TRANSPORT PROBLEMS 2018 Volume 13 Issue 2
PROBLEMY TRANSPORTU DOI: 10.20858/tp.2018.13.2.1

Keywords: speed management; sectional speed; heterogeneity of speed

Robert ZIÓŁKOWSKI
Bialystok University of Technology
Wiejska 45A, 15-351 Bialystok, Poland
Corresponding author. E-mail: robert.ziolkowski@pb.edu.pl

SPEED MANAGEMENT EFFICACY ON NATIONAL ROADS – EARLY EXPERIENCES OF SECTIONAL SPEED SYSTEM FUNCTIONING IN PODLASKIE VOIVODSHIP

Summary. Driving speed is one of the most important factors in road safety, and speed not only affects the severity of a crash, but is also related to the risk of being involved in a crash. Inappropriate speed is responsible for more than a third of all fatal accidents occurring on the roads. In Poland, the problem of speeding drivers is widely common. Hence, effective speed management and enforcement of speed limits on existing road plays an important role. Possible solutions for rural roads are very limited and have focused mainly on administrative speed limitations and speed cameras enforcement. However, due to their limited effectiveness, new solutions are still being sought. High expectations are associated with the latest introduction of sectional speed system in Poland. The aim of this paper is to examine the efficiency of the sectional speed control system implemented on chosen sections of national roads in Podlaskie province. For this purpose, speed surveys included road segments where the system for sectional speed control had been already implemented, as well as in order to evaluate its effectiveness, speed measurements were conducted on other national roads with no further specific restrictions. In addition, to evaluate the possible influence of the sections monitored by the system on driver's behaviour on adjacent segments, the relevant speed data was collected on adherent sectors. On the basis of the conducted measurements, high effectiveness of sectional speed control system was stated together with its impact on adjoining segments, but also some deficiency in terms of speed homogeneity has been revealed.

1. INTRODUCTION

The necessity for traffic management comes from excessive vehicular speed, which is a major contributor in the number of accidents, deaths and serious injuries on roads worldwide [1]. The other aspect that must be considered is speed inconsistency and its multidirectional influence on driver's behaviour while driving, road users' safety and environmental impacts. Higher speeds increase the risk of a crash for a number of reasons such as: difficulties in proper speed assessment, higher possibilities of losing control over a vehicle and also elongates the breaking distance as a driver's reactions to an unsafe situation on a road. In addition, during a crash, higher speed produces the greater amount of mechanical energy that must be absorbed by the impact. On the other hand, road and traffic conditions often lead drivers to uneven behaviour, resulting in severe breaking and accelerating manoeuvres. Frequent deceleration and acceleration manoeuvres may in turn lead to additional dangerous behaviour due to the lack of speed uniformity [2]. In addition, severe and frequent manoeuvres, especially in cities, contribute to higher fuel consumption that unfavorably affects the environment. Hence, traffic and speed management, defined as a range of measures aimed at balancing the safety and the

efficiency of vehicle speed on a road network, is believed to be a successful way of improving the safety and traffic homogeneity, whose importance is rising along with the increasing motorization rate. Speed management aims to reduce the number of road traffic crashes, and the serious injuries and fatalities that can result from them through the employment of a range of measures that include enforcement, engineering and education.

The aim of this paper is to examine the efficiency of the sectional speed control system operating on chosen segments of national roads crossing Podlaskie voivodeship based on spot and section speed surveys.

2. TRAFFIC AND SPEED MANAGEMENT

Traffic management is related to planning, coordinating, controlling and organizing traffic to achieve efficiency and effectiveness of the existing road capacity. This includes techniques and strategies that generally are used to mitigate congestion, minimize delays, ensure smooth, fast, but safe and economically reasonable conditions for vehicular movement from one place to another and are intended to improve the traffic safety for all road users.

Traffic calming is a part of speed management and involves altering of the motorist behavior on a street or on a street network along with other legal, planning or physical modification to a road layout in order to improve the environmental quality, safety for vulnerable road users and reduce accident numbers and severity by lowering the speeds [3, 4-6]. Traffic calming can be considered in four levels:

- local/spot traffic restraint;
- corridor traffic restraint;
- wide-area restraint;
- suppression of traffic demand at the urban or large-scale level.

