VOL. 8, NO. 9, SEPTEMBER 2013 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


www.arpnjournals.com

INTEGRATING ROAD SAFETY INDICATORS INTO PERFORMANCE ROAD SAFETY INDEX

Arowolo Matthew Oluwole, Mat Rebi bin Abdul Rani and Jafri Mohd Rohani
Department of Manufacturing and Industrial Engineering, Universiti Teknologi Malaysia, UTM Johor Bahru, Johor, Malaysia
E-Mail: arowolo.oluwole@yahoo.com

ABSTRACT

This study suggest a set of steps of combining different indicators to form a single index which may become a significant measurement in comparing, ranking and determining road safety levels in different countries and however, to create a valuable road safety performance index in terms of communication, benchmarking, policy making and monitoring. Many composite (multidimensional) indices have been developed internationally and used in different aspects of life to indicate a progress or achievements between countries. They cover environmental issues, sustainable development, globalization issues, agriculture, economy, information technology, and more. Taking the specific road safety case into account, this study describes the different steps that are essential in the construction of a road safety performance index. The selection of indicators and data preparation are described, the issue of weighting and aggregating indicators is discoursed and the degrees of the index in terms of ranking of the countries assessed. These steps are illustrated by two weighting methods of simple average and based on theories using performance indicator data for ten African countries.

Keywords: index, road safety, indicator, ranking, performance, composite.

INTRODUCTION

Road safety is a topic that is presently receiving a lot of attention and concern. Given the high number of accident with casualties and the corresponding suffering and costs, measures are needed in order to reduce the number of road accident and its attended casualties. Worldwide, over 1.2 million people are killed in road crashes each year and 20 to 50 million are injured according to World Health Organization, 2009 [1]. This means that every day around the world, more than 3,000 people die from road traffic injury. Currently in recent time, the use of indicators and indices in the field of road safety has been growing rapidly in view of the ever complex and multidisciplinary character of the road safety phenomenon which requires the consideration of several factors by policy makers [2]. Basically an indicator can be defined as a qualitative or quantitative measure deduced from a series of observed facts to reveal a true positions of objects in an area [3]. These road safety indicators have taken their origin from other domains such as the Human Development Index used by the United Nations; the Technology Achievement Index used by the United Nations Development Programme; the Overall Health System Index used by the World Health Organization (WHO, 2010) [4]; and the Environmental Sustainability Index used by the World Economic Forum among others. In recent time the use of indicators and indices to analyze or measure road safety has been growing rapidly in view of complex and multidimensional character of the road safety occurrence which requires the consideration of several factors by policy makers [5, 6]. [7] stated that majority of road deaths and injuries occur in developing and transitional countries, with approximately half of all fatalities in African countries [8]. Highly developed countries (HDCs) have sixty percent of the total motor vehicle fleet but they contribute only to fourteen percent of the total global road accident deaths. Trends from these data show that the total number of road fatalities in HDCs has been declining or stabilizing during recent decades, whereas the situation in developing countries is particularly severe and the total number of fatalities continues to increase.

According to Millicent (2012) [8], to overcome the obstacle of making international comparisons of road safety performance and to allow for sufficient understanding of the processes that lead to road crashes and causalities, several studies have been contributed to the concept of road safety indicators (e.g. [9, 10, 11, 12, 13, 14 and 15]). ETSC, 2001 [11] define a safety performance indicator as any measurement that is casually related to accidents and casualties and used in addition to a count of accidents and casualties in order to indicate the safety performance or understand the process that leads to accidents.

In some cases countries could be compared on each safety performance indicator separately, the combination of individual road safety performance indicators into a composite index serves as a good and valuable tools as a point of reference or benchmarking the safety situation of a country given the large number of relevant road safety performance indicators. Significant important of the composite index approach over the individual performance indicators is that it gives clear picture of a country to be presented, the impact of safety indicators can then be assessed and countries performance can be easily ranked based on the combined performance of essential road safety risk indicators according to [10]. Also composite indicators equally provide a reasonable and realistic way in making comparisons across countries and are also very useful instrument for policy makers, politicians, the media and the public in road safety as we see in [11, 15]. This comparison using composite indicator indices allows for the easy recognition of best practices and successful implementation of policies that can be

adapted by countries to reduce increases in road crashes and casualties.

