African Sustainable Transport by Numbers

Amir Abbas Rassafi and Manouchehr Vaziri

Abstract: In this paper, sustainability at the transportation sector of the African countries has been evaluated. The database used for the study encompasses different aspects of countries in the form of national indicators. 52 African countries were initially selected for detailed analysis for the period of 1980 to 1995. They have been extracted from centralized information sources of international agencies. The key dimensions of sustainable development i.e. social, environmental, and economic characteristics are used. Firstly, a set of sustainable transportation indicators have been introduced. These indicators, which in fact are elasticities, show the relative change of non-transport variables with respect to transport ones. Then composite indices of each group have been calculated. These indices have been used to perform the taxonomy of African countries based on their transport sustainability. Finally, the comprehensive transport sustainability indices of countries have been introduced and according to these values, the countries have been compared and ranked. Mathematical and statistical analyses of the database quantitatively support the study. The results for the selected indicators show that Chad is the best, and Zambia is the worst among the subset of 52 countries with non-missing data. Having the prediction of the future trends of transportation systems makes beware of sustainability-oriented issues in current century.

Introduction

Around the globe, the last forty years of population, urbanization and economic growths have raised many concerns of undesirable socio-environmental impacts. Sustainable development which is a concept increasingly extended from the decade of 80's, was a natural response to the concerns of negative impacts of past shortsighted developments. It is introduced after the publication of "Our common future" known as Brundtland Report, 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 of future generations (WCED 1987). The report emphasizes on inter and intra generational equitabilities, in the sense of fairness and sharing. Sustainable development favors solutions that effectively integrate economic, environmental and community considerations, and is one of the major challenges of 21st century (Vaziri and Rassafi, 2003). In the last two decades, it has become the development focus of the global community and increasingly has been discussed at different levels of many governments and civil societies.

A massive literature on sustainable development has grown up from the concerns about the relationships among economic activities, social aspects, and environmental considerations (Barter, 1999). The concept of sustainable transportation is derived from these general terms that imply movement of people and goods in ways that are environmentally, socially and economically sustainable (OECD, 1996), (Vaziri & Rassafi, 2001-b). These dimensions will be further studied in this section.

Sustainability is a concept with both simple and complex nature. In its simple form, the concept denotes human populations living within the constraints of nature and having no long-term negative impact on the environment or opportunities for future generations. The complexity of sustainability arises because all industrial societies are, to some extent, living beyond the long-term carrying capacity of the territory that they occupy. The industrial modernization has culminated in value systems, consumption patterns, institutions, and habits that are congruent with environments of resource abundance and unlimited opportunity, but that are much less appropriate for the future, particularly for the dense and growing populations in many of the presently less industrialized areas of the world.

Creating more sustainable societies in the contemporary world means moving toward maximizing human satisfaction while having a minimum impact on environmental services. Thus, perfectly sustainable societies would be those in which economic activity takes place using renewable or recycled resources, thus placing zero long-term burdens on the environment. The policy emphasis would be on meeting human needs rather than human wants and on quality rather than quantity consumption. Progress toward more sustainable societies would be indexed by new definitions of efficiency stressing the effectiveness with which resources are used and the durability of products.

Sustainability involves environmental, economic, social and technological perspectives. The achievement of sustainability is not easily measured and goals will change with time. It can be defined as a process or state that can be maintained indefinitely. Sustainability integrates a viable economy, protection of the environment and social well-being. These are three main component of sustainability. In the followings, these components will be studied.

Environment is the most important part of sustainability. The natural-environmental constraint to development is the main reason for any concern about sustainability. More precisely, the economic processes of production and consumption draw to a greater or lesser extent on services provided by resources of the natural-physical environment. These resources are of two broad types: natural resources, in the conventional narrow sense, and environmental resources. Natural resources of the conventional type, recognized by economists as crucial inputs to most production processes, include non-renewable resources such as minerals, renewable ones such as forests, and all forms of energy. They have been studied for a long time, so that policies dealing with them can build on a whole body of theoretical and empirical knowledge.

Environmental resources have come under the purview of analysts more recently. Nevertheless, fairly well-developed tools are now available for their analysis. In general, environmental resources provide services not only for immediate human consumption but also for use in connection with production as well as consumption processes. The former services sustain the biological basis of human life and well-being as well as provide for enjoyment of natural resources by people. The latter services derive mainly from the absorptive capacities of the physical environment and as such contribute to human well-being.