In these instances, the inclusion of traffic calming on minor routes, which are used to an excessive extent at peak times by individuals aiming to utilize them as rat runs, can be extremely effective. The provision of a series of traffic calming measures reduces the maximum speed obtainable on a given route and thus increases the overall journey time for individuals causing the route to become a less attractive option.

Traffic calming schemes incorporate a wide range of measures intended to both reduce the speed and enhance the environment, although their effectiveness varies according to the measures employed. Specific measures can be grouped into four categories [7]:

- vertical deflection (road hump, bump, lump and table, cushion, rumble strip, raised crosswalk and intersection).
- horizontal deflection (curb-extension, chicane, gateway, raised median island, traffic circle).
- physical obstruction (semi and diagonal diverter, right-in and right-out island, raised median through intersection, street closure).
- signs and pavement markings.

Within spot traffic restraints, from among a number of currently available devices, vertical shifts placed in the carriageway are the most commonly used [8], but their effectiveness is reduced to a very short section, hence particular attention should be given to their locations. Due to constraints relating to their usage, those measures are most common in residential streets, where particular caution should be given due to the presence of children or other unprotected road users and casualties are likely to occur.

Traffic calming measures are put in place on roads for the intention of slowing down or reducing motor-vehicle traffic to an acceptable level, as well as to improve safety for the pedestrians and the cyclists.

The main objectives underlying traffic calming are to:

- reduce the higher speeds of vehicles in the traffic stream,
- create road conditions that encourage motorists to drive carefully and calmly,
- remove extraneous car and commercial vehicle traffic from the road being calmed,

- improve amenity and enhance the environment,
- reduce accident numbers and severity.

However, the key objective is to reduce the high vehicle speed.

Special attention in terms of traffic safety is given to speed management that emerges from the need to limit the negative effects of excessive and inappropriate speeds. Both excessive speed (driving above the speed limits) and inappropriate speed (driving too fast for the prevailing conditions, but within the limits) are within the definition of speeding and are very dangerous and undesirable. Speeding is being a causation factor in around one third of fatal accidents, while speed is an aggravating factor in the severity of all accidents

3. PROBLEM OF EXCESSIVE SPEED IN URBAN AND SUBURBAN AREAS

The problem of speeding drivers is widely common in Poland in both rural and urban areas. Polish experiences from the beginning of the XXI century showed that depending on the type of cross section, the average percentage of drivers exceeding the existing speed limits on rural roads ranged from 50% to over 70%, while in cities, this value ranged from 20% to 65% [9]. The more recent speed investigations conducted in Bialystok confirmed that high number of speeding drivers is still an actual problem and is related to road hierarchy – its function, geometry characteristics and posted speed limits [10]. Conducted investigations have showed that the percentage of drivers exceeding the speed limits varies from 32% (dual carriageway with speed limit of 70 km/h) to up to 100% (single carriageway 1/4, with a speed limit of 40km/h) and it was concluded that the lower speed limit is accompanied by the higher number of speeding drivers. The study has also revealed that in general non-intrusive administrative regulations, as a tool of speed management, are of low efficiency and traffic flow characterizes with a high heterogeneity, regardless of the class of a road and existing speed limit. Histograms of vehicle speeds (Fig. 1) reflect speed survey conducted on a weekday at the time between peak off hours.

The need for more effective traffic management arises from low effectiveness of administrative tools and results in the common use of physical solutions of TCMs such as: speed humps, cushions and raised pedestrian crossings, intersections or median islands often applied in urban areas.

