Available online at www.sciencedirect.com

SciVerse ScienceDirect

APCBEE Procedia 5 (2013) 33 – 37

Procedia APCBEE

www.elsevier.com/locate/procedia

ICESD 2013: January 19-20, Dubai, UAE

Measuring and Evaluating Air Pollution Per Inhabitant: A Statistical Approach

Marina Dobrot [a*], Natasa Petrovic[a], Marko Cirovic[a] and Veljko Jeremic[a]

[a]*Faculty of Organizational Sciences, University of Belgrade, Jove Ilica 154, 11000 Belgrade, Serbia*

Abstract

This paper examines Europe Union member countries air pollution per inhabitant, using a novel statistical approach – I-distance method. The issue is measuring the air pollution per inhabitant and evaluating this measurement by ranking countries. Ranking has been based on six different criteria chosen to determine countries' air pollution. We have found that the worst situation occurs in Luxembourg, Bulgaria, Ireland, Estonia, and Greece, while situation in Sweden, Portugal, Germany, Slovakia, and United Kingdom is much better with far less air pollution per inhabitant. The paper also seeks to explain the results of ranking, which came as a result of this research and abilities of specific countries to cope with the environmental problems such as air pollution. The main contributions of this paper are defining the measurement of the air pollution per inhabitant, which includes the whole set of input parameters, and discovering which of these parameters were crucial for ranking of countries.

Keywords: Air pollution, Evaluating countries, I-distance method

1. Introduction

Some greenhouse gases remain in the atmosphere for decades or even centuries, and therefore can affect the Earth's energy balance over a long time period. Factors that influence Earth's energy balance can be quantified in terms of "radioactive climate forcing." Positive radioactive forcing indicates warming (for example, by increasing incoming energy or decreasing the amount of energy that escapes to space), while negative forcing is associated with cooling. The most common greenhouse gas is carbon dioxide (CO_2) which

* Corresponding author. Tel.: +381-69-889-3386; fax: 381-11-2461-221.
E-mail address: dobrota.marina@fon.bg.ac.rs

doi:10.1016/j.apcbee.2013.05.007

is emitted as a result of consumption of fossil fuels in the energy sector. Though living things emit carbon dioxide when they breathe, carbon dioxide is widely considered to be a pollutant when associated with cars, planes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline and natural gas. In the past 150 years, such activities have pumped enough carbon dioxide into the atmosphere to raise its levels higher than they have been for hundreds of thousands of years. Nevertheless, all sectors of society require energy to perform their function - thus contributing to climate changes [1]. While the developed countries bear the main responsibility for climate change, one could question whether the dynamics of climate change, conflict and forced migration can and should be portrayed as a threat image of masses of refugees flooding over western borders [2].

2. Research Issue

The issue addressed in this paper is measuring the air pollution per inhabitant and evaluating this measurement by ranking countries. The proposed hypothesis is that the measurement of air pollution can be more accurate when set of parameters is used. In this article, ranking has been based on six different criteria chosen to determine a countries' air pollution per inhabitant. All data were collected from Eurostat [3], and present annual values of given variables in 2009 (which are last available data). These are:

- ***Urban population exposure to air pollution by particulate matter* - Micrograms per cubic meter** - the population weighted annual mean concentration of particulate matter at urban background stations in agglomerations.
- ***Emissions of sulphur oxides (SOx) per inhabitant* (tons)** - tracks trends in anthropogenic atmospheric emissions of sulphur oxides.
- ***Emissions of nitrogen oxides (NOx) per inhabitant* (tons)** - tracks trends in anthropogenic atmospheric emissions of nitrogen oxides.
- ***Emissions of non-methane volatile organic compounds (NMVOC) per inhabitant* (tons)** - tracks trends in anthropogenic atmospheric emissions of non-methane volatile organic compounds.
- ***Emissions of ammonia (NH_3) per inhabitant* (tons)** - tracks trends in anthropogenic atmospheric emissions of ammonia.
- ***CO_2 emissions per inhabitant* (tons)** - the level of CO_2 emissions in tons per inhabitant. For EU Member States: this indicator is compiled using the data on CO_2 emissions provided in the official submission of the European Commission to the UNFCCC; and per capita emissions are calculated using Eurostat population statistics.

