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Sustainable Development Index: A Dashboard to Measure a Country's Resilience

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KEYWORDS Economic. Environmental. Social. Technological. Institutional. Indicators

ABSTRACT Indicators are being created to assess the sustainability of corporates, countries and industry, energy. The review of the literature indicated indices are based on three criteria namely economic, environmental and social. With the advancements in technology and the role of governance increasing it is being felt that in addition to the three criteria, technology and institutional also has an important role in sustainable development. In this research, the importance of the criteria is determined using the analytical hierarchical process. The importance of the indices is also determined using an expert opinion survey. It is also found that environmental and social are very important criteria as opined in the green and institutional theory. Among the indices, it is found that increased GNI per capita, reduced CO_2 emission, reduced GINI index, and increased renewable energy consumption are some of the important indices that need to be focused upon for improving sustainability.

INTRODUCTION

Assessing the sustainable development of a country is very challenging. The concept is multidimensional with numerous proposed definitions. Sustainable development is defined as the development that caters to the needs of the present generation without jeopardizing the requirements of the future generations. Living on this planet earth, without causing any harm to the environment is the central principle of sustainable development. Sustainable development tries to maximize economic growth without causing much damage to the environment (Cairns et al. 2019). It is hence expected that there is a strong link between economic development and environmental sustainability (Cairns and Martinet 2014; Fleurbaey 2015). Sustainable development strives to create a balance between the two, without compromising the needs of future generations. Thus, ecologically sustainable economic development entails that the natural resources be it energy or material should be sufficient to support the present economic development as well as pave way for the future developments (Bithas and Nijkamp 2006).

Suffice it to say, sustainable development does not stop here. It also involves a social dimension which needs to be balanced along with economic and environmental sustainability. Only when the basic needs of human beings and their aspirations for a good quality of life are met the real objective of sustainability is supposed to have been attained. Thus social dimension is also very important while assessing sustainability (Hou et al. 2019; Rasouli and Kumarasuriyar 2016). In recent times, with digitization taking the lead, institutions need to be tech savvy to keep themselves abreast with the changing needs. It thus becomes imperative to include both technical and institutional criteria while measuring sustainability.

The sustainability development index must be in a position to

i. Evaluate the sustainability of a country in a systematic scientific manner
ii. Identify the critical factors which are the strengths for a country as well as the weak factors
iii. Assist policy makers and planners in framing policies, strategies and action plans for inclusive governance and sustainability
iv. Ensure all stakeholders (including the future generations) are taken care of in a holistic manner

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Objectives

The objectives of this research are to identify the criteria as well as their importance for sustainable development. Secondly, to identify the indices and their weights to measure the overall sustainable development of a country.

Literature Review

It pays to be green theory, postulate that the intangible value created by voluntary initiatives such as new capabilities, improved reputation, and access to knowledge and eco-friendly measures help to achieve sustainability. Indices will act as a tool to assess if the country is moving towards sustainable development.

A review of the literature was carried out to find the various indices being used to determine sustainable development. To achieve sustainable development, the most important resources to be assessed are the availability of food, energy, and water. Ozturk (2015) have highlighted the importance of food-water-energy nexus in the measurement of sustainable development. The researcher has used dynamic panel modeling in generalized method of moments to measure food, water, and energy sustainability. The research revolves only around economic and environment contexts. Karan et al. (2018) have built a sustainable food-energy-water systems using stochastic approach. Ozturk (2017) have investigated the relationship between agricultural sustainability and food-water-energy in Sub-Saharan African countries. Similarly, Schlor et al. (2018) have also stressed the important role of food, energy, and water in measuring sustainability. They have developed a propensity index to measure a city's sustainability by integrating infrastructure development and environmental sustainability. They have stressed the importance of infrastructure development along with the environment to provide for food, energy, and water to the city's inhabitants. In all these researches, it was found that sustainability is being looked at from the resource point of view. Though economic and environmental dimensions have only been addressed in these researches, it is expected that resource sustainability will ensure the social dimension. Hake et al. (2016) state that ethical dimension has to be included in sustainability index assessment while considering the food, energy, and water in addition to climate change, public health challenges, and pollution. The review highlights that in addition to economic and environmental dimension, it is essential to also consider the social and ethical dimension in the measurement of sustainability.

