BENCHMARKING SUSTAINABILITY WITH RESPECT TO TRANSPORTATION SUPPLY AND DEMAND

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Abstract This paper is an endeavor to quantify the concept of sustainable transportation. The prevailing idea in the context of sustainable development (SD) emphasizes on the reduction of transportation demand in order to reduce the environmental and social consequences of it. Nevertheless, in the current paper using a measure for SD and based on the conformity of the growths of all sectors with transportation supply and demand, the countries are comparatively studied. The measure, elasticity, for each two variables indicates the extent to which those two variables have been changing consistently. Indeed the elasticity values are measures of a "harmonic development" representing sustainability. The database consisted of national variables in transportation, economic, social and environmental categories for 128 countries in the period of 1980 to 1995. The study shed some light on the SD of transportation supply and demand, reflecting the harmony of social, environmental and economic development with respect to transportation supply and demand development. Using individual elasticities, composite sustainability indices were suggested. For comparative appraisal, country groupings were developed. The sustainability appraisal showed interesting patterns of within and between group similarities and differences. The study confirmed the significance of transportation supply and demand balancing and sustainability challenges of the 21st century. The methodology may be applied to any other time and geographic scope for addressing pertinent issues for balancing and SD of transportation systems.

Key Words Road Transportation, Sustainable Development, Transportation Policy, Transportation Supply, Transportation Demand, Comparative Analysis

چکیده این مقاله تلاشی در راستای کمی سازی مفهوم حمل و نقل پایدار است. ایده غالب در زمینه توسعه پایدار بر کاهش اثرات محیطی و اجتماعی آن تاکید دارد. اما در این مقاله با استفاده از یک شاخص برای توسعه پایدار و بر اساس هماهنگی رشد بخشهای مختلف با عرضه و تقاضای حمل و نقل، کشورها به طور مقایسه‌ای مورد بررسی قرار می‌گیرند. این شاخص که همان کشسانی است، برای هر دو متغیر، میزانی را نشان می‌دهد که آن دو به طور هماهنگ با هم تغییر می‌کنند. در واقع مقادیر کشسانی معیارهای یک "توسعه متوازن" و نماینده‌ای برای پایداری هستند. پایگاه داده‌ها شامل متغیرهای ملی در گروه های حمل و نقل، اقتصادی، اجتماعی، و محیط زیستی برای ۱۲۸ کشور در دوره ۱۹۸۰ تا ۱۹۹۵ بود. این مطالعه به تشریح توسعه پایدار عرضه و تقاضای حمل و نقل از طریق هماهنگی توسعه اجتماعی، محیطی و اقتصادی نسبت به توسعه عرضه و تقاضای حمل و نقل می‌پردازد. با استفاده از کشسانی های منفرد، نمایه‌های ترکیبی پایداری پیشنهاد شده و به منظور ارزیابی مقایسه‌ای، گروه‌بندی کشورها ارائه شده است. این مطالعه اهمیت چالش های توازن و پایداری عرضه و تقاضای حمل و نقل را در قرن بیست و یکم نشان می‌دهد. روش مطالعه می‌تواند در هر افق زمانی و مکانی دیگر به منظور بررسی موضوعات مربوط به توازن و توسعه پایدار سیستم های حمل و نقلی به کار رود.

1. INTRODUCTION

Despite of its key role in economic and social development, transportation has many spillover effects such as congestion, safety, pollution and non-renewable resource depletion [1]. The prevailing concern during last forty years has been undesirable socio-environmental impacts of population, urbanization and economic growths.

The publication of "Our common future" known as Brundtland Report, introduced sustainable development (SD) as a key concept addressing the intimate relationships between economic activities and ecology.

The Brundtland Report acknowledges that the basic needs of all people should be met with due consideration to the future generations [2]. The report emphasizes on inter and intra generational equitabilities in the sense of fairness and sharing. SD favors solutions that effectively integrate economic, environmental and community considerations expected to be a major challenge for 21st century [3].

In the last two decades, it has become the development focus of the global community increasingly discussed at different levels by many governments and civil societies. A massive literature on SD has grown up from the concerns about the relationships among economic activities, social aspects and environmental considerations [4]. The concept of sustainable transportation derives from these general terms implying the movement of people and goods in ways that are environmentally, socially and economically sustainable [5-7].

Transportation, as a commodity has a supply side and a demand side, but unlike many other commodities, these sides overlap extensively. Consumers for their own use provide a significant portion of transportation. Therefore, transportation means not only those businesses whose primary activity is to provide transportation services for a fee, but also it includes the transportation activities of other business establishments and consumers. Further, transportation can indicate transportation equipment, infrastructure, and other transportation-related goods and services [8].

