JOURNAL "TRANSPORT TECHNOLOGIES"
Vol. 6, No. 2, 2025

Oleh Hrytsun*, Dmytro Sydorov
Lviv Polytechnic National University
12, S. Bandery Str., Lviv, 79000, Ukraine

ISSN: 2708-2199 (Print)
ISSN: 2709-5223 (Online)

Available online:
https://doi.org/10.23939/tt2025.02.009

RESEARCH ON THE SPEED MODE OF VEHICLES IN DEDICATED LANES

Summary. *The issue of changing the speed mode for vehicles in dedicated lanes for public transport is discussed in the paper. Several arterial streets in Lviv were selected to analyze this concept. The study assesses the impact of various factors, such as traffic volume and composition, on road traffic efficiency. It has been found that in areas with dedicated lanes for public transport, there is a reduction in delays and an increase in traffic capacity. It has also been established that the allocation of dedicated lanes improves the reliability of bus and trolleybus services, which has a positive impact on adherence to transport schedules. The results showed virtually no significant traffic delays on streets with dedicated lanes for public transport. It ensures unobstructed movement of public transport even in conditions of high traffic volume, which is typical for urban environments. A decrease in traffic flow speed was observed mainly in areas located near intersections, pedestrian crosswalks, parked cars, and other objects that can affect the overall traffic dynamics. It has been established that the minimum speeds for private and public transport lanes are almost identical – the difference does not exceed 10 km/h. The data obtained confirms the feasibility of expanding the network of dedicated lanes within the city, especially in areas with high passenger traffic.*

Simulation modeling was performed for each studied section using the PTV VISSIM software package. During the experiment, the traffic volume gradually increased by 10 %, 20 %, 30 %, 40 %, and 50 % from the initial values. It allowed us to assess how the increase in the number of vehicles affects key traffic parameters, particularly the travel time on the studied section, average speed, and maximum queue length. The results obtained were also compared with actual field observations, which confirmed the reliability of the model and its suitability for further research into transport processes. The results obtained can contribute to improving urban transport infrastructure, which, in turn, will help reduce delays and increase traffic efficiency in areas with high traffic loads.

Key words: *road network, traffic flow, traffic volume, speed of movement, traffic capacity, volume-capacity ratio, simulation modeling, field research, public transport.*

1. INTRODUCTION

Effective traffic flow management is becoming increasingly pressing in today's urban environment, especially in large cities where car ownership is constantly rising. The increase in the number of vehicles creates an additional impact on the road network. It leads to increased traffic delays and reduced traffic speeds. Dedicated lanes, especially for public transport, are essential for optimizing traffic flow [1].

Dedicated lanes for public transport can reduce delays for buses and trolleybuses. They contribute to more stable and faster travel. It increases the overall efficiency of public transport, motivating people to choose it over private cars. This, in turn, reduces delays and improves the environmental situation [2].

** Corresponding author. E-mail: oleh.m.hrytsun@lpnu.ua*

A deep understanding of the factors influencing speed modes and delays on dedicated lanes is essential for developing effective transportation management strategies. It includes analyzing the impact of various factors, such as traffic density, road network configuration, traffic light location, and modern traffic management technologies [1].

Considering these factors will allow for a scientifically sound justification of areas where design solutions can be effectively applied. They aim to assess speed limits and vehicles' delays in designated lanes. It will improve the quality of transport services and ensure the sustainable development of urban transport systems.

2. STATEMENT OF THE PROBLEM AND RELEVANCE OF THE STUDY

The efficiency of transport systems is one of the key factors in ensuring the stable development of urban infrastructure. The accelerated growth of cities and the increase in the number of vehicles lead to a decrease in average traffic speed and an increase in traffic delays. Solving these problems requires the development of new approaches to traffic management, among which the allocation of dedicated lanes for public transport is one of the most promising solutions. However, the effectiveness of such measures requires comprehensive research, in particular, analysis of speed limits and traffic delays.

Dedicated lanes are designed to increase the speed and improve the reliability of public transport, while minimizing the impact of private cars on this group of road users. However, there has been insufficient research into how these lanes affect overall traffic flow, particularly regarding vehicle delays, speed limits, and the road network's capacity. Research into these parameters is vital for determining the effectiveness of dedicated lanes depending on traffic volumes, the ratio between private and public transport, traffic light control conditions, and the overall congestion level of the road network. The results allow us to develop practical recommendations on the feasibility of further development and optimization of the dedicated lane system in urban conditions.

One of the main problems in this context is the correct assessment of the impact of dedicated lanes on the overall travel time of the section, vehicle delays, and compliance with speed limits and safety requirements. Adapting traffic light cycles, intersection layouts, and traffic flow management is often necessary depending on the time of day, day of the week, or seasonal factors. It requires using complex mathematical models and simulation modeling to analyze options and make optimal decisions.

