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Road Bumps and Economic Losses in Traffic

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Abstract

More than 270,000 pedestrians die on the world's roads each year. Globally, pedestrians account for 22 per cent of total road traffic fatalities, and in the Republic of Belarus they account for about half of such fatalities. Currently, the main intervention to improve pedestrian safety is the use of road bumps. This is due to the low cost of implementation and high speed of work. At the same time, it should be understood that the use of road bumps reduces the speed of vehicles, which along with the reduction of accident losses gives an increase in environmental and economic losses in road traffic.

The aim of this article is to evaluate the impact of the use of road bumps on economic losses in road traffic by establishing the type of dependence between such losses and the parameters of traffic and pedestrian flows. Achievement of such a goal is made by collecting field data on the operation of real objects where road bumps are installed, simulation modelling of their operation, establishing a regression model between the dependent and independent variables.

Keywords: Road Bump, Road Safety, Traffic Flow Speed, Economic Losses in Road Traffic

1. Introduction

Road bumps (RB), also known as speed bumps or humps, are commonly used traffic calming measures installed on roads to reduce vehicle speeds and enhance safety, particularly in urban and residential areas [1]. These vertical undulations in the road surface aim to force drivers to slow down, thereby mitigating the risk of accidents and improving conditions for pedestrians and other vulnerable road users. As an important element of the transportation infrastructure, the evaluation of RB has been the subject of extensive research, focused on understanding their effectiveness, impact, and optimal design.

One of the primary objectives of installing RB is to reduce vehicle speeds, and a significant body of research has examined their efficacy in achieving this goal. A study by Li Cheng-bin [1] used a simulation approach to investigate the relationship between RB parameters, such as width and height, and their impact on vehicle dynamics and pavement. The findings suggest that common RB used on streets may not be suitable for installation on highways without modifications, as they require a minimum width of 600 mm and a reduced height to minimize impact on vehicles and pavement.

Similarly, Botha *et al.* [2] optimized the profile of a table-top speed hump to enhance ride comfort at speeds at or below the designed speed, while ensuring that the vehicle response remains within boundaries to reduce the possibility of injury or loss of vehicle control. This study highlights the importance of considering both speed reduction and passenger comfort when evaluating the effectiveness of RB.

Boscaino *et al.* [3] developed a dynamic model to analyze the effects of RB on the vertical path of vehicles, identifying scenarios in which drivers may lose adherence and the vehicle's safety may be compromised. These findings emphasize the need for careful design and placement of RB to mitigate potential safety risks.

Aboud *et al.* [4] evaluated the impact of RB with varying severity on traffic characteristics, such as speed, flow, and density. The study found that severe RB can lead to significant reductions in speed, up to 40% compared to the control section, and a corresponding decrease in traffic flow. These findings underscore the trade-offs between speed reduction and potential impacts on traffic flow that must be considered in the evaluation of RB.

Abdulrahman [5] assessed the impact of RB on highway traffic flow properties, observing a significant reduction in mean vehicle speed from 42.11 km/h on the free section to 9.21 km/h on the RB section, as well as a change in the level of service from 'A' to 'E'. These results suggest that while RB may be effective in urban areas, they may not be suitable for highways due to the significant disruption they can cause to traffic flow.

Overall, the literature reveals that while RB can be effective in reducing vehicle speeds, their impact is often localized, and their suitability depends on the specific road context and the balance between speed reduction, safety, and traffic flow considerations.

In addition to their impact on vehicle speeds, the installation of RB can also affect vehicle dynamics, leading to vibrations, shocks, and impacts that can influence ride quality, vehicle wear and tear, and the potential for driver and passenger discomfort or injury.

Saeed and Dougherty [6] reviewed the use of smartphones and their sensors, such as accelerometers, in detecting road surface conditions, including RB and potholes. This approach offers a cost-effective way to monitor road conditions and identify areas in need of maintenance or improvement, which can inform the evaluation of RB effectiveness.

Daraghmi *et al.* [7] proposed a crowdsourcing-based approach to evaluate and index road surface quality, including the identification of RB, using power spectral density and blind source separation techniques to eliminate the effects of vehicle characteristics. This method provides a more comprehensive and user-centric assessment of road conditions, which can be valuable in evaluating the impact of RB on the overall road network.

The Pros and Cons of RB article [8] highlights some of the potential negative impacts of RB, such as increased vehicle wear and tear, risks to emergency vehicles, and the potential for accidents if drivers attempt to avoid them. These considerations are crucial in evaluating the overall impact of RB on the transportation system.

