TRANSPORT TECHNOLOGIES

Vol. 5, No. 1, 2024

Stepan Plesak*
Lviv communal enterprise "Lvivavtodor"
7, Pasiky Halutski Str., Lviv, 79000, Ukraine

© S. Plesak, 2024
https://doi.org/10.23939/tt2024.01.001

STUDYING THE EFFECTIVENESS OF PROJECT SOLUTIONS USING THE TRANSPORT MODELING

Summary. *One of the factors that lead to an increase in congestion on the road network is the growth of motorization levels in the city. Under such conditions, the number of private vehicles on city streets is increasing as delays at intersections and queues. As a result, the passage of the intersection is delayed, as drivers are forced to wait longer for their turn. When reconstructing a street or road, it is proposed to change the traffic management, the number of lanes and the configuration of some intersections to solve the problems described above. However, after the project is implemented, traffic flows are mostly redistributed, and the proposed changes may not be effective. It is imperative to conduct transport modeling, which allows checking the effectiveness of decisions and adjusting the project in the early stages, but not after implementation, to prevent the negative impact of such situations. When performing transport modeling, unnecessary investments that may arise after implementing the project can be avoided, or the feasibility of its implementation can be checked.*

The object of research is a section of the road network located in a settlement. It is worth noting that all approaches to intersections have high traffic volumes, which should be taken into account when creating project documentation. This article presents a design solution that includes reconfiguring the intersection, increasing the number of lanes, and conducting transport microscopic modeling of the existing and projected conditions to determine the effectiveness of changing the traffic management on the studied section of the road network. According to the results of the microscopic modeling, delays and queues on the approaches to the intersection have been reduced, which indicates that the decision was correct. PTV VISSIM software was used to perform transport modeling. After testing the simulation model and analyzing the results, it is possible to assess the impact of design decisions on the road network and, if necessary, make adjustments.

Key words: *level of congestion, traffic delays, queues before intersections, transport modeling, project documentation, simulation model, traffic management.*

1. INTRODUCTION

An increase in motorization levels, especially in large cities, leads to increasing vehicle traffic and congestion on the road network. It, in turn, leads to longer traffic queues and delays on the approaches to intersections, congestion on city streets, longer travel times on a street or road section, and increasing traffic conflicts and accidents [1]. Also, under such conditions, the convenience of driving is significantly reduced as vehicle drivers have to wait longer to pass the intersection in traffic jams [2]. Therefore, it is also worth paying attention to the environmental factor, since as the amount of traffic and the time it takes for vehicles to pass a section of the street to get through the queue increases, so do the emissions of harmful substances into the air, which negatively affects the environment.

* *Corresponding author. E-mail: plesakstepan@gmail.com*

There are several ways to solve these problems. One of them is to reconstruct streets and increase the number of traffic lanes for private vehicles, which will increase traffic capacity and reduce traffic delays. Also, residents should be encouraged to use public transportation to reduce the number of private transport in the city. However, it is necessary to ensure passenger comfort, which includes the following factors: ensuring adherence to schedules, short intervals between trips, and speed of travel to achieve this effect. To fulfil these conditions, a sufficient number of vehicles on the route and allocating dedicated lanes for public transport are necessary. At the same time, it is becoming clear that the uneven development of residential areas and the limited infrastructure capabilities of municipalities will not provide a level of mobility at which the use of private cars is impractical. Therefore, optimizing traffic at intersections by changing the distribution of traffic flows is a relatively cheap and effective way to reduce time delays for public and private transport. However, before implementing the changes, transport modeling should be carried out, after which the effectiveness of a particular project proposal will become clear.

2. RESEARCH STATEMENT

Many methods have been researched to solve the problem of traffic delays in cities, including the design of traffic junctions at different levels or roundabouts [3–4]. By avoiding the interaction with intersecting streets or roads, vehicles do not need to stop, which, in turn, affects the formation of congestion.

Another effective method of reducing delays and queues at intersection approaches is analyzed in [5–6]. However, to achieve this goal, it is necessary to rationalize permissive traffic light signals so that vehicles from all approaches to the intersection would spend a minimum amount of time waiting.

An essential factor at the approaches to the intersection is the permitted left turn maneuver since, under such conditions, as noted by the author [7], there is an increase in queues and delays. It is also worth noting that this maneuver also affects traffic safety as it involves the interaction of a vehicle with an oncoming vehicle.

