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Ecological Study of Transportation Footprint in Pardis Citizens

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Abstract

Increasing sustainability in cities as interface point between human and resource results in consolidation of this relationship. Measuring ecological footprint of surrounding cities and metropolises specifies the effects of human resources community on natural resources and with periodic reviews of these effects in the future, sources and fate will be determined. One of the most important objectives in managing the urban environment is maintaining city sustainability that reducing the degree of ecological footprint can be useful. Ecological footprint is an index of sustainability that assesses the amount of human consumption and the effect of the use on the environment. Several programs have been presented against population density in metropolis that establishment of new cities surrounding metropolis is one of important factors to attract overflow crowd. But, unfortunately, satellite cities have been dealt with significant infrastructure problems. This study aims to measure one of sustainable development indicators (ecological footprint) in Pardis city. The amount of ecological footprint in transport sector was obtained using component method and through calculating the three main products including gasoline, petrol and CNG. The amount of footprint equaled to 0.0042 hectares per person in the transport sector that can be compared to rates of per capita ecological footprint of the city that equals to 0.311. It can be concluded that Pardis city has acceptable ecological footprint in transport sector.

Keywords

Tehran, Pardis, Ecological Footprint, Transport, Sustainable Development

1. Introduction

Urbanization growth has been caused to increasing untapped use of resources

and as a result imposing harmful and irreparable effects on environment. The impacts are unable to be eliminated by city and its resource, and make instability in cities. Today, the best and the most ideal kind of growth is sustainable development when resources are kept that improve quality life of human in future. Ecological footprint is a method which can help to sustain development considerably and is founded to produce based on resource consumption and waste absorption in earth depending on required per capita area [1]. For the first time, Mathis Wacknagel and William Rees in British university of Columbia discovered the term and technique of ecological footprint in the book "our ecological footprint: reducing human impact on earth (1995)". From perspective of these two scholars, each human unit (including individual, city and country) influences on earth, since they apply natural production and services. Their ecological impact equals to natural amount that they have occupied for life stability [2]. Indicator of ecological footprint is an integrated method of consuming natural sources and absorbing wastes. Thus, this indicator has been recognized as potential index regularly to estimate outcomes of untapped use of natural resources in recent years [3]. Ecological footprint is computational means for ecological advantages and it also enables us to determine shortcomings and resources exactly. That means clearly in which region that human put pressure on natural resources. As a matter of fact, this indicator measures the use of individuals, organizations, cities, regions, countries or the entire human population from natural resources. On one hand, measuring ecological footprint of cities indicates pattern of urban consumptions over time and on the other hand, it helps urban managers to balance natural resources application by proper decision making and foster the relationship between human and environment. With regard to published statistics from Food and Agriculture Organization, the need of food will be increased 70% until 2050 that causes raising natural earth and ecosystems and as a result increasing human footprint considerably. According to issued statistics in 2050, human will require 3 earth planets to meet their needs. Furthermore, it will be predicted that population will reach about 9.6 billion people in 2050 and 11 billion people in 2100 that the biological capacity available per person will be reduced significantly [4]. This study measured ecological footprint of transport of Pardis city using component method which this footprint resulted from consuming three main products including gasoline, petrol and CNG. Moreover, this paper examines state and performance of this city in transport sector in connection with the backup area (metropolis of Tehran).

Living planet report was published in 2014 and based on measurement; living planet index has been decreased to 52% from 1970 to 2010. The ecological footprint amount was 18.1 billion hectares and the average ecological footprint per person was 2.6 hectares worldwide. Moreover, a biological capacity was 12 billion hectares or an average of 1.7 hectares per person worldwide that according to the population chart, this capacity reached from 3.2 billion to 7 billion. Thus, when biological capacity was increasing, population rising did not allow compensation for the human footprint on the earth [5].

