International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **2(3),** 46-50, March **(2013)** *Int. Res. J. Environment Sci.*

Definition of Ecological-Economical Optimum of Pavement Evenness on the Results of an Inventory of Greenhouse Gas Emissions by the Road–Vehicle Complex in Uzbekistan

Radkevich Maria
Automobile and Road construction Institute, Tashkent, UZBEKISTAN

Available online at: www.isca.in
Received 14th February 2013, revised 22nd February 2013, accepted 10th March 2013

Abstract

The road transport is one of the main greenhouse gas emissions sources. Existing methods for inventorying greenhouse gas emissions account for only a vehicle, apart from the road, whereas they are indissoluble linked together, forming a road-vehicle complex. Therefore, it is this interface that should be assessed when inventorying the greenhouse gas emissions. The volumes of the greenhouse gases' emissions produced by the «road-vehicle» complex depend on the pavement evenness. An inventorying method for the greenhouse gas emissions produced by the "road-vehicle" complex based upon the results of monitoring of the pavement evenness is suggested hereby. Also ecological-economical optimum of pavement evenness is estimated.

Keywords: Greenhouse gas, a road-vehicle system, evenness, monitoring.

Introduction

In recent decades, it became clear that global climate change is largely caused by the human influence. One of the main "suppliers" of greenhouse gas emissions is road transport (the share of CO_2 emissions produced by the transport comprise 13% of the global emissions' volume)[1,2].

The greenhouse gases are not pollutants in the usual meaning of the term. At the concentrations they are actually observed in the atmosphere, they do not make any direct harmful effect on ecosystems. Therefore, there is no need to monitor the concentration of a greenhouse gas around the industrial enterprises and service centers, it is necessary only to know the absolute value of emissions for a long time, usually a year. It does not matter, whether it was an instantaneous or a gradual emission, because the greenhouse gases "live" in the atmosphere for a long time, get well stirred there, and thus the effect does not dependent on the emission point.

Thereby the global scientific community assigns high priority to the inventorying the greenhouse gas emissions[3-5]. There are currently two main methods of inventorying greenhouse gases emitted into the atmosphere by motor vehicles: i. by the fuel consumption, ii. by the total mileage of the vehicle[6]. The general disadvantage of these methods lies within the fact that the inventorying is made for the vehicle only, apart from the road, while they are indissolubly related to each other, forming a "road-vehicle" interface. Therefore, it is this interface that should be assessed to make a correct of greenhouse gas emissions inventorying.

Material and Methods

Let us consider some properties of the "road-vehicle" interface. The task of the road is to provide a speed limit of traffic, for which it should have some sufficient coating evenness and traction properties. Deterioration of the pavement traction properties is manifested mainly in winter (so-called black ice). In the countries with the short-term period of sub-zero temperatures, we may assume that the only factor that contributes to the speed of vehicles on the roads is the road surface evenness. To maintain the evenness at the proper (acceptable) level over the lifetime of the road, a certain number of repairs is needed, which in turn is related to the amount of emissions. On the other hand, vehicular emissions to a large extent depend on its speed. For each type of vehicles, there is a speed at which the engine operates optimally with both minimum fuel consumption and emissions.

Interaction of the car and the road is as follows: running along the road, a car destroys it and in turn, destroys itself. The lower is the coating evenness, the more the car suffers, the more often it requires maintenance and repair, which is also related to the additional emissions. Accordingly, the higher is the coating evenness, the lesser is the amount of emissions.

Thus, understanding of the patterns of relationships between the coating condition and volumes of emissions produced while driving and repairing vehicles, as well as by road and vehicle repairs provides us the following opportunities: i. to produce the greenhouse gas emissions inventorying based on the road surface monitoring (i.e., indirect indicators); ii. to determine the coating evenness that would result in the minimum greenhouse

gas emissions' volume; iii. to identify the emissions' excess caused by the insufficient road coating condition, this thus can be used as a basis for imposing penalties upon the road service.
Map of study area of research work is shown in figure-1. The study area of research work is «road-vehicle» complex of Republic of Uzbekistan.

For a research intended to identify the relationship between the amount of emissions and the coating evenness, the following models had been chosen: i. Forecasting the road coating evenness[7].

$$IRI\ (t) = IRI0 \cdot exp\ (bt) \quad (1)$$

Where *IRI (t)* is the forecasted coating evenness at certain coating age, *t*, years; IRI_0 - the averaged evenness value at some initial moment of time at t_0; *b* - parameter of the model that depends on climatic conditions and pavement design.

Equation describing the smoothing effect of the road repairs, which makes it possible to calculate the required number of repairs[8].

$$IRI_a = a + b \cdot IRI_R, \quad (2)$$

IRI_a, IRI_R are the actual road surface evenness and its evenness after the renovation activities, accordingly; *a* and *b* are the parameters of the equation, depending on the type of road repairs, for example, thermal superelevation, *a* = 0,495; *b* = 0,58.