The problems with congestion at the approaches to the intersection can be solved by changing the geometric parameters or configuration of the intersection [8]. For example, an unsignalized intersection can be changed to a roundabout if the required area is available, which, in turn, will increase traffic safety at the intersection and equal priority at the approaches to it. It is possible to increase the number of lanes by reducing their width in limited conditions, which will increase the intersection capacity.

However, there are cases when it is impossible to solve the problem with delays at the approaches to intersections using one of the described methods. In some cases, it is necessary to approach the problem comprehensively. For example, simultaneously change the duration of the permissive traffic light signal and the number of lanes on the approaches to intersections.

Although transport modeling has gained popularity, not all cities use it or use it not to the fullest extent. The importance of using software to perform simulation modeling cannot be overemphasized, as it can be used to determine the effectiveness of changes in the road network and, if necessary, make certain adjustments. Such measures will help achieve the most effective result, which will reduce congestion, especially in densely populated cities.

The sources that have been analyzed make it clear that there is no standard method of solving problems with congestion. Each method has its advantages and disadvantages that should be taken into account. It is not always appropriate to transfer the experience of solving problems with congestion in a particular place to all problem areas since each node has its characteristics that should be considered. Transport modeling is a relevant and essential tool for making decisions about changing traffic organization or optimizing traffic light signaling.

The relevance of the research presented in this article is to conduct transport simulation modeling when developing a street reconstruction project before implementation to obtain an efficient project and reduce or avoid unnecessary investments.

The object of the study is a transport node on the city's road network with high traffic volume, and the subject is the patterns of queue changes and delays on the approaches to it.

The aim of the study is to determine the effectiveness of the transport node reconstruction project using transport modeling. It is necessary to solve the following tasks to achieve the aim of the study:

– carry out field studies to determine traffic volumes on the approaches to the intersection;
– create an existing and designed transport model of the studied node in the PTV VISSIM software environment;
– compare the results of modeling the existing and design conditions and determine the effectiveness of design solutions.

The expected result of the transport modeling is to obtain the results of the existing and design conditions, determine the effectiveness of design solutions, and point out the importance of using software to perform transport modeling.

3. CHARACTERISTICS OF THE RESEARCH OBJECT

The object under study is a section of the road network in the city of Lviv. It is worth noting that it has significant traffic volumes, as one of the streets connects two arterial streets. The studied transport node (Fig. 1) has three intersections, one of which is a signalized intersection. Street C is an arterial street that connects the bypass road and the central part of the city. Street A connects arterial street C to another arterial street, so there is quite a lot of traffic. The width of the traffic lanes on the studied streets is 3.75 m. In the current conditions, two-way traffic is organized on the streets.

Fig. 1. The study area on the road network with traffic data collection points marked

Field studies were carried out during peak periods of the day on weekdays to determine the traffic volume at the approaches to the intersections (Fig. 2), the composition and distribution of traffic flows (Fig. 3), the traffic light cycle and phase departures (Fig. 4 and Fig. 5).

