

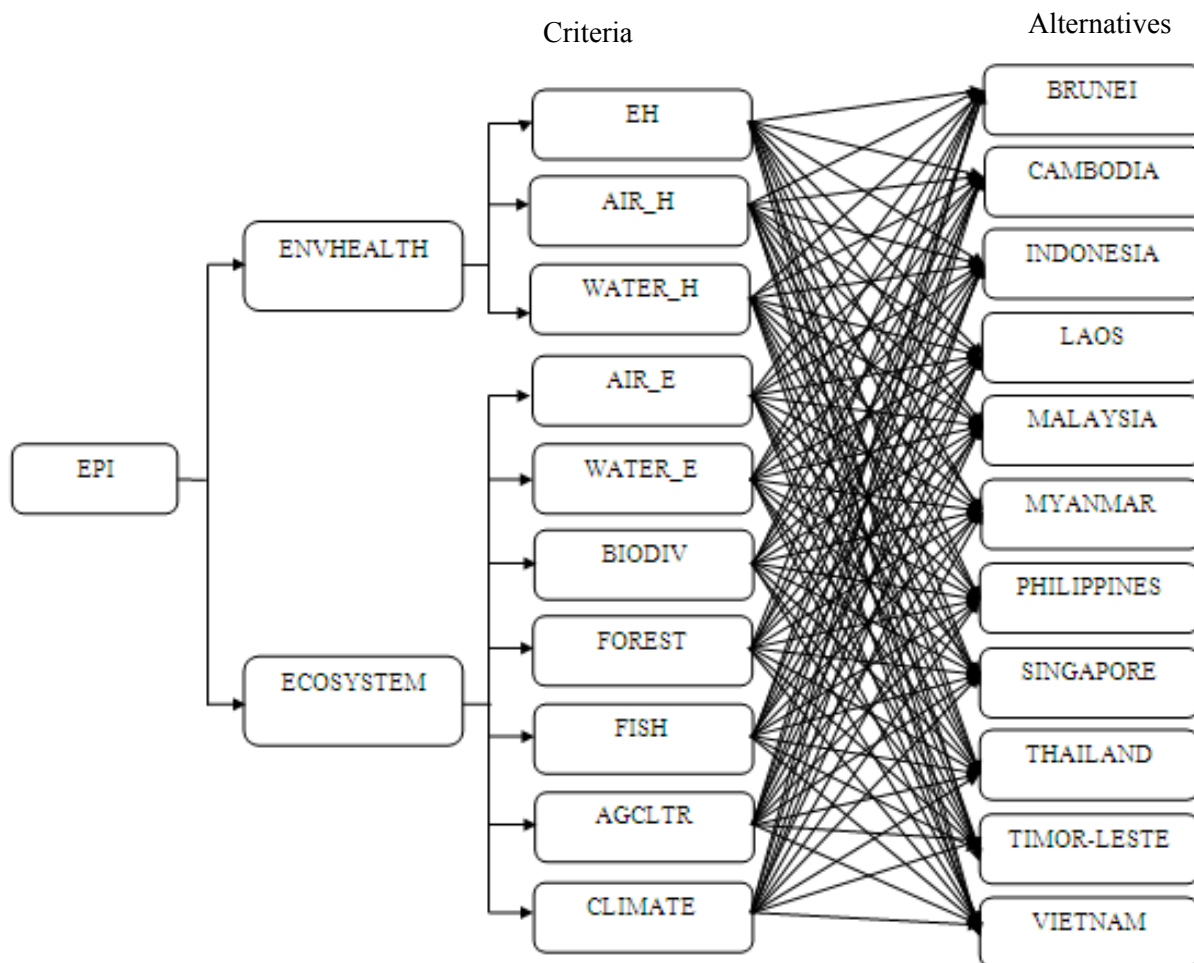
3 Problem Solution

The EPI for Southeast Asia countries are ranked using the IVIF TOPSIS. Southeast Asia countries $A_i, (i = 1, \dots, 11)$ are taken as the feasible alternatives in this study. The alternatives (countries) are A_1 Brunei, A_2 Cambodia, A_3 Indonesia, A_4 Laos, A_5 Malaysia, A_6 Myanmar, A_7 Philippines, A_8 Singapore, A_9 Thailand, A_{10} Timor-Leste, and A_{11} Vietnam. The ten main criteria, $C_i, (i = 1, \dots, 10)$ are C_1 DALY, C_2 AIR_H, C_3 WATER_H, C_4 AIR-E, C_5 WATER_E, C_6 BIODID, C_7 FOREST, C_8 FISH, C_9 AGCLTR, and C_{10} CLIMATE. A committee of three decision makers D_1, D_2 and D_3 was created and requested to rate the alternatives

against the criteria using a linguistic judgment. The three decision makers (DMs) comprise two environmental officers attached to Department of Environment Malaysia, and a Municipal Council respectively, and an academician attached to a public university in Malaysia.

Decision hierarchical structure is constructed based on the interconnected relationship between the selected countries (alternatives) and the evaluation criteria. The structure is presented in Figure 1.

Figure 1 Decision hierarchical structure



The three DMs were invited to assess the importance of the criteria and also to rate the alternatives with respect to each criterion. Linguistic weighting variables and linguistic rating variables are shown in Table 1 and Table 2 respectively.