Forecasting the relationship between the traffic speed and the coating evenness[8]:

$$V = V_0 (1 - \alpha \cdot \frac{IRI - 0{,}247}{0{,}053}) m_0 \quad (3)$$

Where *V* is the averaged traffic speed, depending on the coating evenness, km/h; V_0 is the averaged free traffic speed on the road section with a longitudinal slope of no more than 20 ‰ and evenness to IRI 2, km/h for the general traffic V_0 = 72,12 km/h; α - parameter of the equation that depends on the type of vehicle (for total traffic stream: $\alpha = 8{,}26 \cdot 10^{-4}$); m_0 - a correction factor to the speed reduction due to weather conditions (for Uzbekistan: m_0 = 0,91 ... 0,95)

Forecasting relationship between the changes in the amount of emissions and the speed, which makes it possible to estimate the change in fuel consumption[8].

$$M = \sum_{1}^{n} m_i N_i K_V,\ \text{g / (km • day)} \quad (4)$$

where m_i is the running exhaust emission of the substance produced by the i^{th} type vehicle, g/km • vehicle; N_i is the daily traffic volume of i^{th} group cars, vehicle/ day; K_V is the correction factor which takes into account changes in the amount of harmful substances, depending on the speed of traffic stream (table-1).

Figure-1
Map of study area of research work

Table-1
K_V correction factors values

Speed *V*, km/h	10	15	20	25	30	35	40	45	50	60	75	80	100
K_V*	1.35	1.28	1.2	1.1	1	0.88	0.75	0.63	0.5	0.3	0.45	0.5	0.65

* *For nitrogen oxides, K_V tends to the value of 1.*

Reduction of the vehicle resource usage on uneven roads, which makes it possible to estimate the increase in emissions at inspections and repair of vehicles[9]. Relationship between the wear and tear of the car and the road surface condition is expressed by equation:

$$K_{res} = 36{,}39\ \psi - 0{,}267, \qquad (5)$$

where ψ is the ratio of the total resistance of the road:

$$\psi = 0{,}01 + 10^{-6} \cdot 0{,}7 \cdot \frac{IRI - 0{,}247}{0{,}053} \cdot V^2 = 0{,}01 + 10^{-6} \cdot 13{,}2 \cdot (IRI - 0{,}247) \cdot V^2 \qquad (6)$$

where *V* is the vehicle speed, m/s,

If, for example, a vehicle resource on the rough road is used by 90%, we may assume that the number of repairs and hazardous substances' emissions increases in 100/90 = 1.11 times, and thus 1.11 times increases the volume of substances emitted into the atmosphere, respectively.

Results and Discussion

Having data on emissions when driving a vehicle, and the accomplishment of repair work, as well as the production of fuels and materials, we can determine the total amount of emissions over the lifetime of the road[6,10]. The computer experiment was made in the form of the variation problem, which had been given different values allowed for a different intensity of the road traffic (from 1000 vehicles/day to 10000 vehicles/day). The experiment received a general (for the life of the road) and the average annual amount of greenhouse gas emissions from these sources and found the dependence of the average annual emissions from the evenness of the coating. A graph of CO_2 emissions depending on coating evenness at an intensity N = 4000 vehicles/day is given. Curves of the relationship between the CO_2 emissions and the flatness at different intensities are shown in figure-2 (line 1).

Resulting curves show that for each automobile stream with a certain volume of traffic, road surface evenness index value can be calculated that will cause the minimum emissions of the road-vehicle interface. This evenness can be considered environmentally optimal. These results might serve as a regulatory framework for the greenhouse gas emission volumes' monitoring.

Maintaining a given road surface evenness requires carrying out a certain number of repairs, due to the economic costs. In figure-2, curve "2" shows the relation between the economic costs of the road maintenance and given road surface evenness[8]. In these curves, the economically optimal evenness value can be seen. The joint study of the curves (figure-2) shows that the environmental and economic optimums values of the road surface evenness are almost the same only for the traffic up to 5 to 6 thousand vehicles/day. At higher traffic, environmental optimum offsets the relative economic downward bias of evenness index (improved road surface quality).

To find the environmental and economic optimum evenness the total cost of road maintenance was determined. During the calculations has been accounted for damage caused by "vehicle-road" complex to air quality in the life cycle of the road. To obtain environmental and economic optimal evenness the total cost of road maintenance with an allowance for the air pollution damage of automobile and road complex's during the road life cycle was determined. As a result, the values of optimal road surface evenness, depending on the traffic was drawn (figure-3). When traffic exceeds 5000 car/day, the pavement evenness value for the roads with capital pavement should not exceed IRI 4–4,5.

