Environmental Engineering and Management Journal April 2019, Vol. 18, No. 4, 781-788
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

IMPROVING THE METHOD OF CALCULATING THE ECOLOGICAL FOOTPRINT GENERATED BY ROAD TRAFFIC - CASE STUDY

Angelica Nicoleta Călămar, Alexandru Simion*, Lorand Toth, Sorin Simion, Cristian Nicolescu

National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroşani, 32-34 G-ral Vasile Milea Street, 332047 Petroşani, Hunedoara County, Romania

Abstract

Sustainable development brings in advance a new set of values that will guide the future model of economic and social progress, values that focus on human and his current and future needs, on the natural environment - protecting and preserving it, as well as on mitigating the current deterioration of ecosystems. The present paper aims at improving a calculation method for measuring the ecological footprint generated by road traffic, through modifying the concept of integrating variables, increasing the method's precision and the possibility of applying it both in heavily urbanized and poorly developed areas. In this respect, a case study was carried out in Petrosani, where the proposed calculation method was applied, measuring the impact of road transport in relation to green spaces. For this purpose, data on transport infrastructure, road traffic, climate regime as well as the population Petroşani were collected. Based on the study, the ecological footprint generated by Petroşani road traffic exerts a high pressure on ecosystems against other activities carried out by inhabitants. Upgrading main and secondary arteries, streamlining traffic and restricting circulation in residential areas are some of the practices recommended.

Key words: carbon emissions, ecological footprint, land, road transport, sustainability

Received: September, 2018; Revised final: January, 2019; Accepted: March, 2019; Published in final edited form: April, 2019

1. Introduction

The concept of sustainable development aims to meet "needs of the present, without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). In order to achieve challenges of sustainable development, the United Nations Conference on Environment and Development, also called the Rio Earth Summit, laid the foundations of local Agenda 21, representing the basis and action plan for the concept of sustainable development, where "environmental protection will be an integrated part of the development process and cannot be tackled independently" (United Nations Summit, 1992).

"Transforming the world in which we live", also called Agenda 2030 for Sustainable Development, includes a set of global sustainable development objectives that have replaced the sustainable development objectives of past millennium. Hence, Agenda 2030 provides an answer to global challenges addressing in a comprehensive manner the issue of poverty eradication and the economic, social and environmental dimensions of sustainable development (United Nations Summit, 2015).

The synergy of road traffic with the new environmental objectives for sustainable development requires new correlations between inputs of instruments measuring road traffic pressures on ecosystems and environmental targets. The paper's main objective is to improve a precise and accurate tool to accurately measure the pressure exerted by road traffic on terrestrial and aquatic ecosystems in a

* Author to whom all correspondence should be addressed: e-mail: alexandru.simion@insemex.ro; Phone: +40 254 541 621; Fax: +40 254 546277

given territory being quantified as an area necessary to provide the needed resources and to neutralize generated waste, with the main objective of introducing additional steps in calculating the physical footprint and emphasizing the importance of environmental protection in the 21st century.

In order to measure the ecological impact generated by road transport, a case study was carried out in Petrosani (Romania) on the impact of road traffic on population by using an improved ecological footprint calculation method. Studying the literature in the field (Ghinea et al., 2017; Rockström et al., 2009; Wackernagel and Rees, 1996a; Wackernagel and Rees, 1996b; Wiedmann et al., 2006; Wiedmann and Barret, 2010) we found that there are several methods and methodologies for calculating ecological footprint. Choosing one of these methods was based on the understanding and applying abilities, on the lack of subjectivism and method's advantages. In this respect, the analysis carried out led in selecting the general method of calculating the environmental footprint generated by road traffic developed by Zamba and Hadjibiros (2007). On this basis, a new method has been developed, especially for urban agglomerations or for a particular territory. The new method consists in adding certain coefficients, respectively: coefficients based on the state of the road, climatic coefficients, urban public transport agglomeration coefficients, additional fuel consumption index during stop and start-up cycles, additional consumption when starting the vehicles. In this respect, for a more accurate estimation of the number of kilometres covered by vehicles in one year, a synchronization of the astronomical year with the seasonal one was performed.

The present paper contains a comprehensive overview of the environmental footprint concept in the context of sustainable development, the proposal and application of an improved method for calculating the environmental footprint on an urbanized area and the comparison of the environmental footprint index with other urbanized areas of the world.

The environmental footprint calculation method comes in support of researchers, environmental engineers and to any specialist involved in environmental protection. Also, the results obtained can be compared objectively with other urban agglomerations because the proposed method uses general variables that can be easily calculated or approximated. Being a versatile method, it can be used for a quick assessment of environment's state at one point, but like any other method it may have a lower or higher degree of subjectivity depending on correctness of input data and area dynamics.

