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Research of the Impact of Bumps on Vehicle Speeds

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Abstract. The paper presents the results of research on the impact of selected types of speed bumps, located in the streets of the city road network, on the instantaneous speed of passenger cars in free flow traffic conditions. The research considered different speed bumps. All types of speed bumps occurred to be very effective in a traffic calming. The applied parametric tests of a statistical significance showed that, for the sake of mathematical statistics, the differences in the instantaneous speed of vehicles at the speed bumps are significant in relation to the instantaneous speed of vehicles on the inter-junction sections. The instantaneous speeds of passenger cars at speed bumps were over 60% lower in relation to the speeds achieved by drivers of those cars in the inter-junction sections.

INTRODUCTION

The speed reduction of vehicles and minimizing the speed differences between vehicles in a flow significantly reduce the risk of a road accident and its consequences. Further, the benefits of the speed reduction may also impact the reduction in fuel consumption, noise and exhaust emissions. However, such activity has to be reasonable, and therefore the speed should be managed. It should be consciously developed in order to achieve, with a relatively high level of road safety, both the desired level of service to road network users and at least a sufficient level of economic efficiency of transport of people and goods [1].

Speed and its relation to road and vehicle features, as well as individual drivers' behavior, should be treated not only as an engineering issue but also as a psychological one. Finding effective ways of influencing the speed and adapting it to the requirements of the desired level for road safety reasons should include technical solutions for the road environment, structure and vehicle equipment, as well as various forms of influencing the awareness and behavior of drivers in traffic. In the case of the road environment, speed can be influenced primarily by adequate features of road infrastructure.

The aim of this study is to present results of research on the vehicle speeds recorded on various speed bumps. This issue is still relatively poorly understood in Poland, and the literature on the subject devotes only a little space to it. The knowledge of the impact of individual elements of road infrastructure on the behavior of vehicle drivers is very valuable for road designers and administrators because it enabled them to manage speed rationally and effectively.

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TRAFFIC SPEED ZONES

To achieve the desired level of road safety in the city area it is required, first, to separate speed zones on the road network with strictly defined spatial and generic accessibility, i.e. for individual types of road users [2]. The selected part of the city's road network, a selected route, or just a part of the single street may be such a zone. Separating these zones allows not only rational shaping of the actual speed on the road network but also the possibility to minimize vehicle speeds differences along streets or in areas of intersections, as well as in the given cross-sections of the street.

Base on the literature review [1] the following speed zones may be distinguished:

1) pedestrian traffic zone; it is intended for pedestrian traffic and includes: squares, parks, playgrounds, recreational areas, sports areas, etc.;
2) zone of integrated pedestrian, bicycle and car traffic; pedestrian, bicycle and car traffic uses the same common space; in traffic motor vehicles and bicycles yield pedestrians, hence the vehicle speeds have to be as close as walking speed (5 ÷ 20 km/h); a typical example of an integrated traffic space is a pedestrian (or pedestrian and cyclists) route, in which, from a group of vehicles, only vans and trucks supplying shops may be used at certain hours during the day (in city centers or in commercial areas); another example of integrated traffic zones are the so-called "residence zones" used in housing estates or in recreational areas; the movement of vehicles in such zone is allowed without time limits, but their speed cannot exceed 20 km/h; however, in order to maintain such vehicle speed, it is not enough to use appropriate vertical markings, but the area should be arranged in such a way as to prevent drivers from driving vehicles above this speed limit; in addition, through traffic should be significantly limited or forbidden at all;
3) calm traffic zone, which is dedicated for pedestrian, bicycle and car traffic; it is attributed by low vehicle speeds - maximum 30 km/h and low traffic nuisance to its surroundings; the low-speed requirement has to be forced by appropriate traffic-calming measures; in such a zone there is a low volume of vehicle traffic, and it is serviced on a road separated from pedestrian traffic, while bicycle traffic is usually served in a common area with car traffic (mixed traffic); there should be no public transport or heavy traffic allowed in this kind of zone, and the streets are intended mainly for residents of the given area or for certain facilities, hence the capacity should be limited; the use of these zones is very popular, which results from their many advantages (high level of road safety for all its users and a relatively high level of comfort of living in the area of this zone, which results from low noise and exhaust emissions and the aesthetics of the street area);
4) moderate speed traffic zone; it is intended for car, pedestrian, and bicycle traffic; it borders on a quiet traffic zone, hence transit traffic is mixed with local traffic; this area should be arranged in a way ensuring the safety of pedestrians and cyclists at the vehicle speed limit to 40-50 km/h and that the actual speed should not exceed this speed limit; in order to ensure this, it is also necessary to use specific technical solutions to keep vehicles at such a low speed; pedestrian, bicycle and car traffic should be run on independent paths and may intersect with car traffic in one plane, but with appropriate conditions, creating a low risk of a road accident for unprotected street users; the spatial accessibility to this zone should be partially limited, and it should mainly take place through intersections; in this zone, the public transport service is acceptable;
5) high-speed traffic zone; it is intended mainly for car traffic, including public transport service; in this zone, speed is limited between 60 and 80 km/h, depending on the technical solutions used in the road infrastructure; the intersection of car traffic and pedestrian/bicycle traffic in this zone must be separated in time (by traffic signals - at a speed of 60 km/h) or in space (at a different level - at a speed above 60 km/h); the accessibility of this zone from the road network should already be clearly limited, and entry and exit from this zone should be possible mainly by signalized intersections (at a speed of 60 km/h) or an appropriate acceleration and deceleration lane (at higher speeds); the distance between intersections depends on speed limits, and should be no shorter than 500 m;
6) high-speed traffic zone; it only covers streets intended for car vehicle traffic, such as, for example, a city motorway or an expressway; there is no access to these routes for pedestrian and bicycle traffic; the accessibility of this zone from the road network should be very limited; speeds on these routes may exceed 80 km/h, entry or exit from this zone must absolutely be done with the use of additional lanes enabling the vehicle speed to be changed, thus avoiding speed differences between vehicles.