The relevance of the study is determined by the need to optimize the use of dedicated lanes in terms of their impact on the general traffic flow. Despite the apparent advantages for public transport, the issue of the effect of dedicated lanes on speed limits and delays for other vehicles has not yet been sufficiently researched. This creates the conditions for a more in-depth analysis of the effectiveness of such solutions and the search for priorities among different categories of road users.

Considering current trends in urbanization and urban transport development requires us to adopt new approaches to studying road conditions and applying innovative methods for traffic analysis. Dedicated lanes can significantly change traffic flows, but their effectiveness depends on many factors, including traffic light control, road capacity, and traffic volume. That is why studying speed limits and vehicle delays on dedicated lanes is extremely important for further developing effective solutions in urban transport.

Studying these aspects will enable the development of practical recommendations for optimizing dedicated lanes, which will increase transport infrastructure efficiency, reduce traffic delays, and improve traffic conditions for all road users.

The main purpose of the study is to determine the impact of dedicated lanes on speed modes and vehicle delays in urban conditions to improve the efficiency of the transport system and reduce delays.

To achieve this aim, the following tasks have been outlined:

– analyze existing scientific research and practical experience regarding the implementation of dedicated lanes for public transport;
– collect and analyze data on traffic speeds in dedicated lanes in various urban conditions;
– investigate the impact of dedicated lanes on traffic flows, particularly on speed mode and queue length for private and public transport.

3. ANALYSIS OF THE RECENT RESEARCH AND PUBLICATIONS

Research into the impact of dedicated lanes on traffic flows is of considerable scientific interest to transport engineers, urbanists, and urban infrastructure planners. Several scientific studies, such as [3], emphasize that allocating dedicated lanes for public transport significantly reduces delays for buses and trams, increasing traffic speed and the convenience of using this type of transport. These findings confirm the effectiveness of such solutions in large cities for improving citizen mobility.

Researchers such as Lu, J. & Van Hentenryck, P. [4] studied the impact of dedicated lanes on reducing delays in central urban areas and found that public transport efficiency increases. At the same time, delays for private vehicles increase, especially at intersections where dedicated lanes intersect with general traffic flows. The researchers emphasize the need to properly balance the interests of all road users and optimize traffic light control modes to minimize the negative impact on other traffic flows.

In studies [5], considerable attention was paid to the effectiveness of dedicated lanes as part of an integrated strategy for sustainable urban transport development. It was found that introducing such lanes reduces the use of private cars, encouraging passengers to use public transport. In addition, the report emphasizes the improvement of the environmental situation due to the reduction in the number of vehicles on the roads and the reduction in travel time.

In their paper, Li, Y., & Wang, H. [6] analyze the use of dedicated lanes in densely populated cities. They point out the importance of detailed traffic flow modeling before implementing such lanes, which allows for a preliminary assessment of their impact on the speed and delays of different categories of vehicles. Modeling has shown that dedicated lanes are most effective on routes with high public transport volumes and moderate private transport volumes.

Study [7] investigated the interaction of traffic flows at signalized intersections with dedicated lanes. Scientists found that integrating separate lanes for public transport with optimized traffic light modes can significantly reduce delays for buses and private cars. However, delays may occur in adjacent lanes without proper traffic light control and additional traffic management.

Madadi, B. & Van Arem, B. [8] emphasized in their studies that, in addition to the organization of traffic lanes, the design of street infrastructure and traffic control at intersections play a significant role in improving the efficiency of the transport system. Their research has shown that dedicated lanes are most effective with other measures, such as intersection redesign, transport interchange construction, and intelligent traffic management systems.

According to research [9], the impact of dedicated lanes on the overall level of delays in cities largely depends on the specifics of urban development, street width, and housing density. In densely populated areas with narrow streets, the allocation of dedicated lanes can reduce the overall capacity of the road network for private transport. At the same time, in areas with wider streets and lower traffic volume of private cars, the efficiency of public transport increases significantly.

Research by Italian scientists [10] has shown that in rapidly growing megacities, the effectiveness of dedicated lanes depends on integrating these measures into the overall urban infrastructure planning system. The authors emphasize that introducing dedicated lanes without proper optimization of traffic lights and other road infrastructure elements may have a limited effect. They also point to the need to use intelligent transport systems for adaptive traffic control.

Other researchers, such as Szarata, M., & Bichajło, L. [11], have simulated various options for using dedicated lanes in cities where motor vehicle transport predominates. They found that if the public transport system is underdeveloped, dedicated lanes might not achieve the desired effect. However, in cities with well-developed public transport systems, these lanes can significantly increase the speed of buses and trams, reducing overall passenger delays.