2. Material and methods

The research methods mainly used were scientific abstraction, analysis, synthesis, comparison, induction and deduction. In elaborating the paper, information used consisted of direct field observations, content analysis of official documents (laws, strategies, and applications), materials of the National Institute of Statistics, Ministry of Environment, Water and Forests, analytical data of CCME - Centre for Carbon Management in Edinburgh, the Eurostat database, sources of statistical and socio-economic data of OECD, Global Footprint Network and Petrosani town hall.

The term "ecological footprint" represents the entire extent of Earth relative to number of inhabitants, resulting in an area of Earth that an individual or organization needs in order to secure its resource requirements and to completely biodegrade waste generated along its entire existence (Rockström et al., 2009; Wackernagel and Rees, 1996a). The ecological footprint is measured in global hectares (hag) and for its calculation the entire Earth surface, including water and frozen areas is taken into account (Wackernagel and Rees, 1996a). The environmental footprint may be used within relevant policies and schemes for measuring or communicating the environmental performance of products or organizations throughout their lifecycle.

The interchangeable use of ecological footprint and environmental footprint terms is possible, as they essentially represent the same thing, but it is recommended that the term ecological footprint to be used when referring to individual's impact on the planet, whereas the environmental footprint is much proper when referring to products or objects based on life cycle assessment.

In order to assess the impact of anthropogenic activities on the environment, the literature offers various methods and methodologies such as the global pollution index, the MERI method, the impact matrix etc., but sometimes these methods are either too cumbersome or in some cases highly subjective (Capsa et al., 2016; Petrescu et al., 2015). Therefore, Wackernagel and Rees (1996a) introduced an instrument capable of responding to these challenges, the environmental footprint index which essentially represents the pressure we exert on ecosystems, productivity and regeneration of natural resources levels so that they can meet the needs of mankind and the degree of absorption of waste produced.

Calculating the ecological footprint generated by road transport requires identifying ways in which road transport can directly or indirectly consume biologically productive land (Iojă, 2013). Road transport consumes space through road infrastructure and related facilities, emits carbon dioxide (CO_2) by burning fuels, uses energy for vehicle production and maintenance, uses non-renewable natural resources to build and maintain infrastructure (Yang et al., 2015).

The ecological footprint of road traffic (Fig. 1) is generated mainly by CO_2 emissions from transport and its associated infrastructure, calculated by measuring the physical footprint (PF) and energy footprint (EF) relative to population (P) of the territory taken into consideration (Canadell et al., 2007; Condurat et al., 2017; Fei et al., 2018; Rockström et al., 2009; Wiedmann et al., 2006; Wiedmann and Barret, 2010; Zamba, 2006).

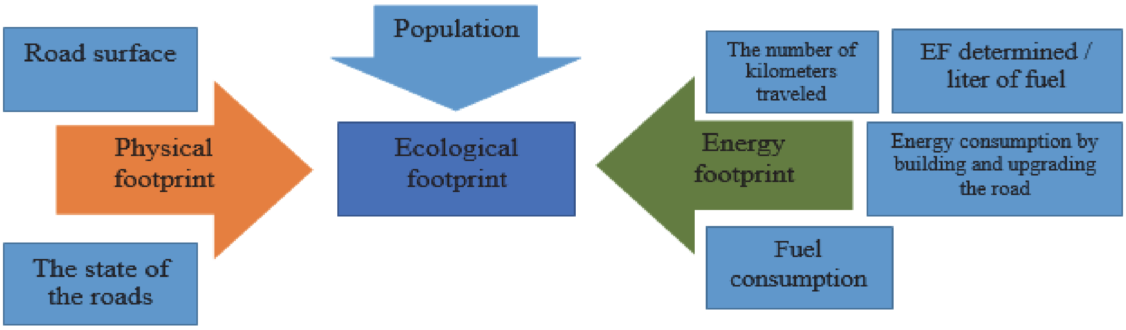

Fig. 1. Computational model of ecological footprint

Table 1. Road coefficient applied based on road condition (GD, 1982)

Road class symbol	***Road coefficient***	***Value***	***Road state description***
I (M)	D1	0.9	Asphalted roads in good condition (asphalt concrete, asphalt macadam, double treatment macadam, bituminous ballast, cement concrete).
II (K)	D2	1.0	Paved roads (with holes, with normal or abnormal pavers) in good condition. Macadamized and grit-blinded roads in good condition.
III (T)	D3	1.1	Asphalted, paved, macadamized and grit-blinded roads in mediocre condition, requiring speed changes on approx. 20% of the way. Dirt roads and groundwork in good condition. Roads paved with raw stone, river boulders and sands, in good condition.
IV (L)	D4	1.2	Roads paved with key stone, gravel or macadamized and paved with rolling stone and cobble, in mediocre condition. K and T category roads with declivities requiring speed changes on approx. 40% of the way.
V (E)	D5	1.4	Roads whose condition requires speed changes on approx. 70% of the way. Earth roads and earthworks, in mediocre condition. Roads paved with rolling cobble or stone in bad condition.
VI (H)	D6	1.6	All other roads with a viability condition or with declivities that do not allow traffic at speeds exceeding 15 km / h over their entire length.

