Revised Human Development Index

Louangrath, P.I.★

About the author

★Louangrath, P.I. is an Assistant Professor in Business Administration at Bangkok University, Bangkok, Thailand. He could be reached by email at: Lecturepedia@gmail.com

ABSTRACT

This paper is a case study of HDI where the ASEAN countries were used as the subject of analysis and the OECD countries were used as a comparison group. We propose to revise the current human development index. HDI employs three components to measure human development, namely life expectancy, education and the standard of living. Each component is accorded equal weight of 0.33. In light of the current UNDP's sustainable development goals (SDG) detailing 17 factors, HDI becomes out of date and in need of revision. We mapped the current HDI to SDG and found that social governance emerges as the fourth factor in assessing human development. The data used consists of the HDI and SGD reading of 35 countries from the OECD and 10 ASEAN countries. The 17 factors of SDG were scored as binary data (1,0) in order to obtain the probability of the factors fallen into each category of development component. We found that our recalculation of HDI components and their weight to be: life expectancy (0.23), literacy (0.23), per capita GDP (0.25), and social governance (0.29). This finding is an evidence to support the attempt to improve existing literature in HDI studies.

Keywords: Development, HDI, Social governance, sustainable development

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1.0 INTRODUCTION

As a case study, two data sets are presented for analysis, namely HDI data of the ASEAN and OECD countries. The ASEAN data set on HDI was used as the main data set for in-sample hypothesis testing. The OECD data set was used as a comparison group. After having examined the HDI data for both groups, we proposed to re-model HDI in two ways: (i) remodeling HDI under logistic growth function in order for the model to be more reflective of development as a growth process, and (ii) modifying the HDI calculation by incorporating sustainability factors; this modification resulted in the reweighing of the HDI components.

Human Development Index (HDI) is used as the indication for human development. Although commonly used as an indicator for development (Noorbakhsh, 1998), HDI does not

completely reflect the current requirement for human development. For instance, the current practice in assessing human development takes into consideration the idea of sustainability. This is a gap in HDI measurement as evidence by the literature calling for alternative indices: Borda Composite index (Dasgupta and Weale, 1992), Modified HDI (Noorbakhsh, 1996) and Principal Component Analysis (Desai, 1991; and Srinivasan, 1994). Despite many proposed changes to the HDI formulation, the UNDP still use its three components of equal weight (life expectancy, education, and per capita GPD).

This paper addresses HDI problems by addressing HDI in a different context than those discussed by the literature. We urge that HDI be read in the context of the current UNDP's sustainable development goals (SDG). We propose to reclassify human development into two main categories of achievement: individual achievement, (ii) macroeconomic structure conducive to development, and (iii) social governance. The current HDI represents the individual achievement; SDG contributes two additional macro-level factors, namely economy and social governance.

2.0 LITERATURE REVIEW

Human Development Index (HDI) had long been criticized as inadequate indicator for human development. The problem of HDI comes from poor data, wrong indicators, wrong specifications, and redundancy (Kelly, 1991). The problem of poor data may result from data unreliability (Srinivasan, 1994, and Ogwang, 1994) and measurement errors (Aturupane *et al.*, 1994).

The problem of wrong indicators may come from the fact that HDI has only three components as indicators for human development, namely life expectancy, education and per capita income. Other factors that are critical to human development are left out. These factors include (i) civil and political liberties (Hopkins, 1991, Dasgupta, 1993, Atkinson et al., 1997, and Dar, 2004), (ii) inequality (Chowdhury, 1991, Hicks, 1997, and Chatterjee, 2005), (iii) the environment (Paul, 1996, Atkinson *et al.*, 1997, Sager and Najam, 1998, and Dar, 2004), and (iv) education (Kelley 1991).

The problem of wrong specification may have come from *arbitrariness* (Chowdhury, 1991; Hopkins, 1991; Kelley, 1991; Ogwang, 1994; and Sager and Najam 1998), and unfixed goal or moving goal post (Kelley, 1991; Rao, 1991; Tabold-Nübler, 1991; Dasgupta, 1993; McGillivray and White, 1993; Aturupane *et al.*, 1994; Doessel and Gounder, 1994; UNDP, 1994; Paul, 1996; Noorbakhsh, 1998a). The use of equal weights for the three components of HDI also had been criticized as a wrong specification.

This paper addresses these problems by using SDG as additional factors in the measurement of human development. The current HDI emphasizes individual achievement in development without adequate attention paid to the economic and social infrastructures that also contributed to the growth and development of the people. This paper proposes an additional class of indicators, namely social governance. Under SDG, social governance factors include: *reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals*. By adding these two classes of indicators: macroeconomic and social governance to the human development equation, the revised HDI would be more inclusive and complete.

