CAN EFFECTIVE SPEED MANAGEMENT CONTRIBUTE TO LOWER VEHICLE POLLUTANT EMISSION?

ZIOLKOWSKI R.

Bialystok University of Technology, Poland, Faculty of Civil and Environmental Engineering, Department of Road Engineering
E-mail: robert.ziolkowski@pb.edu.pl

ABSTRACT

Road transport contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. CO_2 emissions from road transport increased by nearly 23% between 1990 and 2010. Transport is the only major sector in the EU where greenhouse gas emissions are still rising. Light-duty vehicles – most commonly present on urban roads - are a major source of greenhouse gas emissions, producing around 15% of the EU's emissions of CO_2. Road conditions preventing smooth and fluent driving further enhance emissions. Efficient speed management covering vast city areas is belied to improve travel conditions and lower emissions. In developing countries due to high cost implementation speed management focuses basically on a smaller scale and aims at how best to set and enforce speed limits where there are safety concerns. Speed management being a complex issue involves both engineering and behavioural factors. Implementation of engineering issues involving physical and non-physical measures generally ignores behavioural factors that emerge from impediments that drivers face on a roadway which in turn essentially contribute to driving maneuvers and level of emissions. The measurements of instantaneous speed in vicinity of speed management measures including chosen traffic calming measures and roundabouts were undertaken to develop the investigation. The paper presents the results of speed investigations conducted in urban areas under varied roadway geometry conditions in two Polish cities. The examination has focused on drivers' behaviour and the dynamics of speed changes expressed by deceleration and acceleration values which have been evaluated on the basis of individual speed profiles. Data related to emissions were considered based on the literature review.

Keywords: vehicle emission, speed management, drivers' behaviour; dynamics of manoeuvres; deceleration; Acceleration

1. Introduction

Vehicular emissions have become a major source of air pollution in many cities around the world. Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Road transport alone contributes about one-fifth of the EU's total emissions of CO_2, the main greenhouse gas. While emissions from other sectors are generally falling, those from transport have continued to increase also due to the trend toward larger, heavier and more powerful cars (Theodoros and Zachariadis, 2012). More than two thirds of transport-related greenhouse gas emissions are from road transport as the number of kilometres driven in consistency with the greenhouse gas emissions from cars grow.

Pollution from cars comes from by-products of the combustion process (exhaust) and from evaporation of the fuel itself. The main exhaust products are nitrogen (N_2), carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NOx), and hydrocarbons (HC). Presently the transport sector is one of the crucial drivers for the increase in global greenhouse gas (GHG) emissions (Fuglestvedt and Berntsen, 2008). The increase in GHG emissions from transportation is expected to persist. In 2050, 30–50% of total CO_2 emissions are predicted to come from transport (European Environment Agency, 2004), compared with today's 20–25%. Besides the limitation of a car numbers on the streets and new technological solutions another relevant factor that contributes in emissions level and is more commonly pointed is driving style concerning travel speed and fluency.

2. Speed-based emission

A typical driving trip consists of idling, accelerating, cruising, and decelerating. The proportion of a trip spent in these different stages will depend on the driver's behaviour (aggressive vs. mild driving habits), the roadway type (freeway vs. arterial) and the level of traffic congestion. Those conditions highly influence travel speed and fluency what can be represented by speed profiles and eventually the amount of CO_2 that is emitted during the trip. Driving pattern in urban areas characterizes with a lower average speed and higher number of stops and hence emerges dynamic manoeuvres such as decelerations and accelerations.

The most important influence on emission levels for a given vehicle is the driving cycle, with both fuel consumption and pollutant emissions many time higher per vehicle km during acceleration and during deceleration than during cruise (Frey *et al*., 2001). Based on their research it was concluded that there is a significant variation in vehicles emission during temporary event like acceleration, deceleration and cruising. However Unal (Unal et a., 2004) reported wide range of parameters influencing on vehicle tailpipe emissions such as average speed, average acceleration and standard deviation of speed, minimum speed or maximum acceleration has not confirmed the effect of deceleration. Similarly study investigating effect of speed and dynamic manoeuvres (Bokare and Maurya, 2013) showed that emission rates increase with increase in vehicle acceleration rate but deceleration does not influence tailpipe emission. Additionally Wang (Wang *et al*., 2011) pointed that emission estimates should incorporate the acceleration instead of mean speed of vehicle and the effect of acceleration is greater on lower speed than at higher speeds.