According to Living planet report, global ecological footprint and average of ecological footprint per person were 18 billion hectares and 2.7 hectares respectively in 2012. But, global biological capacity and biological capacity per person were only 9.11 billion hectares and 1.8 hectares respectively which indicated that human consumed nearly 50% more than available saving and due to this consumption method, human require 1.5 planet to compensate it and earth planet needs 1 year and six months to restore consumed resources by human in a year [6].

In an analysis of ecological footprint in 1961-1999 period in three countries of Australia, Philippines and South Korea: comparison of common method with regional real method, impact of industrialization and energy consumption increase of three countries of Australia, Philippines and South Korea on amount of ecological footprint was examined: sum of ecological footprint in Philippines was 1.5 gha/cap that had not been changed since past 40 years and major energy contribution reached from 8% to 27% and per capita bio was decreased from 1.22 gha/cap to 0.52 gha/cap that its main reason was population increase and rapid growth of industry. Rapid growth of industry during 40 years in South Korea increased untapped use of natural resources and this made South Korea placed among countries with high ecological deficit that had nearly 5 times of its current biological capacity to meet its population needs. Contribution of fossil fuels footprint in this country was increased from 15% to 62% that revealed changing in consumption energy kind from wood fuel to fossil fuel, due to the fact that consumption contribution of wood fuels reached from 0.06 in 1961 to nearly o in 1991. Australia has high biological capacity and in study period, average of Australia footprint was always more than its biological capacity regarding energy footprint and ecological footprint had nearly fixed amount without regarding energy footprint that energy footprint has been increased since 1961 and in contrast, amount of per capita bio had relatively uniform trend that it means that increasing resource efficiency and balancing agricultural products and generally industrializing resulted in consumption increase in Australia [7].

According to computation in 2006, Islamic countries including Iran, Iraq, Afghanistan, Syria and turkey with 227.7 million people had 9.10 hectares of ecological footprint per person that among these countries, turkey had the most amounts with 2.8 hectares of ecological footprint. In industrial countries including England, America, France, Russia and Germany with population equals to 650.6 million people had 28.1 hectares of ecological footprint. Among these industrial countries, America had the most ecological footprint amount with 9 hectares and in fact, amount of its footprint was nearly equal to overall Islamic countries [8].

In 2013, a paper titled ecological footprint of CO_2 in fossil fuels in Shiraz city examined and measured CO_2 footprint from fossil fuels and compared it with degree of green spaces in city to attract this amount of CO_2. CO_2 emissions from

gasoline and petrol fuels during 2006-2008 were 521,058, 476,767, 490,106 tons respectively and required lands equal to 7816, 7125 and 7352 hectares to absorb CO_2, while area of green space in Shiraz in 2008 equaled to 1869 hectares, thus, it can be concluded that CO_2 gas emissions from gasoline and petrol fuels was 3.9 times against biological capacity in Shiraz [9].

In 2012, a survey titled as measuring ecological footprint of urban transport facilities; a modern approach for planning sustainable transport, Case Study of Urmia City was published in which the degree of sustainability of each method of urban transport in Urmia City was measured and evaluated and the results indicated that the most amount of footprint in this city related to Minibus with 0.00055 hectares and the least amount referred to motorcycle with 0.000016 hectares and through comparing this amount with global standards, it was specified that except bus, other transport means in Urmia city had more footprint amount than global standards [10].

2. Materials and Methods

2.1. Ecological Footprint Measurement Method

Ecological footprint is a sustainable index that evaluates the amount of human consumption and its impact of environment. Measuring ecological footprint shows that nowadays, on one hand, human apply natural resources at the expense of reducing capacity of earth to support future generations and on the other hand, human consumption and waste production are beyond capacity of creating new resources and absorbing waste by earth planet. As a result of this excessive consumption, human economy caused to destroy natural capital in earth planet [11]. The concepts of ecological footprint are placed on following hypotheses:

1) Food consumption, housing, transportation, infrastructure, consumer goods and services are measurable by population.

