TRANSPORT & *LOGISTICS:*
the International Journal
ISSN 2406-1069

Article history:
Received 20th June 2024
Accepted 26th June 2024
Available online 27th June 2024
DOI: 10.46544/TNL.v24n56.07

Article citation info: Rigó, L., Ligárt, D., Solving traffic congestion with a turbo-roundabout using PTV Vissim. Transport & Logistics: the International Journal, 2024; Vol. 24, No. 56, https://doi.org/10.46544/TNL.v24n56.07

Solving traffic congestion with a turbo-roundabout using PTV Vissim

Ladislav Rigó [1*], Daniel Ligárt [1]

[1] Technical University of Kosice, Faculty of Mining, Ecology, Process Control and Geotechnologies, Park Komenskeho 19, 042 00 Kosice, Slovakia, e-mail: daniel.ligart@student.tuke.sk, ladislav.rigo@tuke.sk

[*]Corresponding author: ladislav.rigo@tuke

Abstract:
The article focuses on the analysis, modeling, and simulation of traffic on a section of the road network in the city of Košice, in the Šaca district. The paper aims to address traffic congestion by replacing the X-shaped intersection with a turbo-roundabout. The intersection model and traffic simulations are conducted using the PTV Vissim software. The model will enable the prediction and evaluation of traffic in that road section. The model monitors the dynamics of the transport node, focusing mainly on the analysis of traffic flow and the identification of critical points in the road network. In addition, a proposal for measures was created and a traffic simulation was carried out to verify the effectiveness of the proposed solution.

Key words:
traffic, simulation, congestion, turbo-roundabout, PTV VISSIM

Introduction

With the advent of personal motorized transport and the increasing number of means of transport on the roads, traffic congestion often occurs in some sections. In increasingly large cities, the mentioned phenomenon is seemingly unavoidable (Zhao et al., 2022). The resulting congestions have an adverse effect not only on the transport system of the place (city) from the point of view of the economy but also on environmental degradation (pollution from exhaust gases), (Afrin and Yodo, 2020). Depending on the type of road network, congestion can sometimes be avoided by various measures. The most common of these include widening the road, replacing the intersection with a roundabout, or even charging a section of road, which can logically lead to a reduction in traffic intensity (González-Aliste et al., 2023), (Gkyrtis and Kokkalis, 2024).

An effective method for minimizing traffic congestion is the use of simulation tools (Pell et al., 2017). Several simulation tools are available to deal with traffic situations depending on the requirements, for example, Zochowska et al. (2022) used the universal simulation tool ExtendSim, preferably used for continuous and discrete simulation. On the other hand, Harantová et al. (2021) used mathematical and logical relations, which represent parts of the simulated system. The most frequently used simulation tools are PTV Vistro, PTV Vissim, PTV VISUM, and AIMSUN. For instance, Ziemska-Osuch et al. (2022) used PTV Vissim in the modeling and simulation, and also Dobrota et al. (2023) applied PTV Vissim and PTV Vistro to optimize the signal parameters. To analyze the impact of both an electric car and a conventional car on energy consumption, energy cost, etc. Muzir et al. (2023) choose AIMSUN.

The present article aims to examine the use of the PTV Vissim simulation tool to improve the throughput of the intersection and test the proposed solution.

1 Methods and methodology

From a wide range of software tools, we effectively tackle traffic congestion by running simulations through the PTV Vissim program. Simulation tools are great for data processing and help arrive at the best possible solution. At the same time, they allow us to visualize and graphically materialize our designs (Alghamdi et al., 2021).

1.1 Study area overview

The analysis of traffic on a selected section of the road network provides important knowledge about the intensity of the traffic flow, vehicle driving patterns, as well as the occurrence of congestion, and critical points, which makes it possible to identify potential problems and propose effective measures to improve the flow of traffic and safety on the given section.

The selected section of the road network is located in Šaca (Fig. 1). Šaca is a part of the city of Košice and is located in the Košice region in eastern Slovakia. Approximately 5,690 inhabitants live here. However, the number of people in the township may be higher than the population, as it is home to a high school and many businesses, as well as the largest employer in eastern Slovakia: U.S. Steel Košice. Šaca is 15 kilometers from the center of Košice and is connected by the international road I/16. Road I. class no. 16 runs through the cities of Zvolen, Lučenec, Rožňava and Košice and its total length is 197,032 km.

