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Research Note

Application of Data Envelopment Analysis in Identifying Milestones for Passenger and Freight Transportation Sustainability

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This study is an attempt to quantify the concept of sustainable transportation. The countries are comparatively studied using a pioneer measure for Sustainable Development (SD) and elasticity, that reflects the conformity and harmony of the growths of all sectors with passenger and freight transportation. Firstly, the elasticity of the non-transportation variables, with respect to passenger and freight transportation ones, were developed. Using individual elasticities, composite sustainability indices were suggested. Then, utilizing the Data Envelopment Analysis (DEA) technique, two composite indices, as well as the national variables, are employed to achieve a unique SD efficiency score. Country groupings, based on composite indices, were developed for comparative appraisal. The methodology may be applied to any other time and geographic scope for addressing pertinent issues for the balancing and SD of transportation systems.

INTRODUCTION

Transportation plays a key role in economic and social development. Nevertheless, it has many spillover effects such as congestion, safety, pollution and non-renewable resource depletion. Undoubtedly, the prevailing concern during the last forty years has been the undesirable socio-environmental impact of economic growth. The publication of "Our Common Future", known as the Brundtland Report, introduced Sustainable Development (SD) as a key concept, addressing the intimate relationship between economic activity and ecology. The Brundtland Report acknowledges that the basic needs of all people should be met with due consideration of future generations [1-3]. The concept of sustainable transportation is derived from these concerns that imply the movement of people and goods in ways that are environmentally, socially and economically sustainable [4-6].

Transportation, in a comprehensive view, can be classified into passenger and freight. These categories have different operational and functional characteristics, as well as dissimilar problems regarding sustainability objectives. This is why the study has focused on these two categories of transportation. The study objective is to quantify and to address passenger and freight transportation sustainability through an international comparative assessment.

DATA ENVELOPMENT ANALYSIS

Data Envelopment Analyses (DEA) is a methodology that has been used to evaluate the efficiency of entities (e.g., programs, organizations etc.), known as Decision-Making Units (DMUs), which are responsible for utilizing resources to obtain outputs of interest [7]. Different models have been proposed in the context of DEA [7-9]. In this study, an input-oriented, Variable Return to the Scale (VRS) model is chosen for the analysis [8].

If a given DMU, A, is capable of producing $Y(A)$ units of output with $X(A)$ inputs, then, other DMUs should also be able to do the same if they were to operate efficiently. Similarly, if DMU, B, is capable of producing $Y(B)$ units of output with $X(B)$ inputs, then, other DMUs should also be capable of the same production schedule. DMUs can then be combined to form a composite DMU. Since this composite DMU does not necessarily exist, it is called a virtual DMU

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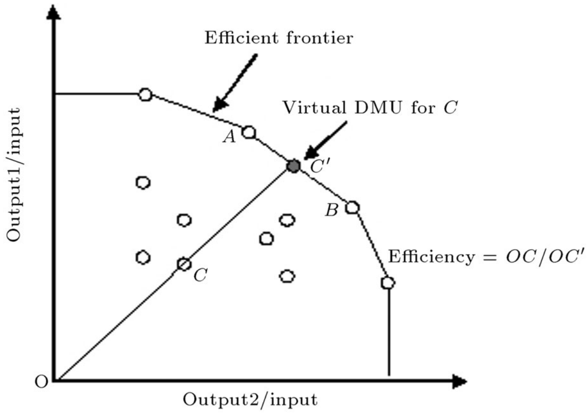

Figure 1. A simple case of the efficient frontier with respect to two outputs and one input.