2) The amount of the population to be converted to the land (e.g., the land occupied by agriculture, the amount of logged land and the amount of land occupied by buildings) required for the production, growth, industry, transportation and disposal of waste, transportation, Infrastructure, consumer goods and consumer services.

3) The amount of land used to produce the resources consumed by the population and the disposal of waste generated is equal to the ecological footprint of that population [5].

The main stages of measuring the ecological footprint for a country, city or organization include:

1) Determining the purpose, considering the reasons for measuring and analyzing ecological footprint.

2) Determining the boundary system, determining the axis of analysis, and deciding on what ecological footprint covers and what it eliminates.

3) Identifying available resources, as much information is needed to calculate

the ecological footprint, adequate funding is needed to provide the required forces.

4) Specify the inputs and outputs of the system.

5) Determining the main areas of production reliance.

6) Publishing the results of strategies development.

7) The Realistic Categorization of Goals [8].

In Table 1, overall methods of measuring ecological footprint were introduced as well as advantages and accuracy of each method was compared. It is necessary to mention that all measurement concerning ecological footprint should be according to standards of ecological footprint that its last version was published in 2009.

2.2. Area of Study

Pardis city locates in Pardis town and 18 km east of the capital and in the surrounding axis of Tehran-Abali. Its area is about 3600 hectares and its average height from free world water level is about 1800 meters. The population of Pardis city in the census of 2011 is estimated at 37,257; according to the growth rate of 1.29 and the calculations made by the experts of the statistics organization, population of the city in 2014 is estimated at approximately 46,900 people. The area of the city is about 3600 hectares and surrounding area of the city is about 11,000 hectares (110 square kilometers).

3. Findings

3.1. Ecological Footprint Measurement of Pardis City in Transport Sector

This paper applied component method to measure ecological footprint in transport sector. Statistics for the petrol, CNG and gasoline sectors have been collected from the National Iranian Oil Products Distribution Company and the Tehran Province Gas Company. Also, for the first time in the field of measuring the footprint instead of the description, the formula is used to have a specific template for other studies.

Table 1. Summary of methods for measuring ecological footprint (source: authors).

No	Method	Summary of method implementation	Application
1	Synthesis method	A method to measure footprint in national level for countries and is achieved through estimating import and export of a country.	This method has less accuracy compared to other two methods, since, details are not considered due to high volumes of data in national level.
2	Component method	This method is used to measure footprint in cities and urban regions and these measurement are conducted through estimating the amount of population consumption in consumer real states.	This method is one the most applicable techniques. The accuracy of this method is higher than synthesis method. Variety of consumer groups are changeable depending of studied subject and data volume.
3	Direct method	This method is applied to measure footprint in individuals, families and companies and correlates with direct consumer data of individuals.	This method has the highest accuracy among other two methods. Its accuracy is provided and calculated based on questionnaire and it depends on questionnaire accuracy.

3.2. Measurement of Petrol Footprint

From six petrol stations whose statistics are used, there are only the Pardisan petrol station, the black stone Kousar in Pardis City. Other three gas stations are in the vicinity of Pardis City, but due to the location of Pardis City and the number of daily trips of the Pardis residents to the metropolis of Tehran, four adjacent gas stations (including Kamrad, Bakhshesshi and Tape seif) have been used in statistics. The total consumption in 2014 is 121,050,800 liters and the average daily amount is 331,646.027 liters [10].

BC = per capita consumption of petrol
K = corresponding fixed rate
B = per capita petrol consumption (gallon)
BS = lead free petrol per gallon
Ab = petrol BTU per gallon
R = relevant fixed rate
Fc = released carbon to tone
H = one hectare of land
Rc = Fixed rate of free carbon
L = required land to absorb carbon (hectare)
P = city population
EFb = total petrol footprint

$BC \div K = B$ $\quad 331646.027 \div 3.7853 = 87614.198$

Each gallon of petrol is 3.7853 liters, converted from liter to gallons using the formula.