***Fig. 1** Šaca area*

The description of the selected section of the road network provides a detailed picture of the transport infrastructure in the given place, emphasizing its structure, composition of lanes and the importance of the intersection between Buzinská Street and Železiarenská Street as a critical node in the transport network (Fig. 2).

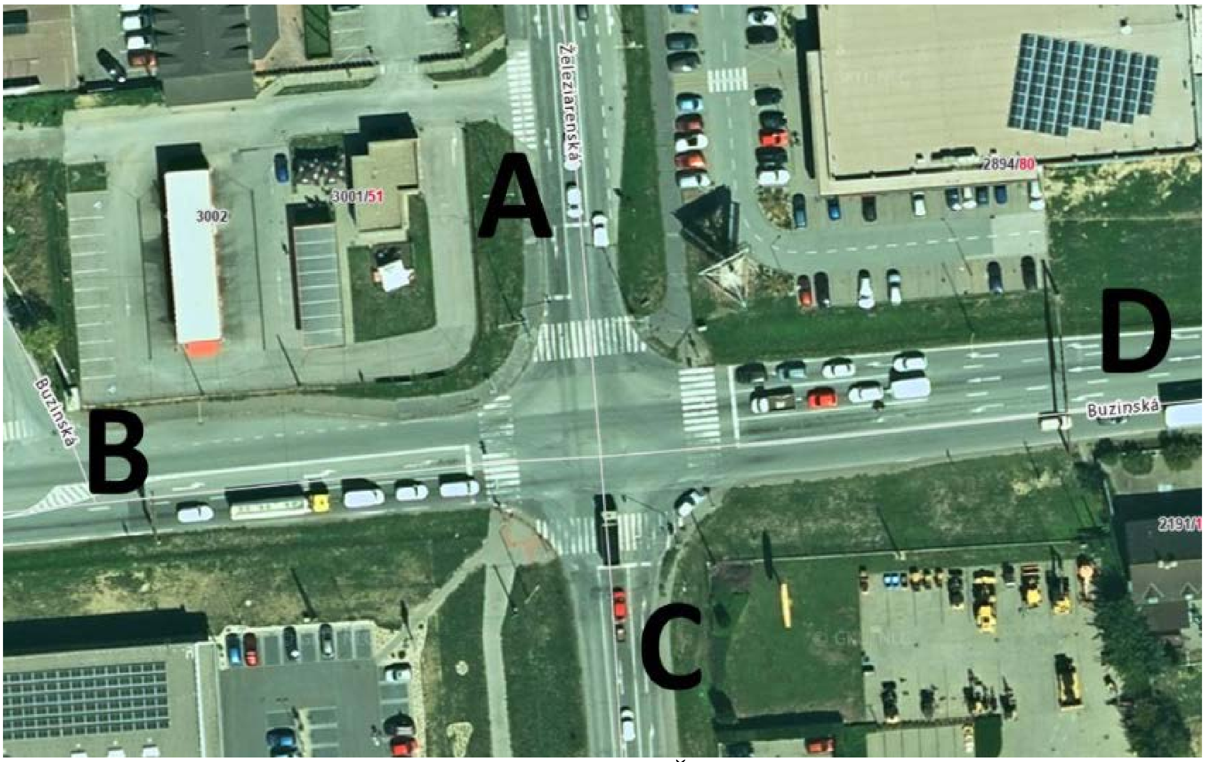

Fig. 2 *Section of the Šaca road network*

The individual parts of the intersection are marked using letters of the alphabet. In the picture, it is possible to see how the main road (B, D) is crossed by a secondary road (A, C). The secondary road marked with the letter A leads to the village of Malá Ida. The main road marked with the letter B leads to Moldava nad Bodvou. The secondary road marked with the letter C leads to the village of Veľká Ida and the main road marked with the letter D leads to the city of Košice. Around the intersection, we can find grocery stores (Fresh, Lidl) that encourage visitors and the use of side roads.

1.2 Research method

The collected real data will be used in the creation of the simulation model. There will be a comparison of the existing situation against the proposed solution (Fig. 3). The proposed solution is the creation of a turbo-roundabout in the given section.