2.1 HDI components and their weight

HDI is an index calculation. Index is the means to quantify trend (Kennedy and Keeping, 1962). In general, an index uses the value of a base-year to track the changes over time. However, in HDI calculation, instead of referencing the current observation to the past value fixed at a referenced period, the target value is used. Thus, HDI is a measure of the present value referenced to an ideal condition by using three indicating values: maximum, minimum and observed value at a given period. The basis for the HDI calculation comes from an index formula:

$$X \text{ index } = \frac{X-a}{b-a} \quad (1)$$

where X = variable whose index is to be determined, a = minimum value and b = maximum value. This method allows the result to be $0 < X < 1$. HDI components are uniformly weighed at 0.33 among life expectancy, education and per capita GDP. The use of equal weight had been criticized as illogical because the three components of HDI may exert different effect intensity on the over all development (Kelly, 1991). The HDI general equation is written as:

$$HDI = 0.33(LEI + EI + GDPI) \quad (2)$$

Life expectancy index is given by: $LEI = (LE - 25)/(85 - 25)$ where LE = life expectancy at birth. The education index is given by: $EI = 0.66ALI + 0.33GEI$ where ALI is the adult literacy rate determined by $ALI = (ALI - 0)/(100 - 0)$ and GEI is the gross enrollment index determine by $GEI = (CGER - 0)/(100 - 0)$. The GDP component of HDI is obtained through:

$$GDP = \left(\log\left(GDP_{pc}\right) - \log(100)\right) \div \left(\log(40,000) - \log(100)\right)$$

Prior literature claimed that there had been data error in HDI. As the result, HDI calculation and classification of countries had been faulty; researchers had recalculated and reclassified countries for their development indication (Wolff *et al*., 2011). The UNDP responded to criticism of the interpretation and use of its HDI classification by reclassifying the level of development labels as: low, medium, and high (Wolf *et al.*, 2011: 843-870). However, this reclassification does not solve the problem since the formula for calculating HDI did not change. Other suggestion includes the argument that the measurement should focus on the development of the individual instead of macro-factor, such as the GDP (Monni and Speventa, 2013: 227-231). This suggestion is also faulty because the development of the individual cannot be divorced from the macro-environment. An individual is a member of a society; changes in that society affects the individual's development. Therefore, a suggestion that HDI should focus on individual development only is faulty.

Despite the correction attempt, the HDI equation remains the same, i.e. consisting of three components of equal weight. Thus, correction attempt had only been superficial. This paper attempts to expand this correction by adding social governance as an additional index component and redistributed the weight for each component.

2.2 UNDP's sustainable development goals (SDG)

Sustainable development means that economic growth must involve "maximizing the net benefits of economic development, subject to maintaining the services and quality of natural resources over time" (Pearce and Turner 1990:24). Writers disagree on what should be included in sustainable development (Redclift, 1993; Sachs, 1999:25; Satterthwaite, 1996:32). The term may be ambiguous (Redclift 1992; Daly 1996; Payne and Raiborn 2001). This ambiguity is reduced into two questions "What should be sustained?" and "What should be developed?" (Kates *et al.* 2008). Sustainability includes economic prosperity, social equity and environmental protection. Under sustainability standard, the current HDI becomes inadequate because life expectancy, education and income look at only individual achievements. Social factors are left out. Under SDG, these social factors may be categorized into a separate category called "social governance." In Table 1, social governance is identified with "1" in column 4.

Table 1: Mapping HDI to SDG factors

Sustainable Development Goals – UNDP Total Factors $n = 17$	Factors*			
	1	2	3	4
No Poverty	1	1	1	
Zero Hunger	1	1	1	
Good Health and Well-being	1	1	1	
Quality Education	1	1	1	
Gender Equality		1	1	
Clean Water and Sanitation	1	1		
Affordable and Clean Energy				1
Decent Work and Economic Growth			1	
Industry, Innovation and Infrastructure			1	
Reduced Inequalities				1
Sustainable Cities and Communities				1
Responsible Consumption and Production				1
Climate Action				1
Life Below Water				1
Life on Land				1
Peace, Justice and Strong Institutions				1
Partnerships for the Goals				1
S	5.00	5.00	7.00	9.00
n	17.00	17.00	17.00	17.00
P	0.32	0.32	0.42	0.53
Q	0.68	0.68	0.58	0.47
weight	0.20	0.20	0.27	0.33
Z	(0.19)	(0.19)	(0.08)	0.03
$F(z)$	0.4013	0.4013	0.4404	0.5120
$W(F(z))$	0.23	0.23	0.25	0.29

*Categories: 1 = life expectancy; 2 = literacy; 3 = per capita GDP; and 4 =social governance.