Cucchiella et al. (2017) have evaluated the sustainability performances of European countries from energy and environmental perspectives. They have used multiple indexes dealing with energy, greenhouses gases, governmental expenditure for environmental protection, recycled materials usage, renewable energy to name a few. Kilkis (2016) have found energy, water and environment system sustainable development index for southeast European cities. Both the studies focus on energy sustainability with the conjecture that the social dimension is also included along with environmental sustainability in the energy consumption component. However, the economic dimension needs to be included. This is to ensure there is an equitable cross flow of goods and services happening in a sustainable manner because of trading across nations for better standard of living. The research highlighted that social, economic and environmental dimensions are very essential for sustainability.

Considering the importance, researchers have assessed the sustainability in the three dimensions social, economic and environmental in four Chinese cities (Dijk and Mingshun 2005). Similarly, Sun et al. (2010) have assessed the sustainability of various regions in China using a multilayer index system considering the social, economic and environmental dimension. Several indices such as per capita GDP, telephones per 1000 people, per capita public finance expenditure, and population growth rate have been used to determine sustainability. However, is the three dimensions sufficiently capturing all aspects in terms of sustainability need to be investigated?

Researchers have developed indices to measure corporate sustainability. Orsato et al. (2015) have proposed a corporate sustainability index (CSI) for businesses. Based on interviews with experts, they have identified the following to contribute to CSI – ease of generating funds, reputation, and competitive advantage, knowledge

sharing about social and environmental issues. However they have concluded that estimating the parameters in terms of cash flow, costs and benefits is a very difficult task. They suggest that researchers need to do more research in this domain. Spangenberg (2016) has proposed a corporate human development index to assess corporate social sustainability.

On the same line of thought, not only for corporate sustainability, De Carvalho (2011) propose a sustainable human development index that includes social, economic and environmental indices to measure sustainability. On the same lines, Biggeri and Mauro (2018) have stated that human development index is the best index for measuring sustainability. They have integrated environment and freedom and have stressed on the importance of environment in their research. They have put humanity and its common future as the core of sustainability. Similarly Zhou et al (2018) have done a meta-analysis on sustainable development and have stressed that environmental sustainability is the core of all sustainability. It is being purported by several researchers that social, economic and environmental dimensions are essential even in the measurement of corporate sustainability.

On the same lines, Garcia et al. (2016) have used a multi-criteria decision model to generate a corporate sustainability index for a Brazilian electricity corporation. Buys et al. (2014) have created a sustainability scorecard for the dairy industry. They have used a Bayesian network to assess sustainability. It is found that all the sustainability indices measurements carried out for corporates or for industries follow the triple bottom line criteria namely economic, environmental and social.

Another line of measuring sustainability was using emergy accounting approach. Giannetti et al. (2010) have used the emergy accounting method to determine sustainability index for Mercosur nations. Again though they have followed a unique approach, the themes considered were the only economic, environmental and social dimension. They have calculated the indices using emergy yield ratio, emergy investment ratio, environmental load ratio, and environmental sustainability index. The same approach has been used by Hossaini and Hewage (2013) for measuring sustainability in various provinces of Canada, by Sun et al. (2016) to measure the sustainability of Shenyang, by Winfrey and Tilley (2016) to assess waste treatment systems. Liu et al. (2016) have assessed the economic and environmental performance through emergy sustainability indicators. They stress the importance of preservation of the natural environment. They have concluded that indicators capable of highlighting this should be developed. All these research stress the need for environmental sustainability as the backdrop for social and economic sustainability.

Furthermore, Frugoli et al. (2015) have compared emergy indices with ten other indices namely GDP, GDP per capita, Democracy Index, Environmental Sustainability index, Ecological footprint, Surplus biocapacity, Wellbeing Index, Human Development Index, Life expectancy and Happiness Index. Correlation analysis has been done. They conclude that socio-economic and biophysical indicators must be considered to arrive at a correct measure of sustainability. Their research highlighted there could be certain other aspects which is gaining prominence in recent years that leads to sustainable development. Concurrently, Giannetti et al. (2015) in their review of literature have corroborated that economic indices being used do not make a holistic evaluation of every aspect. Either economic profits from natural, social and human capital are considered without due credence to the biospheres. For instance the damage caused post-fossil fuel utilization. Their research highlighted that the alternative indices that captures the technological change need to be included and the indices selected should be easy to measure and quantifiable.

