AUDRIUS VAITKUS, Ph.D.[1]
(Corresponding author)
E-mail: audrius.vaitkus@vgtu.lt
DONATAS ČYGAS, Ph.D.[2]
E-mail: donatas.cygas@vgtu.lt
VILMA JASIŪNIENĖ, Ph.D.[1]
E-mail: vilma.jasiuniene@vgtu.lt
LAURA JATEIKIENĖ, Ph.D.[1]
E-mail: laura.jateikiene@vgtu.lt
TADAS ANDRIEJAUSKAS, M.Sc.[1]
E-mail: tadas.andriejauskas@vgtu.lt
DOVYDAS SKRODENIS, M.Sc.[1]
E-mail: dovydas.skrodenis@vgtu.lt
KORNELIJA RATKEVIČIŪTĖ, Ph.D.[1]
E-mail: kornelija.ratkeviciute@vgtu.lt
[1] Road Research Institute
Vilnius Gediminas Technical University
Linkmenų str. 28, Vilnius LT-08217, Lithuania
[2] Dept. of Roads, Vilnius Gediminas Technical University
Saulėtekio Ave. 11, Vilnius LT-10223, Lithuania

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TRAFFIC CALMING MEASURES: AN EVALUATION OF THE EFFECT ON DRIVING SPEED

ABSTRACT

Road accidents are one of the leading causes of death in the world, particularly among young people. Excessive speed is one of the main risk factors in road traffic safety, increasing accident probability and affecting accident severity. Experimental research of the traffic calming measures allocation effect on the driving speed is presented in this paper. The research has been carried out on two aspects. The first one with respect to the mean speed and the second one regarding instantaneous speed. However, the paper is not only restricted by the above research. Standardized survey interview and questioning, a survey of public opinion, was carried out to find out the road users' opinions about the need for traffic calming measures and speed control measures. Finally, the authors presented their insights and recommendations for the installation of speed humps and gateways and their optimum spacing.

KEY WORDS

traffic calming measures; speed hump; gateway; road safety; public opinion;

1. INTRODUCTION

Speed is one of the main risk factors for road traffic safety, influencing accident probability and severity. Many scientists [1, 2, 3] pointed out that speed has a greater effect on the number of accidents and injury severity than almost any other known risk factor. According to the Speed Management [4], speeding is a widespread social problem as, usually, approximately 50% of drivers exceed the speed limits. Speeding is the greatest challenge of road safety in many countries, often contributing to more than one third of all fatal accidents. Speed is also an aggravating factor in the severity of all accidents. In particular, speeding affects the severity of collisions and accidents which involve the most vulnerable road users i.e. pedestrians, cyclists and motorcyclists. Based on the data of the World Health Organization [5], almost half of all deaths on the world roads are among those who are less protected, motorcyclists, cyclists and pedestrians. The analogical situation can be observed on Lithuanian road network, where 49.8% of all fatal accidents in 2014 involved vulnerable road users.

Lithuania, together with all the European Union (EU) Member States has agreed on the ambitious target to reduce the number of road fatalities in 2011-2020 by half. Analysis of road accident statistics shows that today's progress in the field of road safety is not sufficient to achieve the mentioned target. Over the last five years (2011-2015), the number of deaths on the European roads has decreased by 15% and on the roads of Lithuania it decreased by 19% [6]. Lithuania showed a significant progress in the field of road safety improvement in previous years. Lithuania was one of the few EU countries which successfully achieved the target set of the EU White Paper, reducing by 50% the number of road fatalities in the period between 2001 and 2010. The number of fatalities was reduced by 58%, from 706 to 299. However, the data of accident statistics of the recent years (2013-2015) shows that positive changes have stabilized (road fatalities decreased only by 6.5%). It means that road users were able to successfully adapt to new traffic conditions, and the previous traffic improvement means and measures are insufficient. Besides, a higher scattering of road accidents can be observed on the Lithuanian road network. The number of black spots has decreased considerably (by 57.5%), while the number of road accidents has decreased slightly (only by 3.2%). Considering this, it is of utmost importance to assess the effectiveness of road safety measures used and to search for innovative and versatile solutions that would help solve the constantly arising road safety problems. In addition, to reduce both, the number of accidents and, most importantly, the number of people injured and killed on the roads.

One of the main tasks of institutions responsible for road safety, is to ensure that the drivers comply with the speed limits. Norway serves as a good example of the leading country in the field of road safety, which among other road improvement tasks of road safety has set a target that by 2024 there would be 85% of drivers who will comply with the speed limits [7]. This is particularly important in urban areas where pedestrian and bicycle traffic is high. Traffic calming measures, in particular, groups of measures, physically enforce drivers to comply with the speed limit. Traffic calming measures can be implemented individually or in combination. The effectiveness of the mentioned measures is highly affected by a proper selection of their type, distance between, and geometric parameters.

2. LITERATURE REVIEW

Literature review has shown that the first studies related to the effect of traffic calming measures started already in the 1980s [8, 9]. They were related to the determination of the effect of speed limit signs.

Speed management has become a topical issue in the last decade. The introduction of horizontal and vertical traffic calming measures began (e.g., gateways, speed humps, speed cushions, etc.) physically enforcing road users to select the permissible speed on roads and streets. However, in practice, traffic calming measures do not always ensure compliance with the speed limit. This encouraged the researchers from various countries to start assessing the effect of the mentioned measures, to determine their most effective parameters (height, length, gradient, and radius) and displacement. The efficiency of traffic calming measures is most often assessed by means of speed reduction or decrease in accident rate, and, sometimes, by road capacity.