Social governance factors are identified as: affordable and clean energy; reduced inequalities; sustainable cities and communities; responsible; consumption and production; climate action; life below water; life on land; peace, justice and strong institutions, and partnerships for the goals. These items must be separated from the original three factors used by the UNDP: life expectance, literacy, and per capita income. The proposed revised HDI now has four components including social governance factor. Using the Laplace Rule of Success, the probability of success is calculated by: $p = (s+1)/(n+2)$ where each factor that matches its corresponding category is counted as a "success" and scored as 1, else 0. The probability for each factor in Table 1 is calculated by: $w = p_i / \sum p_i$ or life expectancy (0.20), literacy (0.20), per capita GDP (0.27), and social governance (0.33). The DeMoivre-Laplace Theorem was used to obtain the weight probability for each factor in the following steps: (i) find the standard score Z, (ii) obtain the probability F(Z) for each factor, and (iii) multiply F(Z) by the weighted probability (w) where:

$$Z_i = \lim_{n \to k} \left[\frac{X_n - np}{\sqrt{npq}} \right] \qquad (3)$$

where i are the factors: life expectance, literacy, per capita GDP, and social governance. The factor weight is obtained by:

$$W_{F(z)} = \frac{F(z_i)}{\sum F(z_i)} \tag{4}$$

Using discrete probability to assign the new weight to each component, weighted factors are: life expectancy (0.23), literacy (0.23), per capita GDP (0.25), and social governance (0.29).

3.0 DATA

We tracked the HDI performance along with its components of two groups of countries over a period of 10 years. Secondary data were obtained from Asian Development Bank, UNDP and IMF websites. Although these international organizations are considered trustworthy, some countries have missing data. For instance, literacy rates for many OECD countries are not reported. Thus, when analyzing the OECD countries, the missing literacy rate had been substituted with the group mean. There were 13 OECD countries reported their literacy rates; the mean value for the group is: $\mu \pm \sigma = 97.13 \pm 2.06$. The missing data was replaced with $\mu = 97.13$. Countries not reporting their literacy rate are considered advanced in economic development; therefore, by replacing the missing data with the group mean is reasonable option. For the ASEAN countries, all HDI and its components were available.

Linear regression was used to verify the relationship between HDI and its components. One basic requirement of linear regression is that the residuals must be normally distributed (Stevens, 2009; Tabachnick and Fidell, 2006). Non-normal distributions exists when these data are positively or negatively skewed, contain large kurtosis, or have extreme outliers can distort the obtained significance levels of the analysis, resulting in the standard errors becoming biased (Osborne and Waters, 2002). Kurtosis is the measure of lightness or heaviness of the tail of the distribution curve. A data with heavy tail or high kurtosis contains many outliers and vice versa for lighter tail (Joanes and Gills, 1998). Skewness is the measure of the lack of symmetry (NIST, 2013). A normally distributed data has zero skew. This paper tested the data for skewness and kurtosis because normality is a requirement for linear regression modeling.

Skewness is the measure of the degree of asymmetry of a distribution (Abramowitz and Stegun, 1972; Kenny and Keeping, 1962; and Press *et al.*, 1992). This measure is given by:

$$Skew = \frac{n}{(n-1)(n-2)} \sum \left(\frac{X_i - \bar{X}}{S} \right)^3 \tag{5}$$

Kurtosis is the measure of fourth central moment of the data distribution (Moors, 1986; Press et al., 1992; Ruppert, 1987; and Westfall, 2014); it is given by:

$$KURT = \left(\frac{n(n+1)}{(n-1)(n-2)(n-3)} \sum \left(\frac{X_i - \bar{X}}{S} \right)^4 \right) - \frac{b(n-1)^2}{(n-2)(n-3)} \tag{6}$$

Skewness and kurtosis help to put the data distribution into perspective. The ASEAN country has positive skew for HDI, it means that many countries are lagging behind the expected HDI target. In contrast, OECD countries have negative skew for HDI, it means that OCED countries had predominantly achieving its HDI goal.

For kurtosis analysis, positive kurtosis means that the data distribution has sharper peak (leptokurtic) and higher tails. For HDI analysis, positive kurtosis means that the countries are well-developed or have higher level of HDI. This is true for the OECD countries. In contrast, the ASEAN countries have negative kurtosis or platykurtic signifying a flattened shape of the data distribution.

4.0 METHODOLOGY

For each component of the HDI of the OECD and ASEAN, we subjected it to statistical significance testing by using Pearson 2x2 table (Pearson, 1904: 21). The rationale for this test is to verify the significance of the contribution of each component to the HDI measure.