In traditional viewpoints to transportation planning, supply is supposed to meet forecast demand totally. This is an idea that has been challenged extensively, especially after introducing the concept of SD. The widespread sustainable solution in this regard is reducing demand by means of managerial tricks, instead of increasing supply in order to respond the whole demand. To enhance sustainable mobility, demand management to control the growth and usage of private cars has been recommended when balanced

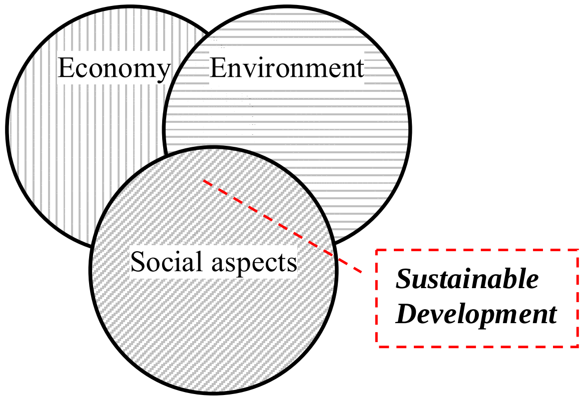

Figure 1. Three dimensions of sustainable development.

transportation infrastructure and services are conducive to economically, financially, socially and environmentally sustainable communities [9].

The paper's center of attention is comparatively studying sustainability with respect to two aspects of transportation including demand and supply in a national level. The paper proposes a different measure of sustainability using elasticity. It presents sustainability indices. Countries are ranked based on these indices. At present, it is hard to conclude exactly where the balance lies, and consequently it is difficult to ascertain where the supply of transportation and the level of provision of infrastructure and services reach an optimum point [10]. However, based on the presented framework the paper attempts to assess the countries comparatively.

The rest of the paper is organized as follows: first, the framework of the study is explained and the use of elasticity as a measure of SD is discussed. The database and its univariate and multivariate analyses will then be described. The individual and composite indices development and taxonomy of countries are also explained.

2. THE STUDY FRAMEWORK

In order to address some of pertinent sustainability issues, as a preliminary step, a comparative

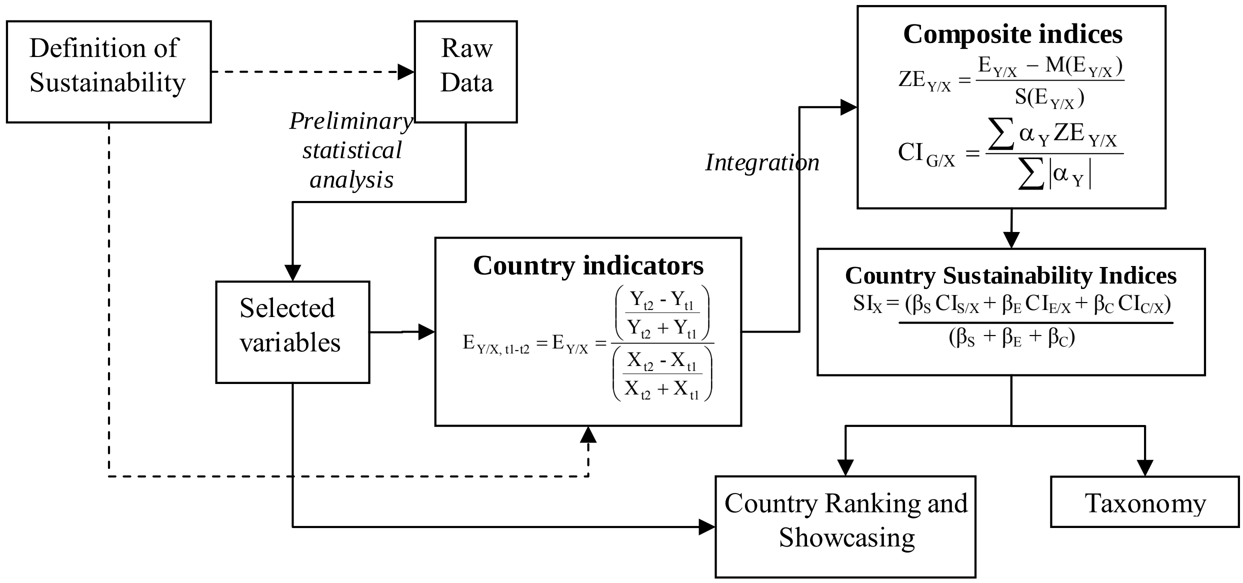

Figure 2. The framework of the study.

macroscopic assessment of transportation supply and demand systems at the national level was conducted from economic, environmental and social (EES) perspectives. The paper aims to uncover the extent of growth consistency between transportation supply and demand, and EES for selected countries. These triple dimensions have been widely used in the previous studies (see Figure 1) [27].

The methodology is to obtain a set of indices, which assigns each country an ordinal value, which specifies the situation of that country among the others. Furthermore, according to their performance, countries are categorised in order to identify the countries with similar trends in their harmonic development. Three dimensions of

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. These indices, which include highly aggregated indicators, top an information pyramid, whose base is primary data, derived from monitoring and data analysis (Figure 3) [26].