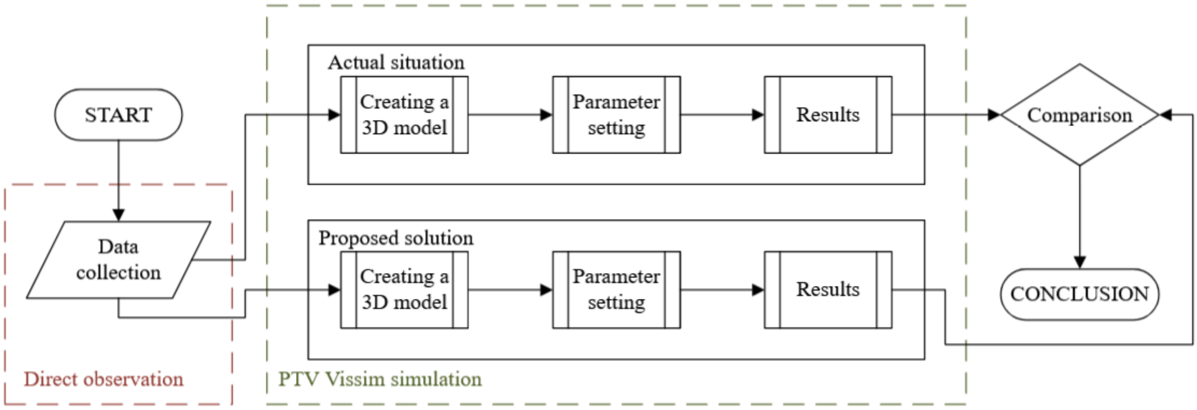

Fig. 3 *Block diagram of the study*

2 Results

2.1 Analysis of traffic intensity

The analysis of traffic intensity on a selected section of the road network provides detailed values about the number of vehicles that pass through this section of the road at different times of the day. The intensity of traffic in Šaca for this intersection (obtained from the traffic census 2022) shows that the heaviest traffic is on the I/16 road at Buzinská street, which is the main drag. This road is mostly used by passenger cars. The data listed in Tab. 1 show the intensity of traffic in 24 hours (Tab. 1).

Tab. 1 *Traffic intensity on the examined section*

Road markings according to Fig. 2	T – trucks	O – cars	M - motorcycles	SUM
C	686	3323	16	4025
A	601	4955	21	5577
D	3400	17605	67	21072
B	2472	11756	45	14273

Source: (National traffic census, 2022)

To compare the results, the quality of the movement of the traffic flow is defined – QSV (Tab. 2).

Tab. 2 *Threshold values of the average waiting time for determining the quality level*

QSV	Average waiting time (s.)
A – very short waiting times	≤ 20
B – short waiting times	≤ 35
C – longer waiting times	≤ 50
D – long waiting times for all participants	≤ 70
E – very long waiting times	≤ 100
F – extremely long waiting times, the intersection is congested	> 100

2.2 Simulation model of the current situation and results

The creation of a simulation model includes the creation of a virtual representation of the transport system, which takes into account its structure, parameters and the behaviour of vehicles in different traffic conditions (Fig. 4 - a, b,).