4.1 Statistical test of HDI component in 2x2 table

According to UNESCO's literacy rate report, the global mean is 86.10. This number is used as the threshold value. For remaining two components, life expectancy and GDP, we use the group's average as the threshold. The 2x2 table is used for frequency analysis and tested under chi squared for significance level (Kanji, 2006:85; and Pearson, 1904:21). In this case, we are counting the frequency of corresponding two factors using the mean value as the threshold to categorize success and failure. The chi square test for 2x2 table is given by:

$$\chi^2 = \frac{(n-1)(ad-bc)^2}{(a+b)(a+c)(b+d)(c+d)} \tag{7}$$

Among the 10 countries in ASEAN, there are two countries that show the correspondence of high per capita income to longevity; no country shows the correspondence of short life expectancy with high per capita GDP. There were three countries that have low per capita income, but high life expectancy. As developing economies, the ASEAN countries have predominantly low per capita income and have shorter life expectancy. Five countries fit this low-low description for life expectancy and per capita income.

Table. 1: Chi Square test under 2 x 2 table for life expectancy and per capita GDP

$\chi^2(obs) = 0.36$	High per capita GDP	Low per capita GDP
Long life expectancy	*2*	*3*
Short life expectancy	*0*	*5*

In the comparison of *per capita income to literacy rate*, we found that only two countries with high per capita GDP have a corresponding high rate of literacy. No country with high income has a corresponding low literacy. In the low-low matching, there are two countries that have low per capita GDP and low literacy rate.

Table. 2: Chi Square test under 2 x 2 table for per capita GDP and life expectancy

$\chi^2(obs) = 0.56$	High per capita GDP	Low per capita GDP
Literacy	*2*	*6*
Illiteracy	*0*	*2*

The observed chi square for ASEAN literacy rate and per capita GDP is $\chi^2 = 0.56$ compared to the theoretical value of $\chi^2 = 3.80$. There is no significant correlation between adult literacy and per capita GDP in the ASEAN countries. The argument that high literacy rate contributes to higher level of per capita GDP is not true in the ASEAN countries. The effect may be secondary, but not direct.

There are five countries in the ASEAN that shows long life expectancy and high literacy rate. Three countries show long life expectancy with low literacy rate. The result of the chi square test from the 2x2 table shows that there is no statistical significance in the incidence of literacy and life expectancy: $\chi^2(obs) = 0.00$

Table. 3: Chi Square test under 2 x 2 table for life expectancy and literacy

$\chi^2(obs) = 0.00$	Long life expectancy	Short life expectancy
Literacy	*5*	*0*
Illiteracy	*3*	*0*

4.2 Social governance factor under SDG

The UNDP listed 17 factors for sustainable development. In this paper, we propose to incorporate these factors into the HDI equation. The current HDI has already incorporate 8 of 17 sustainability factors. We proposed to treat the remaining nine factors by using discrete probability as adjusting coefficient. Using the Laplace rule of success, the 8 factors that are now in the current HDI has a probability of success by: $p = (s+1)/(n+2)$ where $n = 17$ and $s = 7$; the probability of success $p = 0.47$ is and failure $q = 0.53$. In the modification in section 4.3, we will incorporate p and q into the logistic function.

4.3 Revised development index model

The current HDI measurement is an index. As an index, it allows us to read the developmental level as a point in space. It could not allow is to forecast; in order to forecast, we need series of observations from past years and fit the data into a prediction model. In this paper, we proposed to use 10 years of prior HDI data and fit the data into the logistic function. We opt for a logistic function because development should be seen as growth and, thus, must obey growth path as provided by a sigmoid function. This approach is consistent with the tracking of the index over time and the value moves asymptotically to 1. For this reason, linear regression would not be an appropriate model. The general logistic function is given as:

$$Y = \frac{1}{1 + e^{-(a+bX)}} \tag{8}$$

where the term $a + bX$ is the linear equation for the HDI values for the country over a period of 10 years (see Table 10).

If equation (8) represents the growth function for the HDI series, we would adjust the proposed model by incorporated the remaining 9 factors that are absent from HDI calculation. These 9 factors are: *affordable and clean energy, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals*.

5.0 FINDINGS AND DISCUSSION

There are some differences in the development pattern between the ASEAN countries and the OECD. Whether this difference is a result of policy design or emphasis we could not speculate. However, the difference between these two groups allows us to see where group country benefits most from development.

