© Ig. Bugayov, O. Kholodova, M. Buhaiova, O. Kholodov 2024

Ig. Bugayov[1], O. Kholodova[2], M. Buhaiova[2], O. Kholodov[2]

Kharkiv National University of Urban Economy named after O.M. Beketov, Kharkiv, Ukraine [1]
Kharkiv National Automobile and Highway University, Kharkiv, Ukraine[2]

CASE STUDY ON IMPLEMENTING TRAFFIC CALMING DEVICES: AN EXAMPLE FROM THE STREET AND ROAD NETWORK IN KHARKIV

The continuous growth of the car fleet and the underdevelopment of city streets and road networks require constant improvement in traffic management. The article suggests considering modern means, such as traffic calming, an essential component of strategies for ensuring road safety and creating a comfortable public area.

The analysis of existing traffic calming devices and their application practice abroad have proved the need for their widespread implementation to reduce vehicle average speeds to a safer level, reduce the number of road accidents and the severity of their consequences, and improve the conditions for movement on the street and road network for all road users.

The article analyses the implementation of three schemes of traffic management at a pedestrian crossing, namely, with the use of road signs and road markings only; with the provision of an elevated pedestrian crossing, road signs and road markings; with the use of road humps, road signs and road markings. The dependences of the average length of the traffic jam, the average delay time, and the average number of stops of one vehicle on the intensity of traffic and pedestrian flows when arranging a pedestrian crossing under the three options are obtained, which can be used for a preliminary assessment of their arrangement at pedestrian crossings.

It is substantiated that the average value of the traffic jam length, the average number of stops, and the average delay per vehicle are influenced by the traffic flow intensity, where the estimated indicators increase with their increase. As the area of influence of traffic calming devices and their geometric characteristics increases, the evaluation indicators also increase, i.e., since an elevated pedestrian crossing has smaller geometric parameters than a complex of pedestrian crossings with road humps, we have lower values of the evaluation indicators.

Keywords: traffic calming devices, pedestrian crossing, intersection, road hill, markings, transport modelling, criterion, analysis.

INTRODUCTION

Traffic calming is a set of measures and strategies to reduce vehicle speeds and create a safe and comfortable public space for all road users. These measures may include various engineering, educational and legal aspects. The main objective of road calming is to reduce the risk of road traffic accidents (RTAs) and the severity of their consequences, as well as to improve safety for pedestrians, cyclists, and other road users. Around the world, traffic calming is an essential component of road safety and public realm strategies that have been widely adopted, including the "three E's" (engineering, education, enforcement), and help create a safer and more harmonious environment for all road users. It also reflects a modern approach to urban planning and infrastructure.

Adequately applied traffic calming measures reduce vehicle average speeds to a safer level, reduce the number of RTAs and the severity of their consequences, improve conditions for pedestrians, cyclists, and public transport, and reduce transit traffic [1]. This type of measure has rarely been considered in the national urban planning literature and has not been applied in our country.

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

Traffic calming is achieved by street and road network (SRN) changes and technical measures.

First, when creating traffic calming zones, transit traffic through the city centre is eliminated by turning through streets into loop streets, dead-ends, etc. In addition, vehicle speed limits are imposed, which can dramatically reduce the number of conflicts between traffic and pedestrian flows [2]. We want to emphasise that when designing calming zones, street landscaping and space design play a vital role and are considered as a means of influencing traffic modes. The zones are often serviced by public transport, which is given priority in the city. Therefore, it is possible to combine, for example, pedestrian traffic and tram lines (Strasbourg, Saint-Etienne) or pedestrian traffic and bus routes (Dijon). The organisation of street space, landscaping, and design ensure the priority of pedestrian and cyclist movement and stimulate a reduction in vehicle speed. In particular, it allows the capacity of the SRN or some of its sections to be reduced [3].