(see Figure 1). The procedure of finding the best virtual DMU can be formulated as a linear program. Analyzing the efficiency of n DMUs is then a set of n linear programming problems. The following formulation is one of the standard forms for DEA:

$$\min \theta$$

$$\text{s.t.} \sum_j \lambda_j y_{jn} \geq y_{j_0 n} \qquad n = 1, 2, \cdots, N,$$

$$\sum_j \lambda_j x_{jm} \leq \theta x_{j_0 m} \qquad m = 1, 2, \cdots, M,$$

$$\lambda_j \geq 0 \qquad j = 1, 2, \cdots, J,$$

$$\sum_j \lambda_j = 1 \qquad j = 1, 2, \cdots, J, \tag{1}$$

where x_{jm} is the mth input of the jth DMU, y_{jn} is the nth output of the jth DMU, θ is the efficiency of each DMU, λ_j is the model variables representing the weight of each DMU, i.e., the percentages of other DMUs used to construct the virtual DMU and j_0 identifies the DMU under study. The first constraint forces the virtual DMU to produce at least as many outputs as the studied DMU. The second constraint finds out how much less input the virtual DMU would need. The factor used to scale back the inputs is θ and this value is the efficiency of the DMU. It should be emphasized that an LP of this form must be solved for each of the DMUs.

STUDY FRAMEWORK

Figure 2 shows the framework based on which the study was performed. It is an attempt to achieve a unique sustainability index from raw data reported annually for the countries. The main idea behind these steps is to find milestones for passenger and freight transportation SD. One way to perform a comparative macroscopic assessment of passenger and freight transportation at the national level from the Economic, Environmental and Social (EES) perspectives, is the redefining of the popular term "sustainable development" as "harmonic development", because consistency among the changes of all these three aspects, as well as public and private transportation, would, naturally, cause SD. In other words, when a country grows in the economic sector only and diminishes in other dimensions, such as environment, it is not encouraging sustainability, but, when it flourishes in all aspects simultaneously and

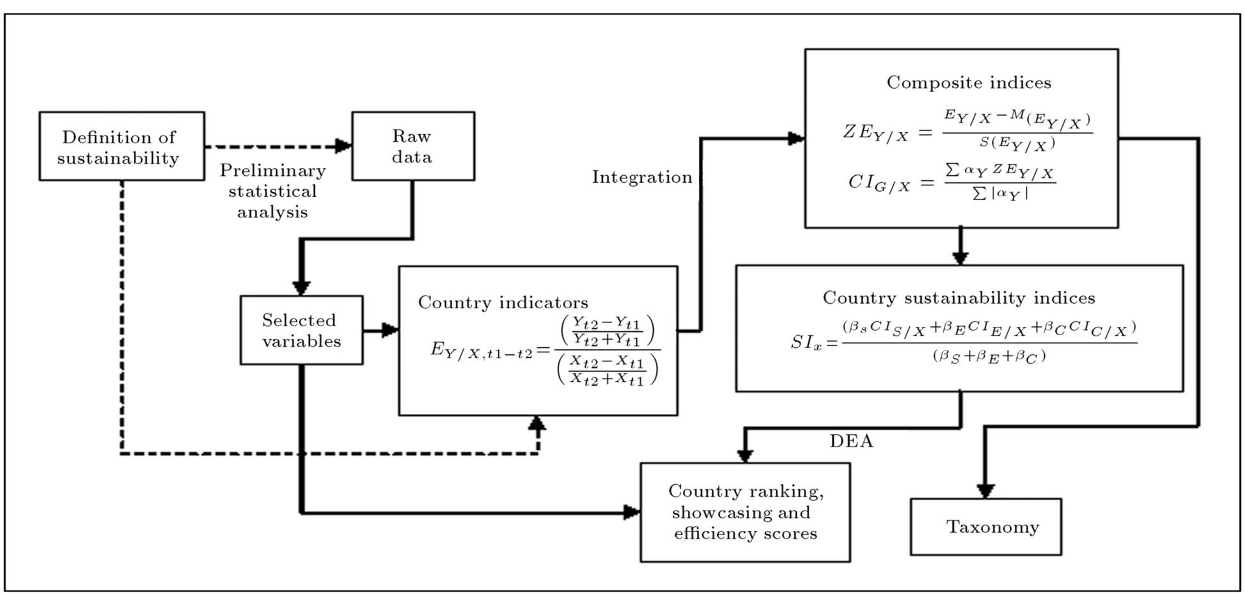

Figure 2. The framework of the study.

harmonically, it could be considered as a country with SD. Therefore, in order to assess sustainability comparatively, elasticities of EES variables, with respect to passenger or freight transportation variables, were computed.

