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Section: Roads and Railways

Analysis of Vertical Traffic Calming Measures in Impacts on Road Safety and Environment in Lithuania State Roads

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Abstract

Several years after implementation of vertical traffic calming measures on roads, crossing cities and settlements, for the first time in Lithuania the research was carried out to determine their effect on the change in the number of accidents, their severity and noise within the operation zone of speed humps, raised pedestrian crossings and speed bumps. The paper present research methodology and analysis of results of vertical traffic calming influence to the road safety and environment in Lithuania roads. It presents that engineering measures have a positive impact on the improvement of the road index to safety. The study of vertical traffic calming measures impact to environment showed that it does not increase equivalent noise level of vehicle in its installation places.

Keywords: Equivalent noise level; injury traffic accident; vertical traffic calming measures.

1. Introduction

In order to maintain or reduce a permissible speed limit, to improve pedestrian and bicycle traffic conditions and a social climate of local inhabitants in the cities, towns and settlements of Lithuania that are crossed by the roads of national significance, since 2007 more than 250 of vertical traffic calming measures have been installed on the roads of the country. After a certain time period from the installation of engineering safety measures it is important to assess their impact on road safety and environment. It is necessary to determine if road safety measures installed in particular locations give a positive impact.

A level of road safety in the country is decribed by the number of fatal and injury acidents, the number of people killed or injured. In 2012, the damage to Lithuanian economy due to 1 person killed on road amounted to LTL 1,9 million, due to 1 person injured – LTL 172,5 thousand [1]. Statistics of road accidents on Lithuanian roads shows that the largest amount of accidents is representd by collisions with pedestrians (in 2012 – 35%) and collisions (in 2012 – 30%).

Noise has the largest negative impact on hearing. Noise also negatively affects human activities and even the whole human organism [2]. Vehicle-generated noise depends on driving speed. Road pavement type affect tyres/road noise that comes out of vehicles when tyres interact with the surface [3], [4]. Noise dispersion depends on local relief and obstacles situated within the road of sound propagation [5].

In foreign countries the effects of vertical traffic calming measures on the change in the number of road accidents, severity and noise have been studied for already many years. 12 streets in Salt Lake City, Utah were assessed by Cottrell, Kim, Martin and Perrin in order to evaluate the impact of speed humps (width 4,3 m) and speed table (width 6,7 m) to road safety [6]. According to Kokowski and Makarewicz [7] the change in noise level due to a road bump (ΔL) was calculated using measurements of sound exposure level. The reduction of road traffic noise by a speed bump has been determined to be $\Delta L \approx 0,4$ dB. The changes in the level of noise emission from a car when passing over two different dimensions speed bumps have been experimentally and numerically investigated by Behzad, Hodaei and Alimohammadi [8].

However, research of the effect of engineering traffic calming measures on road safety and environment is still topical. The effects of vertical traffic calming measures have been evaluated in a number of studies. Based on that studies Elvik, Høye, Vaa and Sørensen presents that implementing speed humps on roads reduces the number of injury accidents about 41% [9]. In New York City where the speed bumps and other 12 safety countermeasures installed reductions in various

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types of accidents were evaluated by Chen, Ewing, McKnight, Srinivasan and Roe [10]. Daniel, Nicholson and Koorey investigated the impacts of the 75 mm speed hump and 100 mm speed hump on light vehicle speed and noise emission [11].

Several years after implementation of vertical traffic calming measures on roads, crossing cities and settlements, for the first time in Lithuania the research was carried out to determine their effect on the change in the number of accidents, their severity and noise within the operation zone of speed humps, raised pedestrian crossings and speed bumps. Noise level measurements at vertical traffic calming measures were conducted by Environmental Protection Institute of Environmental Engineering Faculty of Vilnius Gediminas Technical University (VGTU). The aim of research was to determine if after implementation of vertical traffic calming measures the accident rate within the action zone of measures has reduced and if due to implementation of measures the traffic-generated noise has not increased.