Similarly, Sutradhar [9] and Bridgelall [10] explored the use of various technologies, such as RB integrators and connected vehicle sensors, to detect and localize road surface irregularities, including RB. These approaches can provide valuable data for assessing the impact of RB on vehicle dynamics and ride quality, which are important factors in their evaluation.

The review of these studies suggests that the impact of RB on vehicle dynamics and ride quality is a critical aspect of their evaluation, as it can have significant implications for vehicle maintenance, passenger comfort, and overall transportation system efficiency.

In addition to their effects on vehicle dynamics and traffic flow, the installation of RB can also have implications for the surrounding environment, including noise levels and emissions.

Toplak and Sever [11] used ANFIS (Adaptive Neuro-Fuzzy Inference System) modeling to predict and evaluate the harmful effects of vehicles crossing RB, including increased emissions and ground-borne vibrations. The study found that setting up RB in different locations can significantly increase the level of harmful emissions and ground-borne vibrations, suggesting the need to carefully consider the environmental impacts when evaluating the use of RB.

The GOFAR article [12] and the Sino Concept article [13] further highlight the potential negative impacts of RB, such as increased fuel consumption, vehicle damage, and environmental pollution. These considerations are crucial in assessing the holistic impact of RB on the transportation system and the surrounding environment.

The research by Distefano and Leonardi [14] specifically examines the effect of RB in sequence on noise emission levels from motor vehicles. The study found that the impact of vehicles on the bumps generates noise that can be annoying to residents, emphasizing the need to consider the acoustic implications of RB installations.

These findings underscore the importance of evaluating the environmental and noise impacts of RB, as they can have significant consequences for the local community and the broader transportation network.

Researchers have employed various approaches to evaluate the effectiveness and impacts of RB, ranging from simulation-based studies to field observations and user-based assessments.

Simulation-based studies, such as the work by Li Cheng-bin [1] and Boscaino *et al.* [3], have used computer models to analyze the vehicle-road interaction and predict the dynamic effects of RB. These approaches allow for controlled experiments and the exploration of a wide range of scenarios, but their accuracy relies on the fidelity of the simulation models to real-world conditions.

Field-based studies, on the other hand, involve direct observations and measurements of vehicle behavior and road conditions. For example, Aboud *et al.* [4] and Abdulrahman [5] conducted observational studies to evaluate the impact of RB on traffic characteristics, while Saeed and Dougherty [6] and Daraghmi *et al.* [7] explored the use of smartphone-based sensors for road surface monitoring.

User-based assessments, such as surveys and interviews, provide valuable insights into the perceptions and experiences of road users regarding RB. The Sino Concept article [15] and the Insure 2 Drive article [16] discuss the advantages and disadvantages of RB from the perspective of drivers, highlighting factors like damage to vehicles, travel time, and user comfort.

The combination of simulation, field observations, and user-based assessments offers a comprehensive approach to evaluating the multifaceted impacts of RB, allowing researchers and transportation professionals to make informed decisions about their implementation and design.

As the research on RB evaluation continues to evolve, several emerging trends and future research directions can be identified from the reviewed literature.

One key trend is the increasing use of smart technologies and crowdsourcing approaches for road surface monitoring and bump detection. Studies by Saeed and Dougherty [6], Daraghmi *et al.* [7], and Nguyen *et al.* [17] highlight the potential of smartphone-based sensors and machine learning algorithms to provide cost-effective and widespread assessment of road conditions, including the identification of RB. Further development and validation of these techniques can significantly enhance the ability to evaluate the prevalence and impact of RB across transportation networks.

Another emerging trend is the exploration of alternative traffic calming measures that may offer more effective or less disruptive solutions compared to traditional RB. The Sino Concept article [18] and the Reliance-foundry article [19] discuss various options, such as rumble strips, speed tables, and dynamic/smart RB, which may address some of the drawbacks associated with conventional RB. Comparative evaluations of these alternative measures can provide valuable insights for transportation decision-makers.

Moreover, the research indicates a need for the development of more comprehensive and standardized evaluation frameworks that can account for the multidimensional impacts of RB, including their effects on vehicle dynamics, traffic flow, safety, environmental factors, and user perceptions. The work by Toplak and Sever [11] and the study by Alenezi and Mohammed [20] demonstrate the value of integrated approaches that consider the interactions between vehicle, road, and human factors.