DATABASE

The national variables were collected from centralized available databanks [10-12]. In order to make the final database of the study as integrated as possible, the country values for each variable were mostly selected from only one databank. The selected 116 countries covered all five continents and met minimum data requirements. They were 28 in Europe, 29 in Asia, 23 in America, 31 in Africa and 5 in Oceania. The final database was comprised of 15 variables in the transportation group and 6 variables for each of the three groups of EES and for the period from 1980-1995. Table 1 shows the final study database structure and variables.

ANALYSIS

The arc elasticity, E, of a variable, Y, with respect to a variable, X, for the period $t1-t2$ reflects that the percent variable, Y, changes with respect to one percent change of the variable X, as is shown by the following equation:

$$E_{Y/X,t1-t2}=E_{Y/X}=\frac{\left(\frac{Y_{t2}-Y_{t1}}{Y_{t2}+Y_{t1}}\right)}{\left(\frac{X_{t2}-X_{t1}}{X_{t2}+X_{t1}}\right)}, \tag{2}$$

where $E_{Y/X,t1-t2}$ is the arc elasticity of variable Y with respect to variable X during the period $t1$ to $t2$. For each country, based on non-missing values, a maximum of 270 elasticities for the period from 1980-1995 were computed. For Equation 2, Y's were 18 non-transportation variables listed in Table 1 and X's were passenger or freight variables. Each country was characterized by a profile consisting of 270 measures hinting at different dimensions for SD with respect to the 21 transportation variables.

The individual elasticities were aggregated for a single overall measure that contained information from all dimensions. To make elasticities comparable, Z scores were computed by the following equation:

$$ZE_{Y/X}=\frac{E_{Y/X}-M(E_{Y/X})}{S(E_{Y/X})}, \tag{3}$$

where $ZE_{Y/X}$ is the Z score of the $E_{Y/X}$ and M and S are functions that provide the mean and the standard deviation of their arguments, respectively. The composite index, CI, for each of the social, environmental and economic groups, was computed using the Z scores:

$$CI_{G/X}=\frac{\sum \alpha_Y ZE_{Y/X}}{\sum |\alpha_Y|}, \tag{4}$$

where $CI_{G/X}$ is the composite index of group G, either social, S group, environmental, E group, or economic, C group, with respect to transportation group X, either passenger, P, or freight, F. α_Y's are coefficients that are +1 for elasticities with a desirable positive sign and -1 for those with a desirable negative sign, when Y variable is SAIR, ECEU, ETEU, ECO2, CTEX, CCIN and CTCN and $|\alpha_Y|$ is the absolute value of α_Y. To develop an overall sustainability index, EES composite indices were again aggregated as the following weighted combination:

$$SI_X=(\beta_S CI_{S/X}+\beta_E CI_{E/X}+\beta_C CI_{C/X}) /(\beta_S+\beta_E+\beta_C), \tag{5}$$

where SI_X is the sustainability index of transportation group X and β_C, β_E, and β_S are the weighting factors of EES dimensions, respectively. Table 2 shows the results of the above-mentioned computations, using equal weighting factors, $\beta_S=\beta_E=\beta_C$. Based on Z score computation and usages, as reflected by Equation 3, the negative values for a sustainability index should be interpreted in the context of comparative assessment.

In the context of SD, the larger composite index values reflected comparatively preferred overall EES developments with respect to transportation development. Countries with higher indices are comparatively more sustainable. Countries with high scores can be used as showcases for good practice and experience sharing. For sustainability indices, with respect to passenger transportation, SIT_{PAS}, and with respect to freight transportation, SIT_{FRT}, 53 and 91 countries showed negative values, respectively. 44 countries showed negative values for both SIT_{PAS} and SIT_{FRT}. The highest SI values of both passenger and freight transportation belonged to Denmark. The lowest SI values from passenger and freight transportation were for the Bahamas and Latvia, respectively.