Economy is the vital part of the development. The growth of economies and their structural transformation have always been recognized as being at the core of development. They still are the most important preconditions for the fulfillment of human needs and for any lasting improvements in living conditions. In addition to the quantitative economic aspects of development, an increasing number of qualitative aspects are being recognized too. The main argument is that neither economic growth in the aggregate nor growth of income at the personal level is sufficient to guarantee progress of an entire society. Accompanying qualitative changes are needed as well.

Development has also huge, undesirable social impacts. It encompasses the strengthening of the material income base as well as the enhancement of capabilities and the enlargement of choices. Such a view of development clearly transcends the narrow concept of development as economic growth and emphasizes the importance of social development in the context of sustainable development.

The other argument regarding social issues is equity considerations. They are vital to the notion of sustainable development. More precisely, inter-generational or inter-temporal equity forms one of the cornerstones of the concept. As a consequence, the issue of intra-generational equity cannot be excluded from a comprehensive notion of sustainable development, because doing so would destroy the symmetry of the equity-argument on which the term 'sustainable' is built. Hence, intra-generational equity, covering the whole gamut of social issues in development, such as regional and gender distribution, is rightly considered as an integral part of sustainable development.

Transportation plays a key role in economic and social development. Without access to jobs, health, education, recreation and other amenities, quality of life suffers. Without access to resources and markets, growth stagnates and poverty perpetuates. Nevertheless, transportation has many spillover effects such as congestion, safety, pollution and non-renewable resource depletion. Most of the worlds' population lives in developing countries with inadequate transportation systems. Developed countries have limited resources, to develop further their systems, but are facing decisions to develop infrastructure toward more automobile support and reliance, or to focus on rail, bus, and bicycle infrastructures to give people more non-car choices (Ingram, 1997).

Efficacious and sustainable transportation is a key component to well-functioning and civilized societies. Indeed, both developed and developing countries are confronting critical issues in selecting and planning for their future transportation systems when there is a need towards sustainable development that balances accessibility, mobility, protection of human safety and environment, as well as economic growth and social equity. At present, it is hard to conclude exactly where the balance lies, and consequently it is difficult to ascertain where the level of provision of infrastructure and services reach an optimum point. The study objective shed some light on balancing and sustainability aspects of transportation for different countries around the globe. The methodology can be applied to any other time and geographic scope for further elaboration of the involved issues by conducting similar comparative analyses.

Quantifying Sustainability

The concept of sustainability is to some extent vague, and depends on the attitude and scientific or philosophical background of system analyst (Gudmundsson and Hojer, 1996). Generally, the attempts for measuring or quantifying sustainability include two major set of works, indicators analysis, and modelling. Modelling sustainable development is a way which is getting popularity in the studies (Groller et al, 1996), (Hofkes, 1996), (Leeves and Herbert, 2002), (Moffatt and Hanley, 2001), (Radzicki, 1999), (Seifritz, 1996), (Seifritz, 2001), (Zhang, 1996), but in the current paper will not be pointed out further.

Indicators have been frequently used in many studies. References (Afgan et al, 2000), (Alberta Round Table. 2002) (Bossel, 1999), (Hanley, 2002), (Hardi and Zdan, 1997), (Hart, 2002), (Morse et al, 2001), (Murcott, 2002-a), (Murcott, 2002-b), are only some excerpted ones from gigantic works in this field. The main idea in these works is generally introducing indicators, which describe the different features of the system under study. The important problem in these works is that each indicator is one-dimensional and tries to measure a particular aspect of the system, neglecting the others. Having measured each indicator there should be an efficient technique to combine them. In such studies, the role of combined indicators has been disregarded. For example consider a case in which two indicators have been presented: one shows the annual output of the transportation system (for instance seat-kilometers per year), and the other represents the amount of gases emitted from transportation sector (for instance CO_2 emission). There is no doubt that the desired strategy is minimizing CO_2 emission. Nevertheless, the same is not true about the seat-kilometer, i.e. maximizing this indicator is not a good objective. In this case, the combined indicator CO_2 emission / seat-kilometers are much better than two previous ones, and less controversial.