Finally, the literature review highlights the importance of context-specific evaluations, as the suitability and impacts of RB can vary significantly based on factors such as road type, traffic characteristics, and local regulations. Further research on the implementation of RB in diverse transportation settings, particularly in developing countries where their usage may differ from developed nations, can provide valuable insights for practitioners and policymakers.

The reviewed literature indicates that while RB can be effective in reducing vehicle speeds, their impact is often localized, and their suitability depends on the balance between speed reduction, safety, traffic flow, and other considerations. The evaluation of RB must also account for their effects on vehicle dynamics, ride quality, environmental factors, and user perceptions. The research also highlights the growing importance of smart technologies and crowdsourcing approaches for road surface monitoring and bump detection, as well as the need for more comprehensive and standardized evaluation frameworks that can capture the multidimensional impacts of RB. As transportation systems continue to evolve, the evaluation of RB will remain a critical area of research, informing the development of effective and sustainable traffic calming measures that enhance safety, improve user experience, and minimize negative environmental impacts. The insights gained from this literature review can serve as a valuable foundation for future research and practical applications in this field.

2. Goal setting

It should be realised that the speed reduction associated with the use of an RB has an economic cost as well as a safety benefit. This is due to the fact that when passing an RB, the driver reduces speed and then, after passing it, accelerates again. This results in overconsumption of fuel and increased time for overcoming the street section. At the same time, the greater the intensity of traffic flow, the greater will be the value of such losses. Therefore, the purpose of this article is to assess the impact of the use of RB on economic losses in traffic by establishing the type of dependence between such losses and the parameters of traffic and pedestrian flows.

3 Main part

As objects of the study 5 RB were selected, located at unregulated pedestrian crossings on some streets in Gomel, Republic Belarus. The intensity of traffic and pedestrian flow by hours of the day, as well as geometric characteristics of these objects were determined for these objects. All this served as a basis for creating simulation models of the studied pedestrian crossings in the PTV Visim software product. With the help of such models, the operation of the study objects was simulated and the values of delays and stops of vehicles at them, as well as their costs were determined (Table 1).

Table 1: Pedestrian crossing modelling results (excerpt)

Time	Place	Pedestrian crossing 1	Pedestrian crossing 2	Pedestrian crossing 3	Pedestrian crossing 4	Pedestrian crossing 5
Number of lanes		4	3	4	3	4
07:00–8:00	Intensity of traffic flow, Q, vehicle/hour	1056	726	1194	948	624
	Pedestrian intensity, P, pedestrians/hour	96	36	60	174	390
	RB losses, USD/hr	2,505	1,009	3,334	2,720	8,209
	Losses without RB, USD/hr	1,162	0,499	1,062	1,066	4,865
	Losses due to RB, L, USD/hr	1,344	0,510	2,273	1,654	3,345

Based on the data obtained in this way, a graphical representation of the dependence of losses in traffic from the installation of RB(L, USD/hr) on the intensity of traffic (Q, units/hour) and pedestrian (P, pedestrians /hour) flows was constructed (Fig 1).

Multiple non-linear regression analysis implemented in [21] was used to establish the type of dependence L = f (Q, P). The results of this analysis are presented in Table 2. Table 2 shows that the dependence sought is of the form:

$$L = -0.849627 + 0.000002\, Q^2 + 0.000021 P^2, \qquad (1)$$

It can also be seen that the value of the correlation coefficient is 0.855, which indicates a high degree of relationship between the dependent and independent variables. The value of the coefficient of determination equal to 0.731 indicates that more than 73% of the values of the dependent variable are explained by the values of the independent variables. The values of confidence levels (p-level) are less than 0.05, both in general for the model and for each of its independent variables, which indicates that the obtained model and its coefficients are statistically significant.