DEA is then utilized to achieve an overall score for each country. In this study, countries are DMUs, the database variables in the year 1980 are inputs and two composite indices are outputs. The computed scores reflect the countries' performances, with respect to passenger and freight transportation sustainability, and, thus, are an index of comprehensive sustainability.

Table 3 shows the results of DEA for the selected countries (DMUs). The column titled "score" in the table shows the efficiency scores of countries (values

Table 1. Description and structure of the database variables.

Variable	Category	Description	Dimension
FITA	Freight, air	International total tons-kilometers	Millions
FTTA	Freight, air	Total tons-kilometers	Millions
FTKR	Freight, rail	Railway ton-km	Million ton-km
FNGR	Freight, rail	Number of goods wagons	#
FGTH	Freight, road	Goods transported	Million ton-km
FCVH	Freight, road	Commercial vehicles in use	Thousand units
FGLS	Freight, sea	Goods loaded internationally-sea-born	Million ton
FGUS	Freight, sea	Goods unloaded internationally-sea-born	Million ton
FMSS	Freight, sea	Total merchant shipping fleets	Thousand gross
PIPA	Passenger, air	International passenger kilometers	Millions
PTPA	Passenger, air	Total-passenger kilometers	Millions
PPKR	Passenger, rail	Passengers - kilometers	Million
PNPR	Passenger, rail	Number of passenger coaches	#
PNBH	Passenger, road	Number of buses and coaches	1000 #
PPCH	Passenger, road	Passenger cars in use	Thousand units
SLEX	Social	Life expectancy	Years
STLF	Social	Total labor force	Thousand persons
SUPN	Social	Urban population	% Total population
SSWR	Social	Safe water	% Population with access
SHBD	Social	Hospital beds	Per thousand people
SAIR	Social	Adult illiteracy rate	% People age 15+
EALD	Environmental	Arable land	Thousand hectares
ECEU	Environmental	Commercial energy use	Tons
ETEU	Environmental	Total energy use	Thousand tons
ELAR	Environmental	Land area	Thousand hectares
ECO2	Environmental	CO2 emissions	Thousand tons
ETEP	Environmental	Total energy production	Thousand tons
CTEX	Economic	Total expenditure	% GDP
CGDP	Economic	GDP	Million US$
CCIN	Economic	Consumer inflation consumer prices	Annual %
CIPM	Economic	Interest payments	% total expenditure
CTCN	Economic	Total consumption	Million US$
CTML	Economic	Telephone mainlines	Per thousand people

Table 2. Sustainability indices.

