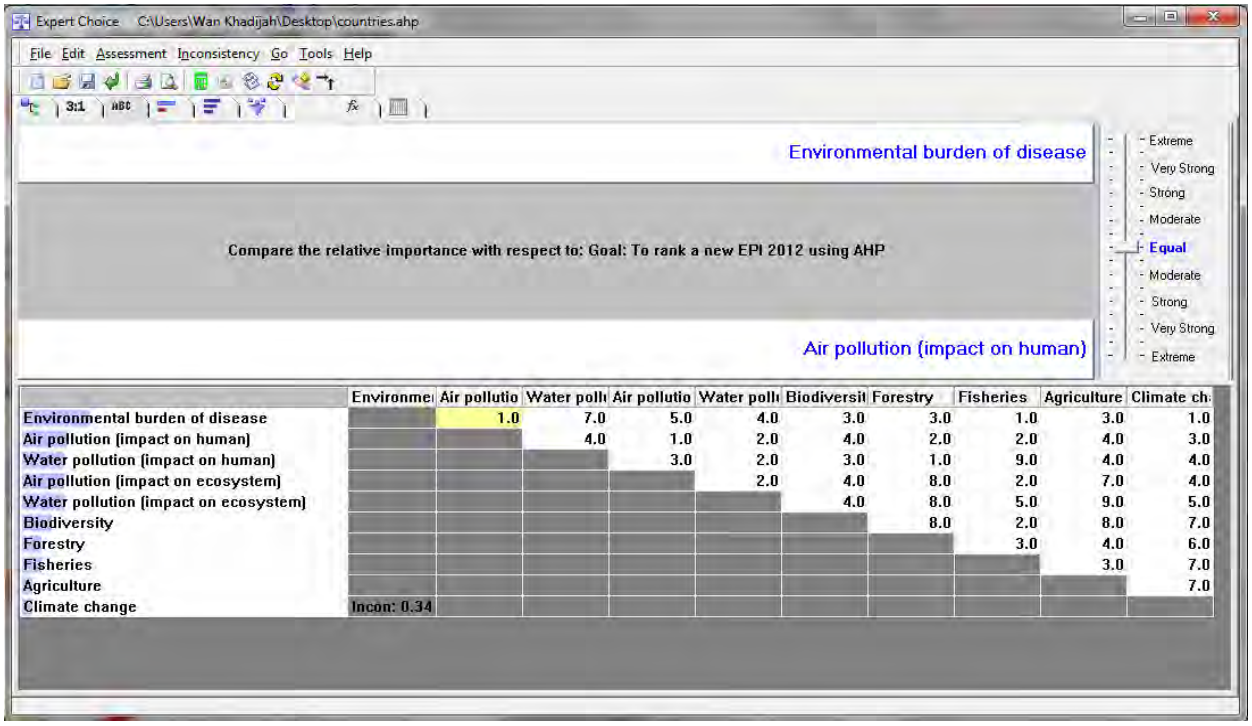

Fig. 4 The scale of relative measurement of the criteria in pair-wise comparison

Step 4: Fill in the scale of relative measurement of each alternatives in pair-wise comparison.

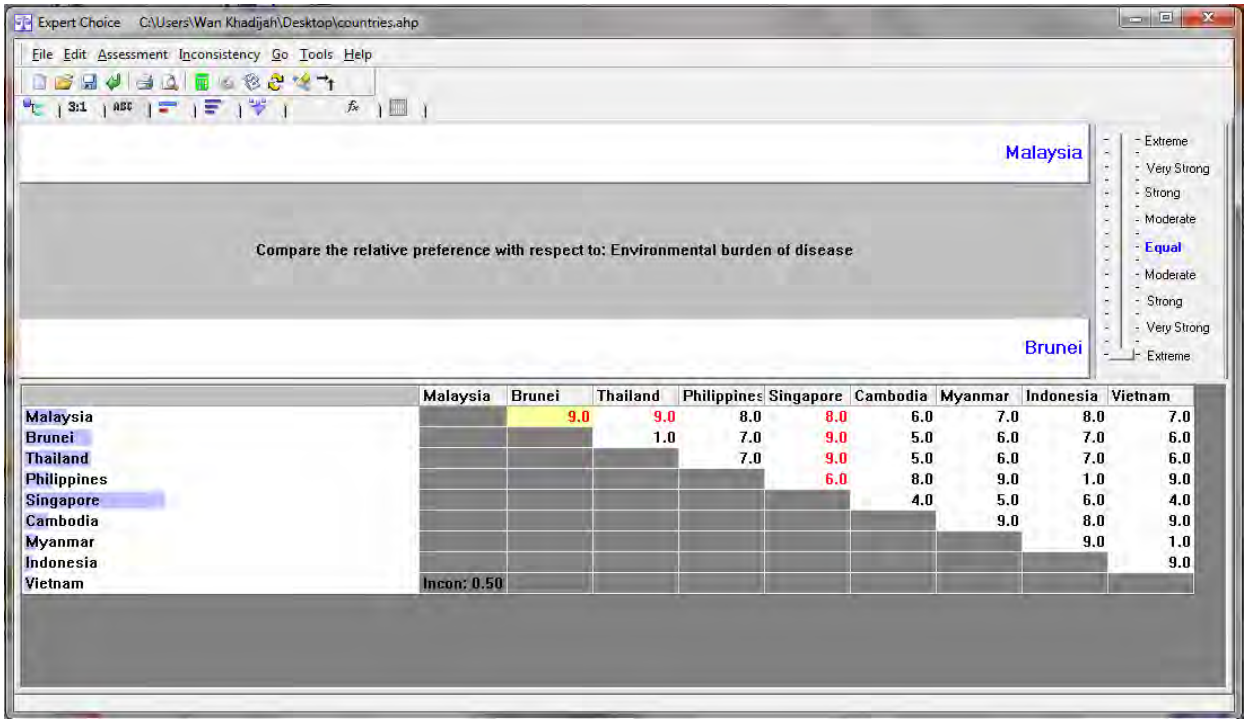

Fig. 5 The scale of relative measurement of environmental burden of disease alternative

Step 5: Compute the overall index in the entire hierarchy. The results are shown in Fig. 6.