The range of techniques and means of traffic calming is extensive: organisation of parking zones;

sewerage, lane separation; use of sharp turns; deviation of the trajectory at the intersection; use of road humps (speed bumps); narrowing of streets; restriction of access; use of roadway elevations with a change in road surface texture; application of restrictions on the size of vehicles; use of dead-end streets; redevelopment of streets; use of roundabouts; use of traffic control elements [4].

When determining the effectiveness of traffic calming, the following main results are achieved by this method: reduction in the number and severity of road accidents in cities at intersections and crossings, reduction in vehicle speed, and reduction in transit traffic in the city.

The specific results of a successful traffic calming policy can be illustrated by the example of Bruges [3], where traffic calming was introduced in the historic city centre in 1992. The following results were achieved: a 30% reduction in traffic intensity in the city centre; an increase in bus speed from 19 to 22 km/h; a 10% reduction in the number of vehicles arriving in the city centre (by 600 vehicles/h); a 33% increase in the number of residents using the bus; a 20% increase in the number of residents using bicycles; a 36% reduction in the number of road accidents in the city centre.

Data on the implementation of traffic calming in Graz (Austria) also indicate positive results: in particular, speed limits significantly impacted traffic safety and contributed to a positive assessment of traffic calming measures by residents and drivers.

In the United States, the first major experiment to implement a calming zone was the Stevens Neighbourhood in Seattle. The project, completed in early 1973, resulted in a 56% reduction in traffic intensity and a 0% reduction in road accidents.

Traffic calming is used to redistribute traffic to the SRN. It should be noted that using calming and speed limit zones implies that maintaining vehicles is performed by other sections and elements of the SRN. This is well confirmed by the data from surveys carried out in the places where these measures are implemented. According to the literature, namely [5], data analysis from 43 international studies showed that using traffic calming measures in cities reduces road accidents by 8-100%. At the same time, there was not a single case of road accidents increasing after introducing these devices, i.e., positive results and feedback were obtained in all cases.

According to [6], there are three groups of traffic calming devices:

1. Arrangement of obstacles on the carriageway (implemented using road humps, elevated pedestrian crossings and elevated intersections);
2. Change the trajectory of traffic (implemented using chicanes, mini-roundabouts, sewerage, and blocking traffic flows).
3. Change the width of the carriageway (implemented using chokers and inserts along the road axis).

Foreign studies in this area are aimed at comparing the number of accidents before and after the introduction of means of traffic calming. So, in [7], an analysis of data on road accidents with fatal consequences and injured on road sections showed that the introduction of means of vertical deceleration reduces the number of dead and injured by 60%; placement of safety islands with horizontal marking and flexible reflective poles - by 72.7%; and the placement of safety islands on the main road - by 35.7%. Interesting developments in [8], where the best measures for slowing down traffic are marked - a raised pedestrian crossing and narrowing of the lane. At the same time, the authors insist that even better results can be obtained when more than one means is used along the street to limit movement, the distance between which is not too large. In [9], the same authors compare the speed reduction from the introduction of increased pedestrian crossings and narrowing of traffic lanes. But it should take into account the effect of the driver's memory, which is stored along the entire length of the narrowed carriageway (for example, due to parking zones), when after the passage of an increased pedestrian crossing the driver does not save slow speed.

A number of other studies highlight the positive impact of using traffic calming techniques on roads, in which the authors see them as an effective tool for achieving peace, ensuring safety and improving the situation on the roads [10], a combination of strategies to reduce the negative impact on the environment, improving the safety and separation of the impact of the vehicle to assess the impact on the individual and society as a whole [11], a combination of predominantly physical measures to reduce the negative impact of vehicle, correct driving style and create better conditions for other road users, including pedestrians and cyclists [12]. Analysis of these sources revealed that traffic calming measures could be classified into 13 broad categories and take the form of diverse combinations or additional applications to existing SRN.

