TRANSPORT TECHNOLOGIES

Vol. 5, No. 2, 2024

Roman Rohalskyy, Romana Bura*
Lviv Polytechnic National University
12, S. Bandery Str., Lviv, 79013, Ukraine

© *R. Rohalskyy, R. Bura, 2024*
https://doi.org/10.23939/tt2024.02.014

CHANGE IN TRAFFIC VOLUMES IN CONSTRUCTION WORK ZONES

Summary. *The problem of bottlenecks on the road network is relevant, especially in cities with radial and radial-ring schemes, since in case of their occurrence on arterial radial streets, it is difficult to choose an alternative route due to the low capacity of secondary streets. One of these bottlenecks is the repair work area, where, due to the closure of one street, the detour is carried out by parallel routes, which increases the load on local streets and driveways. Traffic flow volumes in the repair work areas are investigated in this paper. A site was selected where repairs were carried out in 2023. A citywide street of signalized traffic was closed due to repair work. The authors have forecasted the volumes of traffic flow that will be moving. After the start of the repair work, the actual traffic volume was determined by field surveys. The research was conducted over three months. The results showed that in the first week, the volumes were 2 % higher than predicted; in the second week, they corresponded to the predicted values, and starting from the third week, they began to decrease. Approximately the same volumes were observed between the seventh and twelfth weeks of the study. They were 18% lower than forecasted at the beginning of the study. Since the research results showed that drivers need about a month to choose an alternative route to bypass the most congested sections of the road network, a recommendation was made to install road signs informing about the detour a month before the start of the repair work. In our opinion, this recommendation will allow drivers to plan and choose an alternative detour route in advance so that the detour section is less congested at the beginning of the repair work.*

Keywords: *traffic flow, field research, arterial street, traffic volume, traffic forecasting, road network, traffic capacity.*

1. INTRODUCTION

Constant traffic congestion and delays have been a significant problem in modern cities for quite some time. This is because of the growing number of cars on the road network and insufficient capacity reserves. Therefore, drivers usually choose the optimal route and time of travel to avoid places of constant congestion. However, there are cases when such places are formed for unpredictable reasons, such as traffic accidents, complicated road conditions due to bad weather, and repair work. In such cases, informing residents about such bottlenecks is essential so that alternative routes can be built. The media usually make such notifications. However, if road traffic accidents occur occasionally, the repair work usually takes a long time. And we are talking not about current repair work but about arterial street repairs with the development of temporary traffic management schemes during repair work, indicating the streets that will be detoured.

When it comes to cities with radial and radial-ring schemes, there is an additional problem when repair work is carried out on arterial streets with high traffic volumes. In such cases, the detour is carried out via local streets whose capacity is not designed for such traffic volumes, which causes additional congestion. Over time, drivers find alternative routes to avoid such places. Therefore, the question arises of the possibility

* *Corresponding author. E-mail: romana.r.bura@lpnu.ua*

of installing road signs that would warn residents about the repair work a specific time before it begins so that they have time to adapt and choose the best route and method of transportation. Thus, when such repair work begins, the load on the detoured streets will be less.

2. RESEARCH STATEMENT

The State Standard of Ukraine [1] does not contain information on how long in advance it is necessary to install road signs with warning of repair work on a street section and the need to detour this section. The information provided only states that residents must be notified in advance when setting speed limits. However, when they are informed in advance that their usual routes will be changed, they can plan a new route to avoid the most congested areas.

Therefore, the study aims to investigate changes in traffic volumes in the places where the repair works are carried out. The following tasks need to be accomplished to achieve this goal:

- to analyze the detour scheme during the repair work on the studied areas;
- to conduct field studies to collect data on the traffic volumes on the studied section of the road network;
- to forecast the traffic volume of the traffic flows that will make the detour;
- to analyze changes in traffic volumes throughout the duration of the repair work.