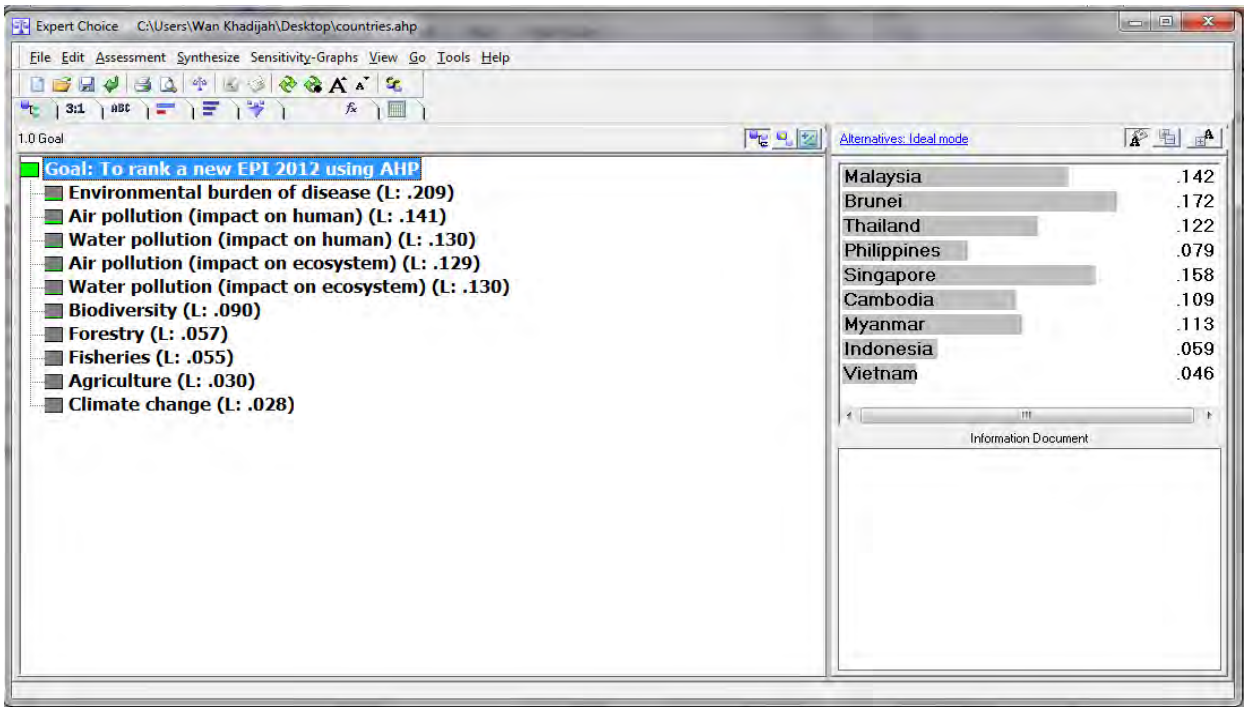

Fig. 6 The AHP result in environmental problem

Fig. 6 shows the index for each country. The larger index indicates the better performance in environmental performance. The new rank obtained and compared with the original EPI 2012 in Table 4.

Table 4 New ranking by using AHP

Countries	EPI score (%)	Ranking	AHP score	New ranking
Malaysia	62.5	1	0.142	3
Brunei	62.5	2	0.172	1
Thailand	60.0	3	0.122	4
Philippines	57.4	4	0.079	7
Singapore	56.4	5	0.158	2
Cambodia	55.3	6	0.109	6
Myanmar	52.7	7	0.113	5
Indonesia	52.3	8	0.590	8
Vietnam	50.6	9	0.460	9

The new ranks are also differs from original EPI 2012. Brunei leads at the first place followed by Singapore and Malaysia. The difference can be related due to weight from the pair wise comparison. It can be explained as this AHP method has the distinct advantages that decomposes a decision problem into its constituent parts and builds hierarchies of criteria (Macharis et al., 2004).

4 Conclusions

This paper has shown the capability of decision tool, AHP in proposing the new rank of EPI 2012 among ASEAN countries. The original version of EPI is only included arithmetic mean of all ten policy categories in the main calculation. The weakness of this simple mathematical operation is that it might neglects some extreme values in the data. Thus, this paper uses AHP method as a better mathematical solution which considers the weight in each of category policies. A new ranking of EPI among ASEAN countries shows that Brunei is the highest followed by Singapore and Malaysia. In addition, the new ranking may offer an alternative measure in evaluating environmental performance among ASEAN countries. It is suggested that the weight of policy categories for each country can be calculated prior to establishing EPI. These measures can be used to determine the policy category that might influenced the value of the EPI.

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