A lot of studies have been researched on the use of the composite road safety index; these have largely focused on European and Asian countries [11, 3, 5] with none on African countries. Here attentions are therefore focuses on using a road safety index to compare the road safety performances of ten African countries. As a result of the small sample data size and the type of data required for this study, the study uses available data to develop a simple composite index for benchmarking ten African countries road safety performances using both a simple average of normalized indicators and based on theories method. Further research has already been undertaken regarding risk factors related to road crashes and casualties [14, 15, 16, 17, 18, 19, 20, 21, and 22]. Some of these risk factors (covering human-vehicle-road-environmental-regulation interactions) are sometimes generally related to road user's behaviour (e.g. alcohol, speeding, and distractions), vehicle (e.g. defects) and the road environment (e.g. maintenance culture) [4]. As reported in [13] on Safety Net project as it provided a further methodological basis for the Safety Performance Indicator's development. Basically some steps are involved in the creation of a composite indicator [3, 4]. The theoretical framework need to be developed, selection of appropriate indicators, weighted values, aggregated and clear presentation.

This paper is therefore organized in this form in section 2 indicators to be used to illustrate the different weighting methods are briefly discussed. Next is the nature and characteristics of the two weighting techniques that is average method and based on theories method are briefly discoursed their strengths and weaknesses stressed. Thereafter the two methods are applied to the road safety data set while section 4 gives evaluation and compares the two methods and deals with the magnitude of the final results. The paper ends with conclusions and recommendation for future work.

Data sources and quality

This study relied exclusively on data from secondary sources largely from international databases. Based upon the potential of different road safety areas for increasing road safety as well as on the experiences and data available, seven problem areas were designated as central to road safety activities in Europe, [25, 26]. They are: (1) alcohol and drug-use; (2) speeds; (3) protective systems; (4) daytime running lights; (5) vehicles (passive safety); (6) roads and (7) trauma management. For each one of these areas, safety index were developed and using the data provided by national representatives of the European countries. Data sources largely from international databases which include the International Road Traffic and Accident Database (IRTAD) [27]; [28] the United Nations Economic Commission for Europe (UNECE) Statistics; the World Road Statistics compiled by the International Road Federation; [29] and national databases such as the UK Department of Transport, SWOV [30]: Institute for Road Safety Research (Netherlands) [31] and Arrive Alive Road Safety Website (South Africa) [32] amongst others. Data on selected socio-economic indicators affecting road safety (e.g. percent of paved roads, adult literacy rate, percent of population urban, life expectancy at birth, GDP, etc.) were taken from the World Bank Human Development Indicators Database and various editions (2003-2008) of the United Nations Development Programme (UNDP) Human Development Reports, Population data for the African countries was collected from the US Census Bureau international database and [33].

WEIGHTING METHODS

Approach-1: using simple average

The method is by using average that focuses on a number of dimensions that are important in human vehicle road safety situation and which are important to explain and predict safety situation in countries and regions with different levels of development, each dimension includes one or more indicators. The selected indicators relate to important variables for each dimension for all countries as possible and availability of data. The indicators can be normalized in this form. [24, 9].

$$I_{i,j} = \frac{\frac{1}{n}\sum_{i=1}^{n} \max(I_i) - I_{real}}{\text{Max } (I_i) - \min (I_i)}$$

$$I_{i,j} = \frac{\frac{1}{n}\sum_{i=1}^{n} I_{real} - \min(I_i)}{\max (I_i) - \min(I_i)}$$

Where n is the simple average included indicator.

$IRSI_j = \frac{1}{n}\sum_{i=1}^{n} D_i$ where D_i is the normalized dimension for country j.

Approach-2 based on theories for each indicator

This approach in some cases, we need to judge in the selection from experience and literature review. The weights proposed here are based on literature experience and evaluation studies where we have to select among several alternatives, making a choice and evaluating the results afterwards. This alternative will not be the one finally chosen, we should review the weighting and the obtained results and if we disagree with this choice, we will make the necessary changes till we reach the optimal one in our perspective and desire. Here the weight for each indicators were assigned, and the sum should be 1.

HVRI = weight X respective indicators. [11, 9].