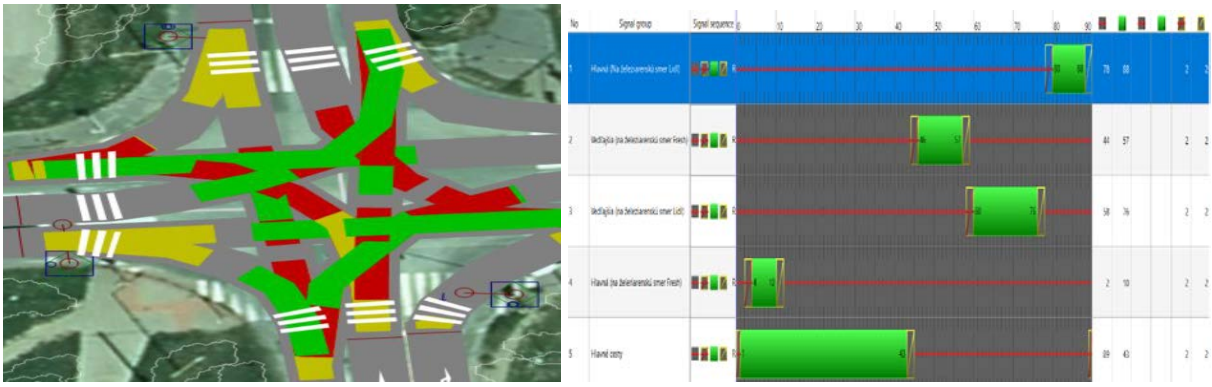

Fig. 4 - a *Determination of conflict zones of the intersection;* ***- b*** *Light signalling time mode*

Based on the set parameters, a simulation takes place, which can also be watched in a 3D environment (Fig. 5).

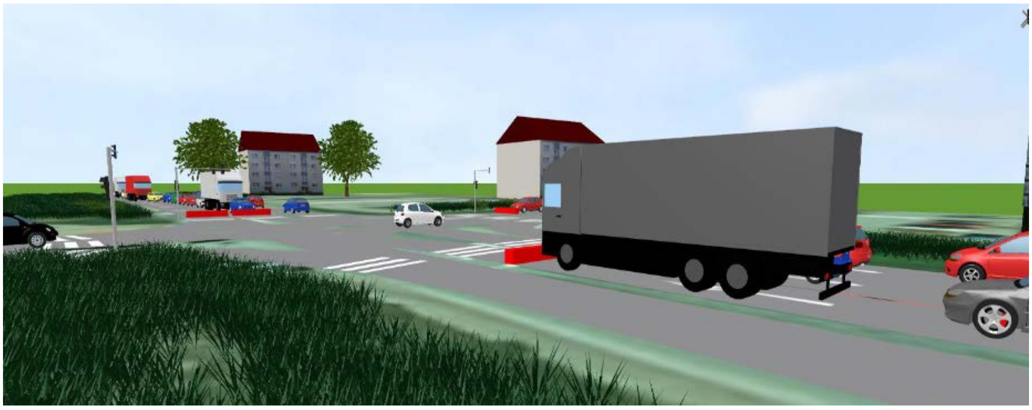

Fig. 5 *Traffic simulation in the PTV Vissim software in a 3D environment*

The result of the simulation is the measured values QSV (Tab. 3).

Tab. 3 *Average vehicle delay, current situation*

Section, Fig. 2.	Direction	Average vehicle delay (s)	Rating QSV
	B	26,38	B
A	C	28,85	B
	D	34,77	B
	A	50,54	D
B	C	18,96	A
	D	19,25	A
	A	43,99	C
C	B	43,53	C
	D	19,08	A
	A	18,98	A
D	B	23,66	B
	C	55,30	D

2.3 Simulation model of the proposed situation and results

The proposed solution for this intersection is a turbo-roundabout (Fig. 6). The Turbo Roundabout is an innovative two-lane roundabout layout that has revolutionized roundabout design since 1998 in the Netherlands. Entering and exiting the previously used two-lane roundabout can be complicated for road users, which in turn leads to road safety problems. The turbo-roundabout concept eliminates some of the most serious points of conflict in a roundabout.

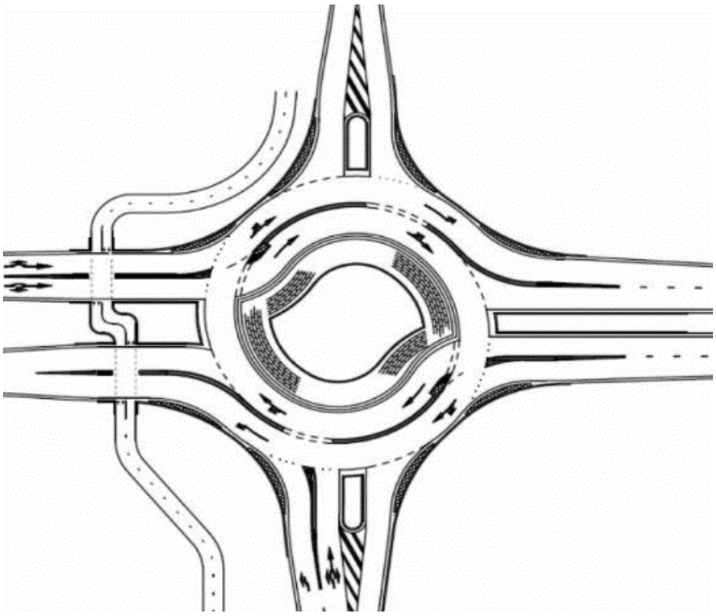

Fig. 6 *Turbo-roundabout* (Engelsman and Uken, 2007)