2.1. Measurement of the physical footprint (PF)

Measurement of the physical footprint consists in identifying the state of the roads in the area taken into consideration (Table 1) and measuring the area occupied by road infrastructure and related facilities (Eqs. 1 - 2). In order to measure the physical footprint it is necessary to analyse roads in the referred to area both quantitatively and qualitatively; the qualitative part of roads state materializes in the increase of the quantitative part of the roadway (road surface).

$$PF = \frac{1}{10} \times L_T \times l_m \qquad (1)$$

where: PF – physical footprint; l_m – average width of roads (m); L_T – total length of roads (km).

$$LT = \sum_{n=1}^{6} L_n \times D_n \qquad (2)$$

where: L_n – length of the road section n (km); D_n – road coefficient applied to road section n.

2.2. Measuring the energy footprint (EF)

Measuring the energy footprint consists in estimating the amount of land needed to sequester CO_2 emissions from vehicles. For calculating it, the following steps need to be completed (the steps from (a) to (e)):

(a) Estimating the number of kilometres per year travelled by vehicles

In order to estimate the number of kilometres travelled per year by vehicles it is necessary to monitor the vehicles on each main artery or street, if possible, then multiply the road traffic in one day by 365.25 which is the number of days in one year (Eq. 3):

$$N = 365.25 \sum_{n=1}^{n} L_n \times T_n \text{ [km/year]} \qquad (3)$$

where: T_n – average daily traffic per each type of road n (vehicles per day); L_n – length of the road on the type of road n.

(b) Estimating fuel consumption per kilometre

$$C_i = C + Q_p + Q_o + U \quad \text{[l/km]} \qquad (4)$$

Ci – fuel consumption index for a type "*i*" vehicle (l/km); C – average fuel consumption of a type "*i*" vehicle (l/km); Q_p – fuel consumption equivalent to starting a type "*i*" vehicle (Eq. 5).

$$Q_p = 0.05 \times C \times n \quad \text{[l equivalent]} \tag{5}$$

where: n – number of engine heating operations per day; Q_0 – fuel consumption equivalent during start-up cycles (Eq. 6).

$$Q_o = 0.25 \times C \times \frac{n}{100} \quad \text{[l equivalent]} \tag{6}$$

where: n – number of engine stops per day; U – urban public transport agglomeration coefficient (Eq. 7).

$$U = \frac{P_e}{100} \times 0.10 \quad \text{[l equivalent]} \tag{7}$$

where: P_e – actual car travel in urban area.

$$C_t = \sum_{i=1}^{n} C_i \times P_i \quad \text{[l/km]} \tag{8}$$

where: C_i – fuel consumption index for a type "i" vehicle (l/km); P_i –share of type "i" vehicles of total.

For a more accurate calculation of fuel consumption, we also introduced the climate correction coefficient, which can be weighted according to the number of cold days in a calendar year (Eq. 9).

$$C_T = \frac{\sum_{i=1}^{3} C_t \times N_i \times A}{\sum_{i=1}^{3} N_i} \quad \text{[l/km]} \tag{9}$$

where: C_t – total fuel consumption of vehicles per km [l/km]; N_i – number of days for a certain climate correction coefficient; A – climatic correction coefficient.

Table 2. Climatic correction coefficient (GD, 1982)

Climatic correction coefficient (A)	
A = 1	During summer (16.03 ÷ 30.11) Summer period considered between 16 March and 30 November (260 days)
A = 1.1	During winter (01.12 ÷ 15.03) Winter period considered between 01 December and 15 March (105.25 days)
A = 1.2	If the outside temperature is lower than -20°C

Insertion of the climatic factor is strictly related to the daily fuel consumption relation with weather conditions of the day, as fuel consumption significantly varies with ambient temperature variations. Thus, unfavourable weather increases the tire - carriageway friction, increases the engine's heating time and stimulates the use of air conditioning.

(c) Estimating the energy footprint resulting from the consumption of one litter of fuel

Considering that 1 hectare of forest annually absorbs CO_2 generated by the burning of 100 GJ of fuel, it results that 1 litter of fuel generates 0.035 GJ / litter (Eq. 10), (Jonsson, 2007; Vlasin et al., 2014; Zamba and Hadjibiros, 2006).

$$\frac{\textit{1 litre combustible} \times \textit{0.035 GJ/litre}}{\textit{100 GJ/ha/year}} = 0.00035\ \textit{ha / year} \tag{10}$$

(d) Energy consumption through construction and maintenance of roads is estimated at 40% of fuel consumption

Energy consumption through road construction and maintenance can be objectively estimated for each area by complex assessment of the road's infrastructure life cycle, in correlation with greenhouse gas emissions (Jonsson, 2007; Zamba, 2006; Zamba and Hadjibiros, 2007).