Lee and Huang (2007) have developed a sustainability index for Taipei. They have identified 52 indicators to measure the sustainable development for Taipei. They have considered four criteria namely economic, environmental, social and institutional. They have concluded that transparency in governance is very important along with the environmental policies and resource management strategies. This indicated that in addition to the social, economic, environmental dimension, other dimensions also contribute towards sustainable development.

Camagni et al. (1998) have examined the sustainability of a city using economy, environment,

and technology. The review also indicated that the calculation of these indices is a cumbersome process involving in some cases experimental data. It was found that the units of measure were different and arithmetically summating may not result in a precise index. Also, researchers have indicated that with the recent knowledge explosion, the sharing of resources is also very essential. This indicates that technology, as proposed by Camagni et al. (1998), is yet another dimension that needs to be sustainable during the coming years. From the review of literature, it is found that for measuring sustainability encompassing, in today's globalized context, it is essential to measure sustainability from five dimensions namely economic, environmental, social, technological and institutional. Indices for these five dimensions have also been identified for framing a sustainability index dashboard.

METHODOLOGY

The research is carried out in two stages.

Identification of Criteria and Prioritization of Criteria Using AHP

The criteria are identified for sustainable development from the review of the literature. Determining the importance of criteria is very crucial in the measuring of sustainability index. Hence Analytic Hierarchy Process (AHP) was used to prioritize the criteria. Pairwise comparison of the criteria (Appendix 1) was carried out as suggested by Saaty (1994) and Saaty and Vargas (2001). The steps used to find the relative importance of the criteria are given below:

Step 1: An n × n matrix is set up for n variable

Step 2: For all the n variables, comparison matrix is determined

Step 3: The comparison matrix is used to find the priority matrix. This priority matrix gives the eigenvalues of the criteria.

Step 4: The judgment error is measured by calculating the Consistency Index (CI) of the comparison matrix, and then by calculating the Consistency Ratio.

- CI: The CI is the first indicator of result accuracy of the pairwise comparisons. It is calculated as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where λ_{max} denotes the maximum principal eigenvalue of the comparison matrix. The closer the value of λ_{max} to n (the number of variables), the smaller the judgmental errors and thus more consistent is the result.

- Consistency Ratio (CR): It is used to check the accuracy of the pairwise comparison

$$CR = \frac{CI}{CR}$$

where, RI is the consistency indices of randomly generated reciprocal matrices from scale 1 to 9 (Saaty 1980).

If the Consistency Ratio is less than 0.1 it is considered to be ideal. Using the results of AHP, the important variables are shortlisted and taken for further analysis.

Identification of Indices for the Criteria and Measurement of the Importance of Criteria

Based on the review of literature, the indices for the criteria are identified. The importance of criteria is determined by distributing the indices to experts. The seven experts were again approached and were requested to kindly fill the importance of each index in terms of percentage.

A framework is then proposed on the calculated ratio of sustainability index. It is suggested that min-max normalization can be used to standardize the indices in the range of 0 to 1. Using the weights for each criterion from the AHP technique and the importance of the criteria, it is proposed that the sustainability index can be calculated.

RESULTS

Identification and Prioritization of Criteria Using Analytic Hierarchy Process (AHP)

From the review of literature, it is found that the majority of researchers have adopted economic, environmental and social as the major themes determining sustainable development. However few researchers have stressed that institutional support is also required for sustainable development.

However, considering the technological explosion happening globally, be it for a higher quality of life or ease in working, technology has taken the front seat in all spheres. Hence it

is important that technology is another emerging theme which needs to be included for sustainable development.

