MATHEMATICAL MODELLING FOR THE EVALUATION OF ROADS ENVIRONMENTAL IMPACT

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ABSTRACT

In this article a proposal of mathematical modelling is presented, after the analysis of several cases addressing the impact of roads in the environment. This general model accounts for factors that boost the detriment of ecosystems and human settlements near roads using a set of relevant variables. Valuable information about roads and ecological detriments can be obtained using this general equation for assessment of environmental impact due to roads.

1. INTRODUCTION

Happiness and Wealth of their citizens is the main concern of every Government on Earth. This can be done in many ways, but certainly funding and building of infrastructure to achieve this goal requires prior knowledge of environmental impact of buildings and roads. Urban centres have come with a lot more challenges than ever known in the past. As cities grow, accumulation of capital intensifies and labour is drawn into the centre of this large pool of concentration [1]. With concentration comes the need to provide collective goods like roads, schools and hospitals.

This can better be understood in terms of the variety of forms and types of impacts, urban centers can entail on the environment. In the first instance, these centers consume resources of the environment and transform it into urban [2]. They survive on the resources from the rural areas, such as water, electricity, resources for trading and industry, and even lands for housing. All of them need the use of a network of roads. It has been identified several measures related to the network requirements and performance of roads [3]. These include:
a) magnitude of initial capital investment;
b) travelling demand levels;
c) anticipated revenues, and operating fees;
d) generation of supplementary activities;
e) user's consumer surplus; f) benefit to the public at large; and
g) partnership potential (the last measure estimates the capacity of the road related effort to draw the private and public sector together in planning, negotiations, and feasibly, project implementation), and, the most important of all,
h) *environmental impact*.

Roads comprise by itself its use for the public and private transportation of commodities, resources and people. But this use led to a severe environmental impact. For instance Bucharest is affected by serious traffic problems, its estimated that 1,5 million cars move in the city daily and the road network progress is insufficient for it [4]. For example in India, in the city off Delhi the vehicular emission contribution is about 67 percent of total pollutants emission [5]. The falling in London of air quality indexes are also linked to traffic [6]. In Mexico, Toluca City face growing pollution due to the lack of planning in road network

[7].There are some ways to temperate the impact of roads using more efficient and greener vehicles: hybrid, electric, bio-fueled cars and bikes [8,9]. Along with the addition and opening of new roads, new itineraries which will better connect the different urban focuses of the city, better maintenance of the streets and roads, intelligent systems for public transportation [10,11]. The changes in policies would help but whilst policy may easily be changed or even reversed, it is a near impossibility to do the same with the spatial physical urban facilities such as buildings and infrastructure, e.g. roads, water reticulation, sewerage reticulation and treatment works, railway lines, telecommunication lines and power lines.

2. DEVELOPMENT OF THE MODEL

Some studies addressed that the degree of air pollution is directly related to road traffic. Air pollution can affect aquatic and terrestrial ecosystems if pollutants dissolve in water or precipitate as rain polluting soils, aquifers and water reservoirs. However, the pollutant concentration in the environment varies in time and space. Being quite difficult to measure impact of roads, it is required to create a system of information of pollutants. The pollutants concentration must be continuously monitored [7, 11-14]. Systematic monitoring of air quality reveals that the level of atmospheric pollution remains high in many areas, exceeding the maximum permitted concentration for many hazards discharged into the environment. The most significant exceeding has to be recorded at suspensive and settled dusts, but also at more dangerous pollutants such as: sulphur dioxide, nitrogen oxides, heavy metals, phenols, hydrochloric acid etc. Some models have successfully been applied to model presence of pollutants near roads [15,16], however, a general model is useless if can't use a general index to monitoring real impact of pollutants and transport phenomena in a single equation. So index of pollutant (**I_p**) can be defined by the following equations:

$$Ip = 1 - \frac{C_m}{C_0}; \quad \text{if } C_0 > C_m \qquad (1)$$

$$Ip = \frac{C_0}{C_m}; \quad \text{if } C_0 \leq C_m \qquad (2)$$

This set of equation (Eq. 1 and 2) states just that the concentration level of pollutant (**C_o**) for human health (concentration of pollutant for 8 hours) is known as indicator of good air and water quality for residential area [14]; these equations also requires the monitoring of pollutant concentration by 8 hours (**C_m**). If **$C_0 \geq C_m$** then **I_p** tends to be unity, but if **$C_0 < C_m$** then **Ip** tends to be zero. In this manner values of **I_p** near to zero indicates high level of pollutant concentration, but values of **I_p** near to unity indicates low levels of pollutants. For a set of pollutants (**p_j**, j=1, 2, …, n) the environmental impact (**E_i**) can be defined as follows (Eq. 3):

$$E_i = \prod_{j=1}^{n} I_{p_j} \qquad (3)$$

Thus **E_i** values define a measure of the continuous the environmental impact due to road network. Similarly values of **E_i** near unity reflects low environmental impact (Figure 1).