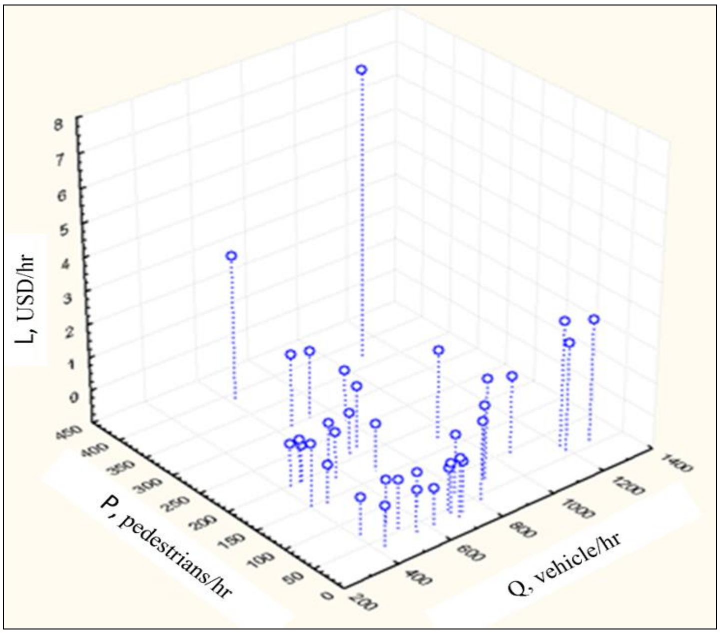

Fig 1: Relationship between the intensity of traffic (Q) and pedestrian (P) flow and the value of economic losses in road traffic due to the installation of RB (L)

Table 2: Results of Multiple Nonlinear Regression

Regression Summary for Dependent Variable: L (Spreadsheet1) R= ,85467965 R^2= ,73047730 Adjusted R^2= ,71363213 F(2,32)=43,364 p<0,05						
	Beta	Std.Err.	B	Std.Err.	t(32)	p-level
Intercept			-0,849627	0,247	-3,436	<0,05
Q^2	0,657	0,092	0,000002	0,000	7,159	<0,05
P^2	0,558	0,092	0,000021	0,000	6,076	<0,05

The distribution of residuals is similar to the normal distribution law, which indicates the adequacy of model (1). Thus, model (1) can be used to predict the additional economic losses in traffic arising from the installation of RB.

The obtained expression 1 can be used to assess the feasibility of applying RB at a particular pedestrian crossing. For this purpose, it is necessary to calculate the intensity of traffic and pedestrian flows at such a crossing and substitute them into expression 1. Thus, obtained value of additional economic losses due to installation of RB should be compared with the value of reduction of accidental losses. If the reduction of accident losses will be higher than the increase in economic losses, it is possible to speak about expediency of application of the RB. Graphically the essence of the above comparison is presented in Fig 2.

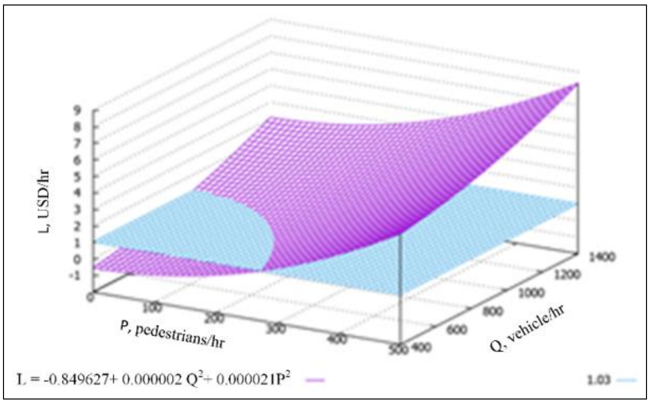

Fig 2: Graph of dependence of economic losses and accidental losses with 1 casualty

In Fig 2, the horizontal plane represents the magnitude of the savings in annual accident losses due to the installation of the RB. In this example it is one accident with injured people. The inclined plane shows the expression (1), i.e. the amount of economic losses that arise due to the installation of RB. It can be seen that such losses increase with increasing intensity of both traffic and pedestrian flow, and these planes intersect to form two sets of values of such intensities:

Set 1: The intensities of traffic and pedestrian flows at which the plane showing equation (1) is below the plane showing the decrease in accident losses.

Set 2: Intensities of traffic and pedestrian flows at which the plane showing equation (1) is above the plane showing reduction of accident losses.

If at the object under study the values of intensity of traffic and pedestrian flows fall into set (1), i.e. the value of increase in economic losses from the introduction of RB is less than the value of reduction of accident losses (horizontal plane in Fig 6 above), then the use of RB can be considered appropriate.

4. Conclusions

This publication considers the urgent task of assessing the impact of the use of pedestrian crossings on the growth of economic losses in road traffic. For such an assessment, a number of pedestrian crossings in Gomel city, where pedestrian crossings are installed, were surveyed. Based on the results of such a survey, their simulation models were built, which were used to estimate the amount of economic losses in traffic accidents from the use of RB (Table 1, Fig 1). A methodology for determining the feasibility of applying RB based on the assessment of the difference between the reduction in accident losses and the increase in economic losses from such application is presented, as well as its graphical interpretation (Fig 2).