2. Selection of vertical traffic calming measures

On sections of the roads of national significance, for the research purposes 53 places were selected by the type of speed humps and 10 additional sections by the settlement. The list of speed humps selected for the research (53 pieces) by their type consists on:

- speed humps of trapeze shape (8 pieces);
- raised pedestrian crossings (20 pieces);
- speed bumps (10 pieces);
- speed humps at the junctions (the humps of various types installed within the junction zone, 15 pieces). Junction zone is a 200 m long distance on the major road and a 150 m long distance on the minor road from the crossing point of the axes of roads [12].

The speed humps, situated more than 600 m distance from each other (sections do not overlap) were analysed as individual objects, because the speed is not constant and the sufficient efficiency of implemented measures cannot be achieved in such distance. And vice versa, when the distance between speed humps is less than 600 m (sections overlap), the implemented measures were analysed as single objects. It is admitted that in this case efficiency of implemented measures is sufficient [13]:

- when a recurring obstacle is visible for the drivers they do not try to increase the speed;
- the driver „wakes up", the factor of surprise works, therefore recurring speed hump is expected.

3. Effect of vertical traffic calming measures on the change in the number of fatal and injury accidents

For the analysis of fatal and injury accidents the data was collected of fatal and injury accidents having occurred 4 years before the installation of vertical traffic calming measure and in a time period after its installation until 31 December 2011 within the zone of measure operation. Since the time periods before and after installation of safety measure differ, in order to properly assess the effect of vertical traffic calming measures on traffic safety the fatal and injury accidents were analysed in time periods of the same length before and after measure installation.

On the sections, where the speed humps of trapeze shape were placed, the number of fatal and injury accidents decreased by 36%, the number of people killed – by 100%, the number of people injured – by about 45%. The obtained results show that the largest influence on the decrease of collisions was made by implementation of trapeze shape speed humps (Table 1).

On the sections where the raised pedestrian crossings were installed the number of fatal and injury accidents decreased by about 65%, the number of people killed – by about 83%, and the number of people injured – by about 68%. The obtained results show that the largest influence on the decrease of fatal and injury accidents when pedestrians or bicycles come into collision was made by implementation of raised pedestrian crossings (Table 2).

On the road sections where the speed bumps were installed the number of fatal and injury accidents decreased by about 73%, the number of people injured – by about 77%. The obtained results show that the largest influence on the decrease of fatal and injury accidents when pedestrians or bicycles have an accident or come into collision was made by implementation of speed bumps (Table 3).

When studying accidents at the junctions it was determined that they are influenced not only by speed humps but also by another complex traffic calming measures, i. e. separating safety islands, information shields, etc. Investigation showed that almost at all junctions the speed humps are installed only on the minor roads. Installation of speed humps on the minor roads results decreased number of entrances to the main roads when the traffic situation in main road is not sufficiently assessed. The driver, when reducing speed or coming to a full stop before the major road, has a possibility to assess the speed of upcoming vehicles on the major road and distance to them. At the junctions where vertical traffic calming measures were installed the number of fatal and injury accidents decreased by about 44%, the number of people killed – by 75%, and the number of people injured – by about 29%. Distribution of fatal and injury accidents before and after the speed humps were implemented at the junctions is given in Table 4.

Table 1. Distribution of fatal and injury accidents on sections where trapeze shape speed humps were implemented

Accident type	Accidents		Killed		Injured	
	before installation	after installation	before installation	after installation	before installation	after installation
Collision	83%	17%	100%	0%	78%	22%
Collision with pedestrian	60%	40%	0%	0%	60%	40%
Collision with bicycle	0%	100%	0%	0%	0%	100%
Collision with obstacle	75%	25%	0%	0%	90%	10%
Overturning	0%	0%	0%	0%	0%	0%
Other accidents	0%	100%	0%	0%	0%	100%
Total	61%	39%	100%	0%	69%	31%

Table 2. Distribution of fatal and injury accidents on the sections where raised pedestrian crossings were implemented

Accident type	Accidents		Killed		Injured	
	before installation	after installation	before installation	after installation	before installation	after installation
Collision	62%	38%	100%	0%	71%	29%
Collision with pedestrian	82%	18%	100%	0%	81%	19%
Collision with bicycle	85%	15%	50%	0%	91%	9%
Collision with obstacle	63%	37%	0%	0%	67%	33%
Overturning	100%	0%	0%	0%	100%	0%
Other accidents	0%	100%	0%	0%	0%	100%
Total	75%	25%	86%	14%	76%	24%