Table 4. Basic data testing of HDI variable components 2017

Component	OECD		ASEAN	
Variables: HDI	Skewness	Kurtosis	Skewness	Kurtosis
Life expectancy	(1.02)	(0.16)	0.54	4.10
Literacy rate	(2.47)	5.44	(1.68)	1.37
Per capita GDP	0.93	1.12	2.10	(0.13)
HDI	(1.35)	2.05	0.45	(0.67)

Table 4 shows the difference in developmental tendency between the ASEAN and the OECD. Under kurtosis analysis, ASEAN countries shows excess kurtosis in life expectancy ($Kurt = 4.10$) compared to the OECD with excess kurtosis in literacy rate ($Kurt = 5.44$). This difference in kurtosis indicates where the two groups benefited most from development. The over-all data distribution for the OECD is beta as indicated by negative skewness. Beta distribution means that the longer tail of the distribution curve is dragging in the left quadrant; this signifies that the majority of the population has accumulated to the right of the curve, as indicated by higher developmental stage of the OECD countries. This fact is contrasted with the ASEAN's skewness of 0.45 indicating that the majority of the data is located to the left of the curve and a small number of data is slanted to the right of the distribution curve. This positive skew indicates that the ASEAN countries are still improving.

We provide an overall picture of HDI for the OECD and ASEAN countries by testing the intra-group significance. This intra-group significance test allows us to see which countries are significantly low and high in each variable: life expectancy, literacy rate, per capita GDP and HDI.

Table 5: HDI for OECD and ASEAN countries, 2017.

Country Group	Life Expectancy	Adult Literacy	Per capita GDP	HDI
OECD	79.11	97.13	38,171.60	0.89
ASEAN	72.04	91.94	11,709.20	0.71

Use OECD as the standard, by employing the Z equation to see difference between ASEAN and OECD, the significant difference between the OECD and ASEAN could be tested.

Table 6: OECD and ASEAN comparison

	Life	Literacy	GDP	HDI
OECD	79.11	98.78	38,171.60	0.89
S	2.62	91.94	11,709.20	0.71
ASEAN	72.04	1.30	21,741.66	0.04
Z	(2.70)	(5.25)	(1.22)	(4.08)
Z*	1.65	1.65	1.65	1.65
Conclude	Significant	Significant	Not significant	Significant

For the OECD countries, the significant high and low had been tested for intra-group studies. Among 35 countries in the OECD, four countries have significantly low life expectancy (Estonia, Hungary, Latvia and Slovakia Republic). There are three countries showing significantly low literacy rate in the group; these countries were Mexico, Portugal, and Turkey. For per capita income, one country has significantly high (Louxembourg). Finally, two countries show a significant low HDI (Mexico and Turkey). The actual values of life expectancy, per capita GDP and GDI appear in Appendix 1. Note that adult literacy rate is not available for the OECD countries.

Table 7: OECD intra-group significance test under standard score method; $n = 35$

OECD Country	Life Expectancy	Literacy Rate	Per capita GDP	HDI 2017
Australia	0.91 *	0.32	0.62	1.18
Austria	0.53	0.32	0.45	0.13
Belgium	0.26	0.32	0.15	0.20
Canada	0.61	0.32	0.10	0.74
Chile	(0.12)	(1.13)	(0.62)	(0.91)
Czech Republic	(0.69)	0.32	(0.90)	(0.21)

Denmark	(0.12)	0.32	0.69	0.86
Estonia	**(1.99)**	0.79	(0.93)	(0.51)
Finland	0.30	0.32	0.16	0.18
France	0.80	0.32	0.14	0.22
Germany	0.42	0.32	0.14	0.88
Greece	0.34	(0.83)	(0.93)	(0.48)
Hungary	**(2.02)**	0.25	(1.17)	(1.16)
Iceland	0.84	0.32	1.14	0.77
Ireland	0.30	0.32	1.28	0.81
Israël	0.76	0.32	0.04	0.27
Italy	0.91	0.33	(0.35)	(0.01)
Japan	1.37	0.32	0.01	0.36
Korea	0.30	0.32	(0.42)	0.31
Latvia	**(1.88)**	0.86	(1.10)	(1.30)
Luxembourg	0.57	0.32	**3.04**	0.24
Mexico	(1.45)	**(3.36)**	(1.39)	**(2.85)**
Netherlands	0.46	0.32	0.30	0.83
New Zealand	0.49	0.32	(0.09)	0.63
Norway	0.57	0.32	1.62	1.40
Poland	(1.34)	0.79	(1.17)	(0.73)
Portugal	0.07	**(2.60)**	(0.85)	(1.01)
Slovak Republic	**(1.64)**	0.63	(1.00)	(0.96)
Slovenia	(0.12)	0.71	(0.79)	0.06
Spain	0.80	(0.52)	(0.53)	(0.07)
Sweden	0.88	0.32	0.62	0.58
Switzerland	1.18	0.32	1.84	1.18
Turkey	**(2.10)**	**(2.90)**	(1.25)	**(2.87)**
United Kingdom	0.23	0.32	0.26	0.49
United States	(0.46)	0.32	0.88	0.74
Mean	*79.11*	*98.78*	*38,171.60*	*0.89*
S	*2.62*	*1.30*	*21,741.66*	*0.04*

*Reported as $Z = (x_i - \bar{x}) / S$ for year ending 2017; the theoretical value is $Z^* = 1.65$. The observed values may be found in Index 1. **For OECD countries without literacy rate data, the group mean of 97.13 was used as a substitute.