Analysis of domestic theoretical studies on the use of means of traffic calming shows that they mainly have a recommendatory nature of their use in Ukraine, based on the effectiveness of their use abroad. For example, in [13] it is indicated that raised pedestrian crossings contribute to the safe movement of pedestrians through the carriageway and should be common in our country, despite the high cost of their arrangement. The work [14] points out the spread of the use of means of traffic calming in some cities of Ukraine, an important advantage of which is the possibility of simultaneous speed control and restriction of transit traffic. Much attention is paid to the effectiveness of introducing mini-rings [15], but the authors note the need to study the design features of mini-roundabouts with the establishment of design parameters for use in domestic design practice, as well as the need for a detailed study of methods for determining the throughput at the junction entrance, since this issue is poorly studied in our country. To assess the level of safety and service efficiency at the design stage of mini-roundabouts, it is recommended to use transport simulation packages.

That is why, as part of this work, we will study implementing traffic calming measures for group 1 road traffic using transport modelling.

PURPOSE AND OBJECTIVES OF THE STUDY

The study aims to evaluate the effectiveness of traffic calming measures, namely, the introduction of various forms of pedestrian crossing organisation, using the example of the SRN in Kharkiv.

Road conditions and traffic and pedestrian flow parameters must be studied to achieve this goal. Based on this, simulation transport models of intersections in the PTV Vision VISSIM software environment can be developed.

RESEARCH RESULT

Fig. 1 shows typical pedestrian crossings near secondary education institutions in Kharkiv, where one can see typical conditions: a residential street (Vasyl Melnykov Street) and a main street of district importance (Oshchepkov Street, Biblik Street, Hromadianska Street) have one lane in each direction of traffic with a width of 3.0 to 4.0 m each. A pedestrian crossing is arranged opposite the main entrance to the educational institution. Due to tree plantations, the visibility of road signs 5.38.1 and 5.38.2 – Pedestrian crossing is limited. There are no road markings indicating a pedestrian crossing. The straight section of the street provokes vehicles to drive at high speeds. Public transport routes are organised on Oshchepkov Street and Biblik Street (before the war): trolleybus and bus routes. In the morning and evening, when children are brought and picked up, many vehicles are parked near educational institutions, further limiting the visibility of the pedestrian crossing.

Secondary school No. 11 (Vasyl Melnykov Street)

Secondary school No. 24 (Oshchepkov Street

Secondary school No. 80 (Biblik Street)

Technological Lyceum No. 9 (Hromadyanska Street)

Figure 1 – Organisation of pedestrian crossings near secondary schools in Kharkiv

DSTU (State Standards) 4123:2020 has arranged traffic calming measures near educational institutions, such as road humps or elevated pedestrian crossings, to improve road safety. To pass these artificial road bumps, drivers must slow down regardless of whether pedestrians are on or in the pedestrian crossing zone. Here, the question of studying the impact of traffic calming devices on the functioning of the transport network arises.

The following indicators will be used as criteria for assessing the effectiveness of traffic calming devices [16-18]: the average delay per vehicle, s ($\overline{T_{zup}} \to \min$), the average length of the traffic jam, m ($\overline{L_{zat}} \to \min$), and the average number of vehicle stops, units ($\overline{N_{zup}} \to \min$). To evaluate the effectiveness of traffic calming devices at a pedestrian crossing, the model analysis was set up in the PTV Vision Vissim software (see Table 1).

Table 1 – Analysis parameters

Parameter name	Parameter description
1. Length of traffic jam	The average length of traffic jam, m
2. Length of traffic jam (max)	The maximum length of the traffic jam during the simulation, m
3. Vehicles (all)	The number of vehicles travelling in a given direction, vehicles.
4. Service level (traffic quality) (all)	Traffic quality level (A...F) according to the assigned service levels
5. Vehicle delay time (average value) (all)	Average vehicle delay time, s
6. Idle time (average) (all)	Average idle time of each vehicle, s
7. Stops (all)	Number of vehicle stops, excluding stops on car parks and units.