2.1 Efficiency of speed humps

Speed humps (circular, parabolic or sinusoidal) are one of the most commonly applied traffic calming measures in urban territories. The review of various guidelines [10, 11, 12] shows that speed humps are usually recommended only on streets where the speed limit is 50 km/h or less, except sinusoidal speed humps that are for less than 70 km/h. Speed humps are used on one-way or two-way streets. Speed humps are not recommended for the use on bus or emergency vehicle routes. Watts (parabolic) hump only for local streets with the volume of less than 3,500 AADT (Annual Average Daily Traffic), while the Seminole County (of trapeze shape) hump can be used on collector roads as well as local roads is recommended by Pennsylvania Traffic Calming Handbook [10]. It is appropriate for streets with the volume of up to 6,500 AADT. Traffic Calming Guidelines by the South Carolina Department of Transportation (SCDOT) [11] recommended using speed humps in residential territories, where the traffic volume is less than 4,000 AADT, and in central business district where the traffic volume is lower than 6,000 AADT. It was pointed out in Pennsylvania Traffic Calming Handbook that speed humps should be avoided on major transit routes. Traffic Calming Guidelines by SCDOT [11] suggested using speed humps when the average speed exceeds a posted limit by 5 mph (8 km/h) or more or the 85th percentile speed exceeds a posted limit by 10 mph (16 km/h) or more. Speed humps, like other speed calming measures, have advantages and disadvantages (noise, vibration, pollution). Therefore, the researchers [13, 14, 15, 16] still continue their studies related to speed humps seeking to determine the most effective parameters, spacing, etc.

Antić et al. [17] investigated vehicle speed at three locations in Belgrade before, on the first and on the 30th day after the speed bumps of 3 cm, 5 cm and 7 cm height had been installed. The speed limit was 50 km/h at all three locations. The study showed that the speed in the space between the bumps decreased with the increasing height of speed bumps. The installation of 3 cm high speed bumps decreased the 85th percentile of speed from 56 km/h to 50 km/h, 5 cm high speed bumps - from 67 km/h to 41 km/h, 7 cm high speed bumps - from 57 km/h to 35 km/h. In addition, it has been shown that the effect of speed bumps on speed reduction is stable, since there was no significant deviation in vehicle speed neither on day 1 nor 1 month after the speed bumps were installed.

Chen et al. [18] assessed the effect of various safety countermeasures implemented in New York City. Simple before and after accident study showed a reduction of fatal and injury accidents by approximately 33% on the sections where speed humps were placed.

Rahman et al. [19] surveyed a number of North American, Australian and European experts from Traffic Authorities concluding with the observation that speed humps are suitable for solving various types of street issues, such as speeding, high volume of cut-through traffic, road accidents, and pedestrian safety concerns, pedestrian safety issues due to the lack of sidewalks or narrow streets.

Garcia et al. [14] evaluated the influence of spacing between traffic calming measures on the capacity of cross-town road and found that there are two critical spacings (50 m and 400 m) between the traffic calming measures that affect road capacity. The effect of traffic calming measures on road capacity is similar when spacing is in 100-400 m range. Spacing of less than 50 m causes cumulative effect since drivers cannot develop their desirable speeds. Therefore, the capacity is highly reduced.

2.2 Efficiency of gateways

Appropriately designed high-to-low speed transition zones are therefore of crucial importance for traffic safety [20, 21]. Galante et al. [22] and Ariën et al. [20] investigated the driving speed on rural highways crossing small urban centres in situations with and without gateways and traffic calming measures. Operating speeds in the transition zones without a gateway were measured in the field. Operating speeds in the transition zones with gateways were estimated from driving simulator runs. The gateways produced speed reduction between 11 km/h and 17 km/h [21].

Ariën et al. [23] investigated the effect of gateways on rural–urban transitions from several viewpoints. Firstly, the effect on the driving behaviour, and secondly, effective distance of the measures. The research study has shown that the displacement of the central island with non-parallel axis has positive effect on the mean speed reduction (1.2-4.0 km/h) at a distance within 200 m before approaching the urban area and 100 m after it. Driving behaviour analysis showed that drivers slightly accelerated between 100 m and 200 m after the gateway to a mean speed which was higher than the speed when there was no gateway construction present and, then, continued driving at the same speed as when there was no gate present.

After the performed analysis of the effect of 12 gateways located on different roads, on traffic speed, Lantieri et al. [21] declared that gradient and safety island types are very important. A gateway with the gradient 4° and raised safety island decreased the traffic speed (v85) by 7.45 km/h. A gateway with a gradient of 3° and marked safety island showed no effect on the traffic speed.

While solving the speeding problems, both engineering and educational measures are necessary [24]. The engineering measures, like any other traffic safety measures, will be ineffective if the road users fail to understand their need and try to avoid them. Considering this, a survey on public opinion was conducted to find out the road users' opinions about the need for traffic calming measures and speed control measures.

3. EXPERIMENTAL RESEARCH ON THE EFFECT OF SPEED HUMPS AND GATEWAYS

In the following sub-sections the methodology and results of experimental studies are presented.

3.1 Methodology

Experimental research was aimed at determining the effect of speed humps and gateways on vehicle speed. The research was implemented in two stages. The effect of speed humps was determined in the first stage. The effect of gateways was in the focus in the second stage. Both measures have been used in the urban area where the speed limit was 50 km/h. The effect of vertical traffic calming measures on vehicle speed was determined by two measurements, mean speed and instantaneous speed. The measurements were taken in summer (July 2015), on a workday, in the light period of the day.