Finally, it should be noted that the obtained optimal pavement evenness is not absolute. It depends on the technology of road construction and maintenance, cost, funding opportunities, etc. In this case, the optimum conditions defined for Uzbekistan have been quoted. Due to the rapid progress in the motor industry and road construction, optimum of the evenness index value must be promptly corrected.

Conclusion

Since the vehicle – road interface is a potent source of greenhouse gas emissions, it is necessary to inventory these emissions. Existing methods do not account for the inventory of all road sector emission sources. The proposed method of greenhouse gas emissions inventorying, depending on the pavement surface evenness value, will allow to assessment of the scale of the country (region) very quickly. In addition, the "evenness-emissions" relationships can be used to inventory the other gases emissions. The resulting environmental and economic value of the optimal road smoothness should be used to adjust the requirements for the road surface quality. The results were obtained for Uzbekistan, but they can be used in other subject considering local characteristics of traffic and roads.

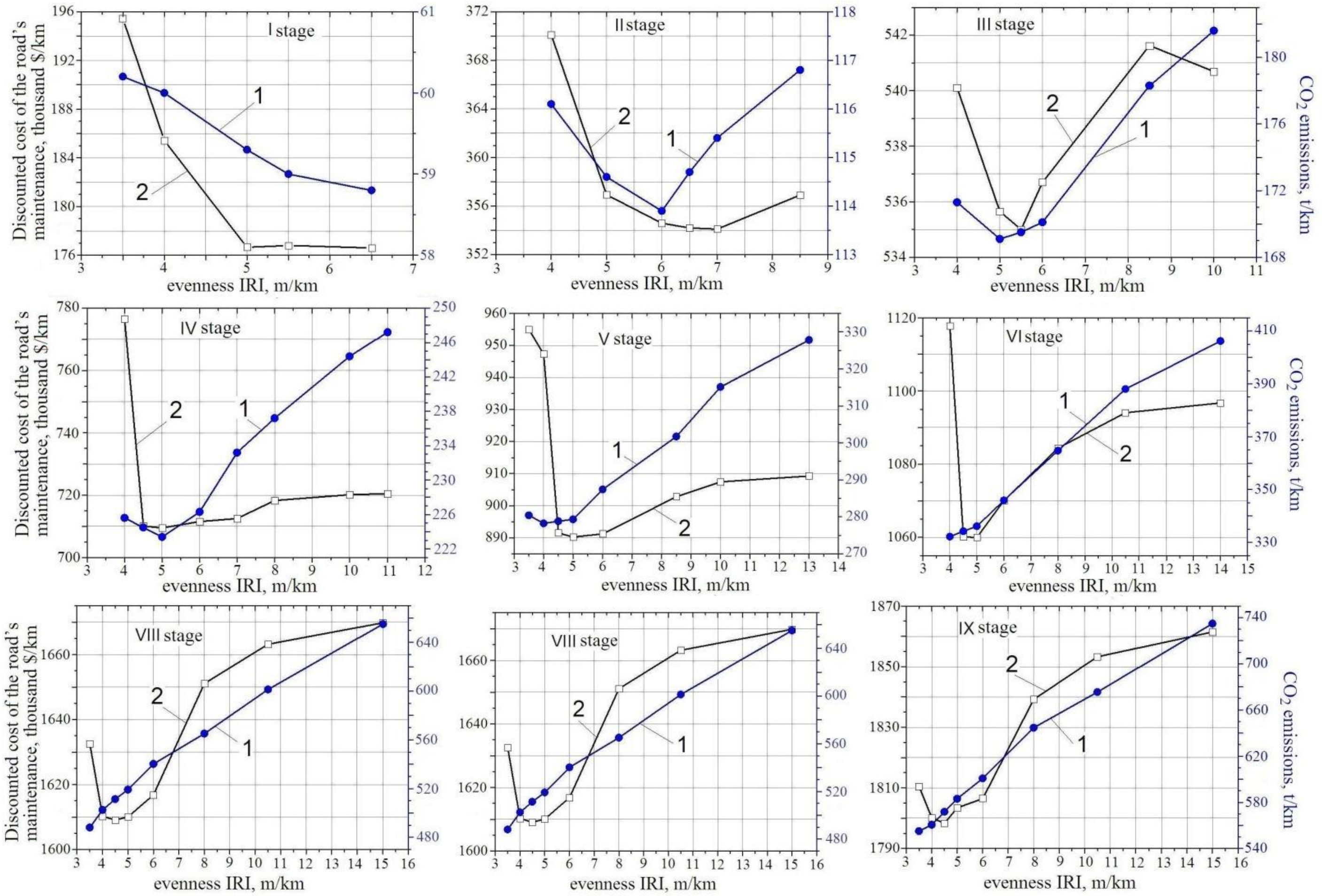

Figure-2

Comparison curves "evenness - CO_2 emissions" and "evenness - road maintenance cost"