The I-distance method allows for the ranking of countries by taking many parameters into consideration. This fact and the fact that the method is becoming increasingly popular, which is evident from the large literature review (see Section 3), are the main reasons for using this particular method for measuring and evaluating air pollution per inhabitant.

3. The I-distance method

Ranking of specific marks can often seriously affect the process of evaluation [4,5,6,7,8,9,10,11]. I-distance is a metric distance in an n-dimensional space, which has recently made a significant breakthrough in a number of scientific achievements. It was originally proposed and defined by B. Ivanovic and has appeared in various publications since 1963 [6,12]. A notable, striking affirmation of the method has been its use in University ranking [4,8], and evaluating the socio-economic development of counties [13]. Ivanovic devised this method to rank countries according to their level of development based on several indicators. Many socio-economic development indicators were considered, but the problem was how to use all of them in order to calculate a single synthetic indicator, which will thereafter represent the rank.

For a selected set of variables $X^T=(X_1,X_2,...X_k)$ chosen to characterize the entities, the I-distance between the two entities $e_r=(x_{1r},x_{2r},...x_{kr})$ and $e_s=(x_{1s},x_{2s},...x_{ks})$ is defined as

$$D^2(r,s)=\sum_{i=1}^{k}\frac{d_i^2(r,s)}{\sigma_i^2}\prod_{j=1}^{i-1}\left(1-r_{ji.12...j-1}^2\right) \quad (1)$$

where $d_i^2(r,s)$ is the square distance between the values of for e_r and e_s, e.g. the discriminate effect,

$$d_i(r,s)=x_{ir}-x_{is},\ i\in\{1,...,k\} \quad (2)$$

σ_i standard deviation of X_i, and $r_{ji.12..j-1}$ a partial coefficient of the correlation between X_i and X_j, $(j<i)$, [5,7,15,16].

The I-distance measurement is based on calculating the mutual distances between the entities to create a rank. In order to rank the entities (in this case, countries), it is necessary to have one entity, in this case with the minimum value, fixed as a referent in the observing set using the I-distance methodology. The ranking of entities in the set is based on the calculated distance from the referent entity [4,6,18,19].

4. Results

The results of both measuring the air pollution per inhabitant using the I-distance method, and evaluating countries by amount of air pollution per inhabitant, through ranking of countries, are shown in Table 1.

As presented in Table 1, if we have measured air pollution per inhabitant, the worst situation occurs in Luxembourg, Bulgaria, Ireland, Estonia, and Greece. These counties are found on the top of the evaluating list and they have the greatest concentration of air pollution per inhabitant, measured by the set of parameters, given in Section 2. On the other hand, situation in Sweden, Portugal, Germany, Slovakia, and United Kingdom is much better and these countries are found on the bottom of the list, with far less air pollution per inhabitant. Explanation of the results gained in this research can be found in Table 2, where Pearson correlation coefficients between I-distance metrics and each of the input variables are presented. This allows for a better understanding of the measurement results of air pollution per inhabitant, as well as evaluation of situation in analyzed countries.

Table 1. I-distance measurement of air pollution per inhabitant

Country	I-distance value	I-distance Rank	Country	I-distance value	I-distance Rank
Luxembourg	40.4	1	France	4.39	14
Bulgaria	29.75	2	Lithuania	4.18	15
Ireland	27.66	3	Spain	4.08	16
Estonia	16.66	4	Belgium	3.63	17
Greece	13.7	5	Austria	3.16	18
Poland	8.32	6	Netherlands	3.07	19
Denmark	7.9	7	Hungary	3.02	20
Romania	7.44	8	Sweden	2.85	21
Latvia	6.35	9	Portugal	2.62	22
Finland	6.03	10	Germany	2.15	23
Czech Republic	5.35	11	Slovakia	2.05	24
Slovenia	5.25	12	United Kingdom	1.43	25
Italy	5.17	13			