3. THE ANALYSIS OF THE MAIN LITERARY SOURCES

The issue of studying the state of traffic flow is complex and multifaceted. It is well known that the main cause of traffic congestion on the road networks of cities is the formation of bottlenecks [2]. Traffic accidents, repair work on the road network, the impact of weather conditions on traffic flow parameters, public events, and ineffective traffic management measures or unsatisfactory street planning parameters are among them [3]. Some authors [4, 5] distinguish between closing streets or their sections, or reconstruction of a part of the road network, and bottlenecks as different phenomena. However, if we consider them as places on the road network where the volume has reached capacity [3], then repair work will also be considered a bottleneck. An analysis of scientific research on determining the parameters of traffic flows during repair work shows that the topic has not been studied in recent years. Most of the publications are by foreign authors. Most studies have been conducted for areas where only a part of the street or road is blocked, so research has focused on traffic safety in repair areas [6–7], the capacity of the roadway narrowing section [8], or reducing traffic speed [9] in repair areas. The authors [10] studied driver behavior on a section of an arterial street where repair work was underway (two of the five lanes were closed). The research showed a decrease in traffic speed under free conditions from 80 km/h to 60 km/h and an average speed from 45 to 40 km/h. Observations also showed that as the roadway's width decreased, road users' behaviour became more aggressive. The authors [11] also confirm the decrease in traffic speed.

In [12], the authors point out that the long duration of repair work or its large area causes irritation to drivers, which leads to a decrease in traffic safety. Therefore, the authors recommend minimizing their negative impact on traffic flow, dispersing vehicles in time to avoid congestion, and installing warning signs indicating the duration of the repair work.

The authors of [13] studied the perception of warnings about road works ahead using road signs and applications on mobile phones. The study results showed that drivers are more likely to perceive a warning about a hazard ahead that sounds on a smartphone or sounds and is additionally displayed on a smartphone screen than a warning on road signs.

Another aspect is the use of alternative traffic routes to avoid congestion on the road network. The authors of [14] studied drivers' choice of alternative routes when traffic on congested arterial streets is high. The studies showed that drivers would choose small side streets over arterial streets even if the time loss before traffic lights on arterial streets and the time loss caused by various restrictions on side streets were the same.

Paper [15] investigated the impact of controlled traffic signs on the route changes of taxi and truck drivers in different traffic situations. Thus, options were considered when controlled traffic signs indicated information about the type of obstacle ahead, the cause of the traffic jam, and the impact on the complexity of road conditions, expressed quantitatively or qualitatively, and information about available alternative routes. The research results showed that the latter two options have a more significant impact on the propensity of professional drivers to change their route.

Paper [16] considers the impact of repair work on a section of the road network in the case of complete closure and the arrangement of alternative detour routes. The authors propose various options for arranging detours: on territories of different sizes or various alternative routes. Thus, the study's results indicate that as the detour area increases, the travel time decreases. Regarding the share of drivers who follow the recommended alternative route, the results showed that the optimal share of drivers with the least time loss is 30 %, and 70 % usually follow their routes. In addition, if there are several alternative routes (the authors considered options for one, two, or three such routes), the greatest time loss is observed if there are three routes and the share of drivers who follow them is 20 %. When comparing time losses during a partial block of a street section for repairs to a complete block, the best option, according to the research, is complete blockage with alternative routes.

The authors [17] conducted a study to develop a method for arranging alternative traffic routes to avoid congestion on sections of the road network based on machine learning. However, they acknowledge that the method does not predict the point at which too many people will choose the same alternative routes. However, researchers [18, 19] propose an approach where each vehicle that can communicate with the central traffic control point in the city will receive information on the optimal route considering the current situation on the city's road network.

Thus, the question arises of the possibility of installing traffic signs that warn of the closure of a street or its section due to repair work a specific time before the closure begins so that drivers can use alternative travel routes to avoid areas with congestion.

4. RESEARCH RESULTS

The study of traffic volumes during the repair works was carried out on the section of Shevchenka Street in Lviv. Shevchenka Street is an arterial street of citywide significance with signalized traffic, located on the border of Shevchenkivskyi and Zaliznychnyi districts of Lviv. The street is one of the radial streets that connects the peripheral parts of the city with the center, so there is a significant traffic flow there.

Field surveys were conducted to collect data on the traffic volume in the study area. The volumes were measured in the areas between the intersections, which were assigned corresponding numbers. The highest volumes on Shevchenka Street were observed between intersections 8-9 and 9-10 and were 2252 and 2291 veh/h in both directions, respectively. The study of the existing traffic volume before the repair work was carried out during a week. The study results are the average traffic volumes during peak periods, considering the daily and weekly coefficients of irregularity. The research results are presented as a graph in Fig. 1.

In the spring of 2023, repair work was carried out on the section of the street from the intersection with Turyansky Street to the intersection with Bortnyansky Street (sections 11–12 and 10–11), so the section of Shevchenka Street from the intersection with Turyansky Street to the intersection with Y. Mudroho Street (sections 11–12, 10–11 and 9–10) was closed to traffic.