The aim of the research on the mean speed in the territory with vertical traffic calming measures was to determine the effect of the group of measures on vehicle speed. The mean speed was measured on two-lane road, on a 1.6 km long section. Six vertical traffic calming measures were installed on the selected road section, five speed humps of trapeze shape and one raised pedestrian crossing. The displacement and spacing of traffic calming measures are given in *Figure 1*. The mean speed was measured by the SpeedCAM cameras, which were installed in two standing vehicles. The cameras detected data of vehicles entering and leaving the selected road section, i.e., their number plates and time (hour, min., s.) (*Figure 1*). Based on the time when the vehicle entered and left the section, the mean speed of each vehicle was calculated.

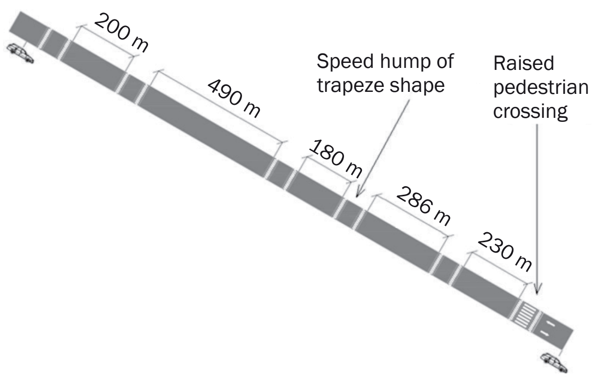

Figure 1 – Allocation of speed humps on the tested road section and picture of cameras used

To determine the distance in which the speed humps of trapeze shape will affect speed reduction or compliance with the speed limit, the research on instantaneous speed was carried out. Vehicle speed was measured at six points (*Figure 2*). Speed was measured between the speed humps of trapeze shape (spacing between them was 286 m) at five points and at the sixth measuring point it was measured on a speed hump. Research on instantaneous speed was carried out by the speed cameras Berkut R.

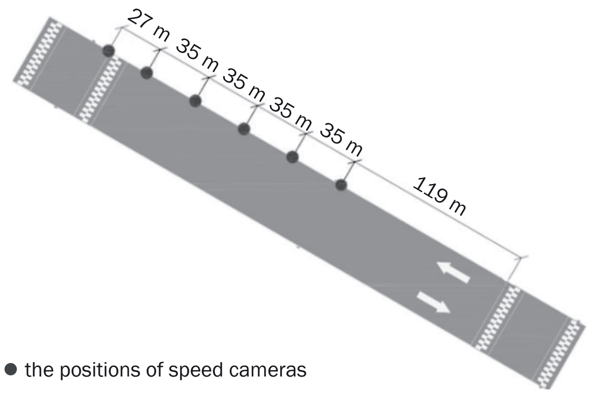

Figure 2 – The scheme of research on instantaneous speed

In order to determine the effect of gateways on vehicle speed and to assess the distance of impact, the research on instantaneous speed was carried out close to four gateways located on the roads crossing the urban area (*Figure 3*):

1) 7 m (3.5 m×2) wide roadway for the entering traffic flow is curved by 60 m long gateway with 3.3 m wide raised safety island (*Figure 3a*). The speed limit in the selected section is 50 km/h. It is a national road of national significance;
2) 7.5 m (3.75 m×2) wide roadway for the entering/leaving traffic flow is curved by 60 m long gateway with 2.5 m wide raised safety island (*Figure 3b*). The speed limit on the selected section is 50 km/h. It is a national road of national significance;
3) 7 m (3.50 m×2) wide roadway for the entering/leaving traffic flow is curved by 60 m long gateway with 5.0 m wide raised safety island (*Figure 3c*). The speed limit on the selected section is 50 km/h. It is a main road of national significance;
4) 7 m (3.50 m×2) wide roadway for the entering/leaving traffic flow is curved by 60 m long gateway with 6.60 m wide raised safety island (*Figure 3d*). The speed limit on the selected section is 50 km/h.

The instantaneous speed of vehicles was measured at three points: (1) 50 m before the gateway; (2) beside the gateway; (3) 50 m behind the gateway.

3.2 Results

Research on the mean speed in the urban area has indicated that 74.12% of drivers exceeded the speed limit, 77.78% of them exceeded the speed limit by less than 10 km/h, and 22.22% of drivers exceeded the speed by more than 10 km/h.

The research on the instantaneous speed between two speed humps of trapeze shape has indicated that (*Figure 4*):

– the speed limit (50 km/h) has not been already ensured at a distance of 119 m behind the first hump;
– the speed limit has been exceeded by more than 10 km/h at a distance of 189 m behind the first hump;
– the speed reduced at a distance of 62 m before the second hump, though it still exceeds the speed limit.

a) *b)* *c)* *d)*

Figure 3 – The selected gateway types: a) one-way; b), c), d) two-way

Table 1 – Detailed results of the research on gateway effect

Loca-tion	Direction	Length of gateway [m]	Width of raised safety island [m]		Speed [km/h]			Speed reduction [km/h]
					50 m before the gateway	Beside the gateway	50 m behind the gateway	
National roads								
1)	entering	60	3.3 (one-way), (Figure 3a)	Mean	76	49	57	27
				Min-Max	50-95	30-46	41-82	
2)	leaving	60	2.5 (two-way) (Figure 3b)	Mean	60.60	63.07	59.68	8
				Min-Max	45-104	42-98.5	41-96	
	leaving			Mean	67.56	67.71	71.76	-
				Min-Max	46-89	47.5-89.5	50-97	
Main roads								
3)	entering	60	5 (two-way) (Figure 3c)	Mean	71.22	61.22	58.27	13
				Min-Max	44-99	40-100	43-94	
	leaving			Mean	59.28	60.31	69.38	-
				Min-Max	46-76	46-81	53-93	
4)	entering	60	3.3 (two-way) (Figure 3d)	Mean	68.54	53.44	49.61	18
				Min-Max	41-103	31.5-80.5	28-77	
	leaving			Mean	55.84	59.74	67.42	-
				Min-Max	38-86	42.5-90	50-95	