For the assessment of infrastructure life cycle, several major activities have to be considered, such as:

- construction stage refers to ground preparation, construction of main constituent parts of the road infrastructure, production and installation of other items (signs, wires, pipes, road furniture etc.).
- operation stage refers to supporting functions that facilitate possibilities to use the infrastructure. These include the following activities: lighting, cleaning, accident control, sand spreading, salting, snow clearance, street-sweeping, maintenance of road markings, vegetation clearing and others (Jonsson, 2007).
- maintenance stage refers to works that are required due to corrosion, erosion and displacement. These include the following main activities: surface coating, manufacturing, maintenance and operation of working machines, painting road markings and additional filling material (Jonsson, 2007).

(e) Measuring the energy footprint (Eq. 11):

$$EF = 1.40 \times 0.00035 \times N \times C_T \tag{11}$$

where: EF – energy footprint; N – Number of kilometres covered by all vehicles; C_T – fuel consumption [l/ km].

The total ecological footprint [hag/inhabitant] is given by Eq. (12) (Zamba, 2006; Zamba and Hadjibiros, 2007):

$$TEF = \frac{PF + EF}{P} \quad \text{[hag/inhabitant]} \tag{12}$$

P – number of inhabitants in the evaluated territory.

3. Results and discussion

In 2017, a case study was carried out in Petroşani, which aimed the assessment of road traffic impact on population, a city with a population of

28,927 inhabitants and an area of 195.56 km^2, situated at an altitude of 615-620 m from sea level.

Road traffic in Petroşani is mainly driven by vehicles equipped with internal combustion engines, with a significant contribution to environment pollution, knowing that the transports release a large number of pollutants, affecting practically all ecosystems. Carbon dioxide along with other gases resulting from combustion of fuels, daily loads the atmosphere of Petrosani, thus making necessary its periodic monitoring.

In order to have an overview of road traffic in the context of sustainable development and environmental impacts generated by road traffic, the ecological footprint of road traffic in Petroşani was measured, using Eqs. (1-12). Estimating the area occupied by road infrastructure in Petroşani was performed by measuring the average lengths and widths of roads, according to road state on Google Earth maps, achieving a total length of approximately 112,47 km and an average width of approximately 5.4 m (Table 3). The infrastructure under study was the section between Petrosani entry (Dărăneşti area) and Petroşani exit (the area of Livezeni deposits). Using Eqs. (1- 2), the total length of the roads in Petroşani (L_T) and the physical footprint (*PF*) were measured. The results are given by Eqs. (13, 14).

$$L_T = 0.9 \times 21.8 + 1 \times 38.49 + 1.1 \times 29.37 + 1.2 \times 18.38 = 112.47\ km \quad (13)$$

$$PF = \frac{1}{10} \times 112.47 \times 5.4 = 60.735 \quad (14)$$

Table 3. Average length and width of roads

Road category	***Road coefficient***	***Length of the sections [km]***	***Average width [m]***
D1	0.9	21.80	5.4
D1	1	38.49	
D3	1.1	29.37	
D4	1.2	18.38	

In order to estimate the total number of kilometres travelled by vehicles and to address the issue of carbon dioxide emissions from road traffic, a number of vehicles were monitored according to their category at certain well-defined hourly intervals (Appendix 1).

Estimation of number of kilometres per year covered by vehicles was achieved considering a daily average traffic of about 8.332 vehicles /day. Measurement of the total number of kilometres travelled by vehicles per year was achieved using Eq. (3), thus the results are given by Eq. (15):

$$N = 365.25 \times 8332 \times 112.47 = 342{,}284{,}919 \quad (15)$$

It should be noted that to approximate the number of vehicles per day, total values of data obtained in traffic monitoring points in one month were summed up, totalling 4 hours of continuously monitored traffic per day, without considering working and non-working days. The result obtained was multiplied by 2 (because a linear distribution of traffic for 8 hours was considered) and for the other 16 hours, traffic was considered to be 35% of the traffic calculated over 8 hours, because we considered that the productive activity of all organizations and inhabitants takes place in an 8-hour shift, and the other 16 hours are strictly dedicated to personal issues, adding the night period in which car traffic is significantly reduced. Fuel consumption /km were estimated by taking into account two types of vehicles: those weighing more than 3.5 tonnes (P1 = 8.62%) with an average consumption of 0.2 l /km and those with a weight lower than 3.5 tonnes (P2 = 91.38%) with an average consumption of 0.07 l/km. The share of vehicles was found by monitoring road traffic (Appendix 1). Goods traffic in Jiu Valley area is mainly driven by cars (trucks) weighing more than 3.5t, which does not people transportation. For the estimation of fuel consumption, it is not necessary to identify cars according to fuel they use, because estimation of energy footprint resulting from consumption of one litter of fuel takes this into account.