The main idea behind these steps is to find milestones for transportation supply and demand SD. The paper attempts to uncover some patterns of the overall development of countries, in order to point to some "good" countries as showcases.

3. ELASTICITY AS A MEASURE OF SUSTAINABILITY

Although there is no unified definition and interpretation of sustainability, most studies have the common feature of quantifying it by the indicators that are related to the three key dimensions of EES [11-19].

In order to perform a comparative macroscopic assessment of transportation supply and demand at the national level from the EES perspectives, one way is redefining the popular term "sustainable development" as "harmonic development", because consistency among the changes of all these three aspects as well as transportation supply and demand would naturally cause SD. In other

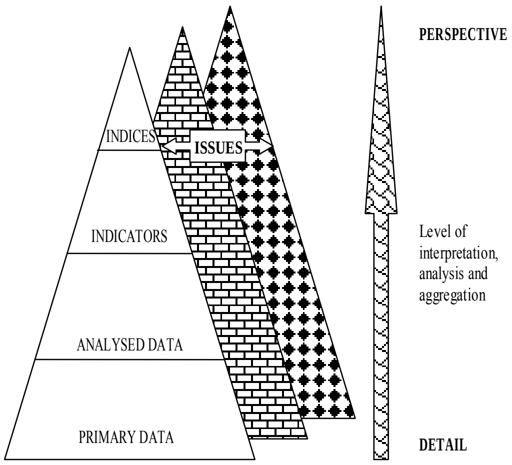

Figure 3. Information Pyramid [26].

In current paper, which comparatively studies the relationship between EES variables; and transportation supply and demand variables, the ordinal values of elasticity among countries are important and are used to assess sustainable transportation of the countries. Information Pyramid [26]

Elasticity has limitations and strengths. It measures EES change with respect to transportation change and therefore is a trend variable [20].

This characteristic also implies that elasticity reflects the relative dynamic behavior of the variables. The term “relative” herein means that elasticity shows the trends of variables but does not reflect the state of them.

words, when a country grows in economic sector only, and diminishes in the other dimensions such as environment, it is not on a sustainable way, but when it flourishes in all aspects simultaneously and harmonically, it could be considered as a country with SD (Figure 1). The current paper proposes elasticity as a measure of sustainability based on this special viewpoint. Therefore, in order to assess sustainability comparatively, elasticities of EES variables with respect to transportation supply or demand variables were computed. In the absence of any perceived and intuitive causal relationships between transportation and EES variables, sustainability is deemed to be characterized by a manifold growth or diminishment, depending on the nature of variables, in harmony and consistency with transportation growth. The Framework of the study

Elasticity is often used for large systems studies with enormous variables when the cause and effect relations are complex and vague. Elasticity gives simple and interpretable results for any type of data, irrespective of dimensionality and/or causality. The basic idea of elasticity is that it measures how strongly people respond to a change in a relevant factor [20]. Generally, elasticities greater than 1 indicates an elastic relationship and those less than one reflect an inelastic relationship [7].

4. DATABASE

Preliminary evaluation of the accessible centralized databases covered the three decades covering years of 1970 to 2000 for more than 190 countries. The initially collected relevant national indicators included more than 450 variables encompassing transportation, demographic, economic, social, environmental, geographical and political categories from centralized available databanks including OECD [21], United Nations [22], and World Bank [23].

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 main encountered problem was the availability and accessibility to comparable relevant transportation data on demand, supply, utilization and impacts at the national level. Few past studies have attempted such a comparative assessment, but mostly have addressed the issues qualitatively [4].

After evaluation of the centralized and accessible time-series databases and their completeness, the limited study resources confined the selected countries to around two third across the globe. Due to many missing data, it was necessary to find a subset of variables presenting key dimensions of sustainability. The process of data refinement and reduction included several stages of univariate and multivariate statistical

TABLE 1. Description and Structure of the Database Variables.

Variable	Category	Description	Dimension
DGLS	Demand, Sea	Goods loaded in international sea-born	Million ton
DGTH	Demand, Road	Goods transported	Million ton-km
DGUS	Demand, Sea	Goods unloaded in international sea-born	Million ton
DIPA	Demand, Air	International Passenger kilometers	Millions
DIPS	Demand, Sea	Incoming passengers in international sea-born	1000 pass
DITA	Demand, Air	International total tons-kilometers	Millions
DOPS	Demand, Sea	Outgoing passengers in international sea-born	1000 pass
DPKR	Demand, Rail	Passengers - kilometers	Million
DTGS	Demand, Sea	Total goods in international sea-born	1000 ton
DTKR	Demand, Rail	Railway ton-km	Million ton-km
DTPA	Demand, Air	Total - Passenger kilometers	Millions
DTTA	Demand, Air	Total tons-kilometers	Millions
DTWH	Demand, Road	Two-wheelers	Per 1,000 people
UCVH	Supply, Road	Commercial vehicles in use	Thousand units
UIKA	Supply, Air	International kilometers flown	Millions
ULRR	Supply, Rail	length of railway Lines	km
UMSS	Supply, Sea	Total merchant shipping fleets	Thousand gross registered
UNBH	Supply, Road	Number of buses and coaches	1000#
UNGR	Supply, Rail	Number of goods wagons	#
UNLR	Supply, Rail	Number of locomotives	#
UNPR	Supply, Rail	Number of passenger coaches	#
UPCH	Supply, Road	Passenger cars in use	Thousand units
UTKA	Supply, Air	Total Kilometers flown	Millions
UTNH	Supply, Road	Total network	km
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