Speed management in rural areas is based mainly on traffic signs and speed cameras installations. Many research results have proved speed cameras to be an effective solution against speeding drivers [11 - 13]. Allsop in his four-year evaluation report [14] pointed out a substantial improvement in compliance with the speed limits; a particular reduction in extreme speeding, reduction at fixed sites in the average speed and an appreciable reduction at mobile sites. Interesting thing in his findings was that in 3.8% of the investigated sites, the number of collision has significantly increased. Pauw et. al [15] achieved similar observations in speed reduction on motorways in Belgium—they found that the driving speed reduced on an average by 6.4 km/h, the odds of drivers exceeding the speed limit reduced on an average by 80%, and the odds of drivers exceeding the speed limit by more than 10% reduced by 86%. Early experiences from the installations of fixed speed cameras along chosen national roads in Poland [9] in order to improve the safety on the roads running through small towns also showed noticeable reduction in crashes, crash fatalities, and injuries (tab. 1). However, further analysis including extended number of camera enforcement sites have not confirmed the statistical correlations in this term. Although the efficacy of speed cameras in speed reduction is quite high and the number of violent drivers and fatality crashes has substantially decreased after their implementation, the main disadvantage is their relatively short area of influence on the drivers. The range of impact is limited to about 500 m before the speed camera localization and another 500 m behind on the rural roads or even much shorter in the urban areas [15].

Another disadvantage arising from the presence of speed cameras is the recorded adverse drivers' manner – being forced to slow down in the direct area of the camera's position, drivers shortly after tend to make up the lost time and accelerate and again travel with an excessive speed [10].

A solution for such a behaviour is believed to be the inclusion of sectional speed system. Enforcing the speed limit over an extensive length results in a calmed flow of traffic. Because everyone is

supposed to drive more or less the same speed, there should be less accelerating and decelerating, which additionally will result in lower pollution and safer conditions on the roads.

Table 1

Changes in the number of victims on national road no 8 registered during "before and after" investigations [9]

	Crash fatalities		Injuries		Crashes	
	A	B	A	B	A	B
Sections with camera	-41.5%	-41.3%	-33.5%	-34.4%	-31.3%	-32.3%
Other national roads	- 4.9%		-4.6%		- 4.9%	
Differences	-36.6%	-36.4%	-28.9%	-29.8%	- 27.8%	-28.8%

4. RESEARCH AREA AND METHODOLOGY

The sectional speed control system implementation had started in 2015 and originally comprised five sections across Poland. Two of those sections put into service in 2015 were placed in Podlaskie voivodeship on national roads NR63 and NR19. Zwierki-Zabłudów-controlled section is a part of the NR19 road and the Kobylin-Stawiski-controlled section is a part of the NR61 road. Those sections have been chosen for detailed study. Kisielnica-Stawiski section is 6.2 km long and the length of the Zwierki-Zabłudów section is 3.9 km. Both the sections were equipped with special ANPR (Automatic Number Plate Recognition) cameras. Despite the fact that those two sections were completely equipped with the necessary equipment, it was only the section Zwierki-Zabłudów that recorded the speed of passing vehicles, and so the speed data on that section was gained from the speed system administrator (CANARD). Speed measurements have been performed on adherent segments to both monitored sections to investigate how the presence of the sectional speed control system can influence drivers' behaviour beyond the monitored areas.

The average speed measurements on the investigated sections were performed by recording the vehicles passing through the check points located at the beginning and at the endpoint of every measured section. The vehicles were detected by video cameras installed on the check points. A camera read the vehicle's number plate and encrypted it using the cryptology methods. When the vehicle exited the section, the number plate was again read and matched to the plate captured at the beginning of the section. Using these two data records and the elapsed time between them, the system calculated the average speed based on the length of the section.

The length of the adherent sections chosen for speed investigations depended on the local conditions – the cameras were placed between the outskirts of existing section start/endpoints–and the analysed section stretched till the nearest built-up area.

Speed measurements investigating the drivers' travel speed on other national roads with similar geometry and functional characteristics, but with no speed control enforcement included six check points located on the roads crossing Podlaskie voivodeship (two check points on each road):

- national road NR8_1 and NR8_2,
- national road NR19_1 and NR19_2,
- national road NR65_1 and NR65_2.