In general, the standard score test for the ASEAN countries show that there is one country (Singapore) with significantly high life expectancy; two countries with significantly low literacy rate (Cambodia and Laos); one country (Singapore) has significantly high per capita GDP; and one country (Singapore) has significantly high HDI.

Table 8: ASEAN intra-group significance test under standard score method;* $n = 10$

ASEAN Country:	Life Expectancy	Literacy Rate	Per capita GDP	HDI 2017
Brunei	0.96	0.62	1.08	1.26
Cambodia	(0.98)	**(2.05)**	(0.59)	(1.16)
Indonesia	(0.35)	0.27	(0.44)	(0.15)
Laos	(1.20)	**(1.67)**	(0.54)	(0.98)
Malaysia	0.51	0.37	(0.05)	0.65
Myanmar	(1.16)	0.16	(0.58)	(1.22)
Philippines	(0.30)	0.61	(0.48)	(0.21)
Singapore	**1.92**	0.68	**2.46**	**1.74**

Thailand	0.37	0.66	(0.33)	0.26
Vietnam	0.21	0.36	(0.53)	(0.20)
Mean	*72.04*	*91.94*	*11,709.20*	*0.71*
S	*5.56*	*7.20*	*17,728.13*	*0.12*

* $Z = (x_i - \bar{x}) / S$ for year ending 2017; the theoretical value is $Z^* = 1.65$.

The HDI intra-group analysis tells us that among the OECD countries, the dispersion is only 0.04. The small dispersion implies that there is a greater degree of uniformity among group members. In development analysis, this small dispersion measurement evidenced that the level of development the OECD members is quite uniform. In contrast, table 8 shows greater diversity of development among the ASEAN member countries. Where the standard deviation for the over all HDI in the OECD is 0.04, the ASEAN shows three times that much.

5.1 HDI modeling in OECD and ASEAN countries

As a group, the HDI data for the OECD was subjected to multiple regression testing. The literacy rate was removed due to missing data. The regression of HDI against life expectancy and per capita GDP shows that $HDI = -0.80 + 0.27X_{life} + 0.05X_{gdp}$ and ANOVA F test shows $F(34,34) = 55.85$ compared to the theoretical value of $F^* = 1.85$. The coefficient of determination of $R^2 = 0.7773$ where $R^2 = 1 - (SSE / SST)$.

Among the ASEAN countries, multiple regression of HDI against its three components: life expectancy, literacy and per capita income, shows that the relationship is $Y_{hdi} = -2.83 + 0.58X_{life} + 0.12\,\mathrm{X}_{lit} + 0.06_{gdp}$. The significance of the model was tested under ANOVA. The ANOVA F test shows $F = 386.20$ compared to the theoretical value at (9,9) degrees of freedom $F^* = 3.18$. Under the conventional model evaluation tool, HDI is a significant model. The coefficient of determination is $R^2 = 0.99$.

5.2 Revised HDI by incorporating social governance as the fourth component

The current HDI index models development as a linear function. We argue that development is non-linear. At some point development would starts to marginalize similar to the behavior of marginalization under utility function. Human development is akin to "growth." As such, we proposed a sigmoid function as a model for human development. This proposed sigmoid function uses the HDI as the variable x in the sigmoid function:

$$\hat{D} = \frac{1}{1 + e^{-x}} \qquad (9)$$

where $x = HDI^*$ or revised HDI to accommodate sustainability factors. The modified HDI is obtained by: $HDI^* = HDI + (\sigma_1 X_1 + \sigma_2 X_2)$. The terms σ_1 and σ_2 are coefficient for macroeconomic conditions conducive to growth (X_1) and good governance factor (X_2). Both X_1 and X_2 are necessary for sustainability.

Since development is a continuous process with asymptotic effect when the development reaches a saturation point ($0 < x < 1$), the probability and distribution functions are given as:

$$P(X) = \frac{e^{-(x-m)/s}}{s\left[1 + e^{-(x-m)/s}\right]^2} \qquad (10)$$

$$D(X) = \frac{1}{1 + e^{-(x-m)/s}} \tag{11}$$

where the mean: $\mu = m$, variance: $s^2 = 0.33\left(s^2\pi^2\right)$, skewness: $\gamma_1 = 0$ and kurtosis: $\gamma_1 = 1.20$.