The combination can be more complicated and of course more expressive by utilizing the trends of selected measures over years, and again here an inter-related set of measures surely helps in better understanding of the system sustainability. This is what will be used in the rest of the paper as a mathematical definition of sustainable development. In the following chapters, the concept of elasticity will be introduced as a criterion that matches with the desired specifications of the indicators.

In this paper, the concept of elasticity is used as a technique for developing indicators that are more comprehensive. The basic idea of “elasticity” is that it measures how strongly people respond to a change in a relevant factor. For instance, when the demand for a product is price elastic, then the quantity demanded changes a lot when the price of the product changes. Conversely, when the price elasticity is inelastic, then the quantity demanded changes only a little when the price changes. Elasticity is widely used in economic analyses that study the relationship between the price of a commodity, and its demand. In such analyses depending on elasticity values, demand can be elastic or inelastic. Indeed, elasticities greater than 1 indicate an elastic relationship and those less than one reflect an inelastic relationship (Vaziri and Rassafi, 2001-a). In current paper, which comparatively studies the relationship between non-transport variables and transport ones, the ordinal values of elasticity among countries are important and are used to assess sustainable transport in African countries.

The process of data reduction and selecting indicators

Due to missing cells of the database, it is necessary to find a subset in which the variables are as complete as possible. Thus, by introducing a cut-off rule, the number of variables in each group will be reduced so that the remaining ones reflect better the group they are representing. The cut-off rule adopted here is selecting variables with at least 40 non-missing cells for at least four years.

Having performed this rule the number of variables in groups was reduced. It should be noted because of the importance, the variables of the transportation group would not be reduced. In this stage, the number of variables in the groups transportation, environment, social, and economy will reduced to 74, 42, 27, and 111, respectively.

The number of economic variables in the database still exceeds 100 and working with this gigantic number of variables is difficult and the results make no sense. Therefore, it seems that the data should be reduced. One of the popular ways of statistically data reduction is factor analysis. Factor analysis is a branch of statistical science, which is originated by a psychologist, Charles Spearman (Harman, 1970). It attempts to represent a set of observed variables in terms of common factors as well as an exclusively unique factor. By this statistical tool, one can summarize a multitude of measurements with a smaller number of factors without losing too much information, and therefore achieve some economy of description (Harman, 1970), (Comery, 1973).

In this study, factor analysis was performed for the economic variables group for years 1980, 1985, 1990, and 1995, using SPSS. The strategy was doing factor analysis with Varimax rotation. In this way, the factor axes are rotated so that each variable gets a high correlation with at least one of the factors. This technique allows researcher to be able to interpret factors in terms of variables categorical characteristics.

The numbers of factors which were introduced for each year were 27, 25, 27, and 29, respectively. If the factor analysis should be done just for one year, finding the best subset of variables would be simple: selecting the most correlated variable with the particular factor among variables belonging to that factor. In this paper, the variables were found in the following way. Firstly, a subset including 27 variables was selected based on the 1980 results, using the previously mentioned rule. Then, for the next years, if for each factor there is not at least one variable belonging to that factor selected before, the most correlated variable of that factor among its variables will be added to the set of selected variables. Number of final variables in the group was reduced to 47, which is comparable with the others. Therefore, the finalized database contains 190 variables forming four main groups.

The selected variables were filtered again by another criterion. **Error! Reference source not found.** shows the structure based on which the variables have been selected. According this figure for having a comprehensive and reasonable-sized set of variables, they should belong to the identified categories. This leads to choose 42 variables among the others as the finalized database.

Database Descriptive Analysis

The finalized database comprises 42 variables, including 24 ones representing transportation modes, and 6 variables for each 3 groups regarding economic, social, and environmental ones. The analyses were done in the period of 1980-1995. **Error! Reference source not found.** describes these variables. To achieve a consistently sustainable system, negative values were found desirable for elasticities of some variables. These variables have been shown in **Error! Reference source not found.** with negative sign.

The univariate statistical analysis of the database including 42 indicators of 52 countries for years 1980, and 1995, shed light on the study database variability. The minimum, maximum, mean, standard deviation and coefficient of variation of 52 countries are summarized in Tables 2 and 3.