The pedestrian crossing in front of the Technological Lyceum No. 9 on Hromadyanska Street was taken as a prototype for studying traffic and pedestrian flows. A model of a pedestrian crossing was developed for three options: option 1 – organisation of a pedestrian crossing using road signs and road markings; option 2 – organisation of a pedestrian crossing using an elevated pedestrian crossing, road signs and road markings; option 3 – organisation of a pedestrian crossing using road humps, road signs and road markings.

When analysing the methods of traffic calming and the use of traffic calming devices for this purpose, it was determined that the parameters for assessing the SRN functioning, namely pedestrian crossings, are influenced by such input characteristics as the input intensity of the traffic flow and the input intensity of the pedestrian flow. It is also known that the values of these intensities change significantly during the hours of the day. Therefore, to vary the model's input parameters, the following indicators were determined in this study: traffic flow intensity and pedestrian flow intensity.

It is determined that the intensity of the traffic flow will vary in the range from 150 vehicles per hour to 750 c vehicles per hour in increments of 150 vehicles per hour, and the intensity of the pedestrian flow will vary from 150 pedestrians per hour to 550 pedestrians per hour in increments of 100 pedestrians per hour. By searching for possible variations in intensity, we find the number of modelling options: 5 variants for changing traffic flows and five variants for changing pedestrian flows; thus, 25 variants of input intensity parameters for each of the three modelling scenarios should be modelled. For example, Fig. 2 shows changes in estimated indicators depending on the intensity of traffic for the proposed study options, which indicate the feasibility of using a particular means of traffic calming.