$B \times B_S = A_b$ $\quad 87614.918 \times 125{,}000 = 10{,}951{,}774{,}750$

Lead-free gas releases 125,000 BTU (produced thermal energy). T hus, using this formula, the BTU gasoline is obtained per gallon.

$A_b \times R = F_c$ $\quad 10.95177475 \times 19.35 = 211.916$

Each gallon of petrol releases 19.35 tons of carbon, so this formula produces the amount of released carbon from the amount of consumed petrol.

$F_c \times H \div R_c = L$ $\quad 211.916 \times 1_{ha} \div 1.8 = 117.73$

Each hectare of fertile soil absorbs 1.8 carbons; in this formula the required land is obtained to absorb carbon.

$L \div P = \underline{EF_b}$ $\quad 117.73 \div 46{,}900 = 0.002$

In final stage, footprint per person is obtained by dividing required land for carbon absorption on city population.

Thus, Pardis residents need a land equals to 117.73 hectares to absorb carbon from daily petrol consumption and their ecological footprint was 0.002 hectares/person in petrol sector.

3.3. Measurement of CNG Footprint

CNG consumption statistics are provided by the Tehran Provincial Gas Company, and for measuring footprint in this section, the CNG gas is converted to

liter of petrol, and the rest of the calculations are performed according to the petrol sector. The CNG consumption figures in the 2014 for municipal and private affiliates were totally 6,547,481 cubic meters or 6,547,801 liters, with an average daily value of 1,783,830 liters, and each liter CNG was 1.32 liters of gasoline [11].

EF = footprint amount in CNG sector

$BC \div K = B$	$2367.855 \div 3.7853 = 625.539$
Each gallon of CNG is equivalent to 3.7853 liters of petrol, converted to liter gallons by using the formula.	
$B \times B_S = A_b$	$625.539 \times 125{,}000 = 78192448.418$
CNG releases lead-free petrol at 125,000 BTU (produced thermal energy). Thus, using this formula, BTU BTU gasoline is obtained per gallon.	
$A_b \times R = F_c$	$0.0781 \times 19.35 = 1.513$
Each gallon of CNG releases petrol equivalent to 19.35 tons of carbon, so this formula produces the amount of carbon released from the amount of consumed petrol.	
$F_c \times H \div R_c = L$	$1.513 \times 1_{ha} \div 1.8 = 0.841$
Each hectare of fertile soil absorbs 1.8 carbons; in this formula the required land is obtained to absorb carbon.	
$L \div P = \underline{EF_b}$	$0.841 \div 46{,}900 = 0.00001$
In final stage, footprint per person is obtained by dividing required land for carbon absorption on city population.	

Accordingly, Pardis citizens need a land with 0.841 hectares to absorb carbon from daily consumption of CNG, and their ecological footprint in the CNG sector was 0.00001 hectares per person. Due to the fact that the number was very small, it can be ignored in the overall calculation of the transport footprint.

3.4. Gasoline Footprint Measurement

From 3 petrol stations, two of them as Kamard and Tapeh Saif adjacent to Pardis city and gas station Kowsar inside the 2nd phase of Pardis city have gasoline products which its total consumption in 1995 is 95,826,500 liters and an average liter per day is 262,538.356 [11].

GC = per capita gasoline consumption

K = corresponding fixed rate

G = Per capita gasoline consumption (gallon)

GS = Lead-free gasoline per gallon

Ag = BTU gasoline per gallon

R = relevant fixed rate

Fc = released carbon to tone

H = one hectare of land

Rc = Fixed rate of released carbon

L = required land for carbon absorption (hectare)