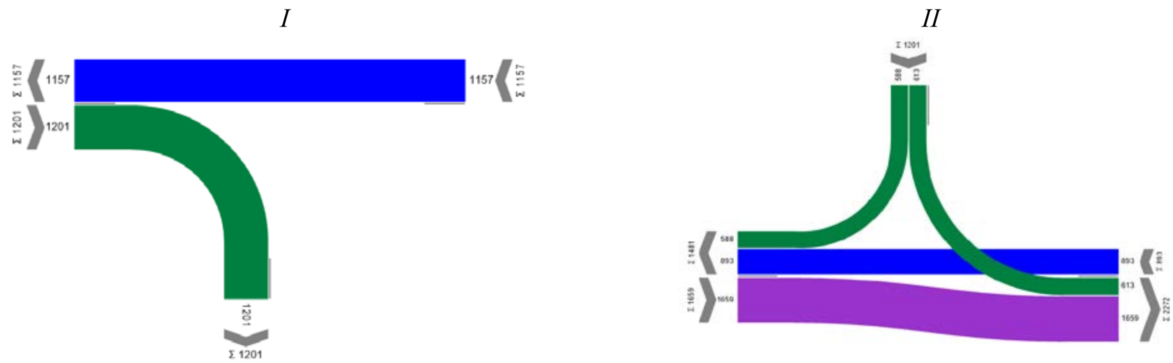

Fig. 2. Traffic volume graphs on the approaches to the intersection

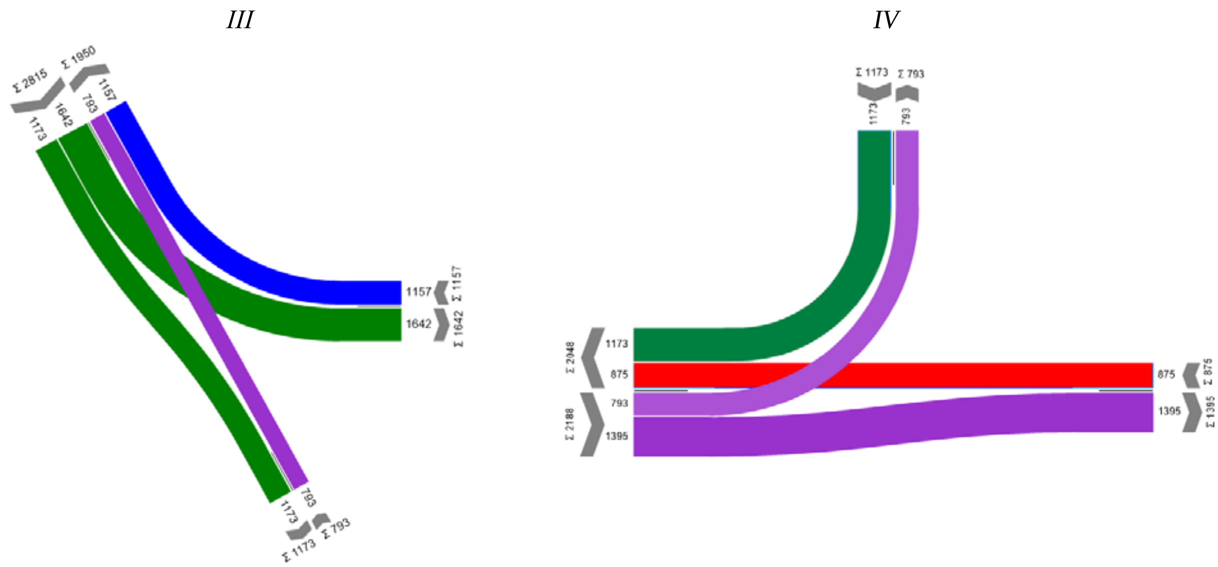

Fig. 2. (Continuation). Traffic volume graphs on the approaches to the intersection

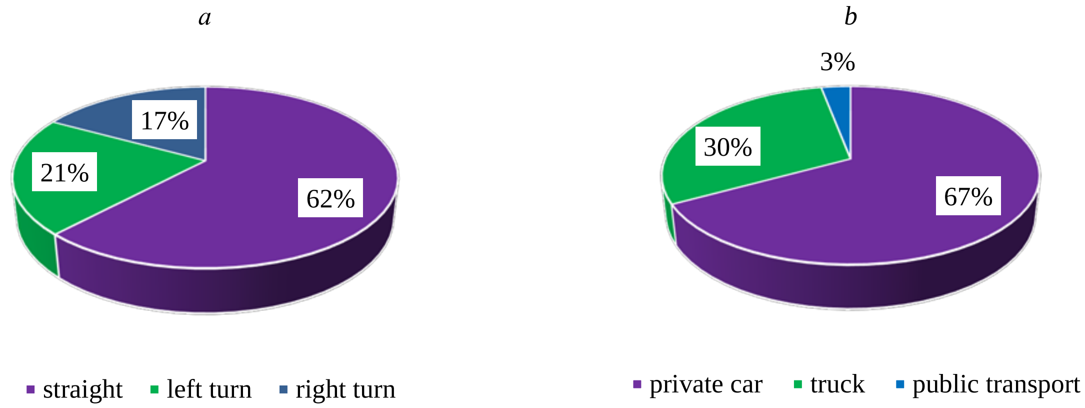

Fig. 3. Distribution of traffic flows in the study area: a – by direction; b – by composition

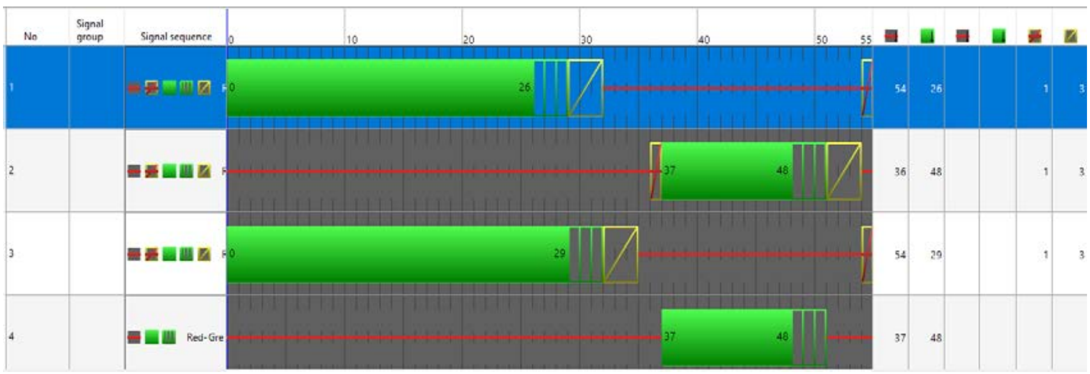

Fig. 4. The existing graph of traffic signal operation, which is included in the PTV VISSIM software environment