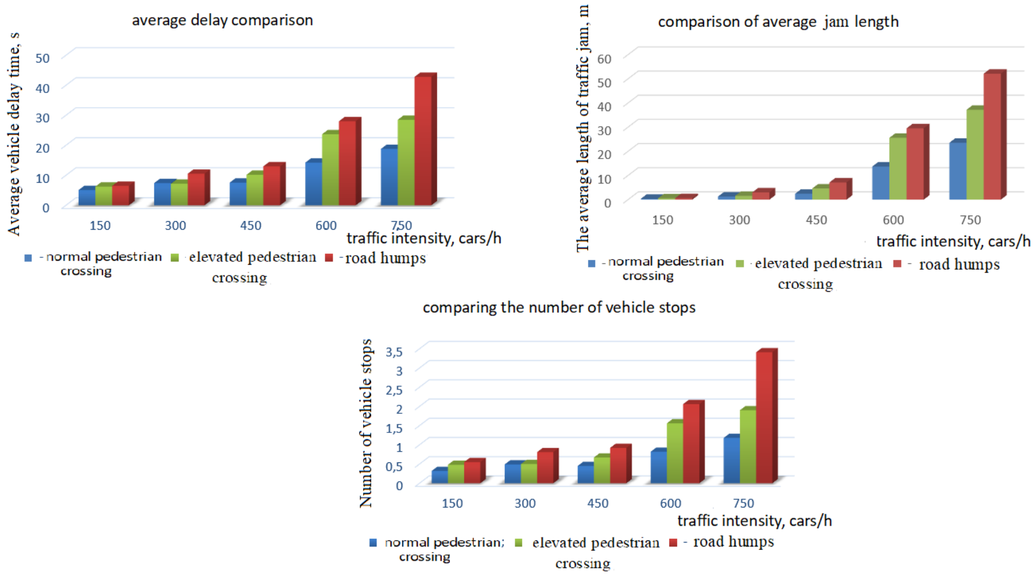


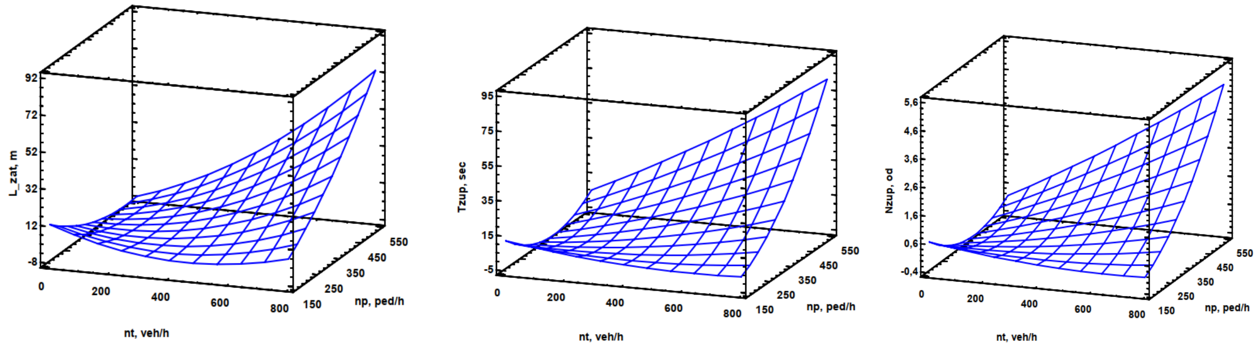
Figure 2 – Comparison of proposed options by estimated indicators

DISCUSSION OF THE RESULTS OF THE STUDY

The analysis of the impact of traffic and pedestrian flows on the indicators of assessing the SRN section functioning on the example of a pedestrian crossing using traffic calming devices can be seen in Figures 3-5. Using the statistical analysis package Statgraphics Centurion, the dependencies of the average value of the traffic jam length, the average number of stops and the average delay on the intensity of traffic and pedestrian flows in different scenarios were found (see Table 2).

Table 2 - Dependencies of the average value of the traffic jam length, the average number of stops and the average delay on the intensity of traffic and pedestrian flows in different scenarios

Scenario number	The resulting dependency
1	$\overline{L_{zat}^{var1}} = 33 - 0.1 \cdot N_t - 0.15 \cdot N_p + 0.00007 \cdot N_t^2 + 0.0003 \cdot N_t \cdot N_p + 0.0002 \cdot N_p^2$
	$\overline{T_{zup}^{var1}} = 40.4 - 0.07 \cdot N_t - 0.25 \cdot N_p + 0.00003 N_t^2 + 0.0003 \cdot N_t \cdot N_p + 0.0003 \cdot N_p^2$
	$\overline{N_{zup}^{var1}} = 2.24 - 0.039 \cdot N_t - 0.013461 N_p + 0.000001 \cdot N_t^2 + 0.00002 \cdot N_t \cdot N_p + 0.00002 \cdot N_p^2$
2	$\overline{L_{zat}^{var2}} = 21.6 - 0.0948819 N_t - 0.1001 \cdot N_p + 0.00009 \cdot N_t^2 + 0.00022 \cdot Nt \cdot Np + 0.000099 \cdot N_p^2$
	$\overline{T_{zup}^{var2}} = 35.41 - 0.0718174 N_t - 0.208 \cdot N_p + 0.000044 \cdot N_t^2 + 0.00025 \cdot N_t \cdot N_p + 0.0003 \cdot N_p^2$
	$\overline{N_{zup}^{var2}} = 1.95 - 0.00402004 N_t - 0.01 \cdot N_p + 0.0000025 \cdot N_t^2 + 0.000015 \cdot N_t \cdot N_p + 0.000015 \cdot N_p^2$
3	$\overline{L_{zat}^{var3}} = 14.7 - 0.0901034 N_t - 0.069 \cdot N_p + 0.00011 \cdot N_t^2 + 0.00022 \cdot N_t \cdot N_p + 0.000064 \cdot N_p^2$
	$\overline{T_{zup}^{var3}} = 41.7 - 0.087 \cdot N_t - 0.44 \cdot N_p + 0.00005 \cdot N_t^2 + 0.0003 \cdot N_t \cdot N_p + 0.00033 \cdot N_p^2$
	$\overline{N_{zup}^{var3}} = 1.7 - 0.00501171 N_t - 0.00941 \cdot N_p + 0.000004 \cdot N_t^2 + 0.000017 \cdot N_t \cdot N_p + 0.00001 \cdot N_p^2$



average length of traffic jam average delay time average number of stops per vehicle