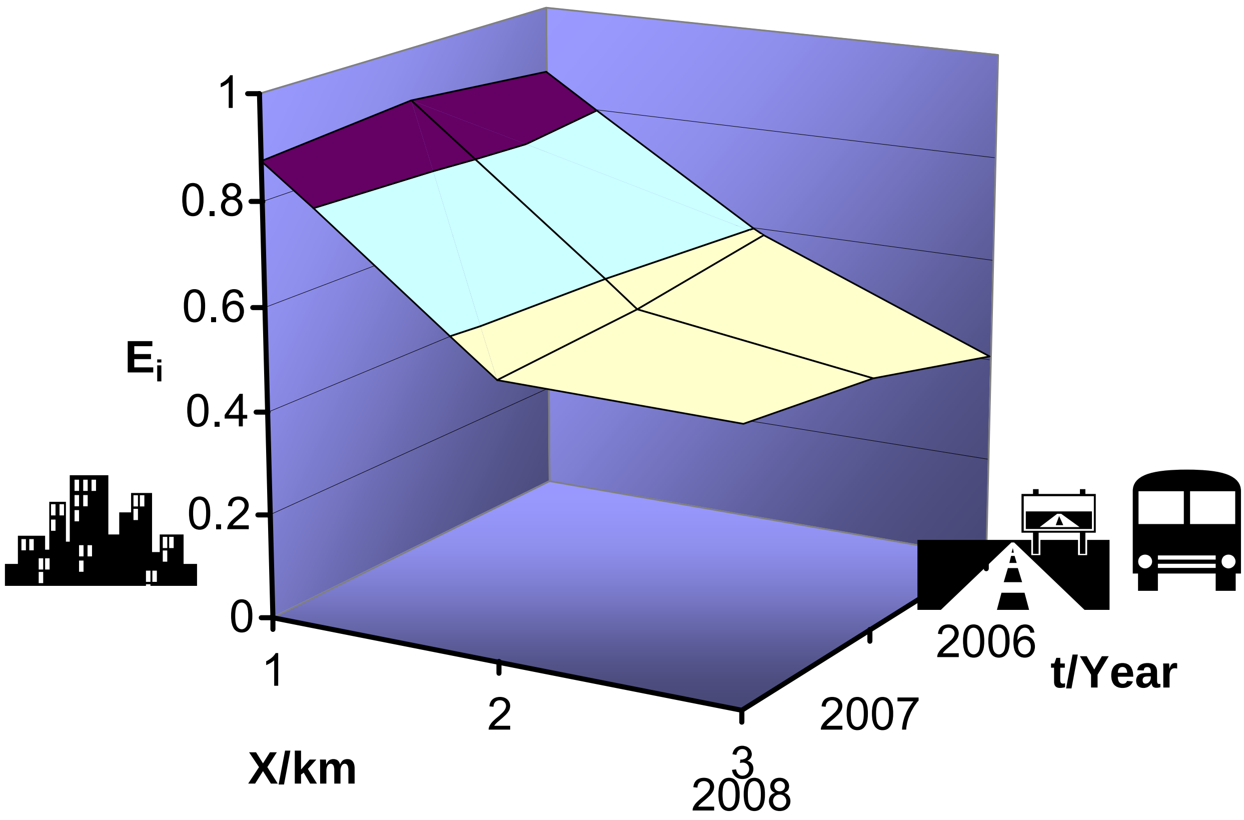

Figure 1. Environmental Impact **(**E_i) as a function of time (t) at different positions (X).

These values can be based on three pollutants that represent a major concern around the world: Suspensive dusts, NO_2 (nitrogen dioxide), O_3 (ozone) and will be able to consider another additional pollutants, e.g. CO (carbon monoxide) and SO_2 (sulphur dioxide), if the data are also available.

On the other hand, in previous works the rise distance of the pollutants, measured as maximum altitude achieved by pollutant in the atmosphere, has been used as a valuable parameter to calculate dispersion of pollutants [15]. However, this parameter can not be used for pollutants in water, the equations involving such parameter requires acquiring the complete data set of pollutant's temperature, also knowledge of the kinematics and dynamics properties of the transport media (fluid) in which pollutant is moving, including the speed (U) profiles of the fluid. Despite of this fact, the equations used to model environmental behaviour of pollutants depends or can be correlated easily to the concentrations of pollutants, these last are easily monitored and do not require complex monitoring or use of approximated values or models (See Fig. 2). Currently a national network of air and water quality monitoring comprises permanent air and water quality monitoring stations, endowed with automatic equipments to measure the concentrations of major air and water pollutants. This system gathers and disseminates information data from stations and transmits them after primary validation for certification. These facilities provide precise and data of pollutants produce by traffic in roads. Furthermore, models may produce large deviation of the resulting forecast data under circumstances out of those used to deduce the model [16] making monitoring stations a better approach to measure environmental impact due to roads.