As can be seen from the graphs shown in Fig. 2, the highest traffic volume is observed on Street A and Street C. It is explained by the fact that Street C is an arterial street, and Street A connects arterial Street C and another street. Private vehicles prevail in the traffic flow, which accounts for 67 % of the total traffic, but there is also a large share of freight traffic (30 %). Also, straight traffic flows prevail at the intersection, and there is an almost equal number of turning traffic. The intersection of Street A and Street C is controlled by traffic lights. The duration of the traffic light cycle, according to the existing graph of the traffic signal facility, is 56 seconds, and the number of control phases is 2.

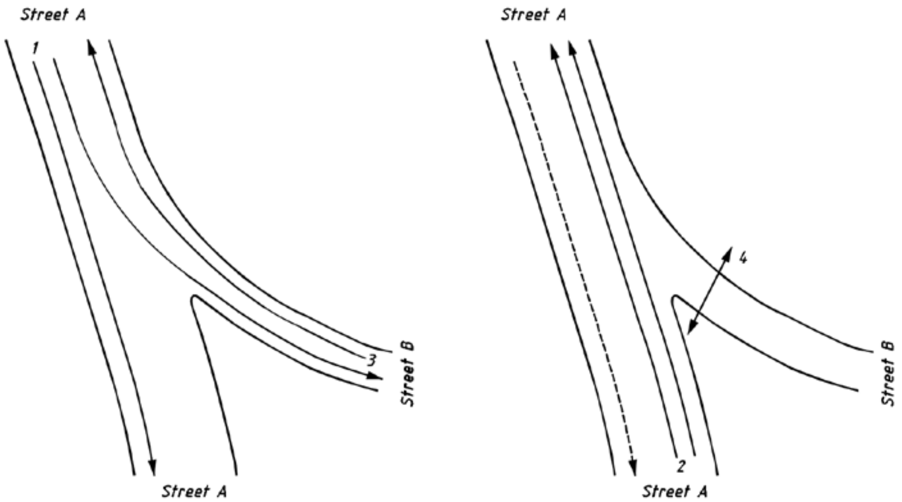

Fig. 5. Phase departure at studied intersection with traffic light control

4. MAIN PART

As of today, PTV Group is a favorite in creating software for transport modeling. It has implemented several digital products for transport simulation modeling that can perform different tasks using different methods, such as macroscopic, microscopic, and others. We use microscopic modeling to reproduce the studied intersection, traffic conditions, and the interaction between pedestrians and vehicles in detail. It can be used to determine the effectiveness of the design solution on the studied section of the road network. For this purpose, we use the PTV VISSIM software [9, 10]. The main indicators that will be studied are:

– average queues;
– maximum queues;
– average delays.

These are the main indicators which are used for analysis and comparison after transport simulation modeling. It is necessary to display the existing conditions of the node in the PTV VISSIM software environment (Fig. 6), indicate traffic volumes, traffic flow composition, its distribution, public transport routes and schedules, traffic light signal graphs and phase departures, if any, and other indicators obtained after field studies to determine the efficiency of a particular transport node. After entering all these indicators and getting the results, it is necessary to create design conditions for the node and get the results from it. It is worth noting that the quality of the modeling results directly depends on the accuracy of the input data and model calibration.

