TITLE: Towards the evaluation of the sustainability of a region, taking different sustainability criteria into account.

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INTENDED CATEGORY: Tools for managing sustainability.

1. Introduction.

This study was carried out under the supervision of the UNESCO Chair of Technology, Sustainable Development, Imbalance and Global Change, which forms part of the Technical University of Catalonia. The Chair was founded in May 1996 as a result of the International Conference on Technology, Sustainable Development, Imbalance and Global Change, held in Terrassa in 1995. The UNESCO Chair's head offices are located in College of Industrial Engineering's building on UPC's Terrassa Campus.

The UNESCO Chair's main activity is to offer training at all levels within the university community that will contribute to the greater integration of the ethical, humanistic and sustainable aspects of the planet's problems. This should give future specialists a global overview that will enable them to analyse and put forward proposals that take into account the impact, uses and applications of technology, as well as the social responsibilities that the latter imply.

Another of the Chair's fields of action is in Agenda 21. The Chair has pioneered and supported the introduction of Agenda 21 in Catalonia. Due to this, it is experienced in defining indicators of sustainability based on the monitoring of the variables that affect sustainable development at a municipal level.

2. Goals of the study.

The goal of this study is to develop an aggregate sustainability index that takes into consideration the different interpretations of the concept of sustainable development. This

will be done with the help of a computer-assisted reasoning program called Globesight. It will enable us to create future scenarios through the application of various policies to the basic variables that make up the aggregate index.

3. Aggregate Indices

3.1 Introduction

Sustainable development is based on finding the right "balance" between the three factors that define the sustainability triangle: social factors, environmental factors and economic factors. The aggregate indices used to measure sustainable development and/or the sustainability of a specific region should include variables (indicators) from the three above-mentioned areas.

The most notable development of both indicators of sustainability and sustainable development began at the end of the 1980s in Canada and in some European countries. However, the final boost came as a result of the Earth Summit (the Rio Summit, 1992). During the United Nations Conference on Environment and Development, the Commission on Sustainable Development (CSD) was developed in order to monitor the progress of Agenda 21 and sustainable development. The Commission immediately recognised the need for instruments to measure the advances made in sustainability, which gave rise to the definition of indicators in the 1990s.

Some countries have worked on the development of indicators, as is the case of Canada and New Zealand. Their proposals are well known, although it should be pointed out that their indicators only make reference to the environmental aspect of sustainable development. Other countries have worked closely with the CSD, within the framework of the United Nations Work Programme, on indicators of sustainable development. It is also worth mentioning the international endeavours at cooperation to advance indicators of sustainability through the SCOPE (Scientific Committee on Problems of the Environment) project.

The first indicators developed were environmental indicators or indicators of environmental sustainability, also called first generation indicators. The second generation of indicators corresponds to those created with a multidimensional focus on sustainable development. These systems are comprised of environmental, social, economic and institutional indicators, aggregated using indices that the CSD also introduced.

The indices developed to the present have had two types of focus. On the one hand, there is the economic focus of the sustainability triangle (Value of World Ecosystem Services, Costanza et al, 1998; Wealth, Nations and Genuine Savings, World Bank;....), which weighs up the various variables considered from an economic (monetary) standpoint. On the other hand, the indices that sustainability triangle represents are considered using other value judgements (LPI, Living Planet Index, WWF, ESI, Environmental Sustainability Index, Global Leaders for Tomorrow Environment Task Force; Ecological Footprint, Mathis Wackernagel & William Rees;....).

3.2. Conclusions of the indices analysed

From the initiatives analysed we can conclude the following:

- There have been many initiatives to date, which have aggregated information into indices for several spheres of sustainable development, basically in the social, economic and environmental areas. Besides reaching a consensus on the indices, their advantage is that a huge amount of information has been collected. This is very positive in the attempt to obtain a global index for sustainable development as stressed by the CSD.
- The environment is the most developed area when it comes to integrating indicators through the aggregation process to the indices. However, the general indices used have little international consensus, and it is therefore unclear which of the indices used to monitor the environmental situation is the closest to reality.
- In the field of economics, the GPI (Genuine Progress Indicator) and the ISEW (Index of Sustainable Economic Welfare) have not been established using a consistent methodology and their aggregate systems tend to be subjective.
- The social area is not sufficiently developed. The most representative index, although far from being complete, is the HDI (Human Development Index). The lack of sensitivity of some of its components is still under question.
- The institutional aspect is not taken into account in the majority of initiatives. There is no general index to measure this dimension.
- In general terms, there is not enough public information about the aggregation process. Details of specific methods used in the aggregation process for several of the initiatives examined have not been published.
- The key to the aggregates is how to establish a weighting system, how to prioritise each component and how to add the components to a general index. Initiatives such as the ESI (Environmental Sustainability Index), shown in the illustration as a Dashboard of Sustainability provides a method with which policy-makers can assign their own weights and priorities, which is interesting as it allows great flexibility.