By tracking the HDI values for each country in the ASEAN over a period of 10 years, we are able to present the developmental pattern under the sustainable development index: $\hat{D}$. With its corresponding PDF and CDF, we are able to assess each country's human development under the sigmoid function. This finding is the first of its kind and we assert this is a contribution to the field.

Table 9. Sustainable HDI under $\hat{D}$ method for ASEAN in 2017

ASEAN Country:	HDI_{2017}	$\hat{D}$	$PDF_{\hat{D}}$	$CDF_{\hat{D}}$	$HDI - CDF_{\hat{D}}$
Brunei	0.865	0.41	0.98	0.85	0.02
Cambodia	0.563	0.41	1.76	0.36	0.20
Indonesia	0.689	0.41	1.86	0.59	0.10
Laos	0.586	0.41	1.84	0.40	0.19
Malaysia	0.789	0.41	1.41	0.76	0.03
Myanmar	0.556	0.41	1.74	0.34	0.22
Philippines	0.682	0.41	1.87	0.58	0.12
Singapore	0.925	0.41	0.70	0.90	0.03
Thailand	0.740	0.41	1.66	0.68	0.06
Vietnam	0.683	0.41	1.87	0.58	0.10
Mean	*0.71*			*0.60*	*T = 4.44*
S	*0.12*			*0.20*	

In Table 9, the HDI for all ASEAN ranges from 0.556 (Myanmar) to 0.925 (Singapore). This number is based on the UNDP calculation. The calculation is based on the tracking of year-to-year HDI index. Under our proposed new HDI calculation under the logistic growth function, the inflated HDI in Table 9 is adjusted and presented in Table 10. Under the logistic function modeling, each country had been tracked over a period of 10 years and each country's HDI trend line $HDI_{1988-2017}$ is represented by the linear equation: $Y_{hdi} = a + bX$. This linear equation is then used to calculate $\hat{D}$ and $CDF_{\hat{D}}$ for each country. The expected value for each country's HDI is the mean of ten years of $\hat{D}$ or $\bar{D} = 1/n\sum\hat{D}_i$ and the achieved HDI under logistic function is given as the mean CDF or $\overline{CDF_{\hat{D}}}$. Although this new calculation does not change the country's HDI ranking, the revised HDI is more reflective of reality in each country. The new reading for development index is $CDF_{\hat{D}}$, The original HDI is inflated. The adjusted HDI is 0.11 points lower. We tested the significance of the difference between the old and new HDI and found that the difference between the two columns ($HDI - CDF_{\hat{D}}$) are significant: $T = 4.44$.

Table 10. Sustainable HDI in ASEAN under logistic growth model

ASEAN Country:	$HDI_{1988-2017}$	$\bar{D}$	$\overline{PDF_{\hat{D}}}$	$\overline{CDF_{\hat{D}}}$	Above/below Mean ± S
Brunei	$x = -0.15 + 0.03X$	0.50	0.98	0.83	Above
Cambodia	$x = -0.64 + 0.12X$	0.49	1.76	0.30	Below
Indonesia	$x = -0.39 + 0.07X$	0.49	1.86	0.53	Within

Laos	$x = -0.56 + 0.10X$	0.49	1.84	0.33	Below
Malaysia	$x = -0.25 + 0.05X$	0.49	1.41	0.72	Within
Myanmar	$x = -0.61 + 0.12X$	0.49	1.74	0.29	Below
Philippines	$x = -0.39 + 0.04X$	0.49	1.87	0.54	Within
Singapore	$x = -0.09 + 0.06X$	0.50	0.70	0.86	Above
Thailand	$x = -0.31 - 0.06X$	0.49	1.66	0.63	Within
Vietnam	$x = -0.40 + 0.09X$	0.49	1.87	0.51	Within
	Mean	*0.49*		*0.55*	
	S	*0.004*		*0.21*	
	Mean + S	*0.494*		*0.76*	
	Mean - S	*0.486*		*0.34*	

Table 10 provides a clearer picture for the ASEAN countries through the average CDF as a measure of sustainable development; the range of $\overline{CDF}\,\hat{D} \pm S$ is $0.34 < \overline{CDF}\,\hat{D} < 0.76$. If a country's mean CDF is below 0.34, it means that the country's HDI performs less than the group's acceptable range. If the country's mean HDI's CDF is larger than 0.76, it means that the country outperforms the group's mean. For the ASEAN group, Brunei and Singapore are two countries with probability for high HDI above the group mean. Three countries had been identified as below acceptable range of development; these countries are Cambodia, Laos, and Myanmar. The remaining countries: Indonesia, Malaysia, Philippines, Thailand, and Vietnam fall within the range of expected HDI. Thus, by using the range $0.34 < \overline{CDF}\,\hat{D} < 0.76$, the ASEAN could be identified into three HDI groups: below, within, and above the range.