A quick scan model shows that the capacity of a turbo roundabout is 25-35% higher than a standard two-lane roundabout (Fig 7). The most important element of the turbo roundabout is the spiral lane marking to eliminate the need to cross into other lanes. The result is an increase in road traffic safety, as well as an increase in the capacity of the roundabout (Engelsman and Uken, 2007).

Fig. 7 *Simulation of a turbo-roundabout*

The result of the simulation is the measured values QSV (Tab. 4).

Tab. 4 *Average vehicle delay, proposed solution*

Section, Fig. 2.	Direction	Average vehicle delay (s)	Rating QSV
A	B	8,01	B
	C	16,75	B
	D	16,19	B
B	A	8,68	D
	C	3,59	A
	D	7,00	A
C	A	17,34	C
	B	18,55	C
	D	1,34	A
D	A	5,49	A
	B	5,78	B
	C	5,03	D

2.4 Comparison of results

By subsequently comparing the results, we will get a comprehensive overview of the impacts of the proposed solution (Tab. 5). It clearly shows that the proposed solution has its meaning and its application would be beneficial in practice.

Tab. 5 *Comparison of results*

Section, Fig. 2.	Direction	Average vehicle delay (s), current situation	Average delay of vehicles (s), proposed solution	% acceleration
A	B	26,38	8,01	33%
	C	28,85	16,75	17%
	D	34,77	16,19	21%
B	A	50,54	8,68	58%
	C	18,96	3,59	53%
	D	19,25	7,00	28%
C	A	43,99	17,34	25%
	B	43,53	18,55	23%
	D	19,08	1,34	142%
D	A	18,98	5,49	35%
	B	23,66	5,78	41%
	C	55,3	5,03	110%

3 Discussion and Conclusions

The aim of the article was to use one of the many simulation tools to increase the quality of traffic in a selected section of the road network. By choosing the Vissim program from the PTV Group company, we managed to successfully implement the assigned task.

From the performed simulations, we have come to the conclusion that by replacing the classic intersection controlled by light traffic markings with a turbo roundabout, we will significantly increase the throughput of the road section. The minimum percentage acceleration of passing through the section was 17%, while the maximum value was 110%, this represents a jump in the QSV (quality of traffic flow) rating from D (waiting times for all participants are long) to A (waiting times are very short). It is obvious that simulations in the area of solving traffic congestion make sense and are a welcome means of modifying selected sections of roads and road junctions.

Although the results presented in the previous sections show that the analyzed transit node is not very permeable in terms of capacity, and in case of extraordinary load there are long waiting times, it is always appropriate to think about whether it is realistic or possible to achieve a change without significant construction modifications or at high financial costs. For example, if we look at how to increase the capacity of a standard traffic structure such as a road or an intersection, it often happens that only additional lanes are added, or those lanes are widened, which often leads to disproportionate use of land, and disproportionate high financial investments (Krivda et al., 2021). In some specific cases, when it is not possible to expand the road network in a given section, the only suitable solution is a roundabout.

The conclusion of this article is, as several scientific works already indicate, that the future lies in replacing classic intersections with turbo-roundabouts (Sołowczuk and Benedysiuk, 2023). At the same time, these turbo roundabouts are safer and smoother than classic intersections with or without traffic lights (Sołowczuk and Majer, 2023).

Computer simulation presents a highly useful tool to resolve transport issues and should be applied as much as possible (Yu et al., 2019.). Experts in transport and infrastructure should consider simulation models as invaluable working tools as Mikušová et al. (2021) mentioned.