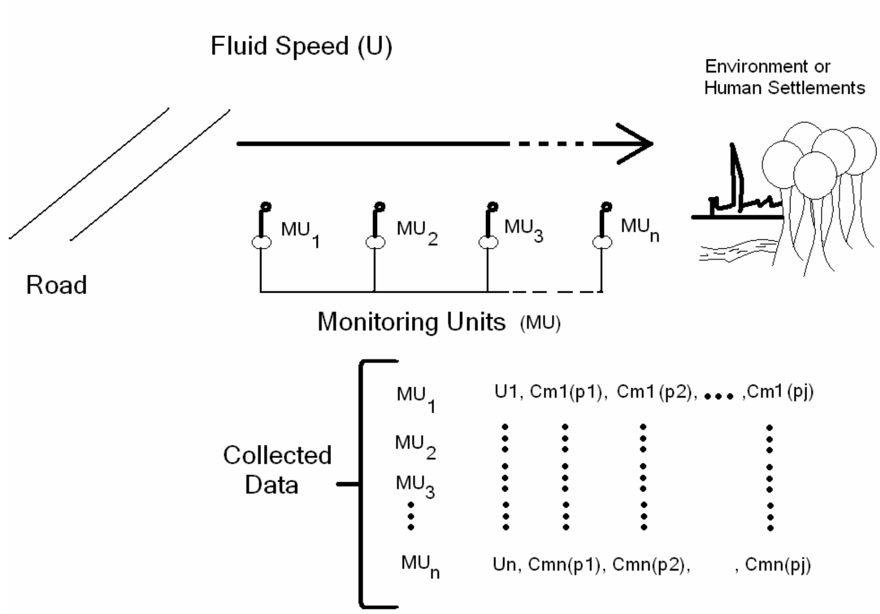

Figure 2. Monitoring system of pollutants concentration.

Equations 1, 2 and 3 can be easily used to fit experimental data sets to measure the environmental impact of roads. Values of E_i have been calculated from some previously reported data for Bucharest [5] (Table 1, Figures 3 and 4). Values of pollutant concentration used were average values year based, however Ip values may be taken monthly, weekly, daily or as C_m were originally defined. Data used to calculate Ip and E_i can be divided according to low and high traffic areas in the city.

Table 1. Ip values for NO_2 , Suspensive Dust, SO_2 and E_i values for Bucharest City.

Year	High Traffic Areas				Low Traffic Areas			
	Ip			E_i	Ip			E_i
	NO_2	Suspensive Dust	SO_2		NO3	Suspensive Dust	SO_2	
2006	0.604	0.601	0.604	0.219	0.892	0.772	0.569	0.391
2007	0.581	0.506	0.716	0.210	0.952	0.733	0.569	0.397
2008	0.597	0.467	0.644	0.180	0.981	0.611	0.624	0.374

In case of nitrogen dioxide pollution, Ip values reflect that Bucharest is one of the most polluted capitals; the tendency is to keep similar levels of pollution by nitrogen dioxide in areas with heavy traffic and drop it in residential areas. In case of suspensive dusts in Bucharest Ip values tend to decrease. In terms of sulphur dioxide pollution in high traffic areas there is a little increase in 2007, in low traffic areas there is an incremental presence of SO_2. This is the most polluted city in Europe [15] and E_i values reflect this trend, reaching values between 0.180 and 0.391. But we can say that the city of Bucharest is at a level below to standards, where data exist for the same years and the trend is generally increasing pollution ($Ei \rightarrow 0$).