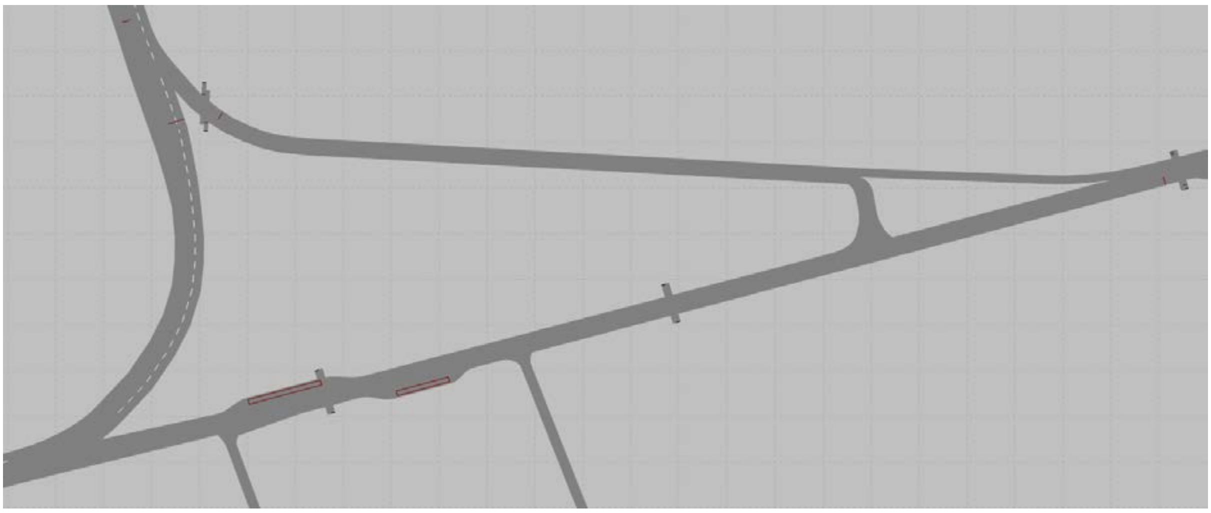

Fig. 6. The model of the existing conditions of the study area in the PTV VISSIM software environment

The design solution proposes the arrangement of a quasi-roundabout (Fig. 7), which provides for an increase in the number of traffic lanes and the number of pedestrian crosswalks in the study area, the installation of new traffic lights and changes in the cycle time of existing ones, and the introduction of dedicated lanes for public transport.

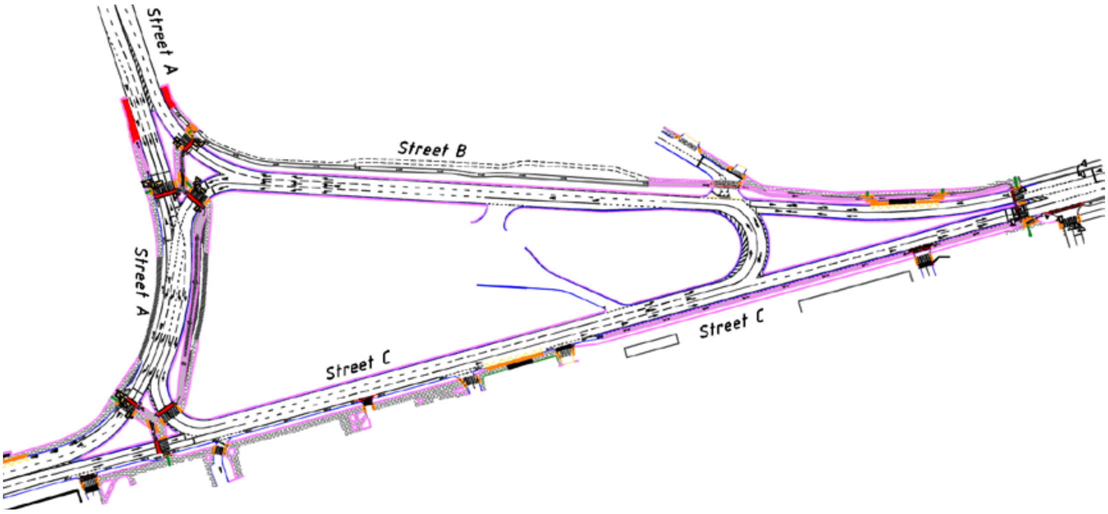

Fig. 7. The designed scheme of traffic management with marked nodes from which the modeling results will be obtained

After making changes to traffic management, designing traffic signal graphs and phase departures in the PTV VISSIM software environment, we will calculate indicators that will be used to compare and determine the effectiveness of the changes. A schematic representation with measurement points and their numbers is shown in Fig. 8. Results of modeling are shown in Fig. 9–11.