3.3. Problematics of the aggregate indices.

The concept of sustainable development is complex and together with its different possible interpretations this means that the analysis of the same data can lead to very distinct assessments. This is due, firstly, to the choice of variables that are included in the index and, secondly, to the weighting assigned to each of the variables.

The creation of aggregate indices for sustainable development and the subsequent publication of data result in a lack of consensus, due to the proliferation of diverging assessments. There is a clear disparity of axiomatic and methodological criteria in creating these indices. If sustainable development or the development of sustainability is understood to be a hugely complex, transversal and intersectorial area, it is obviously very difficult to be objective about or measure how close or far away we are from our ultimate goal.

This disparity of criteria is the result of the different ways of interpreting the concept of Sustainability. It is possible to define two main trends in sustainable development. Firstly, there are criteria of strong sustainability, whose main feature is the non-substitution of natural capital. Secondly, we can talk of criteria of weak sustainability, which accept the exchange of natural capital for other types of capital, thereby accepting the substitution of natural capital for manmade capital.

A clear example of this problem can be observed in the Environmental Sustainability Index-ESI, Samuel-Johnson 2001 versus the ESI as corrected by The Ecologist-Friends of the Earth 2001. The difference in the assessment of the same set of variables (indicators) ended up by producing extremely different results, and it was possible to find countries that one of the indices considered sustainable while the other found them to be unsustainable.

4. Global Index of Sustainable Development Proposal

4.1. Introduction

In order to create a sustainability index within the framework of the CSD, one must review the different theoretical steps involved in the aggregation of variables and consider adapting them to the various indicators. Owing to the numerous dimensions and factors involved in the concept of sustainability, this index should be sufficiently flexible to be able to measure dimensions and factors, whether a single item or several; it should also be able to measure sustainability it all of its complexity.

The purpose of these indices is to give policy-makers information in a summarised form so that they can assess the policies needed that will lead to sustainability and their potential impact.

Some of the greatest problems in the aggregation of information within indices are encountered when setting up a weighted system that reflects all of the data without losing any of its significance; the subjectivity of the weighting, in other words. Given the number of areas it covers, the complexity of defining a weighting system increases when sustainable development is assessed. In short, the setting up of a weighting system on an international scale that could be applied to any country makes the process even more complicated, as each country has different priorities when facing up to its various problems.

Our Global Index of Sustainable Development proposal will be based on a system of variable weighting, using international weighting standards.

4.2. Global Index of Sustainable Development (GISD).

4.2.1. Justification.

After having revised existing aggregate indices, as well as the methods used to weight and represent them, it can be concluded that the most internationally accepted indices use the variable weighting method. This uses a nationally standardised weighting system and a subsequent system that compares the relative positions between countries of the different indicators and sub-indices that make up a given index. This system of measuring sustainable development does not indicate whether a country is close or far away from sustainability. It merely allows comparisons to be made between countries and studies that are sensitive to the various factors involved in diverse problems (environmental, social, economic and institutional).

In our modest opinion, the diverse problems related to sustainability are/have been scientifically examined and contrasted (population growth, emission of gases with greenhouse effect, …). Therefore, in putting forward a Global Index of Sustainable Development, one could start by basing the index on the variables in the above-mentioned problem areas. This makes it possible to establish a standard weighting system that is internationally accepted, and which enables the creation of a scale of sustainability. Knowing whether our planet is coming close to or is far from sustainability is an ambitious task made difficult by the lack of consensus in the definition of sustainability. However, the international community does agree that there is a series of key problems involved in sustainability, while there are many more that are more controversial. We will develop our Index basing ourselves on these recognised problems, thus leaving the way completely clear for the incorporation of new variables that reflect new problems that the international scientific community will define in the future.

The aggregate indicators are used as a support in the political decision-making process. The implementation of this new index using the computer-assisted reasoning tool, Globesight, allows us to envisage future scenarios, which are created by applying diverse policies to the basic variables that make up the aggregate index. We believe that developing an index in this way will make the task in hand (support in the political decision-making process) clearer and more understandable.