The tables' cells show that the variables of maritime transport have more missing data than the others. As can be concluded from the table, in air transport group, the variables showed a relatively average increase of 12.73 %, the variables of road transport group showed a relatively average increase of 4.10 %, the variables of rail transport group showed a relatively average increase of 1.81 %, the variables of maritime transport group showed a relatively average decrease of 5.34 % for the period of 1980-1995. Those variables of economy group with negatively desirable change with respect to increase in transportation variables, showed a relatively average increase of 2.67 % in the period of 1980-1995. Those variables of economy group with positively desirable change with respect to increase in transportation variables, showed a relatively average increase of 1.80 %. The similar values for the negatively and positively desirable change of environment with respect to increase in transportation variables, are 3.76 % and 0.04 %, and for that of society are -0.68 % and 3.31 %, respectively.

Multivariate analysis

To develop an understanding of the interrelationship among 52 countries pairwise correlation analysis was performed. The results have been presented in the Tables 4, and 5, for years 1980, and 1995, respectively. Because of the huge dimensions of the calculated correlation matrix, the results are based on percent of significant correlations between two categories, or a category with itself. It should be mentioned that the correlation of each variable with itself, while calculating the correlations of categories on the diagonal, has been dropped.

Analyzing the correlation matrices shows that there are significant positive correlations among variables. To develop an understanding of individual country's relationship between transportation and environmental, social, and economical issues for each of the selected countries, the elasticity of sustainability characteristic of countries with respect to that of transportation for the period of 1980-1995 were studied.

The elasticity E of a variable Y with respect to a variable X in period t1-t2 reflects the percent variable Y changes with respect to one percent change of the variable X. Equation 1 shows the explanation above:

$$E_{Y/X,\, t1\text{-}t2} = E_{Y/X} = [(Y_{t2} - Y_{t1}) / (Y_{t2} + Y_{t1})] / [(X_{t2} - X_{t1}) / (X_{t2} + X_{t1})] \qquad (1)$$

Where $E_{Y/X,\, t1\text{-}t2}$ is the arc elasticity of variable Y with respect to variable X during the period t1 to t2. In more detailed terms, the elasticities of each group with respect to transportation are computed by the following equations:

$$E_{C_i/T_j,t1\_t2} = \frac{\left(C_{i,t2} - C_{i,t1}\right) / \left(T_{j,t2} - T_{j,t1}\right)}{\left(C_{i,t2} + C_{i,t1}\right) / \left(T_{j,t2} + T_{j,t1}\right)} \quad i = 1\ldots6,\ j = 1\ldots24, \qquad (2)$$

$$E_{E_i/T_j,t1\_t2} = \frac{\left(E_{i,t2} - E_{i,t1}\right) / \left(T_{j,t2} - T_{j,t1}\right)}{\left(E_{i,t2} + E_{i,t1}\right) / \left(T_{j,t2} + T_{j,t1}\right)} \quad i = 1\ldots6,\ j = 1\ldots24, \qquad (3)$$

$$E_{S_i/T_j,t1\_t2} = \frac{\left(S_{i,t2} - S_{i,t1}\right) / \left(T_{j,t2} - T_{j,t1}\right)}{\left(S_{i,t2} + S_{i,t1}\right) / \left(T_{j,t2} + T_{j,t1}\right)} \quad i = 1\ldots6,\ j = 1\ldots24, \qquad (4)$$

in which $C_{i,t}$, $E_{i,t}$, and $S_{i,t}$ are the i-th variables of groups economic, environmental, and social at time t, respectively. They have been introduced in the third column of **Error! Reference source not found.**. The elasticity of 18 non-transport variables with respect to 24 transport ones resulted in 432 sustainable transport indicators for the period. Evaluation of the developed 18 x 24 elasticities shed some light on the interrelationship among sustainable transport issues. For the period of study, a composite index, CI, was developed. Firstly, the Z scores of each elasticity value, ZE, were computed by the following equations:

$$ZE_{Ci/Tj} = [E_{Ci/Tj} - M(E_{Ci/Tj})] / S(E_{Ci/Tj}),\ i=1\ldots6,\ j=1..24, \qquad (5)$$

$ZE_{Ei/Tj} = [E_{Ei/Tj} – M(E_{Ei/Tj})] / S(E_{Ei/Tj})$, i=1…6, j=1..24, (6)

$ZE_{Si/Tj} = [E_{Si/Tj} – M(E_{Si/Tj})] / S(E_{Si/Tj})$, i=1…6, j=1..24, (7)