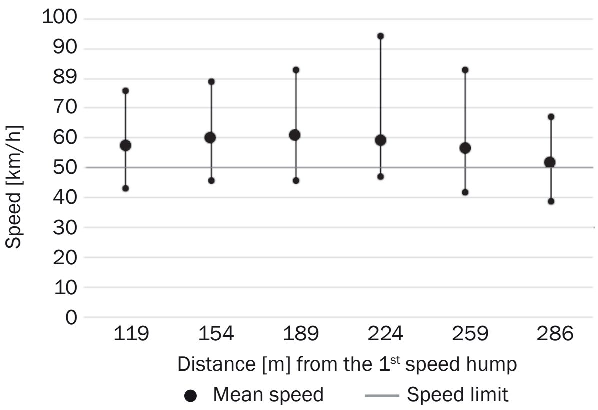

Figure 4 – Drivers' speed between speed humps

Based on the results of the research on the effect of gateways it can be stated that their effect depends on the width and length of the island separating the roadways, and on a visual "enframing" of roadway by using certain measures.

Analysis of research results showed that the largest effect of gateways was determined beside the gateway having the widest raised safety island of 3.3 m. This is the only gateway beside which the permissible mean of instantaneous speed was detected. Another important aspect distinguishing this gateway from the other are additional measures (reflective road markers, traffic signs "Turning direction to the left") on the shoulder visually narrowing the roadway and giving no possibility for the drivers to at least partly circuit the gateway. This tendency was observed, namely, during the research. Most vehicles, when entering the gateway, at the curve, do not change their driving trajectory and drive on the shoulder by one side of the vehicle. Thus, a driving trajectory is not curved and the possibilities are created to avoid deceleration on the section of the gateway. In order to reduce the number of this type of violations, it is recommended to install flexible reflective road markers at the edges of the roadway.

4. A SURVEY OF PUBLIC OPINION

While solving the speeding issues it is important to apply all kinds of traffic calming measures - engineering, control and educational. These measures will not be effective if a traffic participant unable to perceive the necessity of these measures tries to avoid them. Therefore, a public opinion survey on road users approach to speed control and traffic calming measures necessity was made.

4.1 Methodology and methods

A survey of public opinion was based on quantitative research consisting of two types of inquiry; a standardized survey interview (according to a previously prepared questionnaire) and questioning. Questioning was carried out on the internet and "face-to-face" surveys.

During the first standardized survey interview, the aim was to find out the opinion of inhabitants about the automated speed control measures. There were 1,007 respondents interviewed at 65 local points distributed in a way to represent all the regions of the country.

A multi-stage stratified probability sampling method has been used in the survey. This sampling method ensures data representativeness, i.e., each household of the country has equal possibilities to be interviewed and the representative sampling according to the targeting criteria meets the general sampling. The survey results represent opinions and estimations of inhabitants from 18 to 75 years of age.

The second survey was aimed at finding out the public opinion about the need for speed control measures and traffic calming measures and also about the factors influencing speeding. A survey on the public opinion was conducted from 1 to 28 April 2015, including 583 respondents from 16 to 65 years of age.

4.2 Results

In the following sub-sections the results of public opinion are presented and discussed.

4.2.1 Results of standardized survey interview

From the total number of 1,007 respondents, 61.09% were male and 38.91% – female. There were 56.4% of respondents who represented the drivers. There were 55.6% of respondents who declared that speeding is the most frequent violation on the Lithuanian roads. The distribution of other violations, in the opinion of respondents, is given in *Figure 5*.

A survey has shown that all road users as well as the drivers support installation of automated vehicle speed control systems on the roads (*Figure 6*). A majority of respondents think that speed cameras are needed (much needed / more needed) on the roads of Lithuania. 85% support the fixed speed cameras, 79% – the mobile speed cameras, and 78% – the sectorial speed enforcement system.

4.2.2 Survey results

From 583 respondents included in the questioning, 497 were entitled to drive but 381 respondents participated in traffic as drivers. 54% of males and 46% of females participated in the survey. The results of the survey about the most frequent violations of road traffic rules are similar to those of standardized survey interview. 51% of respondents were of the opinion that speeding is the most frequent violation on the Lithuanian roads.

There are 36% of all driving respondents who exceed the speed limit continuously or frequently. There were 37% of respondents who exceeded the speed limit by less than 10 km/h; 54% - by 11-20 km/h and 9% - by more than 20 km/h. There were 55% of all driving respondents who exceed the speed limit only

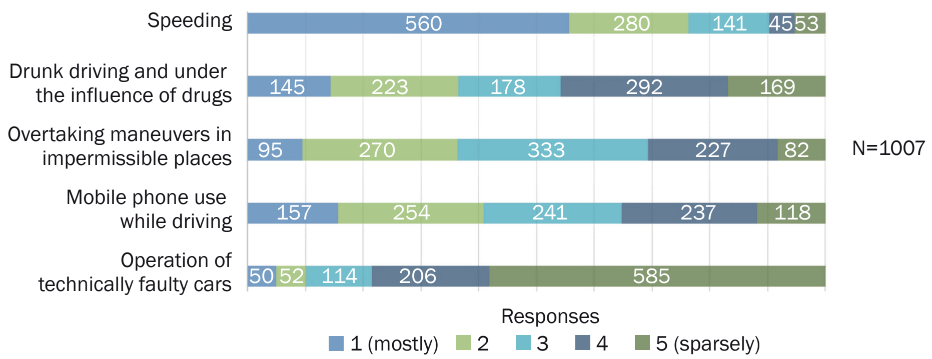

Figure 5 – Distribution of respondents' opinion on traffic rules violations

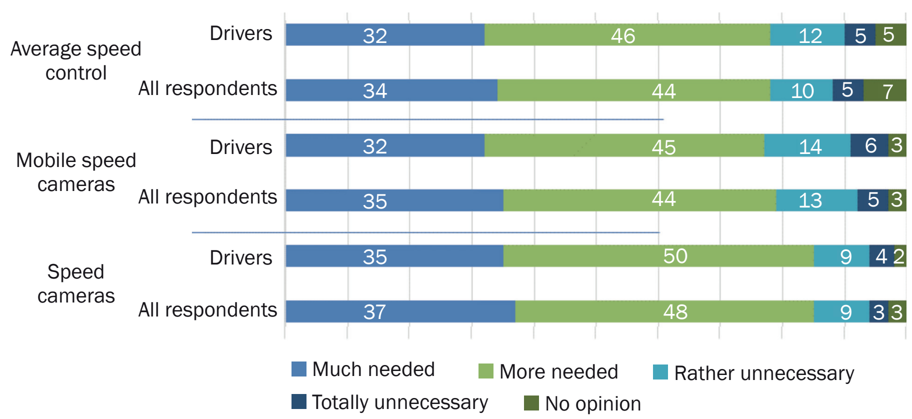

Figure 6 – Distribution of responses of opinion on traffic speed control type needs, %

seldom and most of them by less than 10 km/h (62%). Nine percent of respondents stated that they never exceed the speed limit. The main reasons of speeding, specified by the speeding drivers are given in *Figure 7*.

The respondents also expressed their opinion about the need for traffic calming measures on the roads. A major part (43%) of respondents think that traffic calming measures are necessary since they physically enforce drivers to reduce the speed on dangerous locations from the point of view of traffic safety (*Figure 8*).

Among 583 respondents, 79% have the opinion that automated vehicle speed control systems are necessary for the Lithuanian roads. Road users' opinions about the need for automated vehicle speed control system by the type of road users is given in *Figure 9*. Special attention should be drawn to the opinion of cyclists, of which only 39% think that automated vehicle speed control system is necessary. However, because of speeding, the most vulnerable road users, including cyclists, are subjected to the most painful accident consequences.

Lithuania has only been starting to implement the sectorial speed enforcement system, though the system is supported by 80% of respondents. The respondents have also indicated its advantages; 34% of respondents believe that sectorial speed enforcement system would help the Lithuanian drivers to break

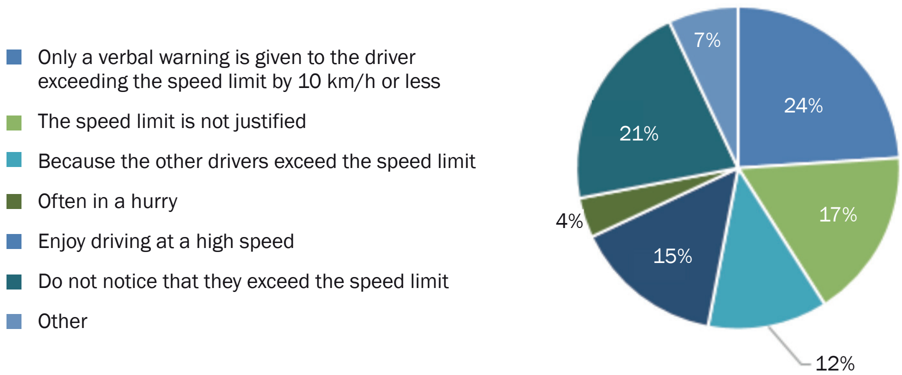

Figure 7 – The main reasons causing the drivers' speeding

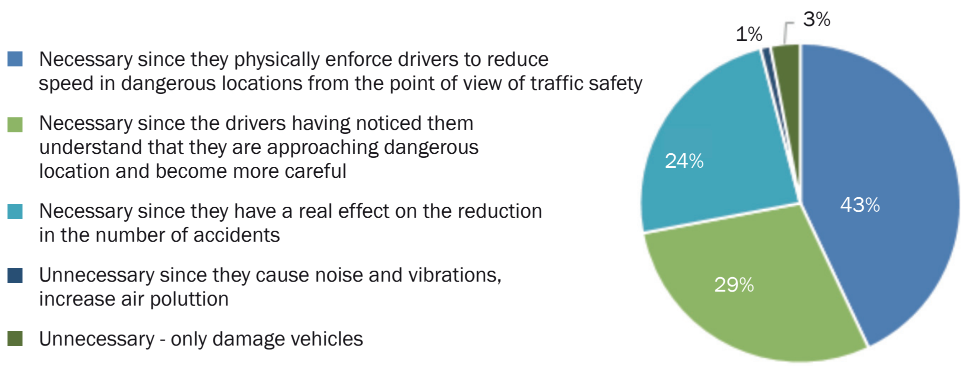

Figure 8 – Respondents' opinions on need of speed humps

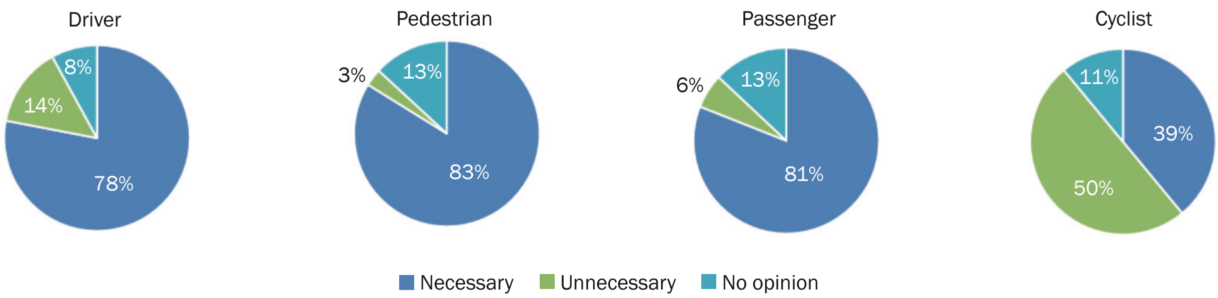

Figure 9 – Road users' opinions on automated vehicle speed control system

their habit of speeding (it would act as educational measure). There are 29% of respondents who think that the system would assist in improving the road safety situation (the number of road accidents would be reduced and their severity would be mitigated). Twenty-two percent of respondents believe that the system would help in looking for the stolen, uninsured vehicles and those that have failed the technical inspection. Only 2% of respondents think that sectorial speed enforcement system has no advantages.

In order to find out the impact of fixed speed cameras on the living environment, the questioning involved 130 people living in close proximity to fixed speed cameras. Forty-two percent of respondents think that fixed speed cameras ensure a safer environment, and 39% feel safer when crossing the road or walking on the shoulder.

5. DISCUSSION

The effect of vertical traffic calming measures on vehicle speed in urban areas was determined by two measurements; mean speed and instantaneous speed. To determine the effect of the group of six vertical speed calming measures (speed humps of trapeze shape and a raised pedestrian crossing), installed on a 1.6 km long section, on speed management the research on the mean speed was carried out. To determine the distance of impact of speed humps of trapeze shape on the speed, the research on the instantaneous speed was carried out between two speed humps installed at a distance of 300 m from each other. Both studies were carried out on the same road and at the same time. During the research, the secrecy of speed cameras was ensured to avoid any possible impact on the driving behaviour.

Research on the mean vehicle speed determined that on a 1.6 km long road section six vertical traffic calming measures do not ensure compliance with the speed limit in the urban area (50 km/h). Fifty-eight percent of drivers exceeded the speed limit by less than 10 km/h, and 17% – by more than 10 km/h. A high percentage of drivers exceeding the speed limit by less than 10 km/h can be affected by the Code of Administrative Offences of Lithuania, which provides that the drivers exceeding the speed limit by less than 10 km/h are given only a verbal warning but not a financial penalty. Speeding may be also affected by road environment since, due to the sidewalks on both roadsides, the roadway is free of pedestrians.

Research on the instantaneous vehicle speed has found that 300 m distance between two speed humps of trapeze shape is too large to ensure compliance with the speed limit. Research results showed that in the urban area the speed limit is already exceeded 120 m behind the speed hump and at a 200 m distance behind the speed hump, the speed limit is exceeded by 10 km/h or more.

Both studies in the urban area have indicated that distances between speed calming measures, recommended by the currently valid Recommendations on the Design and Use of Engineering Safety Measures (R ISEP 10), are too long. The research on the instantaneous vehicle speed has shown that under the speed limit of 50 km/h and the distance, where vertical traffic calming measures is between 200 and 400 m, the compliance with the speed limit has not been ensured on the entire distance. Where distance between two vertical traffic calming measures is 200–400 m, vehicles have time to accelerate and to reach a speed even 10 km/h higher than the speed limit. Taking into consideration the results of their previous studies [25, 26] and the review of foreign legal acts and studies, the authors suggest new recommendations related to the distance between speed calming measures. The currently valid distances in Lithuania (R ISEP 10) and distances recommended by the authors are given in *Table 2*.

Table 2 – Currently valid and recommended after research distances between speed calming measures

Speed limit [km/h]	Distance between speed calming measures [m]		
	The currently valid recommendations R ISEP 10		Recommendations by the authors
	Good	Satisfactory	
50	200–400	401–600	150–200
40	–	–	100
30	100–200	201–400	75

Research on gateways has indicated that vehicles really reduce speed beside gateways, but often not enough to comply with the speed limit (50 km/h). This is directly dependent on physical (width of raised safety island) and visual curve. To strengthen the visual curve of roadway, it is recommended to install flexible reflective road markers, curbs and/or plantings on both sides of roadway. Additional visual curving measures, “enframing” the gateways, would help to reduce the number of cases where vehicles cross the gateways at high speeds as they drive on the shoulder and in this way decrease the angle of curve.

Another important aspect is the distance of gateway impact. The research results showed that 50 m behind gateways the vehicles start accelerating again, though the speed limit remains the same as beside the gateways. The assessment of the driving speed intervals has indicated that the mean maximum speed in the urban area is 87 km/h. This shows that if the road through the urban area is longer than 200 m, the gateway installed at the entrance of the urban area does not ensure the speed limit in the entire urban area. If the road section running through the urban area can possibly be used by the vulnerable road users, in addition to gateway, other safety improvement measures are recommended, such as speed humps or speed bumps, raised intersections, automated vehicle speed control or radar speed signs.

A survey of public opinion has once again proved the extent of the violation of traffic rules, i.e. speeding. More than half (55.6% in the first survey and 51% in the second survey) of respondents reported this violation as the most frequent one.

Having analysed the main reasons of speeding, it is concluded that the drivers do not perceive the risk of excessive speed, especially as they specify such reasons as haste, impunity (in case of exceeding the speed limit by less than 10 km/h), driving with the flow.

The survey results show a rather positive attitude of respondents to speed management measures, both traffic calming measures and traffic control measures (the automated in this case). The installation of traffic calming measures is approved by 95% of respondents. Even 83% of respondents-pedestrians and 78% of respondents-drivers support the automated speed control system of vehicles.

A survey revealed the attitude of road users to the problem of speeding in two different aspects. Though many drivers recognize their mistake of violating this requirement of traffic rules, they approve the measures to curb this violation. This shows that in implementing the engineering speed calming measures the parallel education of road users (drivers) have to be carried out with particular emphasis on the effect of speed on accident risk and accident severity.

6. CONCLUSIONS

The mean speed data from the selected roads with trapeze shape speed humps declined no compliance with speed limit. Within the urban area, 74.12% of drivers speed up from 17 km/h to 44 km/h above the speed limit.

Within the distance of 120 m behind the speed hump, the permitted speed of 50 km/h is violated and at the distance of 190 m the speeding is above 10 km/h.

The collected traffic speed data lead to the conclusion that the gateways are efficient, but still, the permitted speed of 50 km/h is not ensured in all cases. As the main parameter of gateway efficiency the width and length of the island should be indicated, as it very much affects the visual “enframing” of road traffic lanes.

The short lasting effect of gateways on speeding should be indicated, as it lasts for about 50 m after the measure. Therefore, to ensure speed limit throughout the entire limited speed road sector or urban area, the groups of traffic calming measures have to be applied. Gateways should be used as self-explaining road concept elements at the entrance of settlements or urban areas.

The groups of traffic calming measures in the urban areas shall be formed according to the road function, and spacing between the measures shall be differentiated depending on the border of the speed limit. On roads of transit function, where heavyweight vehicles prevail, no vertical speed calming measures are recommended.

Speeding as the most frequent violation of traffic rules was indicated by 54% of road users. Five percent of the interviewed drivers exceed the speed limit continuously and even 31% exceed the speed limit frequently. As many as 62% of continuously speeding drivers exceed the speed limit by 11-20 km/h, 19% - by 21-30 km/h and only 15% - by less than 10 km/h.

The survey results have indicated a rather positive attitude of respondents to the speed management measures. Ninety-six percent of respondents approve of the installation of vertical speed calming measures. Eighty-one percent of respondents support the automated vehicle speed control systems. A survey on public opinion has shown that the public understands the effect of sectorial speed enforcement systems on road safety, since 79% of respondents supporting the automated vehicle speed control systems approve of the measurements of the mean speed.

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AUDRIUS VAITKUS, Prof. Dr.[1]
E-mail: audrius.vaitkus@vgtu.lt
DONATAS ČYGAS, Prof. Dr.[2]
E-mail: donatas.cygas@vgtu.lt
VILMA JASIŪNIENĖ, Dr.[1]
E-mail: vilma.jasiuniene@vgtu.lt
LAURA JATEIKIENĖ, Dr.[1]
E-mail: laura.jateikiene@vgtu.lt
TADAS ANDRIEJAUSKAS, Mgr. [1]
E-mail: tadas.andriejauskas@vgtu.lt
DOVYDAS SKRODENIS, Mgr.[1]
E-mail: dovydas.skrodenis@vgtu.lt
KORNELIJA RATKEVIČIŪTĖ, Dr.[1]
E-mail: kornelija.ratkeviciute@vgtu.lt
[1] Kelių tyrimo institutas, Vilniaus Gedimino technikos universitetas, Linkmenų g. 28, Vilnius LT-08217, Lietuva
[2] Kelių katedra, Vilniaus Gedimino technikos universitetas Saulėtekio al. 11, Vilnius LT- 10223, Lietuva

GREIČIO MAŽINIMO PRIEMONĖS: ĮTAKOS VAŽIAVIMO GREIČIUI TYRIMAS

SANTRAUKA

Eismo įvykiai yra viena iš pagrindinių mirties priežasčių pasaulyje, ypatingai jaunų žmonių tarpe. Važiavimo greičio viršijimas yra vienas iš pagrindinių eismo saugumo rizikos veiksnių, didinantis eismo įvykių atsiradimo tikimybę bei lemiantis skaudžias eismo įvykių pasekmes. Šiame straipsnyje aprašomi eksperimentiniai tyrimai, nagrinėjantys greičio mažinimo priemonių įtaką vairuotojų važiavimo greičiui. Tyrimas atliktas dviem aspektais: transporto priemonių vidutinio greičio bei transporto priemonių momentinio greičio. Šis straipsnis neapsiriboja vien tik minėtais tyrimais. Taikant dvi apklausų rūšis - standartizuotą interviu ir anketavimą - atlikta visuomenės nuomonės apklausa apie eismo dalyvių požiūrį į greičio mažinimo bei greičio kontrolės priemones. Straipsnio pabaigoje autoriai pateikia savo įžvalgas ir rekomendacijas dėl greičio mažinimo kalnelių bei „miesto vartų“ taikymo bei optimalaus veikimo atstumo.

REIKŠMINIAI ŽODŽIAI

greičio mažinimo priemonės; greičio mažinimo kalneliai; “miesto vartai”; eismo saugumas; visuomenės nuomonė;

REFERENCES

[1] Nilsson G. The effects of speed limits on traffic accidents in Sweden. Proceedings of the International Symposium on the Effects of Speed Limits on Traffic Accidents and Transport Energy Use; 1981 Oct 6-8; Dublin, Ireland. Paris: OECD; 1981. p. 1-8.

[2] Wegman F, Aarts L, editors. Advancing Sustainable Safety; National Road Safety Outlook for 2005−2020. Leidschendam: SWOV; 2006.

[3] Elvik R. The Power Model of the Relationship between Speed and Road Safety. Update and New Analyses. Report 1034. Institute of Transport Economics, Oslo; 2009.

[4] Joint Transport Research Centre. Speed Management. Summary Document; 2006. p. 20.

[5] WHO. Global Status Report on Road Safety; 2015. p. 340.

[6] European Union. Statistics – accidents data. Available from: http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm [Accessed 13th May 2016]

[7] National Plan of Action for Road Traffic Safety 2014-2017. Norway; p. 30.

[8] Waltz FH, Hoefliger M, Fehlmann W. Speed Limit Reduction from 60 to 50 km/h and Pedestrian Injuries. Proceedings of the Twenty-Seventh Step Car Crash Conference. International Research Council on Biokinetics of Impacts (IRCOBI). Warrendale, PA: Society of Automotive Engineers; p. 311-318.

[9] Van Houten R, Van Huten F. The Effects of a Specific Prompting Sign on Speed Reduction. Accident Analysis & Prevention. 1987;19(2):115-117. doi:10.1016/0001-4575(87)90030-3

[10] Pennsylvania’s Traffic Calming Handbook. Pennsylvania Departament of Transportation. Publication No. 383; 2012. p. 109.

[11] Traffic Calming Guidelines. The South Carolina Department of Transportation (SCDOT); 2009. p. 35.

[12] Recommendations on the Design and Use of Engineering Safety Measures RISEP 10. 2010. Lithuanian Road Administration under the Ministry of Transport and Communications; p. 123.

[13] Johansson C, Rosander P, Leden L. Distance between speed humps and pedestrian crossings: Does it matter? Accident Analysis & Prevention. 2011;43(5):1846-1851. http://dx.doi.org/10.1016/j.aap.2011.04.020

[14] Garcia A, Torres AJ, Romero MA, Moreno AT. Traffic Microsimulation Study to Evaluate the Effect of Type and Spacing of Traffic Calming Devices on Capacity. Procedia Social and Behavioral Sciences. 1987;16:270-281.

[15] Moreno AT, Garcia A. Use of Speed Profile as Surrogate Measure: Effect of Traffic Calming Devices on Crosstown Road Safety Performance. Accident Analysis and Prevention. 2013;61:23-32. doi:10.1016/j.aap.2012.10.013

[16] Yannis G, Kondyli A, Georgopoulou X. Investigation of the Impact of Low Cost Traffic Engineering Measures on Road Safety in Urban Areas. International Journal of Injury Control and Safety Promotion. 2014;21(2):181-189. doi:10.1080/17457300.2013.796387

[17] Antić B, Pešić D, Vujanić M, Lipovac K. The Influence of Speed Bumps Heights to the Decrease of the Vehicle Speed – Belgrade Experience. Safety Science. 2013;57:303-312. doi:10.1016/j.ssci.2013.03.008

[18] Chen L, Chen C, Ewing R, McKnight EM, Srinivasan R, Roe M. Safety Countermeasures and Crash Reduction in New York City-Experience and Lessons Learned. Accident Analysis and Prevention. 2013;50:312-322. doi:10.1016/j.aap.2012.05.009

[19] Rahman F, Kojima A, Kubota H. Investigation on North American Traffic Calming Devices Selection Practices. IATSS Research. 2009;33(2):105-119. doi:10.1016/S0386-1112(14)60249-1

[20] Ariën C, Jongen EMM, Brijs K, Brijs T, Daniels S, Wets G. A Simulator Study on the Impact of Traffic Calming Measures in Urban Areas on Driving Behavior and Workload. Accident Analysis and Prevention. 2013;61:43-53. doi:10.1016/j.aap.2012.12.044.

[21] Lantieri C, Lamperti R, Simone A, Costa M, Vignali V, Sangiorgi C, Dondi G. Gateway Design Assessment in the Transition from High to Low Speed Areas. Transportation Research Part F: Traffic Psychology and Behaviour. 2015;34:41-53. doi:10.1016/j.trf.2015.07.017

[22] Galante F, Mauriello F, Montella A, Pernetti M, Aria M, D’Ambrosio A. Traffic Calming around Rural Highways Crossing Small Urban Communities: Driving Simulator Experiment. Accident Analysis and Prevention. 2010;42(6):1585-1594. doi:10.1016/j.aap.2010.03.017.

[23] Ariën C, Brijs K, Brijs T, Ceulemans W, Vanroelen G, Jongen EMM, Daniels S, Wets G. Does the Effect of Traffic Calming Measures Endure over Time? – A Simulator Study on the Influence of Gates. Transportation Research Part F: Traffic Psychology and Behaviour. 2014;22:63-75. doi:10.1016/j.trf.2013.10.010

[24] Čygaitė L, Jasiūnienė V, Žolynas A. The Analysis of Implementation Possibilities of Sectorial Automated Vehicle Speed Control Systems on the Roads of Lithuania. The Baltic Journal of Road and Bridge Engineering. 2014;9(2):131-138. doi:10.3846/bjrbe.2014.17

[25] Čygaitė L, Lingytė I, Andriejauskas T, Vaitkus A. Analysis and Evaluation of Effectiveness of Speed Calming Measures in Lithuanian State Roads. XXVIII International Baltic Road Conference, 26-28 August 2013, Vilnius, Lietuva. Vilnius: Baltic Road Association; 2013. p. 1-8.

[26] Čygaitė L, Lingytė I, Strumskys M. Analysis of Vertical Traffic Calming Measures in Impacts on Road Safety and Environment in Lithuania State Roads. Proceedings of the 9th International Conference „Environmental Engineering“, 22-23 May 2014, Vilnius, Lithuania: selected papers. Vilnius: Technika; 2014.