4.2.2. Approach to the Global Index of Sustainable Development (GISD).

We are working to develop an aggregate sustainability index with a selection of variables based on the definition of the loading capacity and the PNUD's indices of human development. This is an overall index that takes economic, environmental and social aspects into account. All of the variables that go to make up the index are weighted against an independent variable, which can take on different values according to the criteria that exist at a given time to define sustainability. This means that the index can be applied to the creation of future scenarios while taking into account different viewpoints about sustainability and the policies applied in favour of sustainability.

The computer tool used to create the index and future scenarios is called Globesight, whose software was developed by Dr.Mihajlo D. Mesarovic (author of the second report for the Rome Club "Mankind at the Turning Point, 1974) from the Case Western Reserve University", Cleveland, Ohio, USA. An assessment of the past and the present allows this

interface to calculate possible future prospects according to the policies applied to the variables studied and the set weighting of criteria.

The advantage of the proposed index within the framework of this methodology is the assessment of certain future scenarios that are created based on specific policies and the different standpoints on sustainability. Furthermore, it allows for the inclusion of other variables and new weighting factors in the future.

4.2.3. Definition of GISD.

The Global Index of Sustainable Development takes three basic aspects of sustainability into account: the environmental, social and economic areas. As this is just a brief study, each area will be defined by an index; the following indices have been chosen:

AREA	INDEX
Environmental	Emissions Index (Ton CO_2/capita * annum)
Economic	GNP Index (GNP/capita * annum)
Social	HDI

In the environmental area, the CO_2/capita*annum index was chosen. This is because the emission of carbon dioxide is a global environmental problem that affects the whole of the planet. Given the dimensions of the problem, this phenomenon has been scientifically studied and contrasted by international organisations, such as the IPCC.

In the economic area, the GNP/capita*annum index was chosen. This is an international standard that measures the economic activity of a region.
In the social area, the HDI was chosen as it the only representative aggregate index. It is also an internationally recognised index for measuring this phenomenon.

The weighting of these "sub-indices" to create the GISD (SDGI???) is worked out as an arithmetic mean. However, the weighting can be modified by adjusting the factors in each sub-index, which are defined by the user in accordance with the criteria or policies of sustainability that are imposed.

$$GISD[r] = ((pignp[r]*ignp[r])+(piem[r]*iem[r])+(pidh[r]*idh[r]))/3$$

Where:

- GISD[r] is the Global Index of Sustainable Development for a particular region [r].
- ignp[r] is the GNP index for a particular region.
- pignp[r] is the GNP index factor, which allows us to vary its relative weighting in the constitution of the global index.
- iem[r] is the emissions index used to measure the environmental factor.

- piem[r] is the index factor of emissions, which allows us to vary its relative weighting in the constitution of the global index.
- idh[r] is the Human Development Index that we use to measure the social factor.
- pidh[r] is the index factor of the Human Development Index, which allows us to vary its relative weighting in the constitution of the global index.

4.2.4. <u>Definition of sub-indices and GISD indicators.</u>

In accordance with the weighting criteria within the CSD framework, the weighting system will be chosen by using the distance from the goal assessment method. This seems to be the preferred method, as the goal of reference of an indicator for a particular subject can be based on internationally agreed upon principles.

The GNP Index was calculated as follows:

$$ignp[r] = ((gnpc[r]-0.1)/(40.-0.1))$$

Where:

- ignp[r] is the GNP index for a particular region.
- gnpc[r] is the GNP per capita of a particular region.
- 40 and 0.1 are the maximum and minimum margins respectively of the income per capita of a particular region (40.000 $ppa, 100 $ppa annually). Taken from PNUD sources.

In the case of incomes of over $40,000 ppa, the maximum value is taken to be the index (the unit).

The Emissions Index was calculated as follows:

$$iem[r] = ((emc[r]-0.1)/(0.806-0.1))$$

Where:

- iem[r] is the emissions index for a particular region.
- emc[r] are the emissions per person and per annum for a particular region.
- 0.806 and 0.1 are the maximum and minimum margins respectively of emissions for a particular region. Source: IPCC, Technical Document 4.

As emissions have an impact on the environment, the weighting given to this index is equal to "-1", with no limitations on the maximum value. That is, if a country exceeds the unit in the index value, the said value is examined.

The Human Development Index is modelled on data from the PNUD, the unit being the maximum value.

Based on these criteria, the GISD gives a relative scale that varies between negative values (non-sustainable) and positive ones (sustainable) around zero.

4.2.5. <u>Methodology for implementing Globesight. Applying different policies.</u>

The variables on which the indices depend are population (pop[r]), GNP (gnp[r]), emissions (em[r]) and the HDI (idh[r]).

In order to apply the global index, we used the same ratio for all of the variables. The ratios used are the result of an integrated equation that represents the dynamic evolution in time of a particular variable. The evolution of a variable in time depends on its initial value and its growth rate in time.