analyses. By using factor analysis and a cut-off rule for minimum number of non-missing data, the number of variables in each group was significantly reduced. The process of data reduction is lengthy and thus is not reported in details herein. The reliability of database was checked as much as possible when the respective governments had reported the data to international

TABLE 2. Descriptive Analysis of the Database for Years 1980 and 1995.

Variable	Mean 1980	COV 1980	Mean 1995	COV 1995	% mean Change Based on 1995
DGLS	34.43	2.57	172.02	6.28	79.98
DGTH	38167.43	2.02	99863.29	1.72	61.78
DGUS	32.80	2.51	52.73	2.38	37.80
DIPA	1301.40	2.40	9742.83	2.79	86.64
DITA	510.96	2.61	1504.73	2.71	66.04
DPKR	21580.52	2.97	23998.26	2.95	10.07
DTKR	22134.70	4.29	19009.51	5.89	-16.44
DTPA	5900.07	4.84	17487.46	4.50	66.26
DTTA	1038.01	4.47	2329.30	4.08	55.44
DTWH	22.56	1.79	28.87	1.35	21.88
UCVH	499.12	3.01	843.68	2.72	40.84
UIKA	29.38	2.25	68.72	2.45	57.25
ULRR	7246.09	1.97	6713.59	1.90	-7.93
UMSS	3642.88	2.17	3491.57	2.50	-4.33
UNBH	63.86	2.28	80.86	2.15	21.02
UNGR	28700.18	1.81	28822.85	2.30	0.43
UNLR	1330.07	1.66	3470.10	4.27	61.67
UNPR	3147.67	1.71	3370.94	1.97	6.62
UPCH	2026.72	5.93	2916.43	2.60	30.52
UTKA	81.50	5.06	154.21	4.89	47.15
UTNH	94417.87	2.26	121360.65	2.40	22.20
ECO2	29704.66	4.06	44438.93	3.51	33.16
ETEU	37348.38	4.30	60172.70	3.59	37.93
ETEP	45154.62	3.55	72398.77	2.94	37.63
EALD	8508.63	2.92	9613.19	2.78	11.49
ECEU	46.89	3.89	60.01	3.53	21.85
ELAR	77814.19	2.26	88968.48	2.52	12.54
SAIR	40.21	0.64	28.13	0.79	-42.92
SHBD	4.41	0.94	3.78	0.97	-16.84
STLF	15108.87	3.73	20158.04	3.73	25.05
SLEX	61.57	0.18	65.91	0.16	6.58
SSWR	62.25	0.47	77.58	0.41	19.75
SUPN	46.51	0.55	54.09	0.46	14.01
CTEX	27.52	0.42	29.80	0.41	7.64
CGDP	10487.21	3.89	1499.45	3.89	30.06
CCIN	19.75	1.16	13.96	2.27	-41.45
CIPM	6.36	0.69	12.29	0.67	48.25
CTML	96.10	1.37	165.67	1.20	41.99
CTCN	89774.52	3.82	135124.93	3.75	33.56

agencies. The selected variables reflected the major required dimensions. The selected 128 countries covered all five continents and met minimum data requirements. They were 29 in Europe, 31 in Asia, 23 in America, 38 in Africa and 7 in Oceania.

In order to reflect transportation relationships and impacts on non-transportation variables, ideally, those that were most influenced by transportation should have been selected. For some of the selected variables, such as energy consumption in the environmental group, the relationships are intuitive. For some other variables, such as hospital beds in the social group, the existence of direct relationship is questionable and vague. After evaluation of more than 450 variables in the initial database, it was decided that EES groups should be presented in order to reflect the three key dimensions of sustainability. Harmonization of development in any of the key dimensions with respect to transportation development is desirable and hints towards SD, even if the direct relationship is perceived fuzzy or questionable.

The final database comprised of 21 variables in transportation group and 6 variables for each of the three groups of EES. The time scope of detail assessment covered the period of 1980-1995. Table 1 shows the final study database structure and variables. The variable names are consisted of 4 characters. The first character for non-transportation group reflects the group membership and for transportation variables shows the supply or demand; the remaining 3 characters reflect the variable description. The last character in transportation variables reflects the mode.