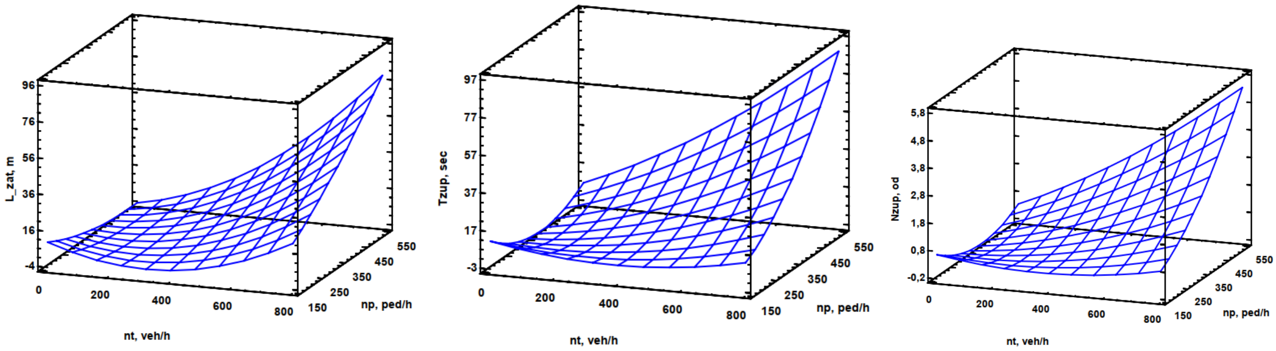
Figure 3 – Dependence of indicators on the intensity of traffic and pedestrian flows when organising a pedestrian crossing with the use of road signs and road markings (scenario No 1)

These dependencies describe accurate indicators with a 91-96% reliability, meaning we can state that the obtained models are adequate.

SUMMARY

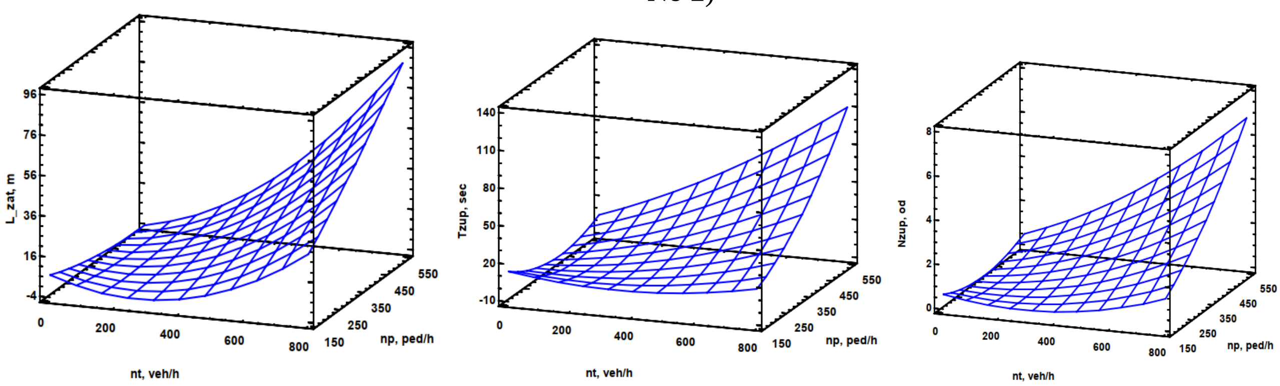
It has been proved that the availability of traffic calming devices affects indicators of the SRN section functioning at a pedestrian crossing, such as the average value of the traffic jam length, the average number of stops, and the average delay per vehicle. The intensity of traffic flows also impacts—as they increase, the estimated indicators also increase.