In this research, it is hence postulated that sustainable development has the following criteria

i. Economic- ensuring good stability in terms of monetary and non-monetary reserves
ii. Environment- safeguarding the environment for the present generation as well as for the future generations
iii. Social- equitable provision for social cohesion among every human being living on the planet earth belonging to different countries, race, gender and groups
iv. Institutional - provide political support to all with participative decision making
v. Technological - providing innovative futuristic technology to match the advances in science

Thus for sustainable development in all the five dimensions, policies must be framed to achieve the following:

- integrate all the objectives of the five dimension
- introduce standard policies for distributional justice to all strata of individual
- include the present and the future generation

Tradeoffs may happen to achieve the above objectives. Sustainable development requires identifying the parameters to be considered under each of the five themes which will lead a country towards sustainability. Integration of all themes is realized to lead a country towards sustainable development where seven experts were identified. The experts who participated in the study were from an academic and industrial background. The questionnaire was administered to the seven experts. The details of experts are as follows: Organization: Academic – 4 nos, Industry – 3 nos; Experience: 0 – 10 years -2 nos, 11-20 years -3 nos, 21-30 years -2. AHP analysis was carried out for each expert. The steps carried for one expert is explained in the following sections.

Step 1: The 5 criteria in the rows and columns of 5 X 5 matrix is set up as per AHP procedure for expert1 to find out the relative value.

Step 2: For all the criteria, pairwise comparisons are performed. The comparison matrix for the criteria of expert 1 is given in Table 1.

Table 1: Paired comparison matrix

Variables	*ECO*	*ENV*	*SOC*	*INT*	*TEC*
ECO	1.000	0.250	0.333	1.000	0.500
ENV	4.000	1.000	1.000	4.000	1.000
SOC	3.000	1.000	1.000	2.000	2.000
INT	1.000	0.250	0.500	1.000	1.000
TEC	2.000	1.000	0.500	1.000	1.000

Step 3: The sum of the 5 columns (column sum) in the comparison matrix is calculated. Next, each element in the matrix is divided by the sum of the column. Finally, the sum of each row is determined as a row sum.

The sum of the rows is normalized by dividing each row sum with the total number of variables. The result of this computation is known as the *priority matrix* and is an estimation of the eigenvalues of the matrix.

$$\textit{Priority matrix} = \begin{bmatrix} 0.464358 \\ 1.575613 \\ 1.444300 \\ 0.605267 \\ 0.910462 \end{bmatrix} = \begin{bmatrix} 0.092872 \\ 0.315123 \\ 0.288860 \\ 0.121053 \\ 0.182092 \end{bmatrix}$$

Step 4: Consistency Index (CI) is now calculated. To find CI, λ_{max} need to be calculated. To calculate λ_{max} ,

i. product matrix = Comparison matrix × priority matrix
ii. the sum of the product matrix (5 x 1) gives λ_{max}

$\lambda_{max} = 5.1783$

Consistency Index (CI) = 0.044593

To find out if the resulting consistency index (that is, CI = 0.044593) is acceptable, it is necessary to calculate the Consistency Ratio (CR). RI is 1.12 for 5 variables from the Random Consistency Index table (Saaty 1980). Therefore, the Consistency Ratio (CR) is

$$\text{Consistency Ratio (CR)} = \frac{\text{CI}}{\text{CR}} = \frac{0.044593}{1.12} = 0.39815$$

As a general rule, a Consistency Ratio of 0.10 or less is ideal (Saaty 1980). The above procedure is repeated for all the seven experts and their Consistency Index and Consistency Ratio values for the five criteria are given in Table 2.

Table 2: Consistency Index and Consistency Ratio values

Expert's opinion	*Consistency index*	*Consistency ratio*	*Status*
1	0.044593	0.039815	Acceptable
2	0.094429	0.084312	Acceptable
3	0.065161	0.05818	Acceptable
4	0.110164	0.098361	Acceptable
5	0.104231	0.093063	Acceptable
6	0.159876	0.142747	Not Acceptable
7	0.241946	0.221946	Not Acceptable

The eigenvalues of the five experts whose values were within 0.1 were selected and the average was then calculated. The values are given in Table 3. The findings of the AHP analysis revealed that environmental is the most important criteria followed by social, economic, institutional and technological.

Identification of Indices for the Criteria and Measurement of the Importance of Criteria

The review of literature helped in identifying the indices for the various criteria. The weights of the indices obtained from the selected five experts were considered for calculating the overall weights of the indices The list of indices along with their weights are given in Table 4.