5. PRIMARY STATISTICAL ANALYSIS

The univariate statistical analysis of the database illustrates the database cross-sectional and time-series variability. The analysis covered computation of statistics such as minimum, maximum, mean, standard deviation and coefficient of variation (COV), Standard deviation/Mean. Table 2 shows that the mean and COV values of selected variables for the years 1980 and 1995. For both 1980 and 1995, the COVs in descending order belonged to environmental, transportation, economic and social variables, respectively. For 1980, the average COVs for transportation, social, environmental and economic variables were 2.88, 1.09, 3.50 and 1.89, respectively. Some of the environmental variables showed less promising trends such as growths in mean values of energy variables ECEU, ETEU and ETEP, and CO2 emissions ECO2. The economic variables, nevertheless, showed favorable growths except CTCN, total consumption.

For 1995, the average COVs for transportation, social, environmental and economic variables were 3.09, 1.09, 3.14 and 2.03, respectively. The last column of Table 2 shows the relative average change of variables during period 1980-1995. Their average annual changes for the period of 1980 to 1995 were not always favorable with respect to SD. The univariate analysis of study database showed significant cross-sectional and time-series variability, as was reflected by the COVs in Table 2. Nevertheless, the changes were not always in support of SD.

In order to develop an understanding of the interrelationship among the database variables, as a first step, pair-wise correlation analysis for both years of 1980 and 1995 was performed. The size of two 39x39 correlation matrices prevented their display herein. The resulted matrices revealed a number of interesting patterns and were found useful in elasticity analysis phase of the study. Many pairs of variables were found correlated at a level of significance 0.05.

For years 1980 and 1995, on the average, a transportation demand variable was found significantly correlated 34.1% of times with other demand variables, 46.8% of times with supply variables, 57.0% of times with environmental variables, 43.5% of times with social variables, and 33.3% of times with economic variables. For years 1980 and 1995, on the average, a transportation supply variable was found significantly correlated 57.8% of times with other supply variables, 74.0% of times with environmental variables, 52.5% of times with social variables, and 37.8% of times with economic variables.

For years 1980 and 1995, on the average, an environmental variable was found significantly correlated 100% of times with other environmental variables, 43.1% of times with social variables, and 48.6% of times with economic variables. For years 1980 and 1995, on the average, a social variable was found significantly correlated 66.7% of times with other social variables, and 58.3% of times with economic variables. For years 1980 and 1995, on the average, an economic variable was found significantly correlated 30.0% of times with other economic variables. Based on the correlation matrices of years 1980 and 1995, on the average, a variable was 51% of times significantly correlated with other variables. The correlation analysis reflected significant correlations among variables.

6. ELASTICITY ANALYSIS

The arc elasticity E of a variable Y with respect to a variable X for the period t1-t2 reflects the percent variable Y changes with respect to one percent change of the variable X as is shown by Equation 1:

$$E_{Y/X,\ t1-t2} = E_{Y/X} = \frac{\left(\dfrac{Y_{t2} - Y_{t1}}{Y_{t2} + Y_{t1}}\right)}{\left(\dfrac{X_{t2} - X_{t1}}{X_{t2} + X_{t1}}\right)} \quad (1)$$

where $E_{Y/X,t1-t2}$ is the arc elasticity of variable Y with respect to variable X during the period t1 to t2. As the period of t1-t2 gets smaller and converges to zero, the arc elasticity converges to point elasticity.

In order to assess sustainability comparatively, elasticities of non-transportation variables with respect to transportation variables were computed. They reflected the elasticity of the EES variables with respect to transportation supply or demand variables. In the absence of any perceived and intuitive causal relationships between transportation and EES variables, sustainability is deemed to be characterized by a manifold growth or diminishment, depending on the nature of variables, in harmony and consistency with transportation growth. In this part, elasticity of 6 social variables, SAIR to SUPN, 6 environmental variables, ECO2 to ELAR, and 6 economic variables, CTEX to CTCN, which are 18 non-transportation variables listed in Table 1, with respect to the 21 transportation variables in that table were studied. In the absence of intuitive relation, elasticity still was found proper to reflect harmony or disharmony between two variables over a period of time.

For each country, based on non-missing values, a maximum of 378 elasticities for the period of 1980-1995 were computed. For Equation 1, Y's were SAIR to SUPN, ECO2 to ELAR, and CTEX to CTCN, and X's were supply or demand variables in Table 1. Study of individual elasticities revealed a number of interesting patterns. Each country was characterized by a profile consisting of 378 measures hinting on different dimensions for SD with respect to the 21 transportation variables. To support sustainability, reductions of non-transportation variables SAIR, ECEU, ETEU, ECO2, CTEX, CCIN and CTCN were found more desirable, irrespective of transportation variables lessening or growth. The developed arc elasticities provided dimensionless and acceptable measures to assess changes for pairs of non-transportation and transportation variables during the period 1980 to 1995. They encompassed key SD dimensions of EES variables with corresponding transportation variables. Each of the developed elasticities represented a unique facet, which influences the final composite indices and consequently hints on SD, harmony and balancing. They were found acceptable indicators for sustainability appraisal addressing specific subjects pertinent to the involved pairs of variables. The developed elasticities offered a profile for each country consisting of 378 indicators. Nevertheless, space limitation prohibited their display herein.