P = city population

EFg = total diesel footprint

$GC \div K = G$	$262538.356 \div 3.37853 = 69357.344$
Each gallon of gasoline is 3.7853 liters that converted to liter gallons using the formula.	
$G \times G_S = A_g$	$69357.344 \times 138{,}700 = 9619863612.8$
Gasoline releases 138,700 BTU (produced thermal energy). Thus, using this formula, the BTU gasoline is obtained per gallon.	
$A_g \times R = F_c$	$9.6198636128 \times 19.95 = 191.9162$
Each gallon of gasoline releases 19.95 tons of carbon, so by applying this formula, the amount of carbon released from the amount of consumed gasoline is obtained.	
$F_c \times H \div R_c = L$	$191.9162 \times 1_{ha} \div 1.8 = 106.620$
Each hectare of fertile soil absorbs 1.8 carbons; by using this formula the required land is obtained to absorb carbon.	
$L \div P = EF_g$	$106.620 \div 46{,}900 = 0.0022$
In the final stage, by dividing the land needed to absorb carbon over the population of a city, footprint per person in city is obtained.	

Pardis citizens need 106.620 hectares of land to absorb carbon from daily gasoline consumption, and their ecological footprint in the gas sector is 0.0022 hectares per person.

$\underline{EF_b} + EF_g + EF_c = EF_t$	$0.002 + 0.00001 + 0.0022 = 0.00421$
The total footprint of transport sector is obtained by sum of footprint in three sectors of Petrol, CNG, and Gasoline.	

Thus, the required land to absorb carbon from transport sector was 225.191 hectares and ecological footprint of Pardis citizens was 0.00421 hectares in transport sector.

4. Discussion and Conclusions

The ecological footprint index conveyed clearly the relationship between human consumption and the effect that this consumption brings to the environment. This indicator facilitates decision making about how and how much resources are used, and identifies the effect of humans over different periods in different climates of the world. It addresses the relationship between biological capacity (natural power) and human footprint (human effect on the use of natural resources) [4]. The Pardis city is a satellite city and has new construction. According to ecological footprint standards, it is not possible to estimate the city's biological capacity (six classifications of land) and the city's biological capacity depends on the biological capacity of the mothers' own region, Tehran. For this purpose, in present paper, the per capita estimation method has been used for comparing the transport footprint as follows. According to the population of 46,900 people and the area of about 3600 hectares with surrounding area about 11,000 hectares, each person in Pardis city will receive about 0.311 hectares of land to meet the needs [6]. Based on statistics in **Table 2**, the ecological footprint of Pardis was proportional to the city's per capita consumption and fuel consumption in the city was acceptable.

Table 2. Summary of ecological footprint amount in transport sector of Pardis city (source: authors).

NO	Consumer	Amount of ecological footprint (hectares/person)	Required land for carbon absorption	Per capita ecological footprint	Ecological footprint deficit
1	Petrol	0.002	117073	0.311	No
2	Gasoline	0.0022	106.620	0.311	No
3	CNG	0.00001	0.841	0.311	No
Total	-	0.00421	225.191	-	-

As it was mentioned above, the city of Pardis has high traffic levels due to its satellite presence in Tehran. Obviously, a large part of the refueling of cars is being carried out in the city of Tehran, which increases the amount of footprint and pollutants from vehicles in Tehran. The statistics of ecological footprint amount was acceptable regarding calculated land per person and based on the calculations made in Table 2 and fortunately, there is still no deficit in the transport sector. Here are some points to note. It is necessary to mention that: first, it can be concluded on the basis of calculations that Pardis city in the transport sector is capable of meeting the needs of its population and even accepting a larger population. This reduces the footprint amount on the motherland of the city, Tehran. On the other hand, because of the lack of complete facilities in the city and the lack of easy access by citizens to public transportation facilities and the lack of operation of all gas stations, the ecological footprint amount in the transportation sector is much less than the ability of the city.