As the area of influence of the traffic calming devices and their geometric characteristics increase, the values of the evaluation indicators also increase. In other words, an elevated pedestrian crossing has smaller geometric parameters than a complex of a regular pedestrian crossing and road humps on both sides and, accordingly, has smaller values of the evaluation indicators, i.e. the average length of the traffic jam, the average number of stops and the average delay per vehicle.



average length of traffic jam average delay time average number of stops per vehicle

Figure 4 – Dependence of indicators on the intensity of traffic and pedestrian flows when organising a pedestrian crossing using an elevated pedestrian crossing, road signs and road markings (scenario No 2)



average length of traffic jam average delay time average number of stops per vehicle

Figure 5 – Dependence of indicators on the intensity of traffic and pedestrian flows when organising a pedestrian crossing using road humps, road signs and road markings signs and road markings (scenario No 3)

As the area of influence of the traffic calming devices and their geometric characteristics increase, the values of the evaluation indicators also increase. In other words, an elevated pedestrian crossing has smaller geometric parameters than a complex of a regular pedestrian crossing and road humps on both sides and, accordingly, has smaller values of the evaluation indicators, i.e. the average length of the traffic jam, the average number of stops and the average delay per vehicle.

The obtained dependencies can be used in a preliminary assessment of installing specific traffic calming devices at pedestrian crossings. In this case, the possibility of introducing an indicator into the model that will take into account the road safety should be considered. The studies conducted provide a useful basis for future, broader research in this area, which is planned to be directed to the use of combinations of traffic calming measures on SRN cities in order to promote the creation of safe, healthy and pleasant urban environments.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

Data will be made available on request.

REFERENCES

1.Kittelson, W. K. Historical Overview of the Committee on Highway Capacity and Quality of Service [Elektronnyi resurs]. – Rezhym dostupu: http://nationalacademies.org/trb/publications/ec018/01_63.pdf

2. Evaluation of Lane Reduction ‘Road Diet’ Measures and Their Effects on Crashes and Injuries (Washington. D. C.: Federal Highway Administration, Highway Safety Information System, 2010).

3. European Pedestrian Crossings Survey Pedestrians join zebra crossings as endangered species on UK roads [Elektronnyi resurs] / For the Road Ahead [sait]. – Rezhym dostupu: http://www.theaa.com/public_affairs/news/aa-pedestrian-crossings-in-europe-survey.html

4. Buhaiov I.S., Kholodova O.O., Buhaiova M.O. Otsinka efektyvnosti vprovadzhennia zasobiv zaspokoiennia dorozhnoho rukhu na perekhresti. Suchasni tekhnolohii v mashynobuduvanni ta transporti. Lutsk. 2023. №1(20). S. 78-85.

5. Chapter 3B –MUTCD 2009 Edition [Elektronnyi resurs] / FHWA [sait]. – Rezhym dostupu: www.fhwa.dot.gov.

6.Bezpeka dorozhnoho rukhu. Zasoby zaspokoiennia rukhu. Zahalni tekhnichni vymohy. DSTU 4123:2020. – [Chynnyi vid 2020-08-06] – 43 s. – (Natsionalnyi standart Ukrainy). Rezhym dostupu: http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=90493.

7.Jateikienė L., Andriejauskas T., Lingytė I., Jasiūnienė V. (2016) Impact assessment of speed calming measures on road safety.Transportation Research Procedia, 14, 4228 – 4236.

8.Gonzalo-Orden H., Rojo M., Pérez-Acebo H., Linares A. (2016) Traffic calming measures and their effect on the variation of speed. Transportation Research Procedia, 18, 349-356.

9.Gonzalo-Orden H., Pérez-Acebob H., Linares A., Arcea M. (2018) Effects of traffic calming measures in different urban areas. Transportation Research Procedia, 33, 83–90.