No.	Country	SI_{TPAS}	SI_{TFRG}	No.	Country	SI_{TPAS}	SI_{TFRG}
1	Afghanistan	-0.07	-0.13	41	Finland	-0.08	-0.05
2	Albania	-0.01	-0.03	42	France	0.08	-0.02
3	Algeria	-0.24	-0.19	43	Gabon	0.07	0.03
4	Angola	0.01	-0.20	44	Germany	-0.03	-0.03
5	Argentina	0.10	0.36	45	Ghana	0.04	0.02
6	Australia	-0.01	-0.06	46	Greece	0.02	-0.02
7	Austria	-0.01	0.01	47	Guatemala	0.04	-0.07
8	The Bahamas	-1.04	-0.06	48	Hong Kong	-0.13	-0.32
9	Bahrain	0.01	-0.03	49	Hungary	0.04	-0.01
10	Bangladesh	0.03	-0.04	50	Iceland	-0.04	-0.05
11	Belgium	-0.04	-0.03	51	India	-0.01	-0.04
12	Benin	0.06	-0.05	52	Indonesia	0.01	-0.07
13	Bhutan	0.04	-0.11	53	Iran	0.00	0.00
14	Bolivia	-0.23	-0.04	54	Ireland	-0.03	0.11
15	Botswana	-0.07	-0.11	55	Italy	-0.01	-0.04
16	Brazil	0.00	-0.02	56	Jamaica	0.00	-0.07
17	Bulgaria	0.07	-0.08	57	Japan	0.02	-0.04
18	Burkina Faso	0.00	0.01	58	Jordan	0.02	0.01
19	Burma	-0.02	-0.09	59	Kenya	0.01	-0.05
20	Burundi	-0.06	0.00	60	South Korea	0.03	0.03
21	Cameroon	0.16	0.14	61	Kuwait	0.00	0.16
22	Canada	-0.01	-0.01	62	Laos	0.04	-0.06
23	Cape Verde	0.05	-0.03	63	Latvia	0.05	-0.46
24	Chad	0.07	-0.04	64	Lebanon	0.07	0.14
25	Chile	0.00	0.34	65	Lesotho	-0.07	0.40
26	China	0.00	-0.03	66	Luxembourg	-0.01	-0.05
27	Colombia	0.02	-0.07	67	Malaysia	0.01	-0.05
28	Comoros	-0.09	0.00	68	Maldives	-0.01	-0.05
29	Republic of Congo	-0.02	-0.31	69	Malta	0.00	-0.07
30	Costa Rica	0.00	-0.07	70	Mauritania	0.04	-0.09
31	Cote d'Ivoire	0.03	-0.12	71	Mauritius	-0.02	-0.06
32	Cyprus	0.00	-0.05	72	Mexico	0.04	0.02
33	Czech Republic	0.04	-0.02	73	Morocco	0.01	0.01
34	Denmark	0.24	0.66	74	Nepal	0.00	-0.04
35	Dominican	-0.03	-0.13	75	Netherlands	0.17	-0.11
36	Ecuador	0.02	-0.06	76	New Zealand	-0.02	-0.03
37	Egypt	0.02	-0.04	77	Nicaragua	-0.11	-0.12
38	El Salvador	0.01	-0.08	78	Niger	-0.09	0.24
39	Ethiopia	-0.04	-0.02	79	Nigeria	-0.07	0.07
40	Fiji	0.01	-0.03	80	Norway	-0.25	-0.03

Table 2. Continued.

No.	Country	SI_{TPAS}	SI_{TFRG}	No.	Country	SI_{TPAS}	SI_{TFRG}
81	Oman	0.01	-0.10	99	Swaziland	0.03	-0.07
82	Pakistan	-0.01	-0.05	100	Sweden	-0.13	-0.15
83	Panama	-0.01	-0.11	101	Switzerland	-0.04	-0.06
84	Papua New Guinea	0.03	0.03	102	Tajikistan	0.03	0.00
85	Paraguay	0.01	-0.04	103	Tanzania	0.03	-0.12
86	Peru	0.04	-0.11	104	Thailand	-0.05	-0.11
87	Philippines	0.01	-0.09	105	Trinidad and Tobago	-0.15	-0.08
88	Poland	0.00	-0.05	106	Tunisia	0.04	-0.01
89	Portugal	-0.01	-0.08	107	Turkey	0.02	-0.08
90	Qatar	0.03	-0.11	108	Uganda	-0.04	-0.10
91	Romania	-0.01	-0.12	109	United Arab Emirates	-0.01	-0.12
92	Russia	0.01	0.03	110	United Kingdom	-0.04	-0.14
93	Saudi Arabia	0.03	-0.07	111	United States	-0.05	-0.09
94	Senegal	0.02	-0.01	112	Uruguay	0.04	0.04
95	Singapore	0.00	-0.12	113	Vanuatu	0.05	0.09
96	South Africa	-0.16	0.00	114	Venezuela	0.04	-0.08
97	Spain	0.10	-0.05	115	Yemen	0.16	-0.04
98	Suriname	0.00	-0.05	116	Zimbabwe	-0.01	-0.10

of θ in Equation 1), based on their performance in creating composite indices of passenger and freight transportation. The countries with 100 percent scores are those on the frontier, based on inputs and outputs. The "Benchmarks" column in the table, for efficient DMUs, shows the number of inefficient ones, which, in achieving their best practices, use current DMU information and, for inefficient DMUs, shows the target efficient ones, which could serve as the best practices of the current case.

Based on values of the efficiency scores of the countries, for a comparative sustainability assessment, a taxonomy of the countries was developed and is presented in Table 4. The classification can be used in learned lessons and experience sharing among and between groups. Each country is unique, due to its multi-faceted background, regarding social, political, economic, geographical, demographic, environmental, climatic and transportation characteristics.