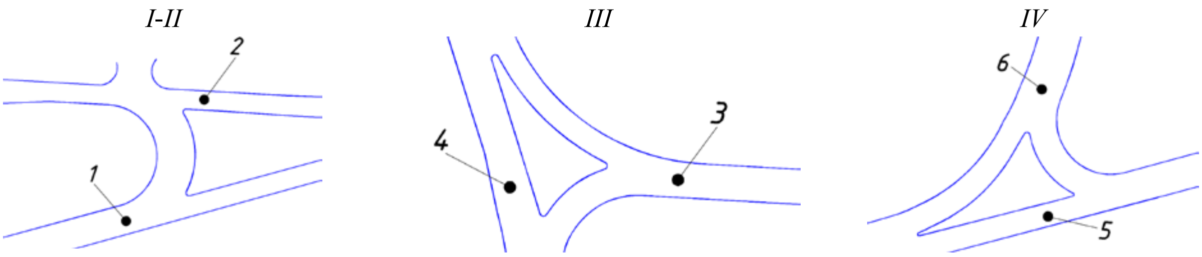

Fig. 8. Schematic representation of measurement point numbers

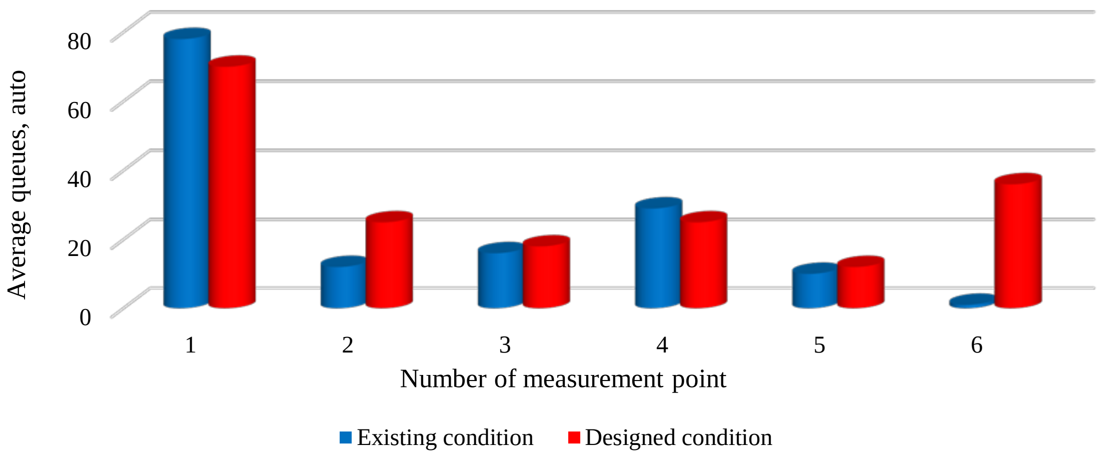

Fig. 9. Results of modeling the average queues at the existing and designed conditions on the studied section of the road network

The average queue values obtained through transport simulation modeling indicate an increase in the indicators, mainly at the approaches to intersections. On the approach to measurement point 6, there is a maximum increase in the average queue from 1 car to 36 cars (an increase of 3500 %).

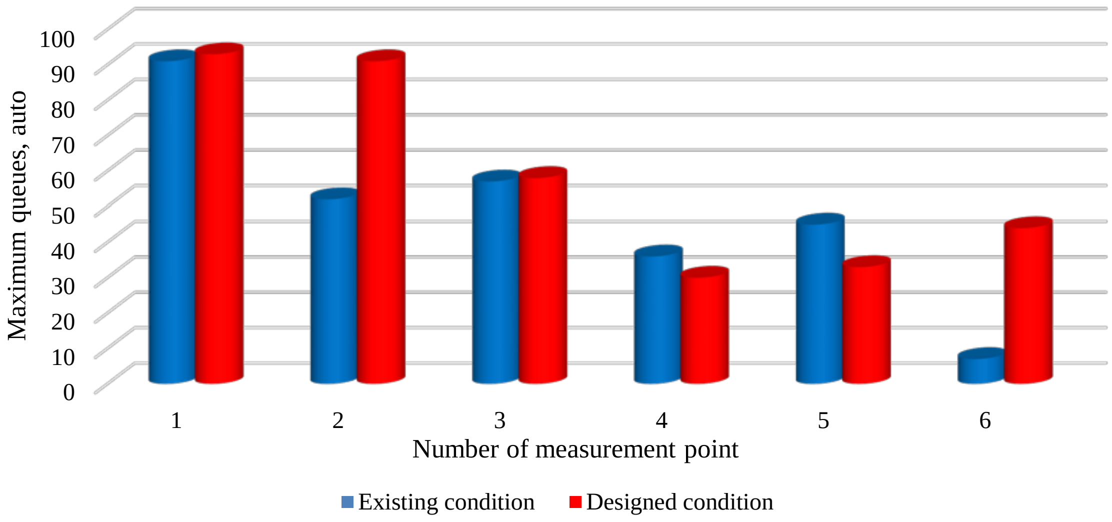

Fig. 10. Results of modeling the maximum queues at the existing and designed conditions on the studied section of the road network

When analyzing the maximum queues, a similar increase in the obtained indicator is observed at the same measurement point as the average queues. The maximum queues increase at measurement point six from 7 cars to 44 cars (529 %) and measurement point two by 75 %. However, other approaches are projected to decrease.