Table 1. Linguistic weighting variables

Linguistic terms	IVIFNs
Extremely important (EI)	$([1.00, 1.00], [0.00, 0.00])$
Very important (VI)	$([0.80, 0.90], [0.05, 0.10])$
Important (I)	$([0.65, 0.75], [0.10, 0.20])$
Medium (M)	$([0.45, 0.55], [0.35, 0.45])$
Unimportant (U)	$([0.25, 0.35], [0.55, 0.65])$
Very Unimportant	$([0.00, 0.10], [0.80, 0.90])$

Source: Izadikhah [21]

Table 2. Linguistic rating variables.

Linguistic terms	IVIFNs
Extremely good (EG)/ Extremely high (EH)	$([1.00, 1.00], [0.00, 0.00])$
Very very good (VVG)/ Very very high (VVH)	$([0.80, 0.90], [0.05, 0.10])$
Very good (VG)/ Very high (VH)	$([0.70, 0.80], [0.05, 0.10])$
Good (G)/ High (H)	$([0.60, 0.70], [0.15, 0.20])$
Medium good (MG)/ Medium high (MH)	$([0.50, 0.60], [0.25, 0.30])$
Fair (F)/ Medium (M)	$([0.40, 0.50], [0.35, 0.40])$
Medium bad (MB)/ Medium low (ML)	$([0.30, 0.40], [0.45, 0.50])$
Bad (B)/ Low (L)	$([0.15, 0.25], [0.55, 0.60])$
Very bad (VB)/ Very low (VL)	$([0.00, 0.10], [0.70, 0.75])$
Very very bad (VVB)/ Very very low (VVL)	$([0.00, 0.10], [0.85, 0.90])$

Source: Izadikhah [21]

Linguistic data were used as input data to the method. After executing a five-step computation (Section 2.1), the final scores of EPI are obtained.

Table 3 shows the final values of EPI for alternatives.

Alternatives	Distance IVIIF PIS	Distance IVIFS PIS	EPI
A_1	0.0739	0.2141	0.7434
A_2	0.1928	0.0953	0.3308
A_3	0.1529	0.1351	0.4691
A_4	0.1400	0.1481	0.5141
A_5	0.0568	0.2313	0.8028
A_6	0.1427	0.1454	0.5047
A_7	0.1238	0.1642	0.5701
A_8	0.1057	0.1824	0.6331
A_9	0.1178	0.1702	0.5910
A_{10}	0.2438	0.0449	0.1555
A_{11}	0.1349	0.1531	0.5316

Higher EPI values reflect the better alternative. The result shows that A_5 Malaysia is the best EPI among Southeast Asia countries followed by A_1 Brunei. A_8 Singapore is the next best performer after Malaysia and Brunei. The worst performer out of eleven countries is A_{10} Timor-Leste.

4 Discussion

The IVIF TOPSIS method for developing environmental performance index has several distinctive characteristics. The IVIFS TOPSIS method encompasses at least three characteristics in which all characteristics are meant to deal with incomplete and vague data. The method was supported by previous theories where interval-valued intuitionistic fuzzy set was purposely invented to handle vagueness, imprecision and uncertainty [22]. Therefore, the first characteristic in terms of the method is the use of linguistic terms, where the assessment was made in interval values. The three memberships of the IFS are the second characteristic entails in the method used. Membership degree, non-membership degree and hesitation degree of IVIFS are completely taken care of all linguistic data during the assessment process. The third characteristic in terms of the method used in this paper is the TOPSIS. The TOPSIS is known as the fundamental method in decision making approach where decisions are made

through the proportion of distance measures. The performance assessment process has five steps where the first step begins with a linguistic assessment by decision makers and the final step ends with the values of closeness of coefficients. These values represent the single measure of environmental performance index. In the case of Southeast Asia countries, the assessment method successfully identified Malaysia, Brunei and Singapore as the three best performers in the environmental performance index. The performances of Malaysia and Brunei are consistent with the list issued by Emerson et al., [12]. However, In comparison with an entropy weighted based decision method, the result showed Singapore as the best performer followed by Brunei and Malaysia [23]. Despite a minor inconsistency in the final results, the chosen method would be used as an alternative method in determining the score of environmental performances. The inconsistency might occur due to the fact that information gathered from decision makers was based on their beliefs and opinions, where different decision makers may develop different results.

5 Conclusion

An important element in environmental assessment is a method which can take into account multiple variables with vague, imprecise and incomplete data. The method should establish a single score

which reflects the contribution of each accounted criteria toward environmental performance index. This paper has employed the IVIF TOPSIS to compute environmental performance score based on decision makers assessments on the criteria and alternatives. The IVIF TOPSIS method provides a systematic structure to process the information required to develop the environmental performance index. It is suggested that a scientific mechanism could be implemented in the future as to test and verify during the process of data gathering. Apart from the distinctive characteristics of the method used in this study, the findings of the case of Southeast Asia countries could be used as a basis for managing an effective environmental criteria toward a better environmental performance. It is also suggested that several other methods could be considered to validate the environmental performance index not only in a specific region, but can also be extended to all countries in the world.

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