The countries were distributed among 27 groups. These groups are the combination of the 3 different states (more desirable, middle, less desirable) for 3 dimensions of EES. First, the average rank of each country for composite indices of one dimension with respect to either passenger or freight, was computed. This resulted in three average ranks for EES dimensions. Then, depending on the position of countries in each dimension ranking, they might take three states. Therefore, each country in each dimension is a member of either three categories.

SUMMARY AND CONCLUSIONS

This study describes an attempt to address passenger and freight transportation sustainability and balancing through an international comparative assessment. For each country, the arc elasticity of the social, environmental and economic variables, with respect to transportation variables, addressing the SD and harmonization issues, were computed. Using individual elasticities, composite sustainability indices for passenger and freight transportation were suggested. Based on elasticities and composite indices and using DEA techniques, the SD efficiency scores and benchmarks for each inefficient country are found. Then, for

Table 3. Efficiency scores and benchmarks based on DEA results.

	DMU	Score (θ)	Benchmarks
1	Afghanistan	0.20	38 (0.09) 82 (0.37) 94 (0.11) 100 (0.36) 103 (0.07)
2	Albania	100.00	7
3	Algeria	100.00	0
4	Angola	78.64	82 (0.37) 103 (0.63)
5	Argentina	100.00	6
6	Australia	1.92	11 (0.07) 38 (0.00) 61 (0.00) 82 (0.62) 83 (0.22) 94 (0.08)
7	Austria	0.45	2 (0.00) 12 (0.91) 34 (0.08)
8	The Bahamas	32.38	49 (0.20) 65 (0.11) 82 (0.47) 103 (0.00) 105 (0.21)
9	Bahrain	0.40	38 (0.29) 94 (0.71)
10	Bangladesh	100.00	0
11	Belgium	100.00	3
12	Benin	100.00	36
13	Bhutan	0.21	12 (0.11) 21 (0.39) 29 (0.50)
14	Bolivia	0.46	12 (0.99) 34 (0.01)
15	Botswana	0.29	2 (0.00) 29 (0.20) 36 (0.54) 60 (0.03) 82 (0.23) 103 (0.00)
16	Brazil	100.00	2
17	Bulgaria	0.39	12 (0.84) 21 (0.16) 29 (0.00) 108 (0.00)
18	Burkina Faso	100.00	0
19	Burma	11.34	1
20	Burundi	3.87	5 (0.09) 38 (0.08) 61 (0.00) 65 (0.02) 82 (0.68) 83 (0.14)
21	Cameroon	100.00	12
22	Canada	100.00	1
23	Cape Verde	0.26	12 (0.03) 21 (0.21) 38 (0.65) 45 (0.11)
24	Chad	100.00	0
25	Chile	100.00	1
26	China	86.61	5 (0.05) 34 (0.00) 38 (0.02) 75 (0.05) 82 (0.87)
27	Colombia	100.00	0
28	Comoros	3.20	5 (0.00) 11 (0.21) 34 (0.00) 38 (0.26) 61 (0.00) 65 (0.03) 82 (0.49)
29	Republic of Congo	100.00	21
30	Costa Rica	0.26	12 (1.00) 38 (0.00) 94 (0.00)
31	Cote d'Ivoire	0.23	12 (1.00)
32	Cyprus	0.24	29 (0.08) 34 (0.04) 82 (0.26) 94 (0.09) 114 (0.53)
33	Czech Republic	31.33	5 (0.09) 16 (0.14) 34 (0.01) 49 (0.34) 65 (0.00) 75 (0.01) 103 (0.41)
34	Denmark	100.00	18
35	Dominican Republic	0.26	12 (1.00)
36	Ecuador	100.00	5
37	Egypt	0.45	2 (0.00) 34 (0.04) 38 (0.75) 94 (0.21)
38	El Salvador	100.00	25
39	Ethiopia	100.00	0
40	Fiji	0.26	12 (0.00) 29 (0.00) 36 (0.00) 38 (0.00) 94 (1.00)

Table 3. Continued.