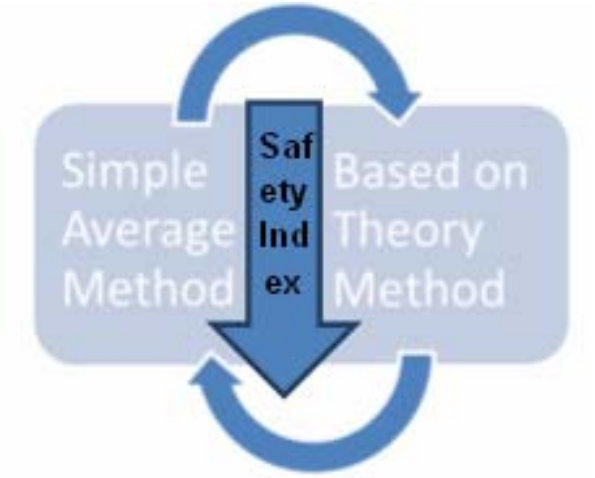

Figure-1. Safety Index Model.

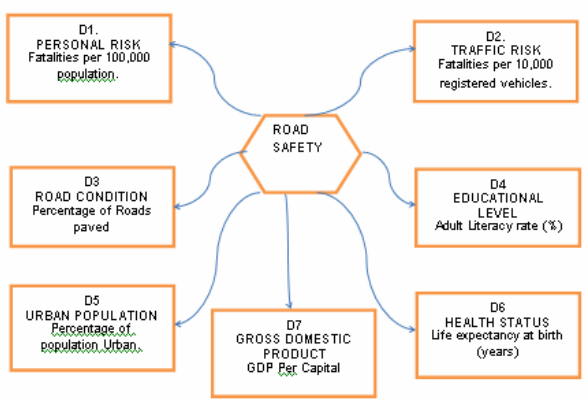

Figure-2. Schematic overview of road safety indicators.

ANALYSIS AND RESULTS

This section gives the analysis and results of the road safety index based on a simple average of the performance technique and based on theories of the indicators used. The previous section deals with the description of two common and useful weighing methods for combining information in one index. Table-1 summarizes the main advantages and disadvantages of the two methods. Here in this section I apply the method of simple averaging to the road safety data presented in Table-2.

Table-1. Summary information on the two approaches of weighting method.

Method	Main advantage	Main disadvantage
Average method	Simple No Normalization needed	No insight in indicator importance. No added value for policy makers. Risk of double weighting.
Based on theory	Optimal weights derived from literature.	Results are relative i.e., influence by the country in the data supplied.

Application of the weighing methods

Table-2. Scores using average method.

Country	D1	D2	D3	D4	D5	D6	D7	Index	Rank
Nigeria	69.7	97.37	35.1	100	27.28	74.5	85.7	69.95	1
Algeria	68.85	92.94	64.9	66.96	17.3	72.6	64.9	64.06	2
Tunisia	55.28	91.32	67.6	62.08	16.11	76.7	68.2	62.47	3
Morocco	63.22	86.73	52.7	57.76	8.39	68.6	36.3	53.37	4
Botswana	29.76	85.71	56.8	25.28	30.8	52.1	75.7	43.43	5
Ghana	76.49	84.39	44.6	5.69	1.61	33	49.9	42.25	6
South Africa	28.9	85.81	59.5	8.31	21.52	3.77	83.6	37.5	7
Guinea	100	91.93	23	10.2	1.28	20.1	4.7	33.76	8
Niger	96.53	77.16	21.8	11.86	16.70	23	0.43	29.85	9
Ethiopia	92.51	37.8	37.83	10.31	0.22	10.4	9.21	17.52	10

Source: Data modified from the World Bank world development indicators report 2008, IRF, OECD, 2013, WHO, 2013.

Method 2 is based on theory of indicators here sizes were assigned to the respective indicators according to values; the weights are shown after the brackets. The most important indicators are: traffic risk and road users behaviour the weight of which is (25%) each. The second most important are: Vehicle safety, road level, and personal risk, each of which has a weight of (10%). The least important indicators are socio - economic indicators: health index and income per capita, each of which has a weight of (5%) so the formula is derived as follows:

$$IRSI = 0.25 X (D1) + 0.10 x (D2) + 0.10 x (D3) + 0.10 x (D4) + 0.25 x (D5) + 0.05 x (D6) + 0.05 x (D7)$$