Under these conditions, we predicted how the traffic volumes will be distributed in the area of repair works – Turyanskoho Street – Zolota Street (sections 12 – 2, 2 – 3, 3 – 4, 4 – 5, and 5 – 9), or Yunakiva Street – Bortnyanskoho Street – Oleny Stepanivny Street – Yaroslav Mudroho Street (sections 13 – 18, 18 – 19, 19 – 20, 20 – 26, 26 – 27, 27 – 28, 28 – 29, and 29 – 9) in the direction of the center and Kleparivska – Zolota – Yeroshenka Streets (sections 6 – 5, 5 – 4, 4 – 3, 3 – 2, 2 – 1 and 1 – 13) in the direction from the center. The work area includes the streets along which detour routes are laid and the section where the repair work

is carried out. The motion was predicted according to the methodology presented in [20]. The forecasting was performed using the formula:

$$N_t = N_0 \cdot (1+\beta)^t. \quad (1)$$

where N_t – forecasted traffic volume for the t-th period, auto/day; N_0 – initial traffic volume, auto/day; β average increase in traffic volumes (calculated by interpolating the traffic volumes observed on the street that was closed for repairs and on the streets that were detoured); t – perspective period.

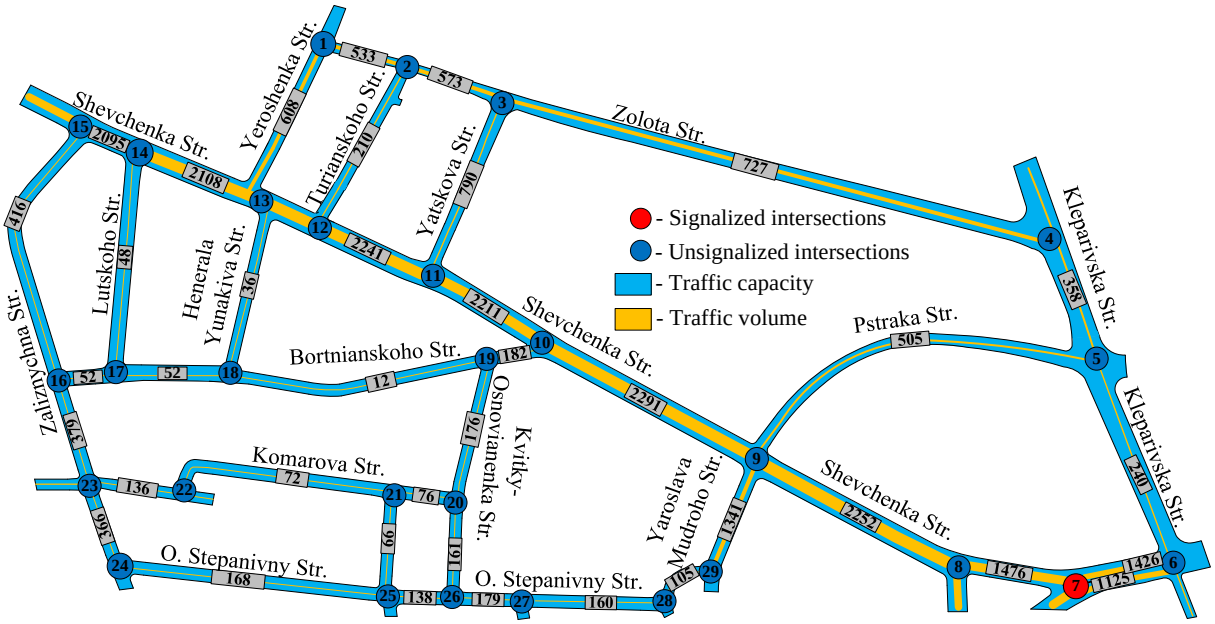

Fig. 1. Graph of traffic volumes on the studied section of the road network

The section with the highest volumes was closed for repair work, so the side streets will experience significant increases in volumes, sometimes at the capacity level, as there are no other arterial streets with high capacity values in the study area. The forecasting results are shown in Fig. 2.