Using the Eqs. (5) to (7), the following were added to the total fuel consumption from Eq. (4): the fuel consumption equivalent when starting a vehicle (Q_p), fuel consumption equivalent during the start-stop cycles (Q_0) and the urban agglomeration coefficient of the public transport (*U*) for each category of vehicles, resulting in the following equations:

For vehicles weighting > 3.5 t the results are given by Eqs. (16-19):

$$Q_p = 0.05 \times 0.2 \times 1 = 0.01 \quad \text{[l equivalent]} \quad (16)$$

$$Q_o = \frac{0.25 \times 0.2 \times 6}{100} = 0.003 \quad \text{[l equivalent]} \quad (17)$$

$$U = \frac{19}{100} \times 0.10 = 0.019 \quad \text{[l equivalent]} \quad (18)$$

$$C_{t1} = 0.2 + 0.01 + 0.003 + 0.019 = 0.232\ [1/km] \quad (19)$$

For vehicles weighting < de 3.5 t:

$$O_p = 0.05 \times 0.07 \times 1 = 0.0035 \quad \text{[l equivalent]} \quad (20)$$

$$Q_o = \frac{0.25 \times 0.07 \times 6}{100} = 0.00105 \quad \text{[l equivalent]} \quad (21)$$

$$C_{t2} = 0.07 + 0.0035 + 0.00105 = 0.0745 \quad \text{[l/km]} \quad (22)$$

Because in Petroşani there are no public transport means with a total weight of <3.5 t, it was considered unnecessary to apply the urban public transport agglomeration coefficient (Eq. 23).

$$C_T = C_{t1} \times P_1 + C_{t2} \times P_2 = 0.232 \times 8.62 + 0.0745 \times 91.38 = 0.08812219 \text{ [l/km]} \quad (23)$$

$$C_T = \frac{C_T \times 105.25 \times 1.1 + C_T \times 260 \times 1}{365.25} = \frac{0.8812 \times 105.25 \times 1.1 + 0.8812 \times 260 \times 1}{365.25} = 0.0906 \text{ [1/km]} \quad (24)$$

$$EF = 1.40 \times 0.00035 \times 342{,}284{,}919 \times 0.090661508 = 14{,}966.54317 \quad (25)$$

Estimated total fuel consumption of vehicles / km was measured by equation 8 resulting in a total consumption of 0.08812219 [l/km] to which, according to Eq. (9), the following were added: the 1.1 correction coefficient for the winter period for 105.25 calendar days (Table 1) and the 1 climatic correction coefficient for the summer period, for 260 days (Table 1), resulting in a total consumption of 0.090661508 [l/km] (Eq. 24). By using equation 10 we found an estimation of the amount of land needed to sequester CO_2 emissions from vehicles (energy footprint) as being (Eq. 25). The total ecological footprint was calculated using Eq. (11) and the results are as follows (Eq. 26):

$$TEF = \frac{(60.73542 + 14{,}966.54317)}{28{,}927} = \quad (26)$$

0.52 [hag/inhabitant]

Thus, the ecological footprint generated by road transport in Petroşani is 0.52 [hag /inhabitant], which includes only the pressures generated by transport (road infrastructure activities, related facilities, carbon dioxide emissions from fuel combustion, vehicle production and maintenance, construction and maintenance of infrastructure).

Calculating the ecological footprint can be similar for several categories of land uses and for different economic activities (Matarazzo et al., 2017; Venetoulis and Talberth, 2008; Wackernagel and Rees, 1996a; Wiedmann et al., 2006; Wiedmann and Barrett, 2010). Although the aggregation of regional values obtained by land use or economic activity categories is not possible, this environmental footprint assessment allows for a more detailed understanding of the interaction of factors to be considered when assessing the environmental impact of anthropogenic activities (Girod et al., 2009; Rockström et al., 2009).

For a review of the global environmental footprint, all pressures generated by population (water consumption, waste water, housing construction, housing size, living standard, food, waste per capita, amount of resources consumed, renewable or non-renewable energy sources, waste recycling, etc.) must be taken into consideration. We mention that in order to validate the improvements to the method this study only considered the footprint generated by road traffic.

A balanced ecological footprint adapted to Planet resources has a value of 1.8 hag /person (Rockström et al., 2009). This calculation represents an average of the world's poorer and richest areas (Rockström et al., 2009). Thus, the third world, that records values below 1.8 hag/person offers developed countries the possibility to exceed their production and consumption limits (Rockström et al., 2009). In Europe, the average environmental footprint is 4.9 hag /person while in the United States the value doubles (Rockström et al., 2009; Wackernagel and Rees, 1996a). Romania has an ecological footprint of 1.4 global hectares per capita (hgc), mostly from carbon emissions (Rockström et al., 2009; Wackernagel and Rees, 1996b). But is it the measure of a better environmental management than the big consumers like the US, or of underdevelopment, like our ranking neighbours, Costa Rica, Mauritania and Niger? According to an annual study of the World Wide Foundation for Nature (WWF) published in the Alive Planet Report, Romania ranks 46th in the world, and 13th in the EU in terms of bio capacity, i.e. the possibility of ecosystems in the country to produce useful biological materials and to absorb the residues (especially CO_2) from its over 21 million inhabitants (WWF, 2014).