Acknowledgement

This paper was developed within implementation of the projects: KEGA_010ŽU-4/2023, KEGA_005TUKE-4/2022, VEGA 1/0674/24, APVV-21-0195, and the operational program Integrated infrastructure with ITMS: 313011T567.

References

Afrin, T. and Yodo, N., 2020. A Survey of Road Traffic Congestion Measures towards a Sustainable and Resilient Transportation System, *Sustainability,* 12(11), 4660.

Alghamdi, T., Mostafi, S., Abdelkader, G. and Elgazzar, K., 2021. A Comparative Study on Traffic Modeling Techniques for Predicting and Simulating Traffic Behavior. *Future Internet,* 14(10), 294.

Dobrota, N., Stevanovic, A., Yang, Y. and Alshayeb, S., 2023. Investigation of Resonant Signal Timing Plans through Comprehensive Evaluation of Various Optimization Approaches. *CivilEng*, 4(2), pp.416-432.

Engelsman, J. C. and Uken, M., 2007. Turbo roundabouts as an alternative to two-lane roundabouts. In: *Proceedings of the 26th Southern African Transport Conference (SATC 2007),* pp.81-589.

Gkyrtis, K. and Kokkalis, A., 2024. An Overview of the Efficiency of Roundabouts: Design Aspects and Contribution toward Safer Vehicle Movement. *Vehicles,* 6(1), pp.433-449.

González-Aliste, P., Derpic, I. and López, M., 2023. Reducing Urban Traffic Congestion via Charging Price. *Sustainability,* 15(3), 2086.

Harantová, V. Kalašová, A. and Kubíková, S., 2021. Use of Traffic Planning Software Outputs When a New Highway Section Is Put into Operation. *Sustainability*, 13(5), 2467.

Krivda, V., Petru, J. Macha, D. and Novak, J., 2021. Use of Microsimulation Traffic Models as Means for Ensuring Public Transport Sustainability and Accessibility. *Sustainability*, 13(5), 2709.

Mikušová, N., Fedorko, G., Molnár, V., Hlatká, M., Kampf, R. and Sirková, V., 2021. Possibility of a Solution of the Sustainability of Transport and Mobility with the Application of Discrete Computer Simulation-A Case Study. *Sustainability*, 13(17), 9816.

Muzir, N. A. Q., Hasanuzzaman, Md and Selvaraj, J., 2023. Modeling and Analyzing the Impact of Different Operating Conditions for Electric and Conventional Vehicles in Malaysia on Energy, Economic, and the Environment. *Energies*, 16(13), 5048.

Pell, A., Meingast, A. and Schauer, O., 2017. ScienceDirect-Review under Responsibility of World Conference on Transport Research Society. ScienceDirect Trends in Real-Time Traffic Simulation-Review under Responsibility of World Conference on Transport Research Society. *Transportation Research Procedia,* 25, pp.1477–1484.

Sołowczuk, A. B. and Benedysiuk, W., 2023. Design of Turbo-Roundabouts Based on the Rules of Vehicle Movement Geometry on Curvilinear Approaches. *Sustainability*, 15(18), 13882.

Sołowczuk, A. and Majer, S., 2023. Design Study for the Construction of Turbo Roundabouts under Constrained Site Conditions. *Sustainability*, 15(17), 13220.

Yu, B., Wu, M., Wang, S. and Zhou, W., 2019. Traffic Simulation Analysis on Running Speed in a Connected Vehicles Environment. *Int. J. Environ. Res. Public Health*, 16(22), 4373.

Ziemska-Osuch, M. and Osuch, D., 2022. Modeling the Assessment of Intersections with Traffic Lights and the Significance Level of the Number of Pedestrians in Microsimulation Models Based on the PTV Vissim Tool. *Sustainability*, 14(14), 8945.

Zhao, X., Hu, L., Wang, X. and Wu, J., 2022. Citation: Study on Identification and Prevention of Traffic Congestion Zones Considering Resilience-Vulnerability of Urban Transportation Systems. *Sustainability*, 14(24), 16907.

Zochowska, R., Jacyna, M., Bindzar, P., Macuga, D., Brodny, J., Tutak, M. and Malindzakova, M., 2022. Use of Universal Simulation Software Tools for Optimization of Signal Plans at Urban Intersections. *Sustainability*, 14(4), 2079.