6.0 CONCLUSION

The goal of this paper is to present a modified HDI by incorporating the UNDP's sustainability factors into the existing HDI equation. Ten ASEAN countries were used as a subject group in a case study. Thirty-five OECD countries were used as a comparison group. We proposed to modify the calculation of HDI to include sustainability factors. As the result the weight for each component for the modified equation is recalculated. The recalculation of HDI components and their weight tare: life expectancy (0.23), literacy (0.23), per capita GDP (0.25), and social governance (0.29). An additional finding made in this paper is the reclassification of the ASEAN countries on the basis of sustainable HDI through the use of CDF after incorporating sustainability factors. Three countries had been identified as not meeting sustainability goal when sustainability factors are incorporated into HDI equation. These three countries are Cambodia, Laos, and Myanmar. Two countries had exceeded sustainability goal, namely Brunei and Singapore. The remaining five countries: Indonesia, Malaysia, Philippines, Thailand, and Vietnam are within sustainable HDI target.

In light for the UNDP's drive towards achieving Sustainable Development Goals (SDG), it is recommended that the current HDI formula be revised to include sustainable development factors; these factors are taken from SDGs announced by the UNDP: *reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals*. In this paper, we categorized these SDG factors as "social governance." We proposed that the revised HDI equation to consist of: (i) life expectancy, (ii) literacy, (iii) per capita GDP, and (iv) social governance.

Additionally, we recommend that where countries are grouped into an economic region, such as the OECD or ASEAN, intra-group and inter-group benchmarking could also be made in order to affect comparison study. To illustrate the benefit of this intra-group benchmarking, this paper uses ASEAN as a case study where the 10 ASEAN countries are reclassified into three groups according to their sustainable HDI performance based on the past 10 years data. By so doing, we discovered that there are three categories: (i) below the range, within the range, and above the range

of sustainable HDI. This type of information may be beneficial to stakeholders in development policy implementation and assessment.

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APPENDIX

Appendix 1: HDI and its three components in OECD countries as a group in 2017

OECD Country	Life Expectancy	Literacy Rate	Per capita GDP	HDI 2017
Australia	81.50	Not report*	51,593	0.939
Austria	80.50	Not report	47,856	0.893
Belgium	79.80	Not report	41,491	0.896
Canada	80.70	Not report	40,409	0.920
Chile	78.80	97.3	24,797	0.847
Czech Republic	77.30	Not report	18,534	0.878
Denmark	78.80	Not report	53,242	0.925
Estonia	73.90	99.8	17,891	0.865
Finland	79.90	Not report	41,690	0.895
France	81.20	Not report	41,181	0.897
Germany	80.20	Not report	41,267	0.926
Greece	80.00	97.7	17,901	0.866
Hungary	73.80	99.1	12,767	0.836
Iceland	81.30	Not report	63,000	0.921
Ireland	79.90	Not report	66,000	0.923
Israël	81.10	Not report	39,125	0.899
Italy	81.50	99.2	30,507	0.887
Japan	82.70	Not report	38,281	0.903
Korea	79.90	Not report	29,114	0.901
Latvia	74.19	99.9	14,187	0.830
Luxembourg	80.60	Not report	104,359	0.898
Mexico	75.30	94.4	7,993	0.762
Netherlands	80.30	Not report	44,654	0.924
New Zealand	80.40	Not report	36,254	0.915
Norway	80.60	Not report	73,450	0.949
Poland	75.60	99.8	12,722	0.855
Portugal	79.30	95.4	19,707	0.843
Slovak Republic	74.80	99.6	16,412	0.845
Slovenia	78.80	99.7	21,061	0.890
Spain	81.20	98.1	26,643	0.884
Sweden	81.40	Not report	51,603	0.913
Switzerland	82.20	Not report	78,179	0.939
Turkey	73.60	95	11,014	0.761
United Kingdom	79.70	Not report	43,902	0.909
United States	77.90	Not report	57,220	0.920

*Literacy rate is obtained from UNESCO compilation. Many of OECD countries does not report literacy rate.

Appendix 2: HDI and its components for ASEAN as a group in 2017

ASEAN Country	Life Expectancy	Literacy Rate	Per capita GDP	HDI 2017
Brunei	77.40	96.40	30,933	0.865
Cambodia	66.60	77.20	1,308	0.563
Indonesia	70.10	93.90	3,895	0.689
Laos	65.40	79.90	2,051	0.586
Malaysia	74.90	94.60	10,756	0.789
Myanmar	65.60	93.10	1,374	0.556
Philippines	70.40	96.30	3,280	0.682
Singapore	82.70	96.80	55,252	0.925
Thailand	74.10	96.70	5,938	0.740
Vietnam	73.20	94.50	2,305	0.683