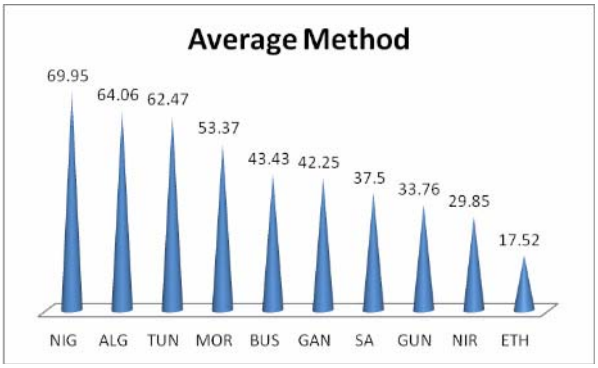

Figure-3. Showing cone ranking representation of Average Method.

Table-3. Scores using based on the theory method.

Country	Traffic risk D1	Personal risk D2	Vehicle safety D3	Road level D4	Road users behaviour D5	Urban population D6	GDP level D7	IRSI	Ranks
Nigeria	17.43	9.7	3.51	10	6.82	3.73	21.43	72.62	1
Algeria	17.21	9.29	6.49	6.70	4.33	3.63	3.20	50.85	2
Tunisia	13.82	9.13	6.76	6.21	4.03	3.84	3.41	47.20	3
Morocco	15.81	8.67	5.27	5.78	2.10	3.43	1.82	42.88	4
Botswana	7.44	8.57	5.68	5.78	7.7	5.21	3.79	38.96	5
Ghana	19.12	8.44	4.46	0.57	0.40	1.65	2.50	37.14	6
South Africa	2.27	8.58	5.95	0.83	5.38	0.19	4.18	25.11	7
Guinea	6.25	9.20	2.30	1.20	0.32	1.01	4.7	19.08	8
Niger	6.0	7.72	6.79	1.20	0.20	1.15	0.02	16.09	9
Ethiopia	5.75	6.10	3.8	1.03	0.06	0.52	0.46	7.82	10

Source: Data modified from the World Bank world development indicators report 2008 and 2010, IRF, OECD, 2013.

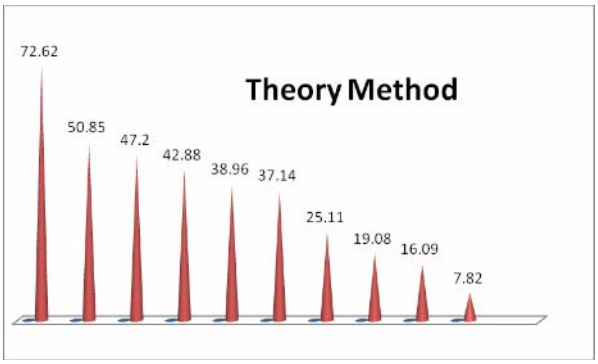

Figure-4. Show cone ranking representation of based on theory method.

DISCUSSIONS

In Table-2 before taking the simple average, all indicators were normalized/standardized to common units before integration to ensure that they are additive and to avoid some indicators like population or GDP in millions and 10000s dominating others like traffic risk in % or life expectancy in years. This involved calculating the distance between the actual value and the maximum and minimum values for each indicator using;

$$\text{Standardised value} = \frac{\text{'Maximum value-Actual value' x 100}}{\text{'Maximum value-Minimum value'}}$$

For the present analysis, all indicators were assumed to have equal weights and a simple average of all (seven) indicators calculated as the safety index as shown in Table-2. For example the road safety index of 69.95 for Nigeria was derived by summing up all the normalized values of the seven indicators (69.7+ 97.37+35.1+100+27.28+74.5+85.7) and dividing the result by seven that is the total sum of the indicators. A higher index in the simple average technique indicates better road safety performance as shown in the ranking. The fact that the road safety based on the simple average technique used equal weights may be biased in the sense of tilting toward one side of high or low values in one or more indicators, an alternate approach using 'based on the theories of indicator method was used as to give weights

(coefficients) to each of the indicators considered and the formula IRSI= 0.25 x (D1) + 0.10 x (D2) + 0.10 x (D3) + 0.10 x (D4) + 0.25 x (D5) + 0.05 x (D6) + 0.05 x (D7) was used for the calculation as in Table-3 as we see in [8, 11], the result was reasonably compared to that obtained in method 1 to rank countries in road safety situations and consequently each countries were ranked according to their respective scores as shown in the two Tables 2 and 3.