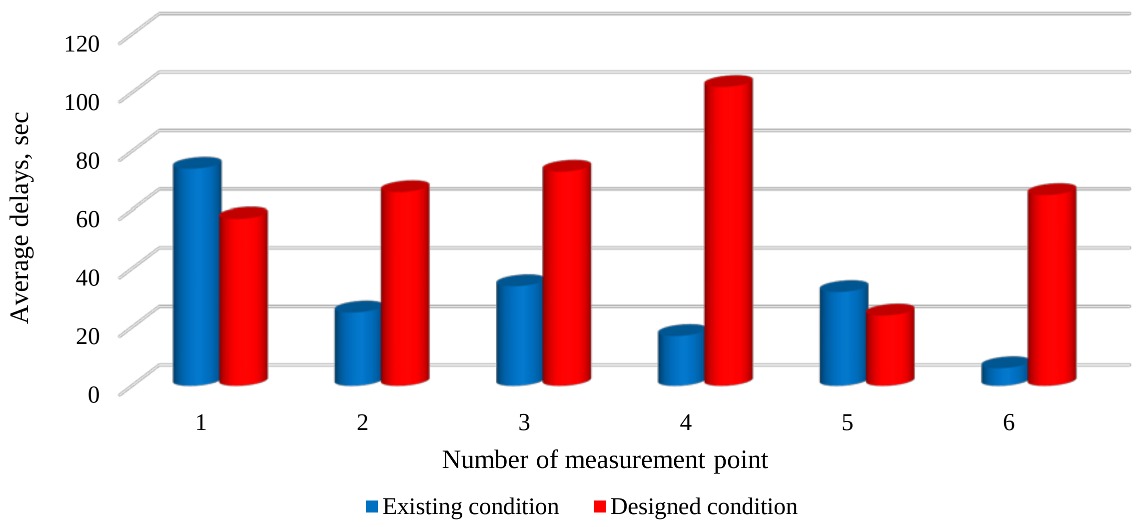

Fig. 11. Results of modeling the average delays at the existing and designed conditions on the studied section of the road network

The average delay duration obtained from the simulation results increases in four out of six approaches. The highest indicators are observed at measurement point 2 –164 %, measurement point 4 – 500 %, and measurement point 6–983 %. It is a critical increase, which can result in longer queues, longer travel times through the study area, and, as a result, more accidents.

5. CONCLUSIONS AND RESEARCH PERSPECTIVES

Field studies were carried out to obtain data on the traffic volume, traffic flow composition, and the share of turning vehicles, after which the results were analyzed. They will be entered into the PTV VISSIM software environment.

A model of the existing conditions was created in the PTV VISSIM software environment based on the data obtained during the analysis of field studies. Transport modeling of the existing conditions was carried out, and results, such as average queue, maximum queue, and average delay, were obtained.

A model of the design conditions was created, which provides for changes in the configuration of the intersection and the number of lanes, additional pedestrian crosswalks, graphs of traffic light cycle operation at new traffic lights, and phase departures proposed in the project. After all the changes were made, simulation modeling was performed, and the results were obtained and analyzed. It is worth noting that the main indicators that were studied have increased to critical levels. The worst performance is observed at measurement point 6, with average queues increasing by 3500 %, maximum queues – by 529 %, and average delays – by 983 %.

After conducting transport simulation modeling of the existing and designed conditions and analyzing and comparing the results, it becomes obvious that it is inexpedient to implement a project of this configuration, as there is an increase in such indicators as average queues, maximum queues, and average delays. If transport modeling had not been used, the implementation of this project could have led to significant complications in the studied section of the road network and significant capital expenditures.

References

1. Postranskyy, T., Afonin, M. & Boykiv M. (2020). Vplyv proektovanoi skhemy orhanizatsii kruhovoho rukhu na nerehulovanomu perekhresti miskykh vulyts na tryvalist transportnoi zatrymky [Influence of the roundabout traffic scheme project instead of the unregulated intersection of city streets on the transport delay duration]. *Suchasni tekhnolohii v mashynobuduvanni ta transporti [Advances in mechanical engineering and transport]*, *2*(15), 99–105. doi: 10.36910/automash.v2i15.397 (in Ukrainian).