5. References

1. Li Cheng-bin. Effects of speed bumps cross-section parameters on impact on pavement and vehicle. None, n.d. Doi: None.
2. Botha T, Els PS, Uys PE, Rudolf Bester. Profile Optimization of Table Top Speed Hump for Speed Control. None, n.d. Doi: 10.1115/DETC2011-48062
3. Gabriele Boscaino, Galuppo G, Claudia Rinoldo, Boscaino G, Galuppo G, Rinoldo C. Analysis of the Effects of Speed Bumps on Vehicle Vertical Path. None, n.d. Doi: None.
4. Aboud GM, Khaled T, Taher E, Hashim I, Al-Humeidawi BH, Evaluation of Speed, Flow, and Density Performance under Different Severity of Speed Bumps. None, 2023. Doi: 10.1088/1755-1315/1232/1/012059.
5. Abdulrahman H. The Impact of Road Bumps on Highway Macroscopic Traffic Flow Properties. None, n.d. Doi: None.
6. Academia. (PDF) A Review of Intelligent Methods for Unpaved Roads Condition Assessment | Nausheen Saeed and Mark Dougherty - Academia.edu. Internet, n.d. https://www.academia.edu/44572803/A_Review_of_Intelligent_Methods_for_Unpaved_Roads_Condition_Assessment.
7. Yousef-Awwad Daraghmi, Tsung-Hsiang Wu, Ts-U k. Crowdsourcing-Based Road Surface Evaluation and Indexing. None, 2022. Doi: 10.1109/tits.2020.3041681.
8. Ablison. Pros and Cons of Speed Bumps | Ablison. Internet, n.d. https://www.ablison.com/pros-and-cons-of-speed-bumps/.
9. Academia. (PDF) Pavement Roughness Prediction Systems: A Bump Integrator Approach | RUMI SUTRADHAR - Academia.edu. Internet, n.d. https://www.academia.edu/66076299/Pavement_Roughness_Prediction_Systems_A_Bump_Integrator_Approach.
10. Raj Bridgelall. Precision Bounds of Pavement Distress Localization with Connected Vehicle Sensors. American Society of Civil Engineers, 2015. Doi: https://doi.org/10.1061/(asce)is.1943-555x.0000234.
11. Toplak S, Sever D. Anfis Prediction and Modelling of Harmful Effects on the Environment Produced by Vehicles Crossing Road Bumps. None, 2018. Doi: 10.2495/HPSM180211.
12. GOFAR. Speed Bumps: A Closer Look at Their Negative Impact | GOFAR. Internet, n.d. https://www.gofar.co/blog/gofar-blog-read-us/.
13. Mamontov A, Oleksandr Ostroverkh, Kozhushko A, Serhii Kryvoshapov. Simulation of Road Surface Impurities Taking into Account the Smoothing Capacity of Tires. Bulletin of the National Technical University KhPI. Series: Automobile and Tractor Construction, 2024. Doi: 10.20998/2078-6840.2024.1.11.
14. Distefano N, Leonardi S. Experimental investigation of the effect of speed bumps in sequence on noise emission level from motor vehicles. None, 2015. Doi: 10.3397/1/376352.
15. Insure2Drive. Driving in areas with traffic calming measures - Insure 2 Drive. Internet, n.d. https://insure2drive.co.uk/news-advice/drive-in-traffic-calming-measures/.
16. Sino Concept. Important Facts about Speed Humps Effectiveness | Sino Concept. Internet, n.d. https://www.sinoconcept.co.uk/purchasing-guides/everything-about-speed-humps/traffic-calming-humps-pros-cons/speed-humps-effectiveness/.
17. Teron Nguyen, Bernhard Lechner, Yiik Diew Wong. Response-based methods to measure road surface irregularity: A state-of-the-art review. Springer Science+Business Media, 2019. Doi: https://doi.org/10.1186/s12544-019-0380-6.
18. Sino Concept. What do traffic calming measures do? | Sino Concept. Internet, n.d. https://www.sinoconcept.co.uk/purchasing-guides/everything-about-speed-bumps/traffic-calming-options/traffic-calming-measures/.
19. Reliance-foundry. Speed Bumps vs. Speed Humps for Traffic Calming. Internet, n.d. https://www.reliance-foundry.com/blog/speed-humps-vs-speed-bumps.
20. Asmaa Alenezi, Mohammed A. Study of the dynamic response of a quarter car model coupled with a human passenger for different speed bumps profiles. None, 2024. Doi: 10.1177/09574565241243397.
21. Statistica 13.3 (Serial number JRR709H998119TE-A).