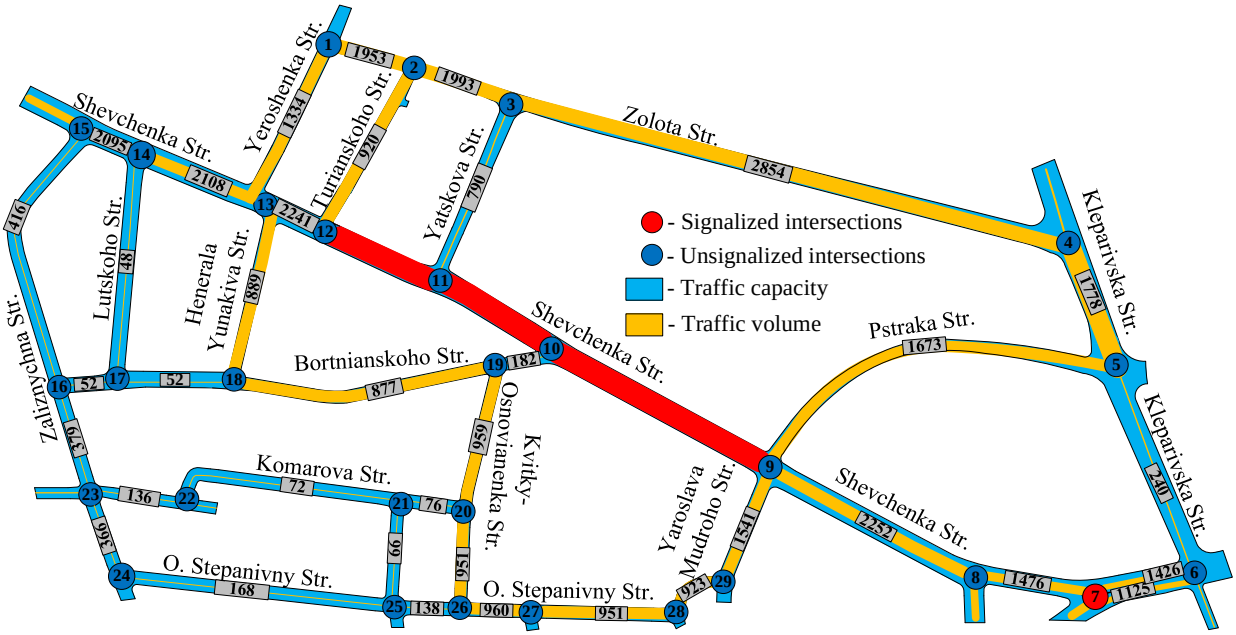

Fig. 2. Graph of forecasted traffic volumes on the studied section of the road network during repair works

A survey was conducted among drivers as part of this study. Since any survey should be representative of the sample size of the general sample, all age groups of the amateur population of Lviv, who, according to the current legislation, can hold a driver's license, participated in the survey. It is worth noting that the share of drivers who pass the study area irregularly – those who do not live in Lviv and potentially will not be aware of the need for a detour – was not considered. Drivers were asked: "How will your route be formed during repair work on one of the street sections you are traveling?" The proposed answers were:

– "I will follow the usual route and bypass streets, taking into account the changed traffic scheme";
– "I will move according to the recommendations of the navigator through the area of repair work";
– "I will follow the recommendations of the navigator while detouring the area of repair work";
– "I will follow my alternative route";
– "I will stop using my private car for the duration of the repair work";
– "other".

The number of responses received was 250. Among the respondents, 36 % were women and 64 % were men.

As for age categories, the distribution was as follows:

– 18 to 25 years old – 19 %;
– 25 to 40 years old – 31 %;
– 40 to 60 years old – 29 %;
– over 60 years old – 21 %.

As for the respondents' employment status, 32 % are students, 42 % are employed, and 26 % are retired.

The general results of the survey are shown in Fig. 3.

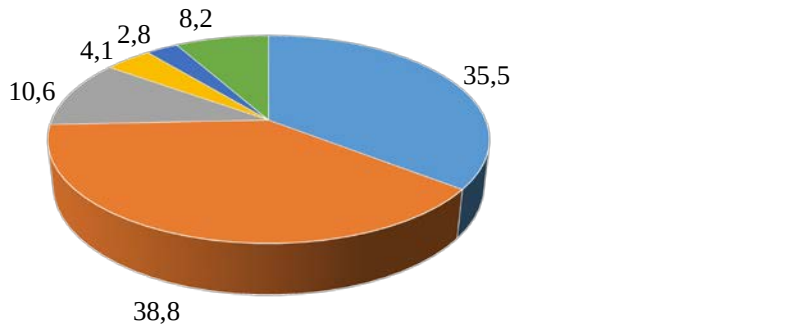

Fig. 3. Results of the survey of drivers on the choice of route in the area of repair works

According to the survey, most respondents plan to follow the usual route, of which 35.5 % will follow a self-selected route, and another 38.8 % will follow the recommendations of the navigator. As for the alternative route, 10.6 % plan to detour using a navigator, and another 4.1 % plan to use a self-built alternative route. In addition, 2.8 % of respondents plan to refuse to use a car for the duration of the repair work.