During the day, more than half of Pardis citizens travel to Tehran to work and cater to different needs. This causes a lot of refueling of the vehicles of this population from the gas station in the city of Tehran, which is impossible to estimate this statistic. Obviously, regardless of population access to facilities and daily emigration, the statistics of ecological footprint in mentioned sector were acceptable and proportionate to the population. One of the important reasons caused that a large ecological footprint is less than world standard, is the lack of a significant portion of residential complexes and the failure to launch all phases of Pardis city. It seems that if all the phases of Pardis city are exploited, footprint degree will undergo significant changes. Given the above cases, it can be stated that instead of being more concerned about population growth in cities, we need to focus more on promoting lifestyles and the pattern of eco-friendly consumption. The results of this study, as in other studies, showed once again that there is a direct relationship between the welfare level and the ecological footprint, which means that as welfare increases, the amount of the ecological footprint becomes larger and more disturbing. It is stressed that although the negative impact of population density on natural resources and the environment cannot be denied, it is now time to talk about traditional thinking about the impact of increasing population on environmental degradation and noble perspective of the impact of lifestyles on environmental degradation.

References

[1] Kharlakhlo, M., Hateminezhad, H., Baghvand, A. and Yalveh, M. (2012) Evaluation of Sustainability of Urban Development by Ecological Footprint Method (Case Study: Kermanshah City). *Journal of Human Geographic Research*, **45**, 120-105.

[2] Kitzes, J., Peller, A., Goldfinger, S. and Wackernagel, M. (2007) Current Methods for Calculating National Ecological Footprint Account. *Science for Environmental & Sustainable Society A*, **4**, 384.

[3] Habibi, K., Rahimi Kakeh Jub, A. and Abdi, M. (2012) Estimation of the Ecological Footprint of Sustainable Transportation, Case Study: Urmia City. *Journal of Geospatial Space* (*Golestan University*), **12**, 36-44.

[4] Monfreda, C., Wackernage, L.M. and Deamling, D, (2004) Establishing National Natural Capital Accounts Based on Detailed Ecological Footprint & Biological Capacity Assessments. *Land Use Policy*, **21**, 231-246. https://doi.org/10.1016/j.landusepol.2003.10.009

[5] Rees, W. and Wackernage, L.M. (1996) Urban Ecological Footprint: Why Cities Cannot Be Sustainable & Why They Are a Key to Sustainability. *Environmental Impact Assessment*, **16**, 223-248. https://doi.org/10.1016/S0195-9255(96)00022-4

[6] Sasanpur, F. (2011) The Basics of Sustainable Development of Metropolises with Emphasis on the Metropolis of Tehran. Tehran City Study and Planning Center Publication, Tehran.

[7] Saraee, M. and Zarehi, F. (2011) Investigating the Sustainability of Ecological Resources Using the Ecological Footprint Index of Iran Case Study. *Journal of Geography and Environmental Planning*, **22**, 106-197.

[8] Sheikh Azami, A. and Divsalar, A. (2010) A Comparative Study of the Effect of Ecological Footprint in the Islamic Countries of Southwest Asia and Western Industrialized Countries. *Proceedings of the Fourth International Congress of Geographers of the World of Islam 2*010, Tenerife, 8-13 August 2010.

[9] Teimuri, A., Salarvandian, F. and Ziari, K. (2014) Ecological Footprint of Carbon Dioxide of Fossil Fuels in Shiraz. *Geographical Quarterly*, **30**, 12-23.

[10] Wackernage, L.M., Monfreda, C., Heinzerb. K., Haberl, H. and Schulz, N.B. (2004) Ecological Footprint Time Series of Australia, the Philippines & South Korea for 1961-1999: Comparing the Conventional Approach an Actual Land Area Approach. *Land Use Policy*, **21**, 261-269. https://doi.org/10.1016/j.landusepol.2003.10.007

[11] Wackernagel, M., Monfreda, C., Schulz, N.B., Heinzerb, K., Haberl, H. and Kransman, F. (2004) Calculating National & Global Ecological Footprint Time Series: Resolving Conceptual Challenges. *Land Use Policy,* **21**, 271-278. https://doi.org/10.1016/j.landusepol.2003.10.006