As the indices are of different units, the values need to be standardized. Min-max normalization needs to be carried out so that the indices are between the value 0 to 1. Further, in some case higher the value better is the index, the value may be used as such. In cases wherein, lesser the value of the index better it is, a transformation may be carried out using $Y^{*}= 1-Y$. After normalization and transformation, the value must be multiplied by their weights to arrive at the criteria index. The sustainable development index for a country may then be calculated using the following function.

Sustainable development index = 0.1487 (Economic index) + 0.3122 (Environmental index) + 0.2749 (Social index) + 0.1081 (technological index) + 0.1561 (institutional index)

DISCUSSION

The AHP revealed that economic, environmental, social, technological and institutional constituents are important criteria that need to be considered for sustainable development. Among the criteria, it is found that the environment is most important with 31.22 percent. This is closely followed by social index with 27.49 percent. The results support green theory which suggests that benefits will outweigh the costs incurred towards green practices (Ji et al. 2017). Also, it confirms institutional theory which postulates that schemes, rules, and procedures become established as authoritative guidelines for social behavior (Scott 2004). The importance of human development is brought out by the social index which has been confirmed in the research carried out by Biggeri and Mauro (2018). The economic index was found to have an importance of 14.87 percent. The research highlighted that for sustainable development because of technological innovations and digitization being witnessed in all spheres, it has become imperative to include institutional and technological dimensions in the measurement of sustainability. The contribution from these two dimensions was found to be 26.42 percent.

Further, a list of indices have been identified and their weights determined. It is found that increased GNI per capita, decreased energy imports, increased food production index and reduced unemployment is very important towards measuring economic index. The total weights from these four indices along are 74 percent. Care has to be taken that these four indices are

Table 3: Eigenvalues for the criteria

S. No.	*Criteria*	*Expert 1 eigenvalue*	*Expert 2 eigenvalue*	*Expert 4 eigenvalue*	*Expert 5 eigenvalue*	*Average eigenvalue*
1	Economic	0.0929	0.1356	0.1179	0.0857	0.1487
2	Environmental	0.3151	0.3623	0.2074	0.3644	0.3122
3	Social	0.2889	0.3623	0.4103	0.2087	0.2749
4	Technological	0.1211	0.0535	0.0754	0.1506	0.1081
5	Institutional	0.1821	0.0863	0.1891	0.1906	0.1561

Table 4: List of indices with their weights

Indices		*Weights*	
Economic			
eco1	GNI per capita	higher better	22
eco2	Labor force total	higher better	5
eco3	Food production index	higher better	18
eco4	Livestock production index	higher better	5
eco5	Unemployment, total	lesser better	14
eco6	Electric power consumption	lesser better	8
eco7	Energy intensity level of primary energy	lesser better	8
eco8	Energy imports	lesser better	20
		Subtotal	100
Environmental			
env1	Water productivity	higher better	20
env2	Disaster risk reduction	higher better	10
env3	Access to clean fuels and technologies for cooking	higher better	6
env4	CO_2 emission	lesser better	40
env5	Annual freshwater withdrawals, total	lesser better	10
env6	Bird species threatened	lesser better	4
env7	Plant species threatened	lesser better	4
env8	Fish species, threatened	lesser better	3
env9	Mammal species, threatened	lesser better	3
		Subtotal	100
Social			
soc1	Life expectancy at birth total	higher better	5
soc2	People using at least basic sanitation services	higher better	15
soc3	GINI index	lesser better	30
soc4	Population density	lesser better	15
soc5	Poverty headcount ratio	lesser better	5
soc6	Cause of death by injury	lesser better	5
soc7	Current health expenditure per capita	lesser better	10
soc8	Urban population growth	lesser better	7
soc9	School enrollment, primary and secondary gender parity index	lesser better	8
		Subtotal	100
Technology			
tec1	Access to electricity	higher better	15
tec2	Individual using the internet	higher better	10
tec3	Secure internet servers	higher better	7
tec4	Fixed broadband subscribers	higher better	5
tec5	Fixed telephone subscribers	higher better	8
tec6	Mobile cellular subscribers	higher better	15
tec7	Renewable energy consumption	higher better	40
		Subtotal	100
Institutional			
ins1	Government expenditure on education, total	higher better	15
ins2	Total reserves	higher better	10
ins3	Tech coop grants	higher better	7
ins4	Investment in ICT with private partnership	higher better	8
ins5	Investment in energy with private partnership	higher better	10
ins6	Investment in transport with private partnership	higher better	12
ins7	Investment in water and sanitation with private partnership	higher better	8
ins8	People using at least basic drinking water services	higher better	10
ins9	Total debt service	lesser better	15
ins10	Vulnerable employment	lesser better	5
		Subtotal	100