	DMU	**Score (θ)**	**Benchmarks**
41	Finland	0.41	34 (0.01) 38 (0.08) 60 (0.10) 82 (0.22) 94 (0.09) 114 (0.50)
42	France	11.61	12 (0.85) 34 (0.12) 43 (0.00) 49 (0.00) 94 (0.02) 103 (0.00)
43	Gabon	100.00	4
44	Germany	0.37	12 (0.02) 29 (0.06) 94 (0.92) 108 (0.00)
45	Ghana	100.00	2
46	Greece	0.45	2 (0.00) 12 (0.03) 34 (0.08) 38 (0.89)
47	Guatemala	0.39	12 (1.00)
48	Hong Kong	2.02	82 (0.64) 100 (0.36)
49	Hungary	100.00	8
50	Iceland	0.36	12 (0.86) 38 (0.01) 94 (0.13)
51	India	0.46	2 (0.00) 12 (0.98) 34 (0.02) 94 (0.00)
52	Indonesia	100.00	0
53	Iran	100.00	0
54	Ireland	100.00	1
55	Italy	100.00	0
56	Jamaica	0.34	34 (0.00) 38 (0.80) 54 (0.00) 65 (0.00) 82 (0.09) 94 (0.11)
57	Japan	4.42	12 (0.07) 21 (0.57) 29 (0.35) 108 (0.00)
58	Jordan	100.00	0
59	Kenya	100.00	0
60	South Korea	100.00	8
61	Kuwait	100.00	6
62	Laos	0.26	34 (0.12) 38 (0.79) 75 (0.03) 94 (0.07)
63	Latvia	0.23	12 (0.99) 29 (0.00) 94 (0.01)
64	Lebanon	0.37	21 (0.99) 34 (0.01)
65	Lesotho	100.00	14
66	Luxembourg	0.09	29 (0.03) 38 (0.06) 82 (0.77) 83 (0.03) 94 (0.11) 100 (0.01)
67	Malaysia	37.74	49 (0.35) 82 (0.65) 103 (0.00)
68	Maldives	3.70	29 (0.07) 36 (0.01) 43 (0.02) 61 (0.00) 65 (0.01) 82 (0.82) 100 (0.02) 103 (0.04)
69	Malta	0.39	29 (0.05) 36 (0.95) 94 (0.00)
70	Mauritania	0.40	12 (1.00) 38 (0.00)
71	Mauritius	0.26	12 (0.99)
72	Mexico	55.78	12 (0.07) 21 (0.21) 94 (0.71)
73	Morocco	0.45	2 (0.00) 12 (0.91) 34 (0.09)
74	Nepal	0.26	12 (0.87) 45 (0.12)
75	Netherlands	100.00	5
76	New Zealand	0.40	38 (0.30) 94 (0.70)
77	Nicaragua	0.21	12 (1.00)
78	Niger	1.87	25 (0.43) 34 (0.10) 65 (0.02) 94 (0.44)

Table 3. Continued.