Recent studies have shown that in certain situations the driver's driving style can result in differences in terms of fuel consumption (and therefore CO_2 emissions) up to 40% between a calm driver and an aggressive one. One of the possible actions to reduce the environmental impact caused by road transport is therefore effective speed management aiming at traffic calming.

3. Speed management

Speed management can be defined as a set of measures to limit the negative effects of excessive and inappropriate speeds. It is related to planning, coordinating, controlling and organizing traffic to achieve efficiency and effectiveness of the existing road networks. This includes techniques and strategies that generally are used to mitigate congestion, minimize delays and ensure smooth. Inappropriate speed is being a causation factor not only in fatal accidents on roads but also has serious consequences on the environment and energy consumption. Seeking effective solutions towards lowering speed and thus vehicle emissions many transport policies in urban areas have been implemented (road pricing, calmed zones) in order to reduce traffic congestion and effectively influence drivers behaviour (traffic calmed zones, dynamic route guidance, intelligent transportation systems). Within wide range of those solutions traffic calming measures (TCMs) can be very effective in speed reduction but their influence on drivers' behaviour depends on the specific solution. On the other hand TCM installations aiming at speed lowering generally omit driving patterns and intensity of deceleration and acceleration manoeuvres which as stated above are very important in terms of emission levels.

This study focuses on the measurements of instantaneous speed and assessment of drivers' behaviour expressed by acceleration and deceleration values. Measurements were conducted in vicinity of different traffic calming measures including mini and small roundabouts.

4. Methodology, results and discussion

Speed measurements were conducted in free flow driving conditions and test rides were employed. The data were collected by utilizing portable wireless Global Positioning System data logger which recorded instantaneous speed in vicinity of tested sections. Decelerations “d” and accelerations “a” were calculated based on the successive second-by-second speed records. Speed profiles with abnormal driving patterns were excluded from calculations of average speed profile.

Speed measurements were conducted along streets situated in two Polish cities: Bialystok and Suwalki. From a variety of calming measures most effective in forcing drivers to slow down are vertical deflections hence the investigations concentrate on various types of such devices and include: speed bump, speed cushion, raised intersection, raised pedestrian crossing and raised median island. The study also includes mini and small roundabouts as they are willingly used to manage the speed and calm the traffic.

As a result a number of individual speed profiles were derived from GPS data logger based on which average individual speed profiles were developed (Figure 1). Averaged speed profiles were further elaborated to calculate the deceleration (d) and acceleration (a) values presented in Table 1.

a) b)

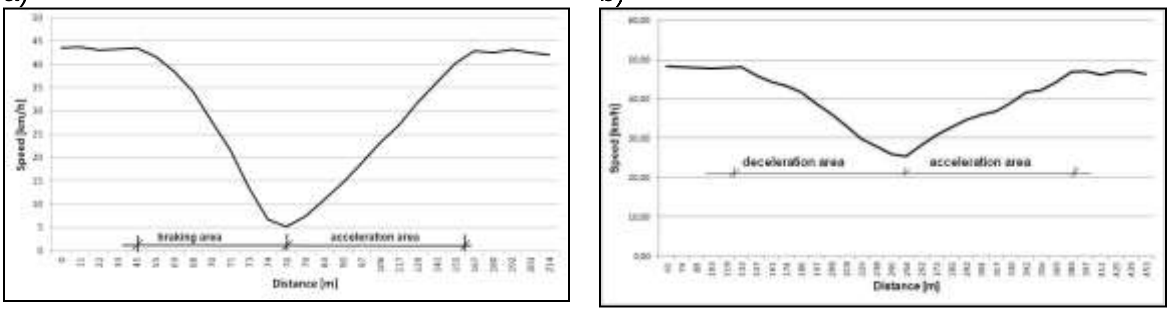

Figure 1: Average speed profiles in vicinity of a) speed bump b) small roundabout

Table 1: Summary of calculated deceleration and acceleration values

Type of calming measure	Approaching speed [km/h]	Speed over the measure	Deceleration “d” [m/s^2]*	Acceleration “a” [m/s^2]*
mini roundabouts	35	15,4	0,28-0,88	0,51-1,01
small roundabouts	59	22,8	0,49-1,42	0,51-1,42
speed bump	43	4,3	1,09	0,9
speed cushion	43	27,1	0,69	0,7
raised intersection	50	4,7	1,37	0,80
raised crossing	40	7,2	1,65	0,86