7. AGGREGATING INDIVIDUAL ELASTICITIES

Each indicator is a single dimension addressing a particular aspect of the system sustainability. Having measured individual indicators, their aggregation has been suggested to reflect the overall system status. The developed composite indices often are not very intuitive to interpret; nevertheless, they reflect all-inclusive measures. They are needed for overall comparative appraisal and benchmarking.

Development of 378 elasticities made available a base to develop composite sustainability indices. The idea behind the concept of sustainability, as discussed earlier, emphasizes on multi-dimensionality of issues and balanced focus on changes of key dimensions. Consequently, the individual elasticities were aggregated for a single overall measure that contained information from all dimensions. The developed aggregate measures of elasticities with respect to either supply or demand of transportation reflected the extent to which all aspects comparatively have changed with respect to changes in transportation supply or demand. The developed composite index for each transportation variable reflected how harmonized the country has overall grown with respect to transportation supply or demand. There are many suggestions to combine different sustainability indicators to develop a single measure to present the approximate overall status [24,25]. As EES are the major dimensions of sustainability, for each group an aggregate measure was developed. To make elasticities comparable, Z scores were computed by the following equation:

$$ZE_{Y/X} = \frac{E_{Y/X} - M(E_{Y/X})}{S(E_{Y/X})} \quad (2)$$

where $ZE_{Y/X}$ is the Z score of the $E_{Y/X}$ as computed by Equation 1, 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 EES groups, was computed using the Z scores:

$$CI_{G/X} = \frac{\sum \alpha_Y ZE_{Y/X}}{\sum |\alpha_Y|} \quad (3)$$

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 supply, U, or demand, D. α_Y's are coefficients that are +1 for elasticities with desirable positive sign and -1 for those with 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,

TABLE 3. Sustainability Indices.

No.	Country	SI_{TSUP}	SI_{TDEM}	No.	Country	SI_{TSUP}	SI_{TDEM}	No.	Country	SI_{TSUP}	SI_{TDEM}
1	Afghanistan	-0.11	-0.16	44	Gabon	0.04	0.04	87	Pakistan	-0.02	-0.04
2	Albania	0.03	-0.04	45	Germany	-0.04	-0.04	88	Panama	-0.07	-0.04
3	Algeria	-0.37	-0.04	46	Ghana	-0.01	0.03	89	Papua New Guinea	0.10	-0.05
4	Angola	-0.02	0.22	47	Greece	0.03	-0.04	90	Paraguay	0.00	-0.04
5	Argentina	0.14	0.15	48	Guatemala	0.02	-0.05	91	Peru	0.02	-0.03
6	Australia	-0.05	-0.02	49	Hong Kong	0.30	-0.45	92	Philippines	-0.01	-0.05
7	Austria	-0.01	0.00	50	Hungary	0.03	0.02	93	Poland	-0.05	-0.08
8	The Bahamas	-1.33	-0.02	51	Iceland	-0.04	-0.05	94	Portugal	-0.03	-0.04
9	Bahrain	0.00	-0.04	52	India	-0.01	-0.04	95	Qatar	0.01	-0.06
10	Bangladesh	0.01	-0.02	53	Indonesia	0.00	-0.04	96	Romania	-0.03	-0.06
11	Belgium	-0.05	-0.03	54	Iran	-0.07	0.04	97	Russia	0.00	0.06
12	Benin	0.04	-0.01	55	Ireland	-0.03	0.03	98	Saudi Arabia	0.02	-0.06
13	Bhutan	0.01	-0.06	56	Italy	-0.01	-0.04	99	Senegal	0.02	0.01
14	Bolivia	-0.28	-0.04	57	Jamaica	-0.01	-0.04	100	Seychelles	0.00	0.04
15	Botswana	-0.12	-0.06	58	Japan	0.01	-0.03	101	Sierra Leone	-0.16	0.15
16	Brazil	0.00	-0.02	59	Jordan	0.02	0.00	102	Singapore	-0.10	-0.01
17	Bulgaria	0.04	-0.03	60	Kenya	-0.01	-0.05	103	Solomon Islands	0.08	-0.02
18	Burkina Faso	0.00	-0.02	61	Kiribati	0.50	0.14	104	South Africa	-0.14	-0.04
19	Burma	-0.06	-0.03	62	South Korea	0.02	0.05	105	Spain	0.09	-0.05
20	Burundi	0.02	-0.09	63	Kuwait	0.02	0.04	106	Sri Lanka	-0.02	-0.03
21	Cameroon	0.27	0.10	64	Laos	0.02	-0.06	107	Sudan	-0.05	0.02
22	Canada	0.00	-0.03	65	Latvia	0.05	-0.21	108	Suriname	-0.01	-0.04
23	Cape Verde	0.06	0.12	66	Lebanon	0.06	0.04	109	Swaziland	0.02	-0.14
24	Central African Republic	0.49	0.14	67	Lesotho	0.28	0.05	110	Sweden	-0.17	-0.14
25	Chad	0.07	0.25	68	Luxembourg	-0.05	-0.02	111	Switzerland	-0.05	-0.05
26	Chile	-0.02	0.23	69	Madagascar	0.01	-0.03	112	Syria	0.39	0.24
27	China	0.01	-0.02	70	Malawi	0.05	0.00	113	Tajikistan	0.04	-0.01
28	Colombia	0.00	-0.04	71	Malaysia	-0.01	-0.04	114	Tanzania	0.01	-0.07
29	Comoros	-0.08	-0.01	72	Maldives	-0.01	0.19	115	Thailand	-0.07	-0.06
30	Republic of Congo	-0.08	-0.05	73	Mali	0.02	-0.02	116	Togo	0.08	-0.02
31	Costa Rica	-0.02	-0.03	74	Malta	-0.02	-0.05	117	Trinidad and Tobago	0.02	-0.27
32	Cote d'Ivoire	0.00	-0.03	75	Mauritania	-0.03	0.01	118	Tunisia	0.02	-0.01
33	Cyprus	-0.01	-0.04	76	Mauritius	-0.03	-0.04	119	Turkey	0.00	-0.04
34	Czech Republic	0.03	-0.02	77	Mexico	0.07	-0.02	120	Uganda	-0.06	-0.14
35	Denmark	0.50	0.26	78	Morocco	0.00	0.00	121	United Arab Emirates	-0.04	-0.06
36	Dominican Republic	-0.08	-0.04	79	Nepal	-0.02	-0.05	122	United Kingdom	-0.07	-0.14
37	Ecuador	0.00	-0.03	80	Netherlands	-0.07	0.08	123	United States	-0.04	-0.09
38	Egypt	0.01	-0.02	81	New Zealand	-0.04	-0.02	124	Uruguay	0.03	0.01
39	El Salvador	-0.02	-0.03	82	Nicaragua	-0.14	0.23	125	Vanuatu	0.07	0.24
40	Ethiopia	-0.04	-0.05	83	Niger	0.10	0.02	126	Venezuela	0.07	-0.08
41	Fiji	0.00	-0.03	84	Nigeria	-0.06	0.03	127	Yemen	0.15	0.24
42	Finland	-0.08	-0.07	85	Norway	-0.28	0.00	128	Zimbabwe	-0.04	-0.05
43	France	0.11	-0.04	86	Oman	-0.02	-0.06	129			