The survey results were also analyzed by category. As for the results by gender, women are more likely to continue to move through the area of repair work – 57 %. Regarding using the navigator, 18 % said they would follow the usual route around the repair area, and 39 % would follow the navigator's recommendations. As for stopping using a car for the duration of the repair work, 23 % of women said yes. As for men, 41.5 % answered the first question in the affirmative, and 27.5 % answered the second. Regarding detours around the area of repair work, 8 % will follow the recommendations of the navigator, and 9 % will follow a self-created route. For the duration of the repair work, 0.7 % of men plan to give up using a private car. “Other” was indicated by 11.3 % of men. The results of the responses by employment and by age category were similar. The distribution of responses by age category is shown in Fig. 4.

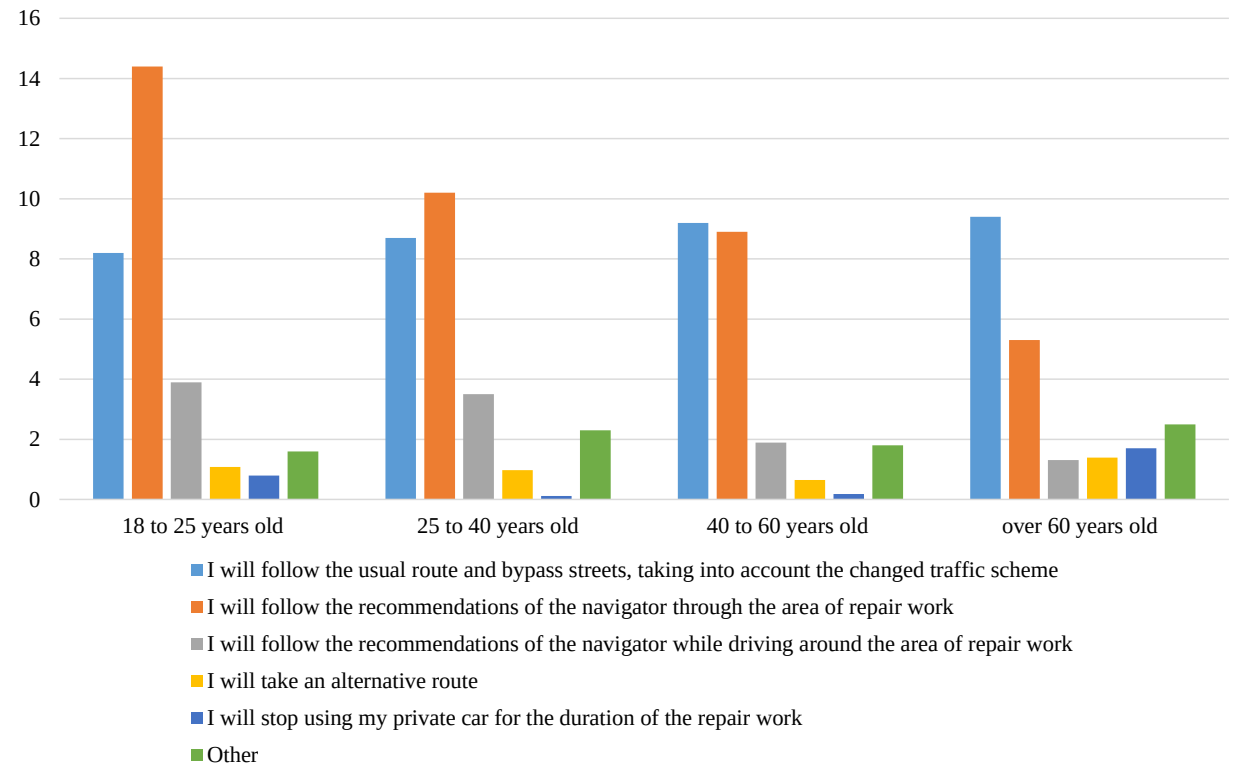

Fig. 4. Results of the driver survey by age category

The distribution of responses by age category differed depending on the question. For example, the number of responses to the first question was approximately the same. As for the second and third questions, the number of responses decreased with the increase in the age category. The largest number of answers to the second question – 14.4 % – was from drivers aged from 18 to 25. As for the age group over 60, we have only 5.3 % of answers to the second question. Regarding using a personal car for the duration of the repair work, most affirmative responses were in the 18–25 age group and over 60 years old.