5. RESEARCH RESULTS AND DISCUSSION

Average values of the vehicles' spot speed parameters gathered on the studied roads are presented in Tab. 2. For each measuring point, the average speed, 85th percentile speed (V85) and standard deviation (SD) have been calculated. The average speed values vary between 89.6 km/h and 100.7 km/h. Both extremes were recorded on the national road NR_8 and the difference between them

reached 11.1%. In case of roads NR19 and NR65, the average speed values slightly exceeded the existing speed limit, however 85th percentile reveals the existing problem with speeding drivers.

Table 2

Speed parameters for investigated referenced national roads

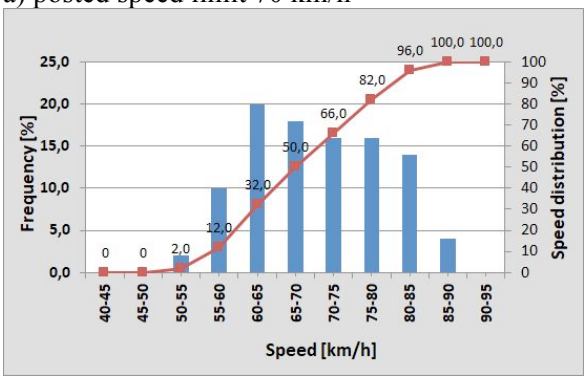
Parameter	NR8_1	NR8_2	NR19_1	NR19_2	NR65_1	NR65_2
Vśr	100.7	89.6	93.5	92.2	93	96
V85	111.7	118	104	105.7	101	109
SD	16.8	15.6	13.5	14.7	15.4	14.6

Fig. 2 presents and reflects the average-sectional speed recorded on the monitored section. The average-sectional speed on Zwierki-Zabłudów section (V_{avg}=71.9 km/h) is almost 20km/h below the posted speed limit. Drivers' average travel speed remains on a constant low level during the whole week – the data were collected twice – in the first and third week of January. The average speed on Zwierki-Zabłudów section is lower by 17.7% and 28.6% when compared with the roads NR8_2 and NR8_1, respectively. If to compare the average-sectional speed on Zwierki-Zabłudów section with the average spot speed recorded on other referenced national roads in Podlaskie voivodeship (V_{avg}=94.2 km/h), the difference reaches to 23.7%.

Fig. 3 demonstrates the average-sectional and spot speed (NRs) values, as well as the calculated standard deviations for investigated roads. The data can be analysed in two aspects. The first is the influence of the sectional speed system or just the presence of the ANPR cameras installations (case of Kisielnica-Stawiski section) on drivers' travel speed, in comparison with the average spot speed on similar roads without such a system. The second is the influence of the sections with the speed control system on the adherent segments.

The data presented in Fig. 3 illustrates the differences in average speeds between the analysed sections adjacent to the controlled ones (Fig. 3a), but also reveals, based on standard deviation values, the existence of speed heterogeneity on all the investigated sections (Fig. 3b). The lowest average values were recorded on the sections adjacent to the section Zwierki-Zabłudów with operating sectional speed control system located on the road NR_19 (V_{avg}=71.8 km/h) and it was lower by 7.5% than the average speed recorded on the sections located on the road NR_65 (V_{avg}=77.6 km/h), where the system installations are present, but doesn't operate. The highest average speed value was recorded on the referenced national roads (V_{avg}=94.2 km/h) and was higher by 17.6% and 23.8% when compared with the values recorded on the roads, respectively, NR_65 and NR_19. The sections with no control installations present distinctly higher values, when compared with other controlled or control-affected sections.

a) posted speed limit 70 km/h



b) posted speed limit 50 km/h

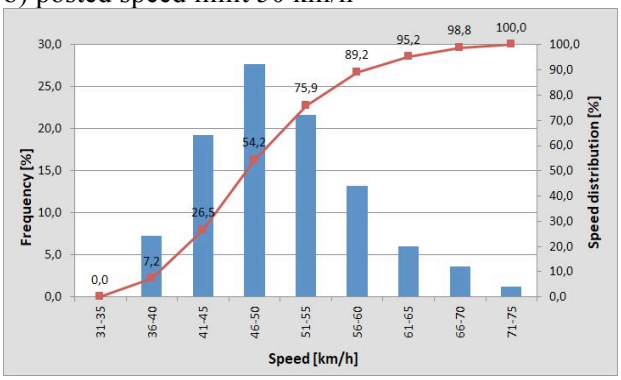


Fig. 1. Histograms of vehicle spot speed on: a) dual carriageway, b) single carriageway