DESCRIPTION OF THE TEST SITE

The speed tests concerned passenger cars running in free flow traffic conditions on the following speed bumps:

a. island speed bump ‘**FIGURE 1’**,
b. plate speed bump in the form of a pedestrian crossing ‘**FIGURE 2’**,
c. a strip speed ramp ‘**FIGURE 3’**.

FIGURE 1. Island threshold

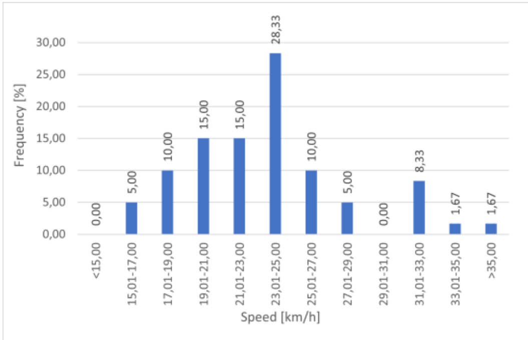
FIGURE 2. Plate threshold

FIGURE 3. Screed threshold

The above speed bumps were located in local streets where drivers of vehicles achieved average speeds of about 55.0 km/h before their implementaion.

MEASUREMENT RESULTS AND THEIR ANALYSIS

The obtained results of speed measurements are presented in the form of histograms **FIGURES 4, 6, 8** and cumulative distribution functions (CDF) **FIGURES 5, 7, 9**.



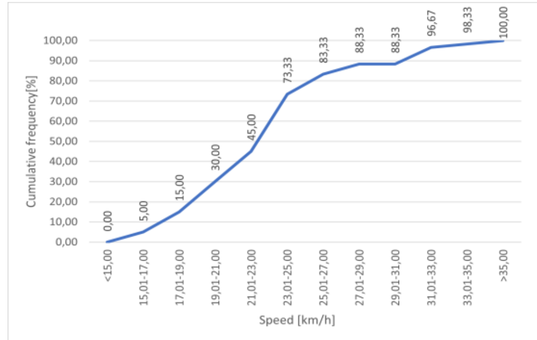
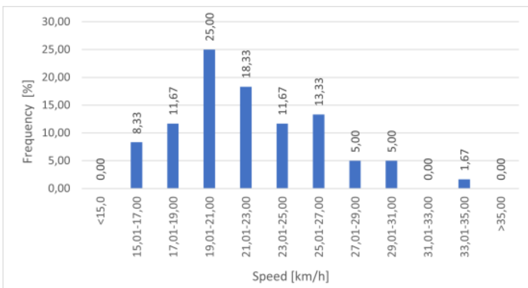


FIGURE 4. Histogram of vehicle speeds - island threshold

FIGURE 5. CDF of vehicle speeds – - island threshold



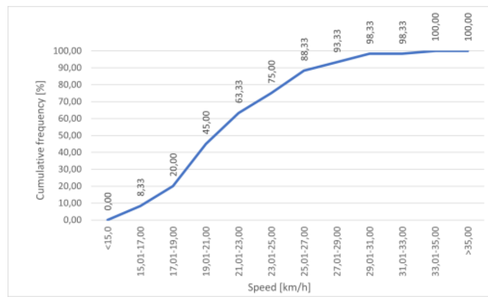
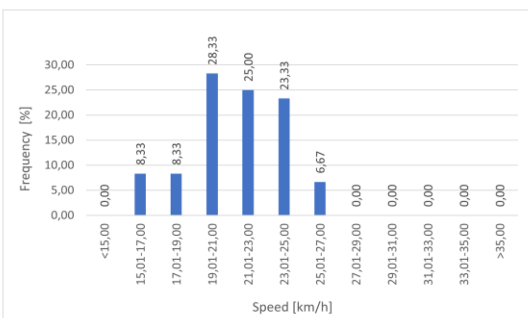