2. Kučera, T., & Chocholáč, J. (2021). Design of the city logistics simulation model using PTV VISSIM software. *Transportation Research Procedia*, *53*, 258–265. doi: 10.1016/j.trpro.2021.02.033 (in English).

3. Tosun, H. B. (2022). Junction Designs Examples and Improvements in Junction Designs. *International Journal of Engineering Research and Development*, *14*(3), 261–267. doi: 10.29137/umagd.1215524 (in English).

4. Novák, J., Ambros, J., & Frič, J. (2018). How roundabout entry design parameters influence safety. *Transportation research record*, *2672*(34), 73–84. doi: 10.1177/0361198118776159 (in English).

5. Pohan, A. H., Latiff, L. A., Dziyauddin, R. A., & Wahab, N. H. A. (2021). Mitigating traffic congestion at road junction using fuzzy logic. *International Journal of Advanced Computer Science and Applications*, *12*(8), 293–299. (in English).

6. Solving a Traffic Congestion Problem at T-intersections using AnyLogic Simulation. Retrieved from: https://munin.uit.no/handle/10037/28421 (in English).

7. Lobashov, O., & Boikiv, M. (2020). Increasing the complex intersections functioning efficiency by restriction of left-turn traffic flows. *Transport technologies*, *1*(1), 54–64. doi: 10.23939/tt2020.01.054 (in English).

8. Sofia, G., Al-Haddad, A., & Al-Haydari, I. S. (2018). Improvement of traffic performance at intersections in Karbala city. In *MATEC Web of Conferences* (Vol. 162, p. 01032). doi: 10.1051/matecconf/201816201032 (in English).

9. PTV Vissim 2022 User manual (2022). Retrieved from: https://www.scribd.com/document/598260467/ (in English).

10. PTV Vissim 10 User manual (2018). Retrieved from: https://usermanual.wiki/Document/Vissim20102020Manual.1098038624.pdf (in English).

Received 21.02.2024; Accepted in revised form 02.04.2024.

ДОСЛІДЖЕННЯ ЕФЕКТИВНОСТІ ПРОЄКТНИХ РІШЕНЬ ПРИ ВИКОРИСТАННІ ТРАНСПОРТНОГО МОДЕЛЮВАННЯ

Анотація. *Одним із чинників, який призводить до збільшення рівня завантаження на вулично-дорожній мережі, є підвищення рівня автомобілізації у місті. За таких умов зростає кількість приватного транспорту на вулицях міст, затримок на підходах до перехресть та черг. Унаслідок цього проїзд перехрестя відбувається із затримкою, оскільки водії транспортних засобів змушені довше очікувати своєї черги. Для вирішення описаних проблем під час реконструкції вулиці чи дороги запропоновано змінювати організацію дорожнього руху, кількість смуг руху та конфігурацію деяких перехресть. Проте після реалізації проєкту здебільшого відбувається перерозподіл транспортних потоків, після якого запропоновані зміни можуть стати неефективними. Щоб запобігти негативному впливу таких ситуацій, обов'язково необхідно виконати транспортне моделювання, під час якого можна перевірити ефективність прийнятих рішень та коригувати проєкт ще на ранніх стадіях, а не після реалізації. Здійснюючи транспортне моделювання, можна уникнути зайвих капіталовкладень, які виникають після реалізації проєкту, або перевірити доцільність його впровадження.*

Об'єктом дослідження є ділянка вулично-дорожньої мережі, розташована у населеному пункті. Варто зазначити, що всі підходи до перехресть є доволі інтенсивними, що варто врахувати під час створення проєктної документації. В цій статті наведено проєктне рішення, яке передбачає зміну конфігурації перехрестя, збільшення кількості смуг руху та транспортне мікроскопічне моделювання наявного та проєктного станів, щоб визначити ефективність зміни організації дорожнього руху на досліджуваній ділянці вулично-дорожньої мережі. За результатами мікроскопічного моделювання спостерігається зменшення затримок та черг на підходах до перехрестя, що свідчить про правильність прийнятого рішення. Для виконання транспортного моделювання використано програмне забезпечення PTV VISSIM. Після апробації імітаційної моделі та аналізу результатів є можливість оцінити вплив проєктних рішень на вулично-дорожній мережі та, за необхідності, вносити коригування.

Ключові слова: *рівень завантаження; транспортні затримки; черги перед перехрестями; транспортне моделювання; проєктна документація; імітаційна модель; організація дорожнього руху.*