Table 3. Distribution of fatal and injury accidents on the sections where speed bumps were implemented

Accident type	Accidents		Killed		Injured	
	before installation	after installation	before installation	after installation	before installation	after installation
Collision	75%	25%	0%	0%	80%	20%
Collision with pedestrian	85%	15%	0%	0%	85%	15%
Collision with bicycle	75%	25%	0%	0%	75%	25%
Collision with obstacle	100%	0%	0%	0%	100%	0%
Overturning	50%	50%	0%	0%	50%	50%
Other accidents	0%	0%	0%	0%	0%	0%
Total	79%	21%	0%	0%	82%	18%

Table 4. Distribution of fatal and injury accidents at the junctions where speed humps were implemented

Accident type	Accidents		Killed		Injured	
	before installation	after installation	before installation	after installation	before installation	after installation
Collision	59%	41%	50%	50%	56%	44%
Collision with pedestrian	50%	50%	100%	0%	0%	100%
Collision with bicycle	67%	33%	100%	0%	0%	100%
Collision with obstacle	100%	0%	0%	0%	100%	0%
Overturning	67%	33%	0%	0%	75%	25%
Other accidents	100%	0%	0%	0%	100%	0%
Total	64%	36%	80%	20%	58%	42%

Investigation of traffic accidents in settlements has showed that the layout of speed humps throughout the length of settlements helps to keep uniform speed. Drivers after passing the obstacle (hump) expect its recurrence and do not increase the driving speed. It should be noted that in the analysis of fatal and injury accidents on the section of settlements some sections duplicate with the previously analysed sections of the roads, separately for each type of traffic calming measures. When investigating sections by the settlements where humps were implemented it was found out that after their implementation fatal and injury accidents decreased on the average – by 49%, the number of people killed – by 75%, and the number of people injured – by 50%. Distribution of fatal and injury accidents before and after vertical traffic calming measures were implemented in settlements is given in Table 5.

The change in the number of fatal and injury accidents after installation of vertical traffic calming measures is shown in Fig. 1.

Table 5. Distribution of fatal and injury accidents on the sections where vertical traffic calming measures were implemented in settlements

Accident type	Accidents		Killed		Injured	
	before installation	after installation	before installation	after installation	before installation	after installation
Collision	64%	36%	100%	0%	66%	34%
Collision with pedestrian	73%	27%	100%	0%	70%	30%
Collision with bicycle	80%	20%	0%	100%	89%	11%
Collision with obstacle	60%	40%	0%	0%	69%	31%
Overturning	50%	50%	0%	0%	43%	57%
Other accidents	0%	100%	0%	0%	0%	100%
Total	66%	34%	80%	20%	67%	33%