EES composite indices were again aggregated as weighted combination:

$$SI_X = (\beta_S CI_{S/X} + \beta_E CI_{E/X} + \beta_C CI_{C/X}) / (\beta_S + \beta_E + \beta_C) \quad (4)$$

where SI_X is the sustainability index of transportation group X, β_C, β_E, and β_S are the weighting factors of EES dimensions, respectively. Table 3 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 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. The composite indices reflected the overall harmony and uniformity between non-transportation groups on the one hand, and each transportation variable on the other hand. In this respect, Table 3 shows the overall comparative sustainability situation of countries. Countries with higher indices are comparatively more sustainable. Although each country is unique due to its inherent characteristics, history and background, it can learn about sustainability from others. Countries with high scores can be used as showcases for good practice and experience sharing. For sustainability indices with respect to transportation supply, SI_{TSUP}, and with respect to transportation demand, SI_{TDEM}, 93 and 69 countries showed negative values, respectively. 54 countries showed negative values for both SI_{TSUP} and SI_{TDEM}. The highest SI values of the both transportation supply and demand belonged Denmark. The lowest SI values from the transportation supply and demand were for Hong Kong and the Bahamas, respectively.

8. TAXONOMY OF THE COUNTRIES

Based on SI_{TSUP} and SI_{TDEM} and the variable CGDP for a comparative sustainability assessment, taxonomy of the countries was developed and is presented in Table 4. It is a systematic classification of peer groups that hints to the relative standing of each nation. Indeed, several classifications were developed, using different combinations of the developed elasticities and indices. The taxonomy reported herein was found superior as it reflected all the involved elasticities in a hierarchical order. It shows a systematic and orderly grouping to identify peer countries with respect to the taxonomy criteria. The taxonomy of countries put forward an acceptable ranking for comparative analysis and show casing. The classification can be used in learned lessons and experience sharing among and between groups. In modeling process, as an example, information of peer countries may be used, as a compliment or instead of including all countries. Each country is unique due to its multi-facet backgrounds on social, political, economic, geographical, demographic, environmental, climate and transportation characteristics. The policies for SD should be tailored and customized to nation's unique circumstance, setting and eminence. Nevertheless, peer comparison would be conducive to policy enhancement.