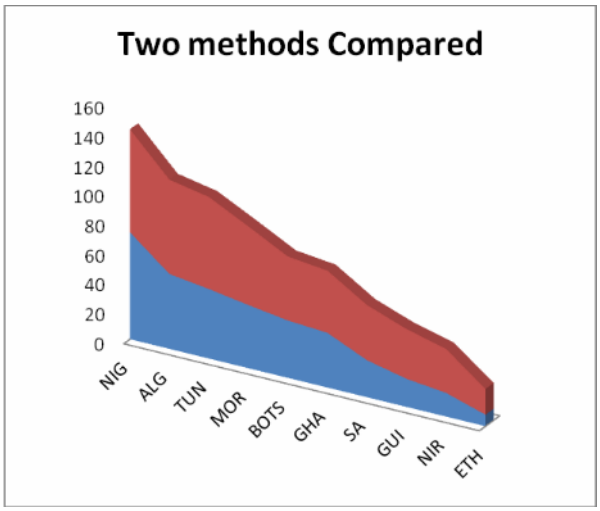

Figure-5. Area comparison of the two methods.

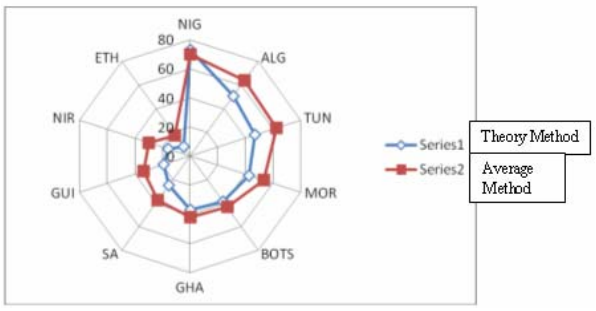

Figure-6. Radar comparison of the two methods.

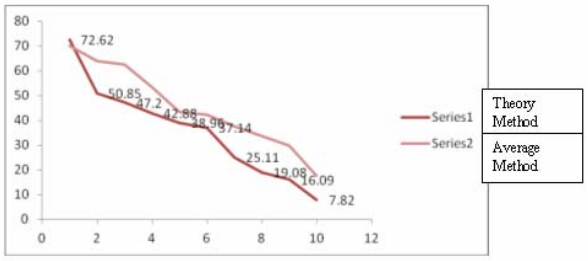

Figure-7. 3-D line comparison of the two methods.

CONCLUSIONS AND FURTHER WORK

In this study, two methods were used to construct a simple road performance index for 10 selected African countries. The first method involved developing a road safety index using simple average technique similar to the one used by World Bank and UN in constructing the Human Development Index while the second is method based on theory of indicators from literatures. The road safety averaging method and that based on the theory of indicators method is challenging but necessary task in road safety research as it help the road users, practitioners and policy makers a useful tools for benchmarking and ranking countries' road safety performances, the integral road information integrates several relevant aspects of road safety together into a simple and aggregate index, allowing meaningful comparisons to be made. From the various comparisons in Figures 5, 6 and 7 based on theory method shows a reliable assessment of weighting method. This integral road safety index therefore has the potential to become a major method of making international comparisons of road safety performance in the future similar to the popularity attained with the Human Development Index used by the World Bank to measure the annual achievements of countries. Further studies on a broad range of countries using best needed (most preferable/ideal) indicators instead of best data available indicators is recommended. The selection of the more weighting method and the inclusion of uncertainty and regression analysis are also essential for the further development of the road safety performance index approach and may form the focus of further research on the Road Safety Performance Index Approach.

REFERENCES

[1] World Health Organization. 2009. Global status report on road safety: Time for action. World Health Organization.

[2] Hermans E., Van den Bossche F. and Wets G. 2008. Combining road safety information in a performance index. Accident Analysis and Prevention. p. 40.

[3] Nardo M., Saisana M., Saltelli A., Tarantola S., Hoffman A. and Giovannini E. 2005b. Handbook on constructing composite indicators: Methodology and user guide. Organization for Economic Co-operation and Development.

[4] 2010. World Health Organization.