This ratio, in the case of GNP, for example, as all are calculated in the same way, is as follows:

/* Compute GNP growth rate */

rgnp[r] = rgnpd[r]*rgnpm[r]

/* Compute GNP */

gnp[r] = (sgnp[r]*(1.+rgnp[r]/100.))

/* Compute GNP per capita */

gnpc[r] = (gnp[r]/pop[r])

- First, the growth rate is calculated (rgnp[r]) according to data on record (rgnpd[r]) in various accessible databases. This is multiplied by the so-called "multiplier" (rgnpm[r]), which is the factor that allows us to modify diverse future scenarios we wish to create. If the multiplier's value is equal to the unit in the time calculation process (annual) a future scenario can be created whose variable values are calculated by following past growth trends. If the value differs from the unit, alternative scenarios can be created, which is the same as applying different political options.

  /* Compute GNP growth rate */

  rgnp[r] = rgnpd[r]*rgnpm[r]

- Below is the calculation for the value of the variable (gnp[r]) based on the value of the last data available or on the calculation of future scenarios, the value for the previous year (sgnp[r]) and the growth rate (rgnp[r]).

  /* Compute GNP */

gnp[r] = (sgnp[r]*(1.+rgnp[r]/100.))

- Finally, should the variable need to be standardised per capita (gnpc[r]), the variable is divided, in the case of GNP (gnp[r]) by the population variable (pop[r]), which is calculated using the same procedure for that year.

/* Compute GNP per capita */

gnpc[r] = (gnp[r]/pop[r])

5. GISD practical case study.

5.1. Introduction

By following the methods described in the section above, the Global Index of Sustainable Development was applied to the following countries: Spain, Denmark, Poland, USA, Venezuela, Argentina, Brazil, Saudi Arabia, Nigeria, Egypt, South Africa, New Zealand, China and Japan. These countries were chosen based on the following criteria:

- Countries representing the five continents.
- Countries with different levels of economic development.
- Countries with different emissions and different environmental impact.
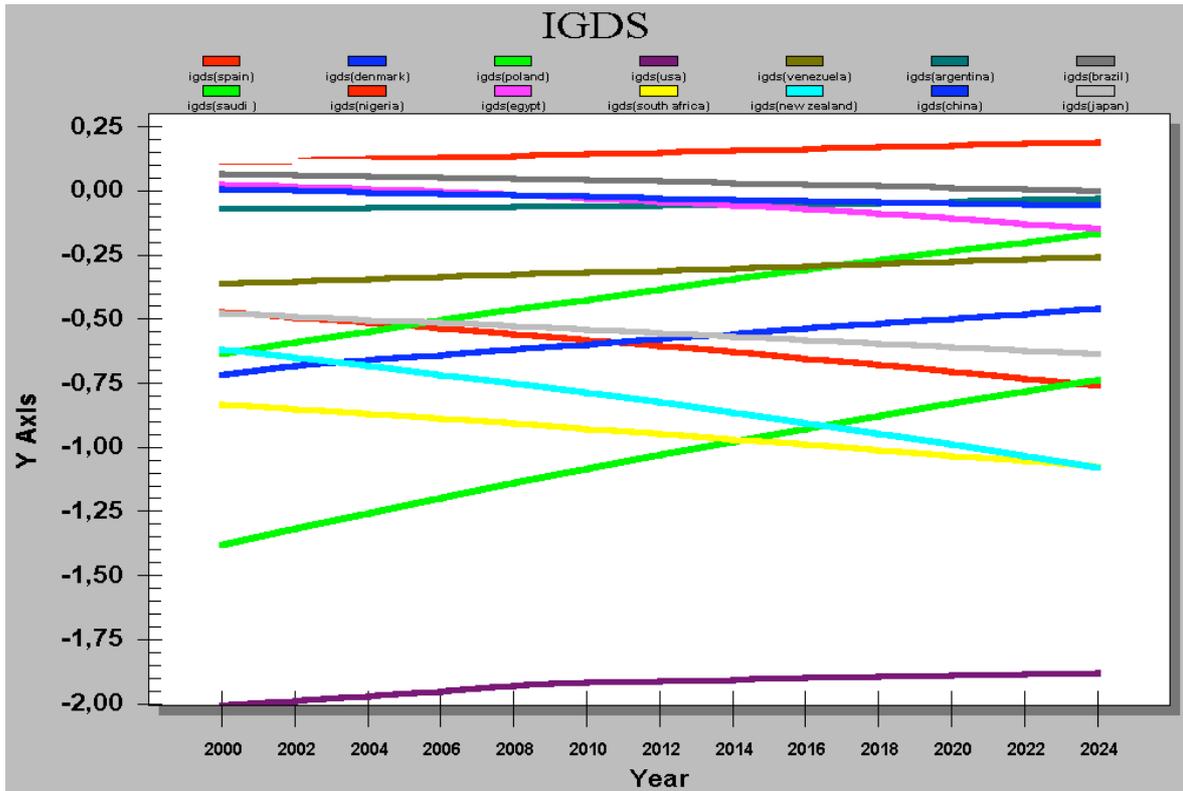- Countries with different levels of human development.