According to the results of our research, the most significant variable for measuring and evaluating air pollution per inhabitant is *Emissions of nitrogen oxides (NOx) per inhabitant*, with r=0.627, p<0.001. It is followed by *CO2 emissions per inhabitant*, *Emissions of sulphur oxides (SOx) per inhabitant*, and *Emissions* *of ammonia (NH3) per inhabitant*. *Urban population exposure to air pollution by particulate matter* and *Emissions of non-methane volatile organic compounds (NMVOC) per inhabitant* are not significantly correlated to I-distance measurement value.

Table 2. Variable importance as measured by correlation with the I-distance

Variables	Correlation with the I-distance
Emissions of nitrogen oxides (NOx) per inhabitant	0.627^{**}
CO_2 emissions per inhabitant	0.553^{**}
Emissions of sulphur oxides (SOx) per inhabitant	0.435^{*}
Emissions of ammonia (NH3) per inhabitant	0.423^{*}
Urban population exposure to air pollution by particulate matter	0.216
Emissions of non-methane volatile organic compounds (NMVOC) per inhabitant	0.114

$^{*}p<0.05$, $^{**}p<0.01$

As indicated before, this issue was very important to investigate, since it explains the measurement value and evaluating position of countries. Luxembourg is registered to have the highest concentration of noxious particles and gases. Even though annual emissions of NOx in this country are 43887 tons for the national territory, their amount is 0.0881 per inhabitant. This is deeply influenced by Luxembourg's small territory area and high population density. CO_2 annual emissions are even 21.7 tons per inhabitant, which is far larger than in any other European country. For comparison, United Kingdom's annual emissions of NOx are 1143284 tons for the national territory and 0.0185 tons per inhabitant, and CO_2 annual emissions are a bit higher, 7.7 tons per inhabitant.

It is important to notice that, except for Luxembourg, which is previously highlighted to be very small and very densely populated, countries with highest amount of air pollution are mostly developing countries, which are poorer compared to other countries in the list. On the other hand, countries which are in the bottom of the list and consequently much less polluted, are wealthy developed countries. It is obvious to conclude that these countries invest more in developing the long term sustainability strategies, and that this one of the main reasons for gaining our results.

5. Discussion and conclusion

The main contribution of this paper is defining the measurement of the air pollution per inhabitant, which includes the whole set of input parameters, which I-distance method succeeded to achieve. One of the most important advantages of this method is the ability to determine the relevance of input criteria, thus the *Emissions of NOx* and *CO_2 per inhabitant* were found to be most important ranking criteria.

The list that was the result of our research, places Luxemburg at the top. This result is in accordance with earlier EU research related to NOx, where 17 countries were above the EU average, with Luxembourg at the top emitting twice as much or 38.5 kg per person. To date, there is no regional plan in place for the prevention and control of troposphere ozone in cooperation with neighboring countries. However, with the limited size of the national territory, Luxembourg cannot win the battle against ground-level ozone by means of national measures alone. The import of ozone precursors from bordering regions makes cooperation necessary, and Belgium is being prioritized as the prevailing winds come from that direction. Cooperation is planned at two levels. Firstly, at the level of information and forecasting, an agreement is being negotiated to enable Luxembourg to participate in the forecasting work on ozone and fine-particle concentrations being done for Belgium by Brussels' Interregional Committee of the Environment. In a second phase, Luxembourg will work with the Belgian authorities to establish an action plan for reducing ozone precursors. As required by Directive 2008/50/EC on ambient air quality and cleaner air for Europe, an air quality plan for the city of Luxembourg is currently under consideration. The main objective is to restrict the transgression of NOx limits in the city centre. Some of the measures proposed include an accelerated renewal of the city bus fleet, the creation of a tramway, and the prohibition of trucks in certain critical sectors of the city [19].