[5] Hermans E., Van den Bossche F. and Wets G. 2009. Uncertainty assessment of the road safety index. Reliability Engineering and System Safety. 94: 1220-1228.

[6] Aimsun. 2008. AIMSUN NG: The Integrated Traffic Environment, from. http://www.aimsun.com.

[7] Jacobs G, Aaron - Thomas A and Astrop A. 2000. Estimating global road falalities. TRL Report 445, Transport Research Laboratory, London, UK.

[8] Millicent Awialie Akaateba. 2012. Comparing Road Safety Performance of Selected EU and African Countries using a Composite Road Safety Performance Index. Journal of National Science Research. 2(8).

[9] Al Haji G. 2005. Towards a road safety development index. PhD Thesis. Linkopings universitet.

[10] Safety Net. 2005. State of the art report on road safety performance indicators. D3.1 of the EU FP6 project Safety Net.

[11] ETSC. 2001. Transport Safety Performance Indicators. European Transport Safety Council.

[12] European Transport Safety Council. 2001. Transport safety performance indicators. European Transport Safety Council.

[13] Hakkert A.S and V. Gitelman (Eds.) 2007. Road Safety Performance Indicators Manual Deliverable D3.8 of the FP6 project Safety Net.

[14] Amditis A., Pagle K., Joshi S. and Bekiaris E. 2010. Driver-vehicle-environment monitoring for on board driver support systems. Use cases and validation. Applied Ergonomics. 41(2).

[15] Hermans E. 2009. A methodology for developing a composite road safety performance index for cross country comparison. PhD Thesis. Hasselt University.

[16] Cacciabue P.C., Re C. and Macchi L. 2007. Simple simulation of driver performance for prediction and design analysis. In: Cacciabue, P.C. (Ed.). Modelling Driver Behaviour in Automotive Environments. Springer-Verlag, London, UK.

[17] Carsten O. 2007. From driver models to modelling the driver: what do we really need to know about the driver? In: Cacciabue, P.C. (Ed.). Modelling Driver Behaviour in Automotive Environments. Springer, London, UK.

[18] Casucci M., Marchitto M. and Cacciabue P.C. 2010. A numerical tool for reproducing driver behaviour: Experiments and predictive simulations. Applied Ergonomics.

[19] Cody D. and Gordon T. 2007. TRB workshop on driver models: a step towards a comprehensive model of driving? In: Cacciabue, P.C. (Ed.). Modelling Driver Behaviour in Automotive Environments. Springer-Verlag, London, UK.

[20] Elke Hermans, Filip Van den Bossche and Geert Wets. 2008. Combining road safety information in a performance index.

[21] Engstro¨m J. and Hollnagel E. 2007. A general conceptual framework for modeling behavioural effects of driver support functions. In: Cacciabue, P.C. (Ed.). Modelling Driver Behaviour in Automotive Environments. Springer-Verlag, London. Network (2005). 2005 environmental sustainability index. Yale University and Columbia University.

[22] Hegeman G. 2008. Assisted Overtaking: an Assessment of Overtaking on Two-lane Rural Roads. TRAIL Thesis Series no. T2008/4. TRAIL Research School, Deft, the Netherlands.

[23] Pennoni F., Tarantola S. and Latvala A. 2005. The 2005 European e-business readiness index. European n DG Joint Research Centre.

[24] Salzman J. 2003. Methodological choices encountered in the construction of composite indices of economic and social well-being. Centre for the Study of Living Standards.

[25] Litman T. 2007. Developing indicators for comprehensive and sustainable transport planning. In: Proceedings of the 86th annual meeting of the Transportation.

[26] Morsink P., Oppe S., Reurings M. and Wegman F. 2007. Development of a footprint methodology for road safety. Transportation Research Record.

[27] 2010. International Road Traffic and Accident Database (IRTAD).

[28] 2011. United Nations Economic Commission for Europe (UNECE) Statistics.

[29] 2012. International Road Federation (IRF).

[30] 2011. UK Department of transport. Transport Analysis Guidance - Web TAG.

[31] Institute for Road Safety Research, Netherlands. 2007. Transport Research and Innovation Portal (TRIP).

[32] 2013. Arrive Alive Road Safety Website (Auto Zone South Africa).

[33] European Commission. 2005. Sustainable development indicators to monitor the implementation of the EU sustainable development strategy. Commission of the European Communities.