Thus, based on the analysis of recent studies and publications, it can be concluded that the effectiveness of dedicated lanes largely depends on many factors, including infrastructure conditions, traffic management, and traffic volume [12–15]. Further research should focus on improving mathematical models and conducting simulation modeling to understand better the impact of dedicated lanes on the transport system.

4. PRESENTATION OF THE MAIN MATERIAL AND RESEARCH RESULTS

Several key arterial streets in Lviv, which are essential transport routes, were selected to study traffic speed modes. In particular, attention was focused on Chornovola Av., Shevchenko Str., and St. John Paul II Av., as they have high traffic volume, especially for public transport. These sections play a strategic role in the city's transport network, connecting different areas and providing access to important destinations.

Key approaches to signalized intersections located in different parts of Lviv were selected for further research. In particular, these are the intersections of Chornovola Av. and Khimichna Str. (Type No. 1), Shevchenka Str., Yaroslava Mudroho Str., and Pstraka Str. (Type No. 2), and St. John Paul II Av. and Bodnarivska Str. (Type No. 3). These intersections were selected for detailed analysis of traffic flows because they are important transport hubs connecting different city areas.

The selection of intersections for the study was based on several criteria, including traffic volume, the presence of pedestrian crosswalks, the type of traffic management, and overall traffic congestion at different times of the day. These factors ensure that the selected locations are representative for studying the effectiveness of traffic management and identifying possible ways to improve traffic organization.

During the research, a detailed analysis of traffic flow components and density in these areas was carried out. In particular, traffic light modes and their impact on traffic were studied. The main characteristics of intersections were also determined, and the length of queues at approaches to signalized intersections was recorded, which allows for an accurate assessment of the situation and the proposal of effective measures to optimize traffic flow in these areas of the city.

The first object of study (Type No. 1) has two lanes for motor vehicle traffic, one of which is allocated for urban public transport. The road surface on the studied section is made of asphalt concrete, and there is a dividing lane on Chornovola Av., which contributes to a more efficient distribution of traffic flows. The longitudinal slope at the approach to the intersection is 5 ‰, which may also affect the traffic speed and the flow organization.

Traffic is regulated by traffic lights, road signs, and markings, ensuring the organized movement of vehicles and pedestrians. The duration of the traffic light cycle at this intersection is 65 seconds, of which the green light at the approach to the section under study is 37 seconds. It allows for regular traffic flow, but additional congestion may occur in conditions of high traffic load.

There is a pull-in bay for public transport before the stop-line. On the one hand, this is convenient for passengers, but on the other hand, it sometimes causes additional delays in traffic flow, as buses that stop can block the lane for other vehicles.

The composition of traffic flow at this intersection includes cars (77 %), trucks (14 %), and buses (9 %). This traffic flow structure requires special attention to the interaction between different types of transport, as many public transport vehicles can affect the speed and efficiency of traffic at the intersection.

The second object of study (Type No. 2) has three lanes for car traffic, one of which is allocated for urban public transport, which is a crucial element for ensuring comfortable and fast travel by public transport. The width of each lane is 3.5 m, which meets the standards for ensuring the safety and comfort of drivers and passengers.

The road surface quality is rated as excellent, ensuring smooth traffic flow and reducing the risk of delays. The traffic light cycle on this section of the street lasts 89 seconds, of which the green light on the section under study lasts 26 seconds for private transport and 14 seconds for public transport. The traffic flow consists of cars (82 %), trucks (11 %), buses, and trams (7 %).

The third object of study (Type No. 3) has two lanes moving in the same direction, and a dedicated lane for urban public transport, which ensures the efficient movement of buses and other public transport vehicles. The width of each lane is 3.75 m. The traffic light cycle at this approach is 54 seconds, of which the green light at the studied section is 24 seconds, which is optimal for maintaining traffic capacity at the intersection.

The traffic flow consists of cars (80 %), trucks (14 %), and buses (6 %). This traffic flow structure indicates the dominance of cars on this section of the road. Still, a significant share of trucks is also substantial, requiring special attention to traffic management and safety for all road users.

Analysis of traffic flow speeds on specific sections of the road network is an integral part of research aimed at collecting real data on vehicle speeds. This process provides accurate information on the efficiency of road infrastructure and identifies factors that affect traffic speeds. The study of such data forms the basis for further assessment of problem areas and improving the traffic management system.

Field studies were conducted to obtain data on the instantaneous speeds of vehicles on the road network. It provided accurate information on the characteristics of traffic flows. The study analyzed 50 vehicles traveling in different lanes on the road sections under investigation. The observations covered the lane dedicated to public transport and the adjacent lane for private cars, which made it possible to compare the traffic speed in these two conditions.