10.Institute of Transportation Engineers. Available: www.ite.org/traffic/tcstate.htm (accessed September 6, 2023).

11.Traffic calming. Available: www.trafficcalming.org (accessed September 6, 2023).

12. City of Winston-Salem Traffic calming policy. May 2005. Available: www.ci.winstonsalem.nc.us/DOT/trafficcalming.html (accessed September 6, 2023).

13.Nahrebelna L.P., Belenchuk O.V., Kononenko A.O. (2018) Pidniati pishokhidni perekhody, yak zasib zabezpechennia bezpeky pishokhodiv. Naukovo-vyrobnychyi zhurnal, №2 (254). 47-50.

14.N.O. Arsenieva, H.R. Fomenko (2022) Praktyka formuvannia zon zaspokoiennia rukhu u mistakh. Komunalne hospodarstvo mist, 170, T.3, 168-173.

15.Liubyi Ye.V., Levchenko O.S., Syromiatnikova M.S. Analiz efektyvnosti vykorystannia mini-kiltsevykh rozviazok. Naukovi notatky. Lutskyi natsionalnyi tekhnichnyi universytet. 2018. Vyp. 61. S. 110 – 117.

16.Renkas, A., Rudenko, D. i Tovaryanskyy, V. 2021. Pidvyshchennia efektyvnosti funktsionuvannia perekhrest z vysokointensyvnymy transportnymy ta pishokhidnymy potokamy. Visnyk Lvivskoho derzhavnoho universytetu bezpeky zhyttiediialnosti. 23, (Lyp 2021), 61-67.DOI:https://doi.org/https://doi.org/10.32447/20784643.23.2021.09

17.Horbachov, P. F., Makarichev, O. V., & Atamaniuk, H. V. (2019). Doslidzhennia zatrymok uchasnykiv rukhu pid chas peretynannia pishokhodamy vulyts i dorih cherez rehulovani pishokhidni perekhody. Avtomobilnyi transport, vyp. 44, s. 40-49. https://doi.org/10.30977/AT.2219-8342.2019.44.0.40.

18.Buhaiov, I.S. Doslidzhennia orhanizatsii rukhu transportu i pishokhidiv na perekhresti zasobamy imitatsiinoho modeliuvannia / I. S. Buhaiov, V. V. Lohvinenko // Innovatsiini tekhnolohii rozvytku ta efektyvnosti funktsionuvannia avtomobilnoho transportu: Mizhnar. nauk.-prakt. internet-konf., 14-15 lystop. 2018 r., m. Kropyvnytskyi: zb. nauk. mater./M-vo osvity i nauky Ukrainy, Tsentralnoukrain. nats. tekhn. un-t, kaf. ekspluatatsii ta rem. mashyn.-Kropyvnytskyi: TsNTU, 2018.-S. 116-120.

Igor BUGAYOV, senior lecturer of Department of Transport Systems and Logistics Kharkiv National University of Urban Economy named after O.M. Beketov e-mail: igorbugayov1@gmail.com. https://orcid.org/0000-0002-9091-0248

*Olga KHOLODOVA**, Ph.D. in Engineering, Associate Professor, Assoc. Professor of Department of Traffic Management and Road Safety, Kharkiv National Automobile and Highway University, e-mail: olgakholodova280781@gmail.com. https://orcid.org/0000-0002-4217-0548.

*Maryna BUHAIOVA**, senior lecturer of Department of Traffic Management and Road Safety, Kharkiv National Automobile and Highway University, e-mail: kazmar2383@gmail.com. https://orcid.org/0000-0003-1889-9555.

Oleg KHOLODOV, first-year student, faculty of transport systems, Kharkiv National Automobile and Highway University, e-mail: kholodovoleg1408@gmail.com.

* Corresponding author.

Received 14 March 2024;
Accepted 29 April 2024
Available online 28 May 2024
DOI: 10.36910/conf_avto.v1i1.1389