In general, according to the survey, the majority of respondents – 74.3 % – will continue to use their usual routes through the area of repair work. Another 8.2 % chose “other”. The remaining 17.5 % said that they would either detour around the repair work area or not use a private car during the repair work.

Further, we measured the traffic volumes during the entire period of repair work on the Shevchenka Street section. The results are divided by week, considering the daily and weekly coefficients of irregularity. The results are shown in Table 1.

Starting from the fourth week, traffic volumes were relatively constant – we combined the most similar ones. The table shows the average volumes for weeks 4–6, 7–9 and 10–12.

Therefore, as we can see, the volume decrease in the first three weeks was significant, but after a month, their values became relatively the same.

Table 1

Results of studies of traffic volumes on the studied section of the road network during the repair works

Name of the street	Average daily hourly traffic volumes over the weeks, auto/h					
	1-st	2-nd	3-rd	4-6-th	7-9-th	10-12-th
Zolota	2205	2128	2000	1783	1748	1750
Generala Yunakiva	908	903	821	780	747	753
Oleny Stepanivny	1003	990	930	813	803	806
Yaroslava Mudroho	1560	1549	1503	1321	1271	1272

We also compared the traffic volumes obtained by field studies and traffic forecasting. The comparison results are shown as a graph in Fig. 4.

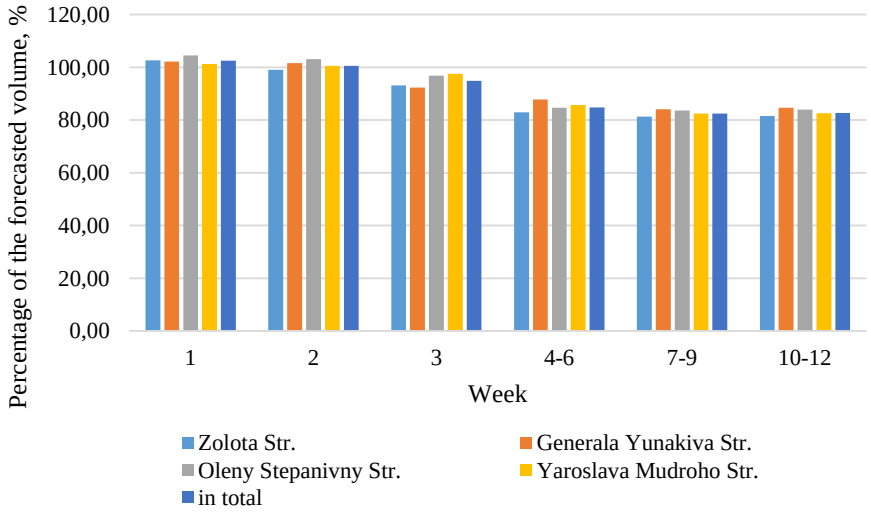

Fig. 4. Results of comparing the forecasted traffic volumes and the results of field surveys on the studied section of the road network

The results showed that, in practice, traffic volumes in the first week were 2 % higher than predicted. In the second week, the results of the field studies corresponded to the results of traffic forecasting, and in the third week, the volumes were 5 % lower than the predicted values. From the fourth to the sixth week, the volumes decreased by another 10 %. From the seventh week until the end of the observations, the traffic volumes were 18 % lower than the predicted traffic volumes before the start of the repair work. It can be explained by the fact that in about a month, 15 % of drivers found alternative routes to avoid the problematic section.

Therefore, if we assume, based on the results of the research, that drivers need about a month to choose an alternative route to avoid the area of constant congestion, we can recommend that in addition to notifying the public through media reports, road signs should be installed in the places where repair work is planned to be carried out a month before the start of the work. It will allow drivers to choose and test an alternative route in advance to reduce traffic congestion in the first weeks after the start of repair work on the sections recommended for detour.

5. CONCLUSIONS AND RESEARCH PERSPECTIVES

The paper investigates the change in the traffic volumes in the places of repair works. Using field studies, we determined the traffic volumes on the studied section of the road network, where, in 2023, repair work was carried out with the closing of a part of Shevchenka Street in Lviv. The streets recommended to be used as a detour from the repair area are analyzed, and the traffic volumes on these streets are forecasted.

A survey was conducted with drivers who frequently pass through the study area to determine which mode of travel they would choose in the event of repair work. According to the results, 17.5 % of respondents plan to detour around the area of repair works using their alternative route or a navigator or plan not to use a private car during the repair works.