In the top half of Table 1 we can find members that joined EU in the last two enlargements - Bulgaria and Romania in 2007, and Czech Republic, Estonia, Latvia, Poland, and Slovenia, in 2004. This can be explained due to the fact that these countries started implementing environmental policies just recently. And then we have countries that are in the ongoing economic crises heartened the most, Greece, Ireland, and Italy. One of the arising statements is that for the real implementation of the environmental policies, countries need solid investments into infrastructural projects, which these countries at the start of the crises in 2007 just could not afford.

References

[1] Petrovic N, Drakulic M, Vujin V, Jeremic V. Climate Changes and green information technologies. *Management* 2011; **16(59)**:35-43.

[2] Cirovic M, Petrovic N. Climate changes: impact on human migration. *Proceedings of The Fifth International Scientific Conference BALWOIS 2012 - Conference on Water, Climate and Environment* 2012; 28 May - 2 June, Ohrid, FYR Macedonia.

[3] Eurostat. 2012. Retrieved on June 15, 2012, from http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics

[4] Jovanovic M, Jeremic V, Savic G, Bulajic M, Martic M. How does the normalization of data affects the ARWU ranking? *Scientometrics* 2012, In press - Online First. doi: 10.1007/s11192-012-0674-0.

[5] Ivanovic B. *A method of establishing a list of development indicators*. Paris: United Nations educational, scientific and cultural organization; 1973.

[6] Radojicic Z, Isljamovic S, Petrovic N, Jeremic V. A novel approach to evaluating sustainable development. *Problemy Ekorozwoju - Problems of Sustainable Development* 2012, **7(1)**:81-85.

[7] Knezevic S, Jeremic V, Zarkic-Joksimovic N, Bulajic M. Evaluating the Serbian banking sector: a statistical approach. *Metalurgia International* 2012, **17(1)**:171-174.

[8] Jeremic V, Bulajic M, Martic M, Radojicic Z. A fresh approach to evaluating the academic ranking of world universities. *Scientometrics* 2011, **87(3)**:587–596.

[9] Radojicic Z, Jeremic V. Quantity or quality: What matters more in ranking higher education institutions? *Current Science* 2012, **103(2)**:158-162.

[10] Jeremic V, Isljamovic S, Petrovic N, Radojicic Z, Markovic A, Bulajic M. Human development index and sustainability: What's the correlation? *Metalurgia International* 2011, **16(7)**:63-67.

[11] Dobrota M, Jeremic V, Markovic A. A new perspective on the ICT Development Index. *Information Development* 2012; In Press – OnlineFirst. doi:10.1177/0266666912446497

[12] Ivanovic B. *Classification Theory*. Belgrade: Institute for Industrial Economic; 1977.

[13] Jeremic V, Bulajic M, Martic M, Markovic A, Savic G, Jeremic D, Radojicic Z. An Evaluation of European Countries Health Systems through Distance Based Analysis. *Hippokratia* 2012, **16(2)**:175-179.

[14] Jeremic V, Markovic A, Radojicic Z. ICT as crucial component of socio-economic development. *Management* 2011, **16(60)**:5-9.

[15] Jeremic V, Slovic D, Radojicic Z. Measuring human capital: A statistical approach. *Actual Problems of Economics* 2012, **131(5)**:359-363.

[16] Jeremic V, Seke K, Radojicic Z, Jeremic D, Markovic A, Slovic D, Aleksic A. Measuring health of countries: a novel approach. *HealthMED* 2011, **5(6)**: 1762-1766.

[17] Maletic P, Kreca M, Jeremic V, Bulajic M, Djokovic A. The Ranking of Municipalities in Serbia through the Development Level of SME in Agribusiness. *International Journal of Agricultural and Statistical Sciences* 2012, **8(1)**:7-13.

[18] Jeremic V, Vukmirovic D, Radojicic Z, Djokovic A. Towards a framework for evaluating ICT infrastructure of countries: a Serbian perspective. *Metalurgia International* 2011, **16(9)**:15-18.

[19] EEA – Europe Environmental Agency, The European environment – state and outlook 2010, Retrieved on June 20, 2012 from http://www.eea.europa.eu/