So, we are one of the "capable" countries in terms of services provided by nature. The soil is still not poisoned and wasted and can produce food, the forests have not yet been cut and can produce oxygen and absorb carbon, the waters are still filtered by vegetation and soil, succeeding to quench our thirst and wet our fields. Moreover, the ecological footprint per capita places our country on 70th place in the world and best in the entire European Union. Ecological footprint is the measure of the pressure man puts on the environment. Each year, the ecological footprint is calculated according to the productive area of soil and water required to produce the resources consumed by an individual and to absorb the carbon generated by the process (Fan et al., 2017; Stankovic et al., 2015; Ştefan et al., 2013; Torretta and Capodaglio, 2017). Experts believe that the outcome has to do more with the industry collapsing than with the strategic vision of the Romanian governments. Although a few steps have been taken on the sustainability trajectory in the management of forests and rivers, there is no holistic approach to embedding climate change and nature protection in general planning processes. The challenge of Romania is to significantly increase economic prosperity without increasing the carbon footprint. To succeed, it is necessary to focus efforts on modern sustainable techniques and practices and to prioritize energy efficiency. International organizations (WWF and others) are advocating for resource management solutions within the Earth's ecological limits: expanding protected areas, preserving and regenerating forests, managing water resources, protecting species or rebuilding wetlands.

Along with these direct investments, our efforts must focus on **investing in bio capacity** - introducing, on a large scale, sustainable farming practices and economic activities that maintain the balance between ecosystem integrity and long-term productivity.

4. Conclusions

The modified method of measuring the ecological footprint generated by road traffic includes both a safety component derived from the fuel consumption components for as many territory operations completed as well as precision components such as road category index, climate index and synchronization of astronomical and seasonal years.

The ecological footprint generated by road traffic for Petrosani achieved by using the modified method has a value of 0.52 [hag /inhabitant] representing a relatively high value because only the ecological footprint generated by road traffic is taken into account without considering other elements of modern society (water consumption, food, etc.). Because the value of the ecological footprint is relatively high, Petrosani Town Hall recommended annual monitoring of road traffic ecological footprint, by the proposed method.

Based on the principle of precaution, prevention, rectification of pollution at source and from research performed, a number of environmental policies which could improve environmental quality in Petrosani were recommended to local authorities, namely: encouraging the use of vehicles driven by electric motors, encouraging public transport, setting up the first bicycle program, limiting vehicle access to residential areas, stimulating the business environment (through tax cuts) for organizations using ecological materials in road construction / maintenance, efficient management by fusing off circulation on main roads and so on. So, any policy chosen to reduce environmental impact should reduce scientific uncertainty related to a possible risk. Also, the above recommendations can be extended to other cities in order to reduce impact on the environment.

Therefore, the method can be used for fast assessment of environment state, technical reason of the evaluator should consider the method's subjectivism and introduce input data so as to obtain real values of the ecological footprint.

Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no. PN-16-43-01-16, entitled ”Expanding the scope of environmental laboratory competence for the determination of carbon monoxide in the environment (imissions)”.

References

Brundtland G., Khalid M., Agnelli S., Al-Athel S., Chidzero B., Fadika L., Hauff V., Lang I., Shijun M., Botero M.M., Singh M., Okita S., Ramphal S., Ruckelshaus W., Sahnoun M., Salim E., Shaib B., Sokolov V., Stanovnik J., Strong M., (1987), Report of the World Commission on Environment and Development: Our Common Future, U.N. General Assembly created the World Commission on Environment and Development.

Canadell J.G., Le Quéré D., Raupach M.R., Field C.R., Buitenhuis E., Ciais P., Conway T.J., Gillett N.P., Houghton R.A., Marland G., (2007), Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks, *Proceedings of the National Academy of Sciences*, **104**, 18866-18870.

Capsa D., Barsan N., Felegeanu D., Stanila M., Joita I., Rotaru M., Ureche C., (2016), Influene of climatic factors on the pollution with nitrogen oxides (NO_x) in Bacau city, Romania, *Environmental Engineering and Management Journal*, **15**, 655-663.

Condurat M., Nicuță A.M., Andrei R., (2017), Environmental impact of road transport traffic. A case study for county of Iași road network, *Procedia Engineering*, **181**, 123-130.