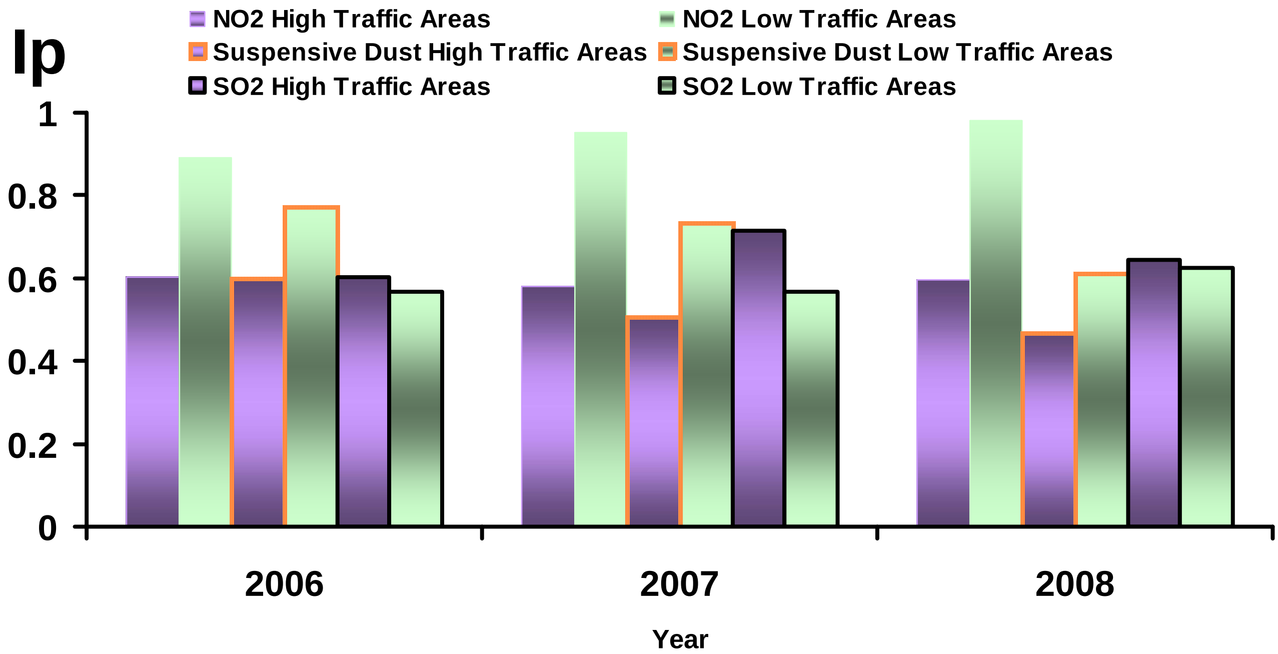

Figure 3. Ip values for NO_2, Suspensive Dust, SO_2 for Bucharest City.

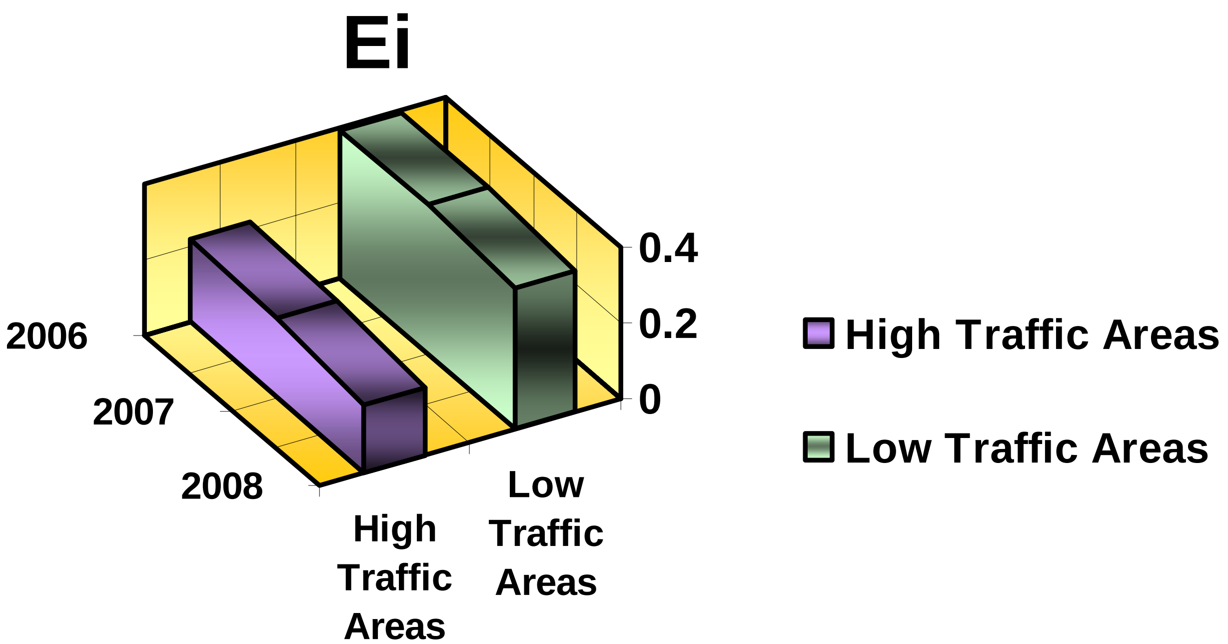

Figure 4. E_i values for Bucharest City.

CONCLUSIONS

The proposed model to account the influence of roads in the ecosystems can give reliable information and may help the automatization of the monitoring system of pollutants. This results in a novel way to address this complex behaviour in a logical and simple manner for collecting data, for planning, modification and control of vehicle transport in the road network, thus providing a stockpile of information for the creation and prospecting of specific policies to particular cases of study.

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