Traffic volumes were measured on the streets that were used to bypass the repair site. The study lasted three months. The study results showed that in the first week, the volumes were higher than predicted, but starting from the third week, they gradually decreased. The values were 15 % lower than forecast from the fourth to the sixth week. The volumes remained approximately the same after the sixth week and until the end of the study period. The actual results of the field studies were 18 % lower than the results of the traffic forecasting conducted before the start of the field studies. At the same time, all the streets detoured had volumes that reached the capacity level. Therefore, based on the research results, we can recommend the installation of traffic signs warning of the start of repair work a month before the beginning of the work so that residents of the adjacent areas can build alternative traffic routes.

References

1. Bezpeka dorozhnoho rukhu. Ohorodzhennia ta orhanizatsiia dorozhnoho rukhu v mistsiakh provedennia dorozhnikh robit [Road safety. Fencing and traffic management at road works sites]. (2017). *DSTU ISO 8749:2017 from 1st January 2019*. Kyiv: DP "UkrNDNTZ" (in Ukrainian).

2. Riabushenko, O. (2023). Methodology for determining bottlenecks on the city's street-road network by analyzing GPS track data. *Automobile transport*, *52*, 71–79. doi: 10.30977/AT.2219-8342.2023.52.0.08 (in English).

3. Hale, D., Jagannathan, R., Xyntarakis, M., Su, P., Jiang, X., Ma, J. & Krause, C. (2016). *Traffic bottlenecks: identification and Solutions* (No. FHWA-HRT-16-064). United States. Federal Highway Administration. Office of Operations Research and Development (in English).

4. Stepanchuk, O., Lapenko, O., & Chernyshova, O. (2022). Osoblyvosti vykorystannia metodiv modeliuvannia transportnykh potokiv na vulychno-dorozhnii merezhi mista [Peculiarities of using modeling methods of traffic flows in the city street network]. *Teoriia ta praktyka dyzainu [Theory and practice of design]*, *25* (2022), 110–119. doi: 10.18372/2415-8151.25.16787. (in Ukrainian).

5. Systematics, C. (2004). *Traffic congestion and reliability: Linking solutions to problems* (No. FHWA-HOP-05-004). United States. Federal Highway Administration. (in English).

6. Mashhadi, A. H., Rashidi, A., & Markovic, N. (2024). *Construction Work Zone Safety: Spatio-Temporal Analysis of Construction Work Zone Crashes* (No. UT-24.08). Utah Department of Transportation. (in English).

7. Ren, T., Xie, Y., & Jiang, L. (2021). New England merge: A novel cooperative merge control method for improving highway work zone mobility and safety. *Journal of Intelligent Transportation Systems*, *25*(1), 107–121. doi: 10.1080/15472450.2020.1822747 (in English).

8. Mashhadi, A. H., Farhadmanesh, M., Rashidi, A., & Marković, N. (2021). Review of methods for estimating construction work zone capacity. *Transportation research record*, *2675*(9), 382–397. doi: 10.1177/03611981211002202 (in English).

9. Zhang, H., Liu, D., & He, J. (2020). Traffic Organization Scheme Design of Freeway Work Zone. In *CICTP 2020: Transportation Evolution Impacting Future Mobility* (pp. 1653–1665). doi: 10.1061/9780784483053.139 (in English).

10. Raju, N., Arkatkar, S., & Joshi, G. (2020). Effect of construction work zone on traffic stream parameters using vehicular trajectory data under mixed traffic conditions. *Journal of Transportation Engineering, Part A: Systems*, *146*(6), 05020002. doi: 10.1061/JTEPBS.0000353 (in English).

11. Lu, C., Dong, J., Sharma, A., Huang, T., & Knickerbocker, S. (2018). Predicting Freeway Work Zone Capacity Distribution Based on Logistic Speed-Density Models. *Journal of Advanced Transportation*, *2018*(1), 9614501. doi: 10.1155/2018/9614501 (in English).

12. Wang, Z., & Chen, L. (2016, August). Research on the Impact of Road Construction on Traffic Congestion. In *2016 International Conference on Management Science and Management Innovation* (pp. 209–212). Atlantis Press. doi: 10.2991/msmi-16.2016.50 (in English).

13. Craig, C. M., Achtemeier, J., Morris, N., Tian, D., & Patzer, B. (2017). *In-vehicle work zone messages* (No. MN/RC 2017–19). Minnesota. Department of Transportation. (in English).

14. Ringhand, M., & Vollrath, M. (2019). Effect of complex traffic situations on route choice behaviour and driver stress in residential areas. *Transportation research part F: traffic psychology and behaviour*, *60*, 274–287. doi: 10.1016/j.trf.2018.10.023 (in English).