The 128 countries were distributed among 16 groups. The groups in the first row of the Table 4 had negative values for both SI_{TSUP} and SI_{TDEM} reflecting comparatively less sustainable situations in each income level category, i.e. columns of Table 4. The groups in the last row of the table were in better harmonization, balancing and sustainability status than the rest. They had positive values for both SI_{TSUP} and SI_{TDEM} reflecting comparatively more sustainable situations in each income group. They may offer information on their good practices and development experiences. The second and third rows are the countries in the middle situation with respect to sustainability comparatively. The columns in the table reflect the countries with different level of income. Thus, development processes of the countries in the lower rows of each column, i.e. more sustainable ones, can be used as targets for the countries in upper rows of that column.

The elasticity analysis raised concerns about balancing and sustainability of national transportation supply and demand during period 1980 to 1995. The taxonomy presented a logical framework for comparative analysis and peer group appraisal. It facilitates good practices,

TABLE 4. Taxonomy of the Countries.

	$CGDP<2.5*10^9$	*$2.5*10^9<CGDP<1.0*10^{10}$*	*$1.0*10^{10}<CGDP<9.0*10^{10}$*	*$9.0*10^{10}<CGDP$*
$SI_{TSUP}<0$ $SI_{TDEM}<0$	Comoros, Fiji, Republic of the Congo, The Bahamas, Malta	Botswana, Bolivia, Panama, Nepal, Zimbabwe, Iceland, Jamaica, Paraguay, Mauritius, Costa Rica, El Salvador, Dominican Republic, Ethiopia, Kenya, Sri Lanka	Uganda, Singapore, Romania, Oman, Philippines, Pakistan, Colombia, Portugal, Cote d'Ivoire, New Zealand, Luxembourg, Poland, Algeria, Malaysia	United Kingdom, Sweden, Finland, Thailand, South Africa, Belgium, Australia, United States, Switzerland, Italy, Indonesia, Turkey, India, Canada
$SI_{TSUP}<0$ $SI_{TDEM}>0$	Swaziland, Burundi, Laos, Bhutan, Albania, Solomon Islands, Togo, Tajikistan, Malawi, Madagascar, Burkina Faso, Mali, Benin	Trinidad and Tobago, Latvia, Papua New Guinea, Bahrain, Guatemala, Peru, Jordan	Ecuador, Bulgaria, Czech Republic, Bangladesh, Tunisia, Morocco, Venezuela, Greece, Egypt	Hong Kong, Saudi Arabia, Spain, France, Japan, Brazil, Mexico, China
$SI_{TSUP}>0$ $SI_{TDEM}<0$	Sierra Leone, Mauritania, Maldives	Nicaragua, Ghana, Angola	Nigeria, Ireland, Chile	Norway, Iran, Netherlands, Austria, Russia
$SI_{TSUP}>0$ $SI_{TDEM}>0$	Seychelles, Lesotho, Cape Verde, Central African Republic, Kiribati, Vanuatu, Chad, Niger	Senegal, Gabon, Lebanon, Uruguay, Cameroon	Hungary, Kuwait, Syria, Israel	South Korea, Argentina, Denmark

learned lessons and experiences information sharing. Nevertheless, the study results were directly influenced by the selected variables. Relevant data on transportation supply and demand, and their direct EES impacts, are needed to improve national transportation policy. Comparative assessment could be a compliment to other types of analyses to enhance national policies to support SD.

9. CONCLUSIONS

This paper describes an attempt to address transportation supply and demand sustainability and balancing through an international comparative assessment. The study database was consisted of 39 national variables for 128 countries. The variables were 21 for transportation, and 18 for 3 categories of EES. The selected variables and the period of 1980 to 1995 were suitable in the context information availability, reliability and completeness. Availability of more relevant comparative national data on transportation supply and demand, and their more direct EES impact could have greatly enhanced the study results. Consequently, the study results would be of more methodological interest, and their direct national policy implications render caution. Nevertheless, the applied comparative assessment methodology could be used as a compliment to any other types of assessment to enhance national policies to support sustainable transportation development. The study also revealed relevant data scarcity when appraisal of national transportation SD is significantly hampered.

For the selected countries, the database univariate analysis showed significant cross-sectional and time-series variations. The observed trends however were not always in favor of SD. The pair-wise correlation analysis showed that for both 1980 and 1995, on the average, a variable was 51% of times significantly correlated with other variables. As a preliminary exploration into transportation supply and demand sustainability, for each country, the arc elasticity of the EES variables with respect to transportation variables, addressing the SD and harmonization issues. Using individual elasticities, composite sustainability index for transportation supply and demand were suggested. Based on elasticities and composite indices, for comparative sustainability assessment, taxonomy of the countries was developed. The taxonomy resulted in 16 groups with one outstanding group in each income level category. It facilitated comparative appraisal among and between the identified peer groups. The outstanding groups reflected countries with superior values for composite indices. They could be used for show casing, experience and good practice information sharing. The study confirmed the significance of transportation supply and demand balancing and SD challenges, especially for the developing countries.

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