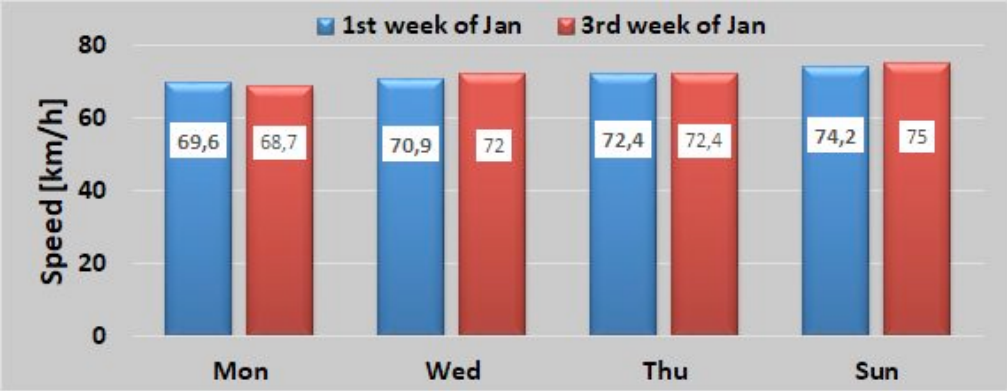
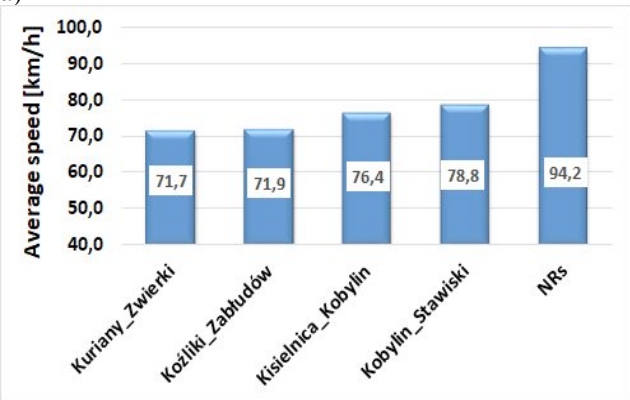


Fig. 2. Average-sectional speeds recorded on Zwierki-Zabłudów section

a)



b)

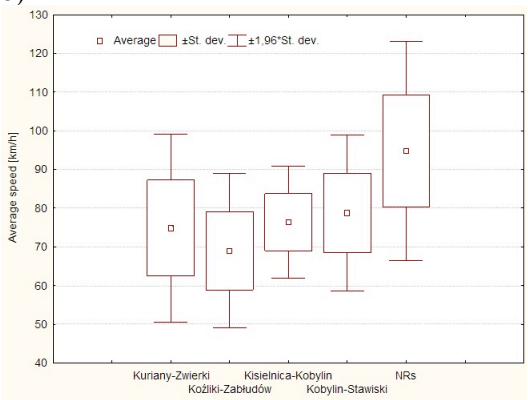


Fig. 3. The values of: a) average speeds and b) standard deviations

Considering the second aspect of the presented data, it can be stated that drivers are mentally affected by just the presence of the speed control system and the possibility of being controlled. The average section speed V_{avg}=71.8 km/g recorded on Kuriany-Zwierki and Koźliki-Zabłudów is practically equal to the average speed recorded on the controlled section of Zwierki-Zabłudów, with V=71.9 km/h. Considering the Kisielnica-Kobylin section, the influence of the sectional speed system is visibly similar to the Zwierki-Zabłudów section. There is no significant difference between the average speed on Kisielnica-Kobylin section (V_{avg}=76.4 km/h) and Kobyli-Stawiski section (V_{avg}= 78.8 km/h). The difference between the average speed values is only 3%.