improved upon for economic sustainability. In the case of the environment, it is found that reduced CO_2 emission is the most important index followed by increased water productivity, reduced disasters, and reduced freshwater withdrawals. The above four indexes contribute 80 percent towards environmental sustainability. In the case of a social index, it is found that the

lesser GINI index is very important. This is followed by lesser population density, higher access to a sanitation facility, lesser expenditure towards health issues. Together it is found that the above four indices contribute 70 percent towards social sustainability. In the case of technology, the utilization of renewable energy is said to contribute the maximum to technological sustainability. This is followed by higher access to electricity, higher mobile cellular subscribers and higher individuals using the internet facility. The total contribution from these four indices is 80 percent towards technological sustainability. In the case of institutional sustainability, indices namely higher expenditure on education, lesser debt, higher investment in transport, energy, higher reserves, higher availability of drinking water services contribute 72 percent.

The analysis reveals the important indices that needs attention for achieving sustainable development. Policy makers and planners need to identify measures and implement them to become sustainable. It requires a concerted effort from all stakeholders namely, the public, the consumers, the global society in addition to the policymakers and researchers.

CONCLUSION

As an emerging field, sustainability measurement has its own challenges such as developing uniform standards and metrics across borders and systems. Distinct research has been done in various fields for measuring sustainability. However, they are yet to be collated and standardized. The review highlighted the growing interests and concerns in this area. It is found that all the five criteria namely environmental, social, economic, technological and institutional need to be sustainable for a country to grow holistically. Among the five dimensions, it is found that the environmental and social dimension are very important. The indices and their relative importance have also been identified for each of these criteria using expert judgment method. Furthermore, among the indices, it is found that reduction in CO_2 emission and reduced GINI index is very important for sustainable development. The research provides a dashboard which can be easily used for measuring the sustainability index. Policymakers can design policies and strategies keeping the importance of the criteria and indices.

RECOMMENDATIONS

The research results in the following recommendations: Firstly, among the criteria identified for the sustainability index, it was found that environmental index have to be given importance and hence it is recommended that all societal advancements and economic developments need to focus on environmental sustainability ensuring there is reduction in CO_2 emission. Secondly, it is recommended that social sustainability should ensure that human sustainability is given its due importance by ensuring GINI index is minimized. Thirdly, it is recommended that future research can be undertaken to validate the framework by measuring sustainability in the various dimensions using the indices identified.

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APPENDIX

1 - Prioritization of criteria using AHP

SCALE: 5 point scale used for evaluating criteria

Intensity of importance	*Definition*	*Explanation*
1	Equal importance	Two criteria contribute equally to the objective
2	Weak importance of one over another	Experience and judgment slightly favor one criterion over another
3	Weak importance of one over another	Experience and judgment strongly favor one criterion over another
4	Very strong importance	The criterion is strongly favored and its dominance is demonstrated in practice
5	Absolute importance	The evidence favoring one over another is of the highest possible order of affirmation

INSTRUCTIONS

While doing a pairwise comparison between two criteria- say economic (L.H.S.) and environment (R.H.S), when you put "X" under 2 on L.H.S towards criteria economic, it means criteria 'economic' is twice as important than 'environment' in influencing sustainable development.

Importance of criteria for sustainable development

Indicators	*Rating*									*Indicators*
	5	*4*	*3*	*2*	*1*	*2*	*3*	*4*	*5*	
Economic										Environment
Economic										Social
Economic										Institutional
Economic										Technological
Environment										Social
Environment										Institutional
Environment										Technological
Social										Institutional
Social										Technological
Institutional										Technological