Fan Y., Qiao Q., Xian C., Fang L., (2017), A modified ecological footprint method to evaluate environmental impacts of industrial parks, *Resources Conservation and Recycling*, **125**, 293-299.

Fei M., Wenlin W., Qipeng S., Fei L., Xiaodan L., (2018), Ecological pressure of carbon footprint in passenger transport: spatio-temporal changes and regional disparities, sustainability, **10**, 317; DOI: 10.3390/su10020317.

GD, (1982), Governmental Decision No. 14/1982 for the approval of fuel and motor oil consumption legislation for cars, *Romanian Official Monitor*, Part I, No. 14 from 28th of September, 1982.

Ghinea C., Campean T., Gavrilescu M., (2017), Integrating sustainability indicators for tracking anthropogenic pressure on the earth the footprint family, *Engineering and Management Journal*, **16**, 935-948.

Girod B., Wiek A., Mieg H., Hulme M., (2009), The evolution of the IPCC's emissions scenarios, *Environmental Science and Policy*, **12**, 103-118.

Iojă I.C., (2013), *Methods of Research and Evaluation of the State of the Environment* (in Romanian), Etnological Publishing house, Bucharest, Romania.

Jonsson D., (2007), Indirect energy associated with Swedish road transport, *European Journal of Transport and Infrastructure Research*, **7**, 183-200.

Matarazzo A., Gambera V., Suriano E., Conti M.C., (2017), Water footprint applied to construction sector, *Environmental Engineering and Management Journal*, **16**, 1739-1749.

Petrescu V., Ciudin R., Isarie C., Cioca L.I., Trif B., Neverita V., (2015), The impact of traffic related pollution on air quality in Sibiu region, *Environmental Engineering and Management Journal*, **11**, 2637-2642.

Rockström J., Steffen W., Noone k., Persson A., Chapin F.S., Lambin E., Lenton T. M., Scheffer M., Folke C., Schellnhuber H., Nykvist B., De Wit C.A., Hughes T., van der Leeuw S., Rodhe H., Sörlin S., Snyder P.K., Costanza R., Svedin U., Falkenmark M., Karlberg L., Corell R.W., Fabry V.J., Hansen J., Walker B., Liverman D., Richardson K., Crutzen P., Foley J., (2009), Planetary boundaries: exploring the safe operating space for humanity, *Ecology and Society*, **14**, http://www.ecologyandsociety.org/vol14/iss2/art32/.

Stankovic S., Vaskovic V., Petrovic N., Radojicic Z., Ljubojevic M., (2015), Urban traffic air pollution: case study of Banja Luka, *Environmental Engineering and Management Journal*, **14**, 2783-2791.

Ştefan S., Radu C., Belegante L., (2013), Analysis of air quality in two sites with different local conditions, *Environmental Engineering and Management Journal*, **12**, 371-379.

Torretta V., Capodaglio A.G., (2017), Strategic environmental assessment: a critical review of procedural soundness and reliability, *Journal of Environmental Management*, **16**, 105-112.

United Nations Summit, (1992), Agenda 21: The Earth summit strategy to save our planet, Earth summit Rio de Janeiro, Brazil.

United Nations Summit, (2015), Transforming our world: the 2030 Agenda for Sustainable Development, New York, SUA.

Venetoulis J., Talberth J., (2008), Refining the ecological footprint, *Environment, Development and Sustainability*, **10**, 441-469.

Vlasin N.I., Lupu C., Ghicioi E., Chiuzan E., Tomescu C., (2014), Environmental soundness of virtual simulations for coal bed degassing processes, *Environmental Engineering and Management Journal*, **13**, 1439-1444.

Wackernagel M., Rees W., (1996a), *Our Ecological Footprint: Reducing Human Impact on the Earth*, New Society Publishers, Canada.

Wackernagel M., Rees W., (1996b), Urban Ecological Footprints: why cities cannot be sustainable-and why they are a key to sustainability, *Environmental Impact Assessment Review*, **16**, 223-248.

Wiedmann T., Minx J., Barrett J., Wackernagel M., (2006), Allocating ecological footprints to final consumption categories with input-output analysis, *Ecological Economics*, **56**, 28-48.

Wiedmann T., Barrett J., (2010), A review of the Ecological Footprint Indicator – Perceptions and methods, *Sustainability*, **2**, 1645-1693.

WWF, (2014), Living Planet Report: Species and spaces, people and places, World Wide Fund for Nature, Gland, Switzerland.

Yang H., Wang W., Wei B., (2015), System dynamics for urban traffic jam management in Beijing, *Environmental Engineering and Management Journal*, **14**, 1875-1886.

Zamba A., (2006), *Estimating the ecological footprint of road transport in Athens*, PhD Thesis, National Technical University of Athens, Athens, Greece.

Zamba A., Hadjibiros K., (2007), *Estimating the Ecological Footprint of Vehicles in the City of Athens*, Proc. 10th Int. Conf. on Environmental Science and Technology, University of the Aegean, Rhodes, 1638-1645.