Past growth rates for the following variables were calculated: population, emissions and GNP based on data from the E.I.A. (Energy International Agency), whose last data date from 2000. The data corresponding to the HDI was taken from the PNUD's annual reports.

A future scenario was created for the period up to 2025. Past growth rates for the different variables (which we call the reference scenario) were maintained for the GISD, as well as the various indices from which it is compiled.

5.2. Presentation of results

In the following graph the GISD can be seen, with data from 2000 and its evolution up to 2025, according to past growth rates of the various components that were taken into account.

Reference scenario for the GISD

IGDS

Legend: igds(spain), igds(denmark), igds(poland), igds(usa), igds(venezuela), igds(argentina), igds(brazil), igds(saudi), igds(nigeria), igds(egypt), igds(south africa), igds(new zealand), igds(china), igds(japan)

5.3.   Conclusions.

As far as the social aspect is concerned, which is represented by the HDI, it can be seen that although there were great differences between the countries studied in 2000 (between 0.5 and 0.9 approximately), there was a general upward trend in the HDI factor for all countries. It can also be observed that in relative terms there was a convergence between the countries that in 2000 had the highest and lowest values for this index.

Regarding the environment and the impact of emissions, the paradigmatic case of the USA among developed countries stands out compared with developing countries. Among developed countries, two trends can be observed; those which in 2000 had an #IEM# of over 4 and those below 4. The index of the latter tended to rise while it fell in the case of the former. The index dropped considerably in former Eastern block countries, represented by Poland in this study.

Concerning the economy, there are great discrepancies in IGNP trends, which in some countries are on the increase while in other countries they are on the decrease. It should also be pointed out that Japan, the USA and Denmark reached the maximum value allowed for this index in a very short space of time.

As regards the Global Index of Sustainable Development, it can be seen that among the countries studied the scale of sustainability in 2000 (from the least to the most sustainable) was as follows: USA, Saudi Arabia, South Africa, Denmark, Poland, New Zealand, Japan,

Spain, Venezuela, Argentina, China, Egypt, Brazil, India and Nigeria. This group of countries undergoes the following changes in the scale of sustainability with the application of the different tendencies for 2005: USA, New Zealand, South Africa, Spain, Saudi Arabia, Japan, Denmark, Venezuela, Egypt, Poland, China, Argentina, Brazil, India and Nigeria.

The trend toward sustainability and unsustainability for different countries can also be observed. The countries tending towards sustainability are: USA, Saudi Arabia, Denmark, Poland, Venezuela, Argentina and Nigeria. Those tending towards unsustainability are: Brazil, Egypt, China, Japan, Spain, New Zealand and South Africa.

6. Final conclusions.

- The Global Index of Sustainable Development is the first step in the attempt to lay down international standards for criteria of sustainability, following CDS guidelines.
- The GISD index has variable weighting as recommended by the CDS.
- It is by no means a restricted Index; we have only provided a brief example of the methodology's applications.
- We believe that it is an effective tool for measuring sustainability under its different criteria, which can be done thanks to the introduction of weights to the GISD methodology in the various indices that form or will form the index.
- Another advantage of the GISD method is the incorporation of multipliers to each of the variables or indicators that make up the indices. These multipliers allow us to attribute different policies to the indicators, which may help centres of political power to reach decisions, as well as giving them a sensitive outlook of their influence on the global index.
- With the computer-assisted reasoning program, Globesight, models of calculation for the variables and/or indicators can be implemented (cause and effect models amongst others), which makes their transparency and influence on the global index far clearer.
- Besides allowing the implementation of the GISD, Globesight also makes it possible to create future scenarios, with which we can observe the results of different policies and criteria of applied sustainability (multipliers and weights respectively) on a medium and long term basis.
- The main advantage of the Global Index of Sustainable Development is its methodology, which is totally transparent and allows it to be applied by adapting to the needs and criteria of the user.
- Globesight has subroutines to present the results in graphs that are easily and rapidly understood.