**Mechanics Transport Communications**
*Academic journal*
**ISSN 1312-3823**
**volume 11, issue 3, 2013**
**article № 0853**
http://www.mtc-aj.com

# THE GREENING OF THE TRAFFIC CALMING METHODS

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***Key words:*** *sustainable transport, traffic calming, car exhaust emissions, traffic simulation*

***Abstract:*** *The interaction between the motorized traffic and the non-motorized trips or the environment raises particular matters. The traffic calming methods are useful in alleviating the adverse effects of this interaction. While some of the warning methods leave to the ethics of the drivers whether they observe or not the limitations, the physical methods are more effective in enforcing the traffic rules observance. The reverse is denoted by increasing exhaust emissions. The paper presents a method to assess the vehicles emissions on road infrastructures equipped with traffic calming elements (speed humps, turn-around etc.), based on computer traffic simulation and pollutant emission factors. The VISSIM software is used in modeling transport infrastructure, traffic rules, vehicles flows (volume, composition) and to collect output data from computer simulation. The emissions are estimated based on the average speed models proposed by European Environment Agency in the Air Pollutant Emission Inventory Guidebook. The case-study proves the excess in vehicle emissions (CO2, CO, NOx, VOC) due to the presence of the traffic calming elements. The study urges traffic engineers, urban planners and local authorities to balance the positive aspects (traffic diverting, safety increasing) with the negative ones (exhaust emissions, noise) in applying the traffic calming elements.*

## INTRODUCTION

The increase of the urban car traffic generates for some areas the run-off of their environmental capacity. The initial traffic management techniques diverted the traffic from residential streets into main routes using street closure, pedestrian exclusive areas or turning bans [1]. At the mid-1980s the new traffic calming methods consist in changes to the horizontal and/or vertical alignments of the traffic ways. These methods are applied in built-up areas (e.g. residential, recreational and shopping areas) for reducing cars speed and increasing safety, in cities center to urge the pedestrian use and in villages without bypasses to return the villages to their inhabitants [2,3]. Due to the increase in cars exhaust emissions with the speed reduction, a balance between the traffic volume reduction, the safety increasing and the amount of emissions should be considered. Beside the traffic calming measures, the oriented education and the promotion towards the pedestrian, public and cycling transport support the sustainable development of human communities [4,5,6].

## TRAFFIC CALMING METHODS

Traffic calming techniques can be grouped into the following categories [7,8,9]:

- legislation and enforcement;
- surface treatment and road signing;
- vertical and horizontal deflection;
- gateways and entries.

Legislation and enforcement methods consist in restrictions on movement and parking (e.g. speed limit, one-way streets). The enforcement effects deteriorate as long as drivers get familiar. Surface treatment could be colored or textured small areas of carriageway or whole block work paved streets. Traffic signs are very effective in giving authority but should be used with other methods for increasing driver's awareness when entering special areas. Vertical deflection consists in road humps, rumble strips, cushions and speed tables. The narrow humps can be passed at high speed with minimum discomfort for drivers and passengers, but drivers usually avoid doing so having fear not to damage the vehicles suspensions or losing vehicle control. Road humps are used on residential areas access, where vehicles speed can be excessive and reduction is necessary. The main disadvantages of standard road humps are:

- public transport operators and emergency services are unpleased with them, but accept long speed tables with slower gradient (1:15 or less);
- depending on the hump separation and their height, the deflected traffic on adjacent roads can contribute to congestion;
- long-wheel base vehicles could ground when passing.

Speed tables may be used as an alternative to circular humps, where the carriageway is lifted up to the footway level, possible in contrasting color or different texture. The measure is particularly applied outside schools, shops, zebra, pelican crossing and on-street public transport stations. Speed cushions are perceived as being more user-friendly for buses and emergency vehicles. They are not as wide as road humps and are designed so that large vehicles (e.g. buses, trolleys) can pass without interference. Rumble strips are raised areas designed for catching the drivers' attention by producing vibrations. The gateways have the role to notify about the changes of the road characteristics (e.g. residential area, speed limit area). Also chicanes located each side of the carriageway can be effective in reducing cars speed.

(a) road hump

(b) rumble strips

**Fig. 1 Different traffic calming methods**

## ASSESSING CARS EXHAUST EMISSIONS THROUGH COMPUTER SIMULATION

Microscopic simulation can be applied for assessing traffic outputs that are difficult to be quantified through the field measurements, such as fuel consumption, exhaust emissions, air quality impacts and accident risk factors. An outstanding property of micro-simulation traffic models is the tracing of the individual vehicles activity over a series of short time intervals or run distances. Boulter et al. [10] and Barceló [11] provide useful guide-lines to the principles of traffic simulation. Tate et.al [12], Panis et al. [13], Jayaratne et al. [14], Xia and Shao [15] present examples for integrating traffic simulation and vehicles exhaust emission models.

Figure 2 depicts the proposed methodology for evaluating cars exhaust emissions, combining traffic data, computer traffic simulation using VISSIM software and emission factors estimated through European Environmental Agency (EEA) models [16].