Appendix 1. Road traffic in Petrosani

Geographic coordinates[*]		*Date*	*Time slot*	*Vehicle category*		*Total*
N	*E*			*Under 3,5 t*	*Over 3,5 t*	
45°26'2.18"	23°21'41.09"	25.01.2017	10:15 ÷ 11:15	391	62	453
45°23'20.06"	23°22'23.11"	26.01.2017	13:03 ÷ 14:03	786	91	877
45°24'1.25"	23°22'23.67"	26.01.2017	11:52 ÷ 12:52	820	81	901
45°24'26.69"	23°22'20.38"	25.01.2017	13:35 ÷ 14:35	736	63	799
45°25'9.64"	23°22'4.25"	25.01.2017	11:26 ÷ 12:26	690	87	777
45°24'33.47"	23°22'31.58"	25.01.2017	12:29 ÷ 13:29	861	81	942
45°25'0.62"	23°22'22.37"	26.01.2017	10:37 ÷ 11:37	917	39	956
45°24'57.64"	23°21'46.05"	26.01.2017	14:21 ÷ 15:21	16	0	16
45°26'2.18"	23°21'41.09"	22.02.2017	10:34 ÷ 11:34	481	59	540
45°23'20.06"	23°22'23.11"	23.02.2017	12:41 ÷ 13:41	951	83	1,034
45°24'1.25"	23°22'23.67"	23.02.2017	11:35 ÷ 12:35	1,021	116	1,137
45°24'26.69"	23°22'20.38"	22.02.2017	14:04 ÷ 15:04	834	79	913
45°25'9.64"	23°22'4.25"	22.02.2017	11:44 ÷ 12:44	718	69	787
45°24'33.47"	23°22'31.58"	22.02.2017	12:52 ÷ 13:52	637	62	699
45°25'0.62"	23°22'22.37"	23.02.2017	10:24 ÷ 11:24	861	28	889
45°24'57.64"	23°21'46.05"	23.02.2017	13:48 ÷ 14:48	8	0	8
45°26'2.18"	23°21'41.09"	22.03.2017	10:05 ÷ 11:05	419	73	492
45°23'20.06"	23°22'23.11"	23.03.2017	13:39 ÷ 14:39	852	69	921
45°24'1.25"	23°22'23.67"	23.03.2017	12:28 ÷ 13:28	794	75	869
45°24'26.69"	23°22'20.38"	23.03.2017	11:23 ÷ 12:23	709	97	806
45°25'9.64"	23°22'4.25"	22.03.2017	11:14 ÷ 12:14	659	87	746
45°24'33.47"	23°22'31.58"	23.03.2017	10:18 ÷ 11:18	734	47	781
45°25'0.62"	23°22'22.37"	22.03.2017	13:45 ÷ 14:45	1,005	43	1,048
45°24'57.64"	23°21'46.05"	22.03.2017	12:34 ÷ 13:34	15	1	16
45°26'2.18"	23°21'41.09"	18.04.2017	10:31 ÷ 11:31	462	27	489
45°23'20.06"	23°22'23.11"	18.04.2017	13:58 ÷ 14:58	768	53	821
45°24'1.25"	23°22'23.67"	19.04.2017	12:27 ÷ 13:27	731	68	799
45°24'26.69"	23°22'20.38"	18.04.2017	12:52 ÷13:52	684	76	760
45°25'9.64"	23°22'4.25"	19.04.2017	10:17 ÷ 11:17	581	63	644
45°24'33.47"	23°22'31.58"	19.04.2017	11:21 ÷ 12:21	693	36	729
45°25'0.62"	23°22'22.37"	18.04.2017	11:38 ÷ 12:38	893	42	935
45°24'57.64"	23°21'46.05"	19.04.2017	13:44 ÷ 14:44	17	2	19
45°26'2.18"	23°21'41.09"	11.05.2017	10:07 ÷ 11:07	439	64	503
45°23'20.06"	23°22'23.11"	12.05.2017	14:41 ÷ 15:41	861	118	979
45°24'1.25"	23°22'23.67"	12.05.2017	13:37 ÷ 14:37	814	73	887
45°24'26.69"	23°22'20.38"	12.05.2017	12:34 ÷13:34	793	94	887
45°25'9.64"	23°22'4.25"	11.05.2017	11:12 ÷ 12.12	738	84	822
45°24'33.47"	23°22'31.58"	11.05.2017	13:20 ÷ 14:20	823	51	874
45°25'0.62"	23°22'22.37"	11.05.2017	12:15 ÷ 13:15	1,035	61	1,096
45°24'57.64"	23°21'46.05"	12.05.2017	11:21 ÷ 12:21	9	3	12

*Note: * Geographic coordinate system: GCS WGS 1984*