15. Poulopoulou, M., & Spyropoulou, I. (2019). Active traffic management in urban areas: Is it effective for professional drivers? The case of variable message signs. *Transportation research part A: policy and practice*, *130*, 412–423. doi: 10.1016/j.tra.2019.09.060 (in English).

16. Memarian, A., Rosenberger, J. M., Mattingly, S. P., Williams, J. C., & Hashemi, H. (2019). An optimization-based traffic diversion model during construction closures. *Computer-Aided Civil and Infrastructure Engineering*, *34*(12), 1087–1099. doi: 10.1111/mice.12491 (in English).

17. Xu, J., Zhang, Y., & Xing, C. (2018). An effective selection method for vehicle alternative route under traffic congestion. In *2018 IEEE 18th International Conference on Communication Technology (ICCT)* (pp. 494–499). IEEE. doi: 10.1109/ICCT.2018.8600055 (in English).

18. Bohuto D., Komarov V., Nikoliuk P., & Nikoliuk P. (2018). Intelektualnyi alhorytm upravlinnia miskym trafikom transportnykh zasobiv [Intelligent algorithm for managing urban traffic of vehicles vehicles]. *Visnyk Kharkivskoho natsionalnoho universytetu imeni V. N. Karazina [The Journal of V. N. Karazin Kharkiv National University]*, *38*, 4–13. (in Ukrainian).

19. Liebig, T., Piatkowski, N., Bockermann, C., & Morik, K. (2017). Dynamic route planning with real-time traffic predictions. *Information Systems*, *64*, 258–265. doi: 10.1016/j.is.2016.01.007 (in English).

20. Metodychni rekomendatsii z vyznachennia isnuiuchoi ta prohnozuvannia perspektyvnoi intensyvnosti rukhu [Methodological recommendations for determining the existing and forecasting future traffic volume]. (2008). Retrieved from: https://online.budstandart.com/ua/catalog/doc-page?id_doc=46647 (in Ukrainian).

Received 08.08.2024; Accepted in revised form 18.10.2024.

ЗМІНА ІНТЕНСИВНОСТІ РУХУ ТРАНСПОРТНИХ ПОТОКІВ У МІСЦЯХ ПРОВЕДЕННЯ РЕМОНТНИХ РОБІТ

Анотація. *Проблема вузьких місць на вулично-дорожній мережі є актуальною, особливо у містах з радіальною та радіально-кільцевою схемою, оскільки у разі їх виникнення на магістральних радіальних вулицях важко вибрати альтернативний маршрут руху через низьку пропускну здатність бічних проїздів. Одним із таких вузьких місць є ділянки виконання ремонтних робіт, коли через перекриття однієї вулиці об'їзд здійснюється паралельними шляхами, що збільшує навантаження на місцеві вулиці та проїзди. У роботі досліджено інтенсивності руху транспортних потоків у зонах виконання ремонтних робіт. Вибрано ділянку, де у 2023 р. виконували ремонтні роботи. Вулицю загальноміського значення регульованого руху було перекрито для руху транспорту через ремонтні роботи. Автори здійснили прогнозування інтенсивності руху транспортних потоків. Після початку виконання ремонтних робіт методом натурних досліджень визначено фактичну інтенсивність руху транспортних потоків. Дослідження здійснювали протягом трьох місяців. Результати показали, що упродовж першого тижня значення інтенсивності були вищими від прогнозованих на 2 %, упродовж другого відповідали прогнозованим, а починаючи з третього тижня почали зменшуватися. Між сьомим та дванадцятим тижнями досліджень спостерігалися приблизно однакові значення інтенсивності руху. Вони були на 18 % нижчими за прогнозовані на початку дослідження. Оскільки результати досліджень показали, що водіям необхідно приблизно місяць, щоб вибрати альтернативний маршрут руху для об'їзду найзавантаженіших ділянок вулично-дорожньої мережі, то розроблено рекомендацію щодо встановлення дорожніх знаків, які повідомляють про об'їзд ділянки, за місяць до початку виконання ремонтних робіт. Така рекомендація, на нашу думку, дасть водіям змогу спланувати та вибрати альтернативний маршрут об'їзду заздалегідь, щоб на початку ремонтних робіт ділянка об'їзду була менш завантажена.*

Ключові слова: *транспортний потік, натурні дослідження, магістральна вулиця, інтенсивність руху, прогнозування руху, вулично-дорожня мережа, пропускна здатність.*