Where $ZE_{Y/X}$ is the Z score of the $E_{Y/X}$, M() and S() are functions that return the mean and the standard deviation of their arguments, respectively. Secondly, the composite indices for elasticities of variables of each non-transport group Y, with respect to all of transport variables, were computed by the following equations:

$$CI_C = \frac{\sum_{i=1}^{6}\sum_{j=1}^{24} k_{C_i} . ZE_{C_i/T_j}}{\sum_{i=1}^{6}\sum_{j=1}^{24} \delta_{C_i/T_j}} \quad (8)$$

$$CI_E = \frac{\sum_{i=1}^{6}\sum_{j=1}^{24} k_{E_i} . ZE_{E_i/T_j}}{\sum_{i=1}^{6}\sum_{j=1}^{24} \delta_{E_i/T_j}} \quad (9)$$

$$CI_S = \frac{\sum_{i=1}^{6}\sum_{j=1}^{24} k_{S_i} . ZE_{S_i/T_j}}{\sum_{i=1}^{6}\sum_{j=1}^{24} \delta_{S_i/T_j}} \quad (10)$$

$$\delta_{Y_i/T_j} = \begin{cases} 1 & \text{the elasticity } Y_i \text{ with respect to } T_j \text{ exists} \\ 0 & \text{Otherwise} \end{cases} \quad (11)$$

in which CI_Y is the composite index of non-transport variables of group Y with respect to transport in the period 1980-1995, and k_{Yi}'s are coefficients which equal +1 for those elasticities with desirable positive sign, or -1 for those elasticities with desirable negative sign shown in **Error! Reference source not found.**. If unequal weighting for elasticities are desirable, equations (8)-(10) should be modified accordingly. δ_{Y_i/T_j}'s are dummy variables which show that Y_i and T_j have non-missing data and were used in calculating the index. Suppose a particular country has no missing data for all of the elasticity values. Thus, for that country and each non-transport group Y, $\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{Y_i/T_j}$ will be equal to the multiplication of 6, showing the number of variables of that group, multiplied by 24, the number of transport variables, i.e. 144. The result of this stage is the amounts of averaged elasticity of each non-transport group variables with respect to transport, totally 3 indices. Then the sustainability index for elasticities was computed by the following equation:

$$SI = \frac{CI_C\left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{C_i/T_j}\right) + CI_E\left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{E_i/T_j}\right) + CI_S\left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{S_i/T_j}\right)}{\left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{C_i/T_j}\right) + \left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{E_i/T_j}\right) + \left(\sum_{i=1}^{6}\sum_{j=1}^{24}\delta_{S_i/T_j}\right)} \qquad (12)$$

where SI is the sustainability index. The Z score of sustainability index for elasticities was computed by the following equation:

$$ZSI = [SI - M(SI)] / S(SI) \qquad (13)$$

Where ZSI is the Z score of sustainability index of all non-transport groups with respect to transport for the identified period. **Error! Reference source not found.** shows the Z scores of the composite indices as well as sustainability index for the period of 1980-1995. Taxonomy of countries based on composite indices has been shown in Table 7. Countries in descending order of Sustainability Z scores are listed in Table 8. In this table, due to lack of data needed for calculating sustainability index, countries Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Guinea, Liberia, Libya, Mozambique, Namibia, Rwanda, and Somalia have been dropped.

Conclusion

There are now innumerable definitions, and many declarations and statement of principles for sustainable mining, forests, sport, tourism, transportation, landfills etc. Even many years after publication of the Brundtland report there is no unique definition of sustainable development. A clear definition may be unnecessary to design action programs, however, basic conceptual guidelines must be drawn to set sustainability goals. Brundtland report has proposed a brief, widely quoted description of sustainable development, which defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). This definition offers a formula on which most of the more elaborate definitions of sustainable development draw. Starting from this formula and its various interpretations, in particular, the one contained in Agenda 21, three main dimensions of sustainable development can be identified: Economic aspects, social issues and environmental concerns.

According to this interpretation, the paper studies the relationship between these three components in one hand, and transportation on the other hand. In order to measure the extent to which transportation has developed in harmony with the known components of sustainability, combinatorial indicators were introduced. These indicators were constructed borrowing the concept of elasticity from economics, which reflects how strongly people respond to a change in a relevant factor.