Although there is a clear and positive influence of the sectional speed system on drivers' average travel speed, the individuals' speeds characterise with high heterogeneity. This is confirmed by the standard deviation values calculated for the conducted speed measurements and also by a sample of speed records taken on the NR61 road and presented in Fig. 4. The lowest value of standard deviation was achieved for Kisielnica-Kobylin section (SD=7.38km/h), while the highest for cumulative values from the other sections of the national roads (SD=14.47km/h).

Considering the average speed values on the sections adjacent to the ones with cameras installations, the differences have been confirmed. However, even though the difference between the average values on the tested sections reaches almost 10%, the heterogeneity of the registered speeds concludes that there is no statistically significant difference ($p = 0.2236$) between the analysed road sections. This is additionally confirmed in Fig. 5, which presents the median and the extremes values of the recorded speeds on the chosen tested roads.

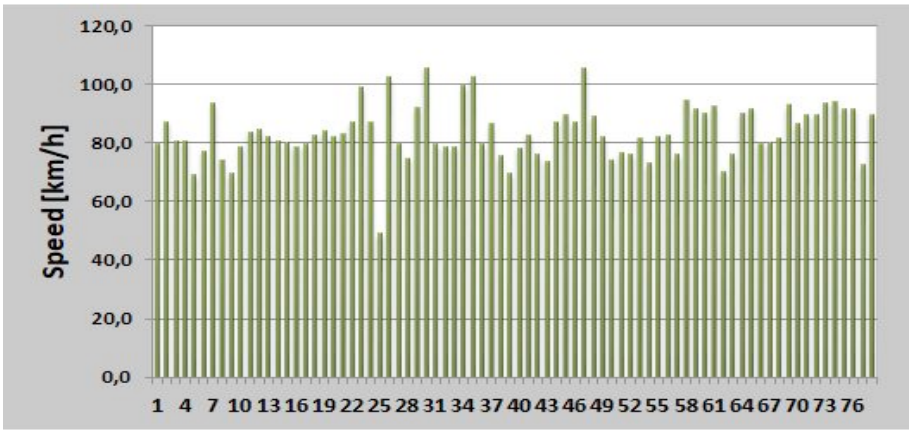


Fig. 4. Sectional speed record values recorded on the Kobylin-Stawiski section

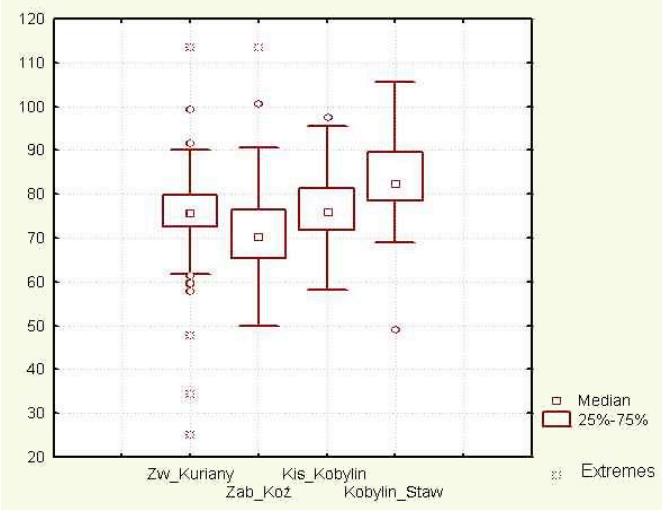


Fig. 5. Plot of the average-sectional speeds on roads NR_19 and NR_65

6. CONCLUSIONS

This paper evaluated the effectiveness and influence of the sectional speed system on the drivers' travel speed and their behaviour on adherent segments. Speed measurements were conducted on chosen national roads situated in Podlaskie voivodeship. Investigations focused on the speed surveys carried out on the road sections employed with sectional speed system and adherent segments. The conducted measurements and comparisons showed highly positive influence of such a system, resulting in effective reduction of the average speed. The average speed recorded on Zwierki-Zabłudów section was lower by 23.8% than the average spot speed recorded on similar in geometry and functional characteristics national roads with no speed control devices. Additional positive trend emerging from the presence of the sectional speed system was observed on adherent segments, where the average speeds also remained on considerably lower level, comparing to the roads where speed was managed by administrative speed restrictions.