FIGURE 6. Histogram of vehicle speeds - plate threshold

FIGURE 7. CDF of vehicle speeds - plate threshold



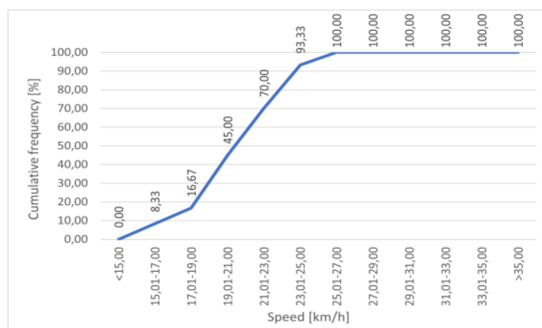


FIGURE 8. Histogram of vehicle speeds - screed threshold

FIGURE 9. CDF of vehicle speeds - screed threshold

On the other hand, the average vales of vehicle speeds at the tested deceleration bumps and their standard deviations are presented in **TABLE 1**.

TABLE 1. Average vehicle speeds and their standard deviations

Type of speed bump	Average speed [km/h]	Standard deviation [km/h]
Island	23,6	4,6
Plate	22,2	4,0
Strip	21,4	2,6

The data analysis presented in the above **FIGURES 4 – 9** and **Table 1** shows that the applied speed bumps are an effective measure of traffic-calming. The average speed of passenger cars did not exceed the value of 24.0 km/h. It should be emphasized that in the streets of the same technical class, but without speed bumps, car drivers reached speeds of about 55.0 km/h, and the value of the standard speed deviation was like 8 km/h. Hence, the speed bumps resulted in a speed reduction of nearly 60%.

In the further analysis of the research results, it was decided to check the hypothesis whether, for the reasons of mathematical statistics, the differences in vehicle speeds between individual trials and their variances are significant. For statistical analysis, parametric tests were used, i.e. the test for two means and the test for two variances [2, 3].

The performed statistical analysis of the measurement results for the significance level of 0.001 showed that there is no reason to reject the hypothesis that at the considered deceleration thresholds, both in terms of vehicle speeds and their variances, the tested samples come from the same population.

The adjustment of an appropriate distance between the speed bumps in technical solutions is an important engineering issue either. Hence, further research was undertaken, consisting in measuring the speed of passenger cars in the middle of a 90.0 m long section ending on both sides with slat speed bumps. The histogram and CDF for vehicle speed for such a case are shown in **FIGURES 10 and 11**.

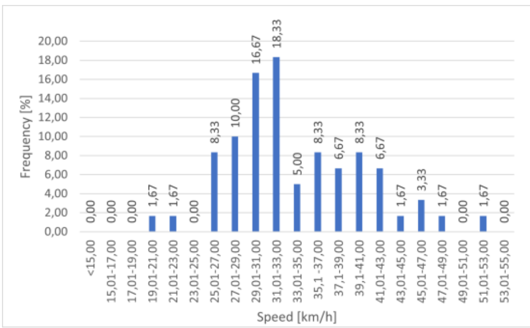


FIGURE 10. Vehicle speed histogram - cross-section between slat sills

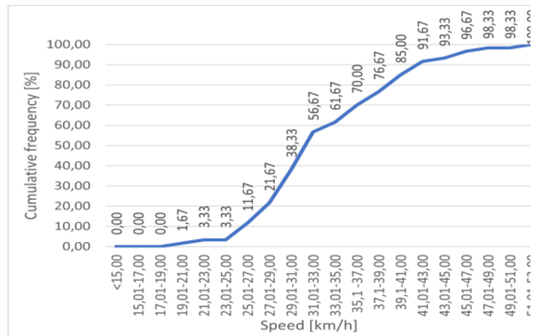


FIGURE 11. CDF plot for vehicle speed - cross-section between slat sills

In this test section, the average speed was 33.9 km/h, and the standard deviation was 6.5 km/h. Hence, the reduction in the average speed was over 11.0 km/h, i.e. by 38% in relation to the section of the street without speed bumps.

The issue of the distance adjustment between speed bumps requires further research, where different cases of distances between the speed bumps should be considered and analyzed.

CONCLUSION

Based on the conducted tests of the speed of passenger cars for the selected types of speed bumps considered in the study, it can be concluded that:

1) Speed bumps are an effective means of traffic calming. The average speed of passenger cars did not exceed the value of 24.0 km/h, and the values of standard deviation ranged from 2.6 km/h to 4.6 km/h. In the streets of the same technical class, but without speed bumps, drivers of private cars reached the speeds of about 55.0 km/h, and the value of the standard deviation was about 8 km/h. Hence the speed bumps resulted in a speed reduction of nearly 60%. Creation of user-friendly zones and improvement of the operating conditions of these areas enabled much better quality of public spaces in central areas.
2) The performed statistical analysis of the measurement results for the significance level of 0.001 showed that there is no reason to reject the hypothesis that at the considered deceleration thresholds, both in terms of vehicle speeds and their variances, the tested samples come from the same population.
3) In further works, the authors will focus on an important engineering issue, which is the adjustment of an appropriate distance between the speed bumps depending on the desired vehicle speed.

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