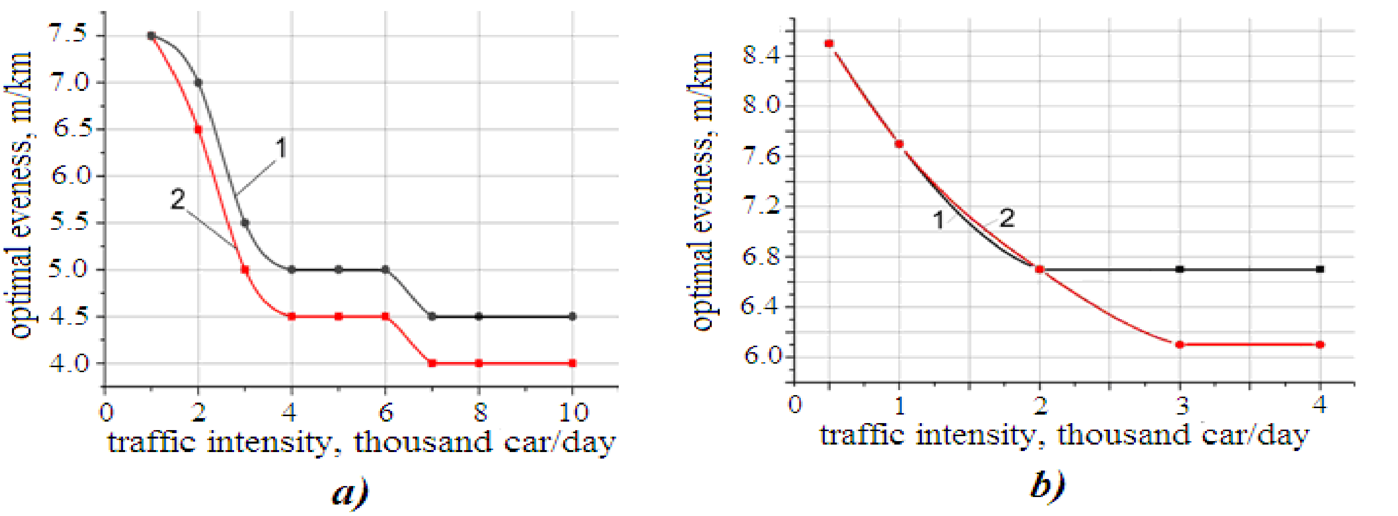

Figure-3

The value of the optimal evenness of pavement depending on traffic:

a) - for roads with capital pavement, b) - for roads with a lighted pavement. 1- curve of optimal evenness without an allowance for damage to the environment, 2 - curve of optimal evenness with an allowance for the damage to the environment

References

1. Saini B., Verma R., Himanshu S. K. and Gupta S. Analysis of Exhaust Emissions from Gasoline Powered Vehicles in a Sub-urban Indian Town, *Int. Res. J. Environmen Sci.*, **2(1)**, 37-42 **(2013)**
2. World Development Report 2010: Development and Climate Change. Overview: The new climate for development, *World Bank*, Washington (**2010**).
3. Sugirtharan M. and Venuthasan T. Farmers' Awareness on Climate Change Related Issues at some Irrigable Areas of Batticaloa District, Sri Lanka , *I. Res. J. Environmen Sci.*, **1(2)**, 29-32 **(2012)**
4. Arya Richa, Gupta Anil K.and Yunus Mohammad Flood Resilience through Climate-change adaptation: A case of Gorakhpur, Eastern Uttar Pradesh in India, *I. Res. J. Environmen Sci.*, **1(2)**, 25-28**(2012)**
5. Kumar S., Himanshu S.K. and Gupta K.K. Effect of Global Warming on Mankind - A Review, *I. Res. J. Environmen Sci.*, **1(4)**, 56-59**(2012)**
6. Ruszky A.V. etc. The design instruction (technique) for inventory of emissions of motor vehicles into the air. *OAO "NIIAT"*, Moscow (**2006**)
7. Nesterovich N.V., Bogdanovich S. Content management system covering in Belarus, *Roads and Bridges*, **№ 2 (2)**, 67-72 **(2008)**
8. Krasikov O.A. Justification repair strategies of non-rigid pavements. Ph. D. Thesis, Almaty **(1999)**
9. Shmuylovich A.V., Arkhipov V.F., Golumidova A.V. Economic evaluation of wear of vehicles caused by road conditions / / Electronic Journal of Vladimir State University (http://journal.vlsu.ru/index.php?id=128) **№ 18**, Part 2 (**2007)**
10. Lukanin V.N., Trofimenko Y. Industrial and transport ecology. *Higher School* , Moscow (**2001)**