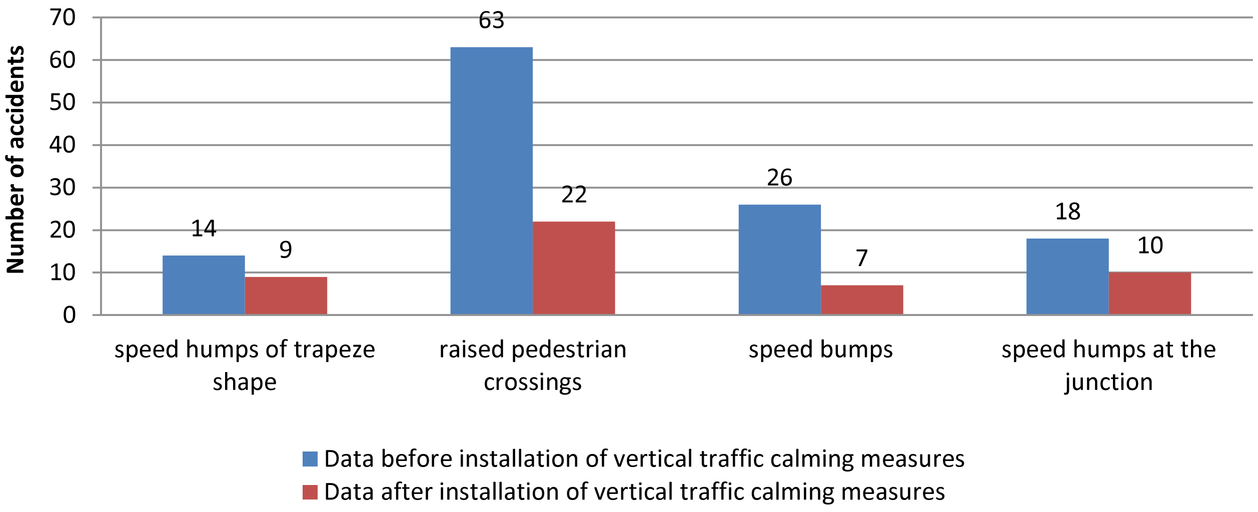

Fig. 1. Change in the number of fatal and injury accidents after installation of vertical traffic calming measures field

4. Traffic-generated noise investigations at the sites of vertical traffic control measures

Before noise level measurements 22 sites were selected from the list of previously analysed vertical traffic calming measures according to fatal and injury accidents. They were divided into two groups:

- Speed humps of trapeze shape or raised pedestrian crossings of trapeze shape (3 m long and 10 cm high on the average). This group includes 1 asphalt speed hump of trapeze shape and 14 asphalt or prefabricated raised pedestrian crossings (Table 6).
- Speed bumps (0.5 m long and 5 cm high on the average). This group includes 7 circular speed bumps from prefabricated plastic segments (Table 6).

The following investigations were carried out in the sites of vertical traffic calming measures and adjacent road sections:

- Noise level measurements;
- Traffic flow measurements.

4.1. Noise level measuring methodology

In the selected sites of vertical traffic calming measures, noise levels are determined in three measuring sites where measurements are taken simultaneously using three noise meters and the passing traffic flow being the same. Two measuring sites are selected close to a vertical traffic calming measure – in sites where the largest noise emission is formed (A, B), and the third – check measuring site is selected at a larger distance from a calming measure where noise emission has no effect on the vehicles passing through vertical traffic calming measure (C). In case of uninterrupted traffic flow measurements are taken for 30 min, in case of interrupted traffic flow, i.e., less than 1 vehicle in 1 min, noise level is measured for each vehicle individually.

Noise levels are assessed by comparing measurement results, obtained at vertical traffic calming measure, with noise level values measured at the check point where noise level is not affected by vertical traffic calming measure. A principle scheme of noise measuring sites is given in Fig. 2. The generated noise is measured at a 1.5 m distance to the edge of road, a microphone is raised to 1.5 m height from the ground surface at a distance of at least 0.5 m from the specialist who take measurements in a way of targeting microphone to the side of noise source.

Table 6. The list of vertical traffic calming measures selected for the measurements

Road number	Location	Settlement	State road maintenance enterprise (RK)	Type of vertical traffic calming measure
132	24,130 km	Seirijai	Alytaus RK	Trapeze shape
138	0,109 km	Vilkaviškis I	Marijampolės RK	Raised pedestrian crossings
138	0,381 km	Vilkaviškis II	Marijampolės RK	Raised pedestrian crossings
171	0,662 km	Avižieniai	Vilniaus RK	Raised pedestrian crossings
182	4,380 km	Netičkampis	Marijampolės RK	Raised pedestrian crossings
186	0,375 km	Kybartai I	Marijampolės RK	Raised pedestrian crossings
5214	2,910 km	Klevinė	Vilniaus RK	Raised pedestrian crossings
102	84,700 km	Švenčionys	Vilniaus RK	Raised pedestrian crossings
116	1,500 km	Širvintos	Vilniaus RK	Raised pedestrian crossings
122	105,260 km	Vaivadai	Panevėžio RK	Raised pedestrian crossings
131	26,550 km	Simnas	Alytaus RK	Raised pedestrian crossings
172	52,657 km	Molėtai	Utenos RK	Raised pedestrian crossings
185	0,571 km	Vilkaviškis III	Marijampolės RK	Raised pedestrian crossings
202	10,830 km	Pagiriai	Vilniaus RK	Raised pedestrian crossings
220	49,627 km	Pivašiūnai	Alytaus RK	Raised pedestrian crossings
A7	40,063 km 40,097 km	Kybartai II	Marijampolės RK	Circular shape
120	53,511 km	Svėdasai	Utenos RK	Circular shape
121	16,336 km 16,369 km	Troškūnai	Utenos RK	Circular shape
138	11,251 km 11,282 km	Žalioji	Marijampolės RK	Circular shape
147	1,440 km 1,490 km	Tauragė II	Tauragės RK	Circular shape
164	141,020 km 141,070 km	Tauragė I	Tauragės RK	Circular shape
5106	0,212 km	Vilkaviškis IV	Marijampolės RK	Circular shape