The first results taken in Podlaskie voivodeship showed this mean of traffic management to be inevitably a very effective tool at least in terms of lowering the average travel speed. However, still there is much to improve in terms of speed heterogeneity. According to the fundamentals of effective traffic management, it should also keep the speed of the individuals on a similarly low level.

Acknowledgment(s)

The research was supported by the Project No S/WBiIS/1/15 and it was financially supported by the Ministry of Science and Higher Education, Poland.

References

1. *Traffic Calming*. Department for Transport. Local Transport Note 1/07. 2007. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/329454/ltn-1-07_Traffic-calming.pdf
2. Wåhlberg A. Driver celeration behavior and the prediction of traffic accidents. *International Journal of Occupational Safety and Ergonomics*. 2006. Vol. 12. No. 3. P. 281–296.
3. Lee, G. & Joo, S. & Oh, C. & Choi, K. An evaluation framework for traffic calming measures in residential areas. *Transportation Research Part D.* 2013. Vol. 25. P. 68-76.
4. Kyoungho, A. & Rakha, H. A field evaluation case study of the environmental and energy impacts of traffic calming. *Transportation Research Part D*. 2009. Vol. 14. No. 6. P. 411-424.
5. Juhász, M. & Koren, C. Getting an Insight into the Effects of Traffic Calming Measures on Road Safety. *Transportation Research Procedia*. 2016. Vol. 14. P. 3811-3820.
6. Gonzalo-Ordena, H. & Rojoa, M. & Pérez-Acebob, H. & Linares, A. Traffic Calming Measures and their Effect on the Variation of Speed. *Transportation Research Procedia*. 2016. Vol. 18. P. 349-356.
7. *Traffic Calming: State of the Practice ITE/FHWA*. Washington: Institute of Transportation Engineers. 1999.
8. Garrod, D. Guy, S.R. & Willis, K.G. Estimating the Benefits of Traffic Calming on Through Routes: A Choice Experiment Approach. *Journal of Transport Economics and Policy*. 2002. Vol. 36. P. 211-231.
9. Gaca, S. & Jamroz, K. & Ząbczyk, K. System monitorowania zachowań kierujących pojazdami w Polsce. In: *VI Konferencja Bezpieczeństwa Ruchu Drogowego.* Zegrze, 2004. [In English: Monitoring system of drivers' behaviour. In: *VI Road Traffic Safety Conference*].
10. Ziolkowski, R. & Saleh, W. Traffic calming measures: Technically efficient to achieve their goals? In: *6th International Symposium on Travel Demand Management*, Dalian, 2013.
11. Willis, D. *Speed Cameras an Effectiveness and a Policy Review.* Center for Transportation Safety. Texas Transportation Institute. 2006.
12. Elvik, R. & Vaa, T. *The Handbook of Road Safety Measures*. Oxford: Elsevier. 2004.
13. Blaisa, E. & Carnis, L. Improving the safety effect of speed camera programs through innovations: Evidence from the French experience. *Journal of Safety Research.* December, 2015. Vol. 55. P. 135-145.
14. Allsop, R. *The effectiveness speed cameras. A review of evidence.* RAC Foundation. November, 2010.
15. De Pauw, E. & Daniels, S. & Brijs, T. & Hermans, E. & Wets, G. Behavioural effects of fixed speed cameras on motorways: Overall improved speed compliance or kangaroo jumps? *Accident Analysis and prevention*. December, 2014. Vol. 73. P. 132-140.
16. Ziolkowski, R. Speed Profile as a Tool to Estimate Traffic Calming Measures Efficiency. *Journal of Civil Engineering and Architecture*. 2014. Vol. 8. No. 12. P. 1585-1592.

Received 11.01.2017; accepted in revised form 26.05.2018