	DMU	Score (θ)	Benchmarks
79	Nigeria	59.42	5 (0.10) 22 (0.09) 61 (0.00) 65 (0.05) 82 (0.76)
80	Norway	100.00	0
81	Oman	0.21	12 (0.11) 21 (0.40) 29 (0.49)
82	Pakistan	100.00	26
83	Panama	100.00	4
84	Papua New Guinea	100.00	0
85	Paraguay	0.44	12 (0.00) 60 (0.00) 94 (1.00)
86	Peru	100.00	0
87	Philippines	0.46	2 (0.00) 12 (0.98) 38 (0.02)
88	Poland	58.11	49 (0.58) 65 (0.00) 82 (0.31) 100 (0.11) 103 (0.00) 105 (0.00)
89	Portugal	100.00	0
90	Qatar	44.47	43 (0.02) 49 (0.00) 61 (0.40) 75 (0.08) 82 (0.06) 103 (0.45)
91	Romania	0.21	12 (0.05) 29 (0.35) 94 (0.60)
92	Russia	23.13	5 (0.10) 16 (0.09) 49 (0.12) 65 (0.02) 82 (0.67)
93	Saudi Arabia	80.44	49 (0.01) 60 (0.93) 75 (0.01) 82 (0.05) 103 (0.00)
94	Senegal	100.00	31
95	Singapore	0.26	12 (0.17) 38 (0.83)
96	South Africa	86.37	12 (0.72) 21 (0.27) 29 (0.00) 65 (0.00) 94 (0.00)
97	Spain	33.52	12 (0.06) 21 (0.66) 29 (0.28) 108 (0.00)
98	Suriname	0.33	29 (0.08) 34 (0.05) 82 (0.26) 94 (0.09) 114 (0.52)
99	Swaziland	0.26	12 (1.00)
100	Sweden	100.00	7
101	Switzerland	0.41	38 (0.08) 60 (0.09) 82 (0.23) 94 (0.09) 114 (0.51)
102	Tajikistan	0.34	12 (0.43) 21 (0.20) 94 (0.37)
103	Tanzania	100.00	12
104	Thailand	0.27	1
105	Trinidad and Tobago	100.00	2
106	Tunisia	0.39	12 (0.79) 21 (0.20) 65 (0.00)
107	Turkey	0.46	12 (0.98) 38 (0.00) 60 (0.00) 94 (0.00) 114 (0.01)
108	Uganda	0.45	12 (0.01) 38 (0.99)
109	United Arab Emirates	1.09	29 (0.07) 82 (0.58) 83 (0.23) 94 (0.08) 100 (0.04)
110	United Kingdom	7.04	21 (0.00) 29 (0.28) 38 (0.56) 65 (0.00) 94 (0.11) 103 (0.05)
111	United States	4.49	12 (0.52) 19 (0.02) 29 (0.23) 112 (0.24)
112	Uruguay	94.85	34 (0.07) 65 (0.01) 82 (0.06) 94 (0.86) 104 (0.01)
113	Vanuatu	100.00	0
114	Venezuela	100.00	5
115	Yemen	100.00	0
116	Zimbabwe	0.37	38 (1.00)

Table 4. Taxonomy of countries with respect to sustainability dimensions*.

Different Categories				
		C1	**C2**	**C3**
E1	**S1**	France, Jordan, Uruguay, Vanuatu	Bulgaria, Canada, Hungary	Papua New Guinea, Russia, Saudi Arabia
	S2	Comoros, Gabon, Mexico, Tajikistan	Brazil, Chad, Czech Republic, Kuwait, Malaysia, Paraguay, Philippines, Swaziland	Fiji, Qatar, Suriname
	S3	Benin, Burundi, Cape Verde, Denmark, Ireland	Algeria, Belgium, Burkina Faso, Cote d'Ivoire, Sweden	Bolivia, Republic of Congo, Luxembourg, Panama, Turkey, Zimbabwe
E2	**S1**	Senegal	Austria, Germany, Ghana, Lesotho, Nepal, Peru	Ethiopia, Niger
	S2	Bangladesh, Egypt, Kenya, Laos, Venezuela	Costa Rica, Ecuador, South Africa	Angola, Australia, Burma, Switzerland, Tanzania, United Arab Emirates
	S3	Albania, China	Cyprus, Latvia	The Bahamas, Finland, Hong Kong, Nicaragua, Portugal, Trinidad and Tobago, Uganda, United Kingdom, United States
E3	**S1**	Argentina, Chile, Colombia, Greece, Guatemala, Japan, Lebanon, The Netherlands, Spain, Yemen	Bahrain, Italy, New Zealand, Pakistan, Poland	Iran, South Korea, Mauritius, Romania, Singapore
	S2	Cameroon, Maldives, Morocco, Tunisia	Bhutan, India, Jamaica	Afghanistan
	S3	El Salvador, Indonesia, Mauritania, Nigeria	Botswana, Iceland, Malta, Oman	Dominican Republic, Thailand

* C: Economic, E: Environmental, S: Social, 1: More desirable, 2: Middle, 3: Less desirable

comparative sustainability assessment, a taxonomy of the countries was developed. The taxonomy resulted in 27 groups.

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