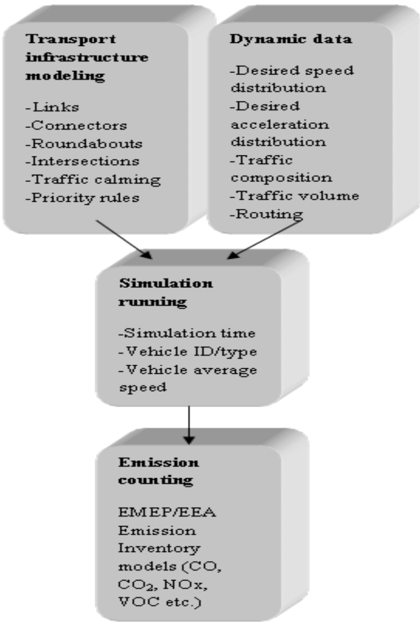



**Fig. 2 Assessing cars exhaust emissions flow-chart**

According to the emissions calculation, the pollutants are divided in four groups [16]:

♦pollutants which have a direct estimation based on specific emission factors (e.g. CO, NOx, volatile organic compounds – VOC, CH4, N2O, NH3, particulate matter – PM);

♦pollutants estimated based on fuel consumption (e.g. CO2, SO2, heavy metals – Pb, Cd, Ni);

♦pollutants estimated based on a simplified methodology due to the lack of detailed data (e.g. polycyclic aromatic hydrocarbons, polychlorinated dioxins);

♦pollutants derived as a fraction of non-methane volatile organic compounds (e.g. alkanes, alkenes, ketones, cycloalkanes).

The emissions of pollutants are computed by:

(1) $E_{i,k,m,r} = n_{k,m} \times d_{k,m,r} \times e_{i,k,m,r}$

where:

$E_{i,k,m,r}$ is the exhaust emission for the pollutant i [g], produced by the vehicle of technology k, using the fuel m, driven on a road of type r;

$n_{k,m}$ - number of vehicles [veh] of technology k and fuel m;

$d_{k,m,r}$ - mileage per vehicle [km/veh] driven on road r by vehicle of technology k and fuel m;

$e_{i,k,m,r}$ - emission factor [g/km] for pollutant i by vehicle of technology k, fuel m on road type r.

For the pollutants in the 1st and the 3rd group, the emissions factors are directly expressed as an average speed dependent function. These generic functions, depending on fuel, engine capacity and technology could have exponential, quadratic or polynomial ratio expression. For passenger cars the generic function used for carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOC) emissions is:

(2) $e_{i,k,m,r} = \left(a + cv + ev^2\right) / \left(1 + bv + dv^2\right)$ ,

where v is the average car speed [km/h] and the coefficients a-e are provided for each pollutant, fuel, car technology (Euro 1-5) and engine capacity. The determination coefficients for such generic relations are above 0.85, reflecting a strong dependence between the emission factors and the vehicles average speed.

The emissions of the pollutants in the 2nd group are expressed based on the fuel consumption. The fuel consumption factor is dependent of the vehicle average speed and technical data (engine standard and capacity, fuel type). The reduction of the vehicles speed generates fuel consumption boost and consequently the exhaust emissions increasing. Thus, despite the accomplishment of some objectives by the traffic calming methods, they could also contribute to the negative externalities of the car traffic.

The pollutants in the 4th group are derived as a fraction of total non-methane volatile organic compounds (NMVOCs) emissions that belong to the 1st group with direct assessing methodology.

## CASE STUDY – ROAD HUMPS EFFECT ON CARS EXHAUST EMISSIONS

Road humps are highly used traffic calming methods in residential, school and commercial areas in Bucharest. Their main goals are car speed reduction, safety increasing and traffic diverting. Humps are not well qualified for enhancing environment. Their effect on car exhaust emissions is proved on a study-area located in Militari residential zone (Figure 3).


**Fig. 3 Case study area in Militari residence - Bucharest**

The area is a residential one, with mixed level buildings and variable population density. Along the streets there are placed road humps (75 mm height) with 75-125 m space between them and 30 km/h speed limitation signs. The cars emissions are estimated through the methodology described above, using VISSIM traffic simulation software. A scalable GIS map with infrastructure elements (streets, intersections, speed limitations, humps placement) is used. The desired speed distribution at top hump according to its characteristics is set as a ”S” shape, with mean 25 km/h for passenger cars and light-duty vehicles and 20 km/h for heavy-duty vehicles [17, 18]. The computer simulation experiments have been conducted by recording 1200 tests for each vehicle category (personal car – PC, light-duty vehicle – LDV and heavy-duty vehicle – HDV). Each individual vehicle trajectory is thoroughly monitored. Based on the average speed and the technical characteristics of each vehicle, the corresponding emissions are computed. Figure 4 depicts the variation in vehicles speed along a sector of the route.