A radar was used to measure the instantaneous speed of vehicles, which allows the speed of each vehicle passing through a specific point on a section of the road to be accurately recorded. This equipment provides high measurement accuracy, which is critical for obtaining reliable data on vehicle speed in real conditions. The equipment layout for studying vehicle speeds is shown in Fig. 1, which shows how the radar was installed at selected locations for data collection.

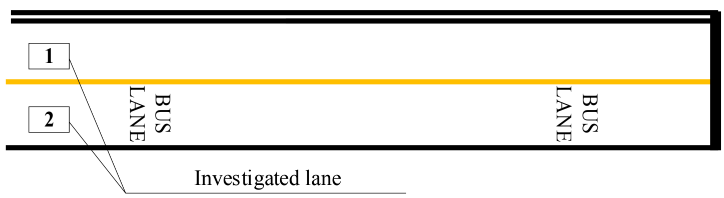
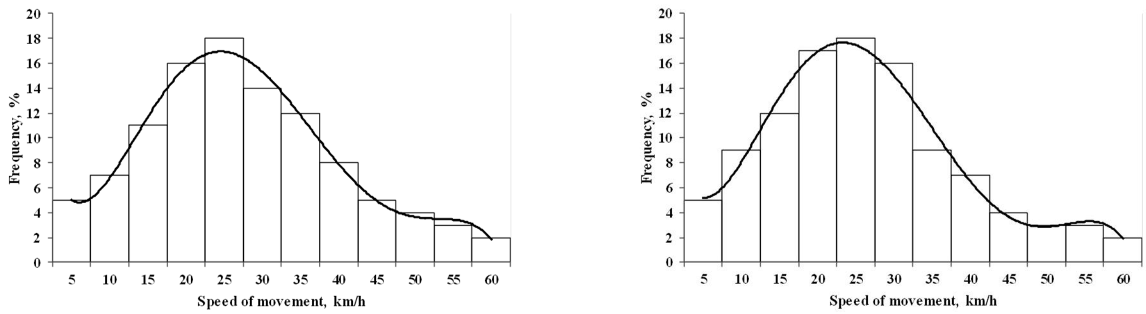


Fig. 1. The layout for the research on vehicles' speed

The overall results of the study of the instantaneous speed of private and public transport at the Type No. 1 test site are shown in Fig. 2. This graph compares the speeds for different lanes, allowing for a more detailed assessment of their characteristics and interaction when traveling on this section of the road.

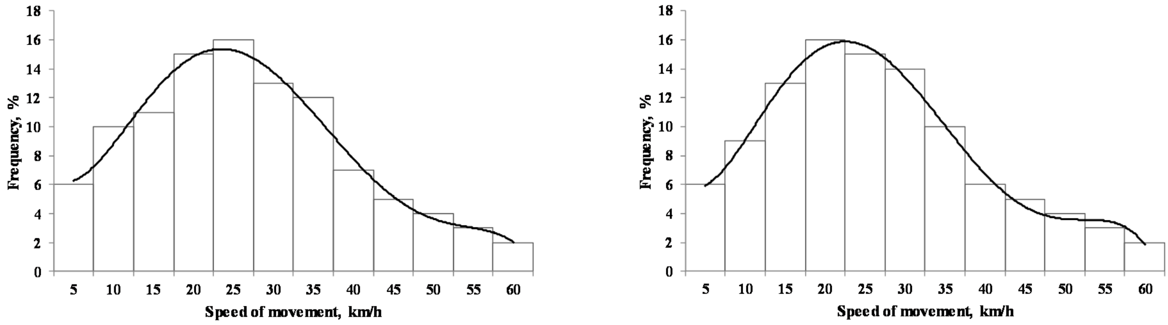


a *b*

Fig. 2. Research on the instantaneous speed at Type No. 1 intersection:
a – for private transport; b – for public transport

From the analysis of the data presented in Fig. 2, it can be seen that the largest proportion of private car drivers (19 %) drive at speeds between 24 and 26 km/h. It indicates that most drivers maintain a moderate speed, not exceeding the established speed limits. At the same time, among public transport drivers, the largest group (17 %) chooses speeds between 22 and 24 km/h. It may be due to various factors, such as frequent stops to pick up and drop off passengers or the influence of other vehicles on the road. Looking at the average values, the speed of private cars on this section of the street averages 28 km/h, which is several kilometers per hour faster than public transport, whose average speed is 23 km/h. Such differences may be due to the difference in the maneuverability of these vehicles and the specifics of the route for public transport, where there may be additional speed restrictions or delays due to the heavy traffic on this street.

The overall results of the study of instantaneous speed for private and public transport at the Type No. 2 test site are presented in Fig. 3. This graph allows comparing the speeds of both types of transport, which makes it possible to evaluate their characteristics on this section of the road and identify the factors that affect speed indicators.