In the paper, African countries have been studied from the national transportation sustainability point of view. The database was constituted of 42 national variables including 24 transportation variables, 6 variables for each 4 mode of air, road, sea, and rail, as well as 18 variables for 3 categories of social, economic, and environmental issues.

For a fifteen-year period of 1980 to 1995 elasticities of national economic, environmental, and social characteristics with respect to different aspects of transportation were developed. Each computed elasticity shows how consistent a transport variable changes with respect to non-transport one. The next stage in the analysis is aggregating the indicators, i.e. elasticities. This stage is of great importance and encompasses difficulties. The difficulty inherent in such problems originates from the multilateral nature of different indicators.

Firstly, assuming equal weights for each indicator, composite indices for three groups of economic, environmental, and social variables with respect to transport ones were calculated. Based on economic composite index countries can be categorized in two groups. In the first group Tunisia, Nigeria, Kenya, Benin, Mauritania, Morocco, Sierra Leone, Senegal, Gabon, Sudan, Burundi, Uganda, Lesotho, The Gambia, Swaziland, Cameroon, Chad, and Central African Republic with desirable economic change in harmony with transportation variables. On the other hand Zambia, South Africa, Guinea-Bissau, Comoros, Niger, Angola, Tanzania, Botswana, Zimbabwe, Seychelles, Sao Tome and Principe, Republic of the Congo, Mali, Madagascar, Algeria, Ghana, Cote d'Ivoire, Ethiopia, Jordan, Togo, Egypt, Malawi, and Burkina Faso are the countries with undesirable changes with respect to transportation.

The similar classification based on environmental composite index shows that countries Central African Republic, Sierra Leone, Tunisia, Zambia, Cameroon, Botswana, Lesotho, Nigeria, Uganda, Mauritania, Sudan, Niger, Algeria, Republic of the Congo, Morocco, Senegal, and Ghana have undesirable change, and countries Zimbabwe, Kenya, Seychelles, Madagascar, Ethiopia, Cote d'Ivoire, Egypt, Benin, Swaziland, South Africa, Mali, Togo, Burkina Faso, Burundi, Tanzania, Jordan, Gabon, Sao Tome and Principe, Malawi, The Gambia, Comoros, Guinea-Bissau, Angola, and Chad have desirable environmental change with respect to transportation.

The composite social index indicates that countries Comoros, Zambia, Uganda, Botswana, Burundi, Cote d'Ivoire, Algeria, Tanzania, Sierra Leone, South Africa, Mali, Benin, Burkina Faso, Malawi, Nigeria, Mauritania, Republic of the Congo, Morocco, Madagascar, Egypt, Zimbabwe, Swaziland, and Tunisia have undesirable change, and countries Togo, Kenya, Ethiopia, Gabon, Senegal, Jordan, Chad, Lesotho, Ghana, Guinea-Bissau, Cameroon, Angola, Sudan, Sao Tome and Principe, Seychelles, The Gambia, Central African Republic, and Niger have desirable environmental change with respect to transportation.

Given all three indices, one can perform the following taxonomy of countries. The group of "sustainable" countries, that are countries with desirable sign for all three indices, includes Chad, Gabon, The Gambia, and Kenya. The group of "unsustainable" countries, which are countries with undesirable sign for all three indices, includes Algeria, Botswana, Republic of the Congo, and Zambia. The "partly sustainable" countries, which have two positive signs among three composite indices, include Togo, Angola, Benin, Burundi, Cameroon, Central African Republic, Ethiopia, Guinea-Bissau, Jordan, Lesotho, Sao Tome and Principe, Senegal, Seychelles, Sudan, and Swaziland. Similarly, "partly unsustainable" countries, which have two negative signs among three composite indices, include Nigeria, Tunisia, Zimbabwe, Burkina Faso, Comoros, Cote d'Ivoire, Egypt, Ghana, Madagascar, Malawi, Mali, Mauritania, Morocco, Niger, Sierra Leone, South Africa, Tanzania, and Uganda.

Finally, using composite indices of three categories, comprehensive sustainability index were suggested. The indices show that Chad is the best, and Zambia is the worst country among the countries.

This research is of more methodological importance. The methodology can be applied to any other time and geographic scope for further elaboration of the involved issues by conducting similar comparative analyses.

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