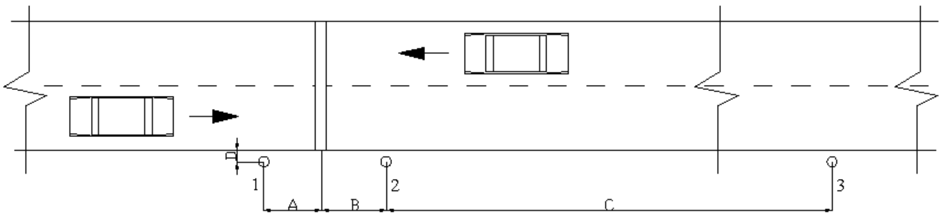

Fig. 2. A principle scheme of noise measuring sites

To measure noise from mobile sources a precision hand-held sound lever meter *Bruel&Kjaer 2260* is used. Using the on-site measurement instrument *Bruel&Kjaer 2260* the values are determined with an error of 1.5%. Before taking noise level measurements meteorological weather conditions are determined: relative humidity, air temperature and wind speed.

4.2. Traffic flow measuring methodology

The aim of measuring traffic flow is to determine the flow of passing vehicles and its effect on noise level. Traffic flow is measured in all traffic directions. It is measured simultaneously with noise level. Measurement of traffic flow helps to calculate how many and of what type vehicles pass in one or another direction in the given road location at the given time interval.

4.3. Analysis and evaluation of traffic flow measurement

Having measured the values of equivalent noise in all measuring sites at raised pedestrian crossings and at a speed hump of trapeze shape, a conclusion could be made (Fig. 4) that raised asphalt crossings have no effect on the increase in noise level since the approaching vehicles reduce speed and when passing through the crossing do not cause increase in noise emission.

Once the vehicles passed through a raised asphalt crossing, noise level increases since the vehicles pick up speed causing more engine revs and higher noise emission. At raised crossings the equivalent noise level in the second measuring sites is in all cases higher than that when vehicles pass through the crossing itself. The highest noise levels were recorded in check sites where vehicles travel at a usual speed allowed in settlement, without any obstructions. This is conditioned by the fact that the higher driving speed the higher noise level.

Fig. 5 gives the measured equivalent noise level values in all measuring sits at circular speed bumps. Based on measurement data, it can be concluded that circular speed bumps have no effect on the increase in noise level since the coming vehicles reduce speed, and the measured equivalent noise level is in all cases higher in the check measuring site compared to the first and the second measuring sites at the bump.