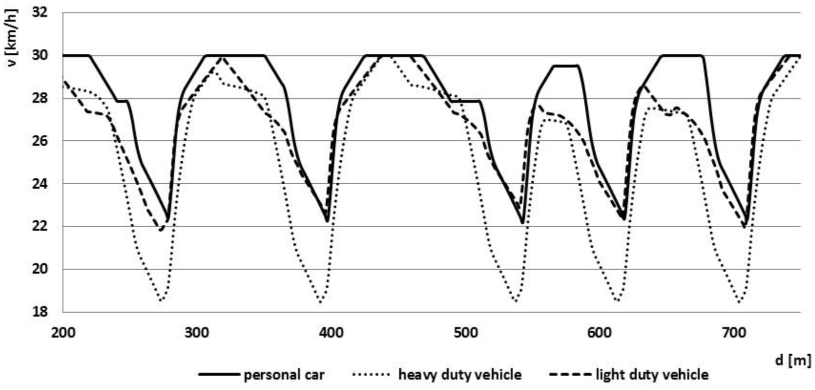
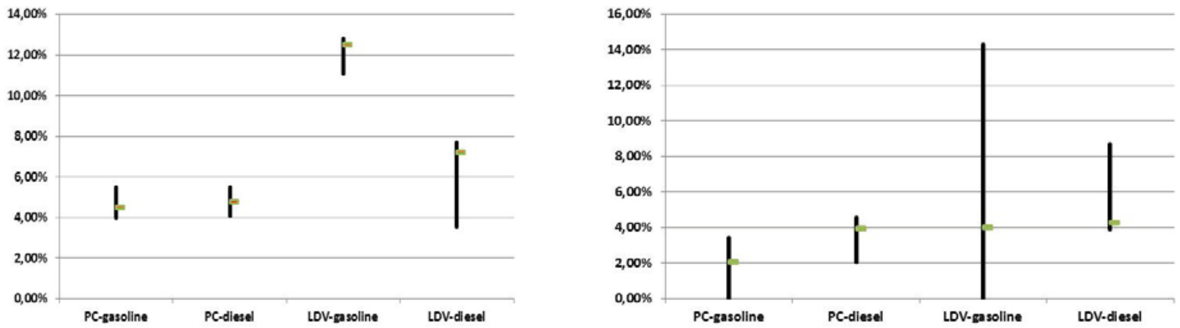



**Fig. 4 Vehicles speed variation**

The relative limits (min and max) and the mean values of CO and NOx emission increasing for different vehicle classes due to road humps presence compared to their absence is shown in figure 5.




(a) CO (b) NOx

**Fig. 5 CO and NOx relative increase due to road humps**

The CO exhaust excess is smaller for personal cars, but more significant for light-duty vehicles, and especially for those on gasoline. The acidification emissions (NOx) also rise, but the relative values are quite equal.

## CONCLUSIONS

The use of the traffic calming methods and particularly of the road humps contributes to vehicles speed reduction and thus is quite important in terms of traffic safety (less accidents and alleviation of injury severity), traffic diverting and smoothing drivers' behavior. At the same time, by running vehicle engines at low speed, the exhaust emissions increase inducing adverse effects to the environment. The application of the traffic calming methods should be analyzed with respect to the locations, balancing all positive and negative aspects involved.

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# ЕКОЛОГИЗАЦИЯТА НА МЕТОДИ ЗА ОБЛЕКЧАВАНЕ НА ПЪТНОТО ДВИЖЕНИЕ

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***Ключови думи:*** *устойчив транспорт, облекчаване на пътното движение, емисии от отходни газове, симулация на трафика*

***Резюме:*** *Взаимодействието между моторизирания трафик и немоторизираните пътувания или околната среда повдига специфични въпроси. Методите за облекчаване на пътното движение са полезни за намаляването на неблагоприятните последици от това взаимодействие. Докато някои от предупредителните методи зависят от етиката на шофьорите дали да спазват или не ограниченията, физическите методи са по-ефективни по отношение на спазването на правилата за движение. Увеличаването на емисиите от отходни газове показва обратното. Статията представя метод за оценка на емисиите от превозните средства по пътните инфраструктури, оборудвани с елементи за облекчаване на пътното движение (ограничители на скоростта, кръгово обръщане и т.н), базиран на компютърна симулация на движението и фактори отчитащи емисионните замърсители. Софтуерът VISSIM е използван за моделиране на транспортната инфрастуктура, правилата за движение, потоците от превозни средства (обем, състав) и за извеждане на заключения от изходните данни от компютърната симулация. Емисиите се изчисляват въз основа на моделите за средните скорости, предложени от Европейската агенция по околната среда в Наръчника за емисиите замърсяващи въздуха. В случая се доказва излишък на емисиите от превозни средства (CO2, CO, NOx, VOC) поради наличието на елементи за облекчаване на пътното движение. Изследването мотивира транспортните инженери, урбанистите и местните власти да балансират позитивните аспекти (отклоняване на трафика, увеличаване на безопасността) с негативните такива (емисии от отходни газове, шум) при прилагане на елементите за облекчаване на пътното движение.*