* in case of roundabouts average value depends on driver’s direction movement

Speed profiles presented in Figure 1 not only show high effectiveness of TCMs in speed reduction but also substantial disturbances in vehicles’ speed and fluency. From the graph it emerges that the type of calming device also essentially influences average speed and drivers technique. The presence of speed bumps, raised intersections and pedestrian crossings affect the velocity most significantly and the average speed at the location of those measures drops below 10 km/h and varies from 4.3 km/h to 7.2 km/h. The decrease of average speed over a speed cushion is also noticeable but is not as severe as over aforementioned vertical deflections and the drop doesn’t exceed 40% of the average approaching speed.

The character of changes occurring in vicinity of roundabouts is very similar considering the shape of a speed profile to those in vicinity of vertical deflections. The main difference comes down to the speed values on circulatory roadways. In case of small roundabouts the average speed value is lower by about 10 km/h when compared to the medium ones where average speed has dropped to 27 km/h.

From Table 1 it appears that braking processes in each case proceed more rapidly than accelerations and the decelerations gain highest values in the presence of raised intersections and pedestrian crossings, respectively d=1,37 m/s_2 and d=1,65 m/s_2. This can be explained by the fact that drivers trying to avoid significant reduction in speed postpone the slowdown process as long as possible which entails rapid maneuvers shortly before an obstacle. The lowest deceleration values were obtained in vicinity of roundabouts (0,28 m/s_2 and 0,49 m/s_2) however those values depend a lot on the driver's movement direction.

Considering acceleration values, according to many research more important in terms of emission levels, similarly to decelerations they are very dispersed and are associated with the size of a roundabout. Maximum calculated values for small and mini roundabouts are respectively 1,42 m/s^2 and 1,01 m/s^2 and also depend on driver's movement direction. Analysing acceleration values within vertical obstructions it can be stated that lower average speed value over the device is related with higher acceleration.

It can be stated that most aggressive driving techniques occur in vicinity of small roundabouts. Higher approaching speeds together with a relatively small size of central islands' diameter create conditions for violent drivers behaviour (d=a=1,42 m/s^2). Although they are very effective in speed reduction at the same time they contribute to undesirable high dynamics of speed changes and aggressive manoeuvres.

Intensive driving manoeuvres contribute to higher fuel consumption and pollutant emission. Models describing fuel consumption and emissions of vehicles operating in dynamic conditions (Pelkman *et al*., 2004) and CO_2 emission (Cornelis *et al*., 2005; Panis *et al*., 2006) as a function of acceleration show its intensive increase for average speed at a level of 20-30 km/h and acceleration values exceeding 1,0 m/s^2 which are characteristic for roundabouts. Furthermore speeding can contribute to even 40% increase in NO_x emission level hence effective speed management is of great importance not only in terms of safety but also emission levels. Speed management strategies shouldn't be limited to short sections and placed at spots of higher risk but should be elongated to longer sections so that they would force drivers to travel with moderate speeds and prevent them from local increased decelerations and accelerations and eventually improve environment al impact.

5. Conclusions

Speed management is undoubtly very important in terms of traffic safety but it can also influence vehicle emissions essentially. This study has considered the evaluation of traffic calming measures and their effectiveness in relation to pollutant emission in terms of the dynamics of speed changes.

The study results showed that the most effective devices from the investigated ones in terms of speed reduction are vertical deflections especially speed bumps and raised intersections. Their effectiveness is much higher than effectiveness of roundabouts but entail more violent braking resulting in highest deceleration values.

Roundabouts which are willingly used as speed management measure to smooth the traffic fluency in fact occur to contribute to high differentiation of speed. Especially the presence of small roundabouts create conditions for violent decelerations and accelerations depending on approaching speed and drivers' movement direction.

Speed management can provide effective lowering vehicle's emission and should be incorporated but require much attention at a planning level. At a local level, decisions of public authorities towards creation of environmentally friendly driving pattern conditions through introducing traffic calming measures can change drivers' behaviour and have an important influence on fuel consumption. However those activities require deepened and considered analysis including drivers' manoeuvres in relation to a specific installation, otherwise, as presented results revealed, they can cause the opposite effect.

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