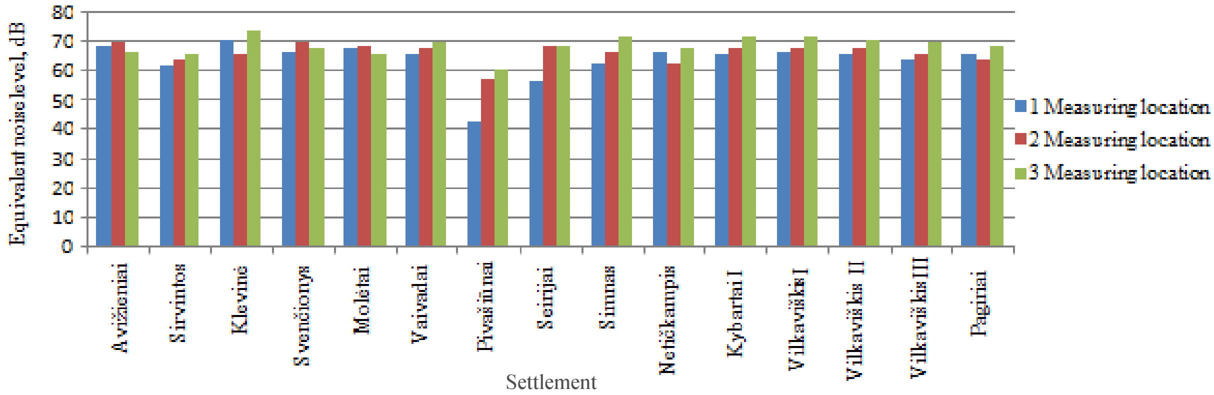

Fig. 4. The equivalent noise level measured at raised pedestrian crossings and at a speed hump of trapeze shape

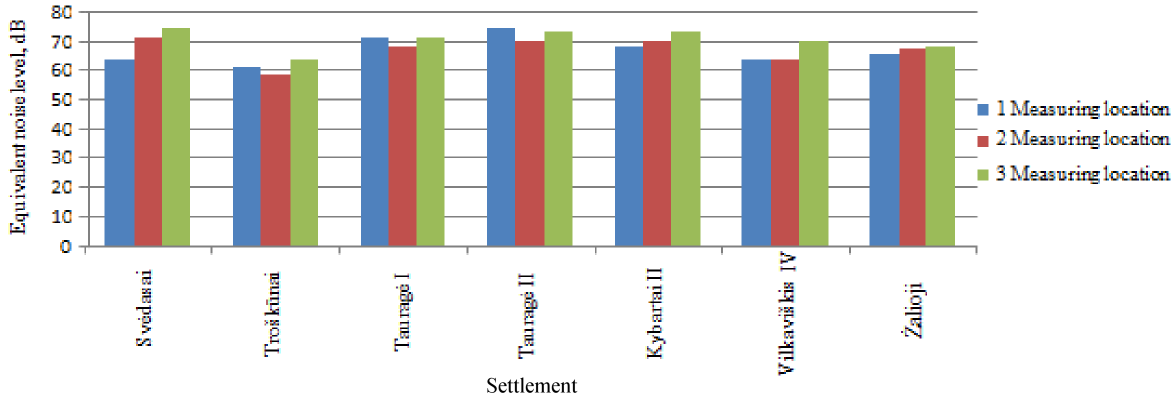

Fig. 5. The equivalent noise level measured at speed bumps

Once the vehicles passed through a circular speed bump, as distinct from raised crossings, in many cases noise level at the bump was higher than in the second measuring site where the vehicles pick up speed causing more engine revs and higher noise emission. The highest noise levels were measured in check measuring sites where vehicles travel at a usual speed allowed in settlement, without any obstructions. This is conditioned by the fact that the higher driving speed the higher noise level.

The increase in equivalent noise level at vertical traffic calming measure compared to the check site from 22 selected measuring sites was recorded only in 4: Avižieniai, Švenčionys, Molėtai and Tauragė (II).

5. Conclusions

Research on the impact of vertical traffic calming measures on the environment has determined that the studied measures in sites of their installation do not increase the traffic-generated equivalent noise level. Results of the measurements of equivalent noise level showed that at speed humps of trapeze shape and raised pedestrian crossings in the first measuring site almost in all cases noise level was from 1 to 18 dB lower than in the check measuring site. In the second measuring site where the vehicles pick up speed almost in all cases noise level was by 2 to 8 dB lower than in the check measuring site. Results of the measurements of equivalent noise level showed that at speed bumps in the first measuring site almost in all cases noise level was from 2 to 11 dB lower than in the check measuring site. In the second measuring site where the vehicles pick up speed almost in all cases noise level was by 1 to 7 dB lower than in the check measuring site.

It was determined that before the installation of vertical traffic calming measures 121 accidents took place where 147 people were injured and 11 people were killed. After their installation 48 road accidents were recorded where 55 were injured and 2 were killed. After installation of vertical traffic calming measures the number of fatal and injury accidents decreased by 60%, the number of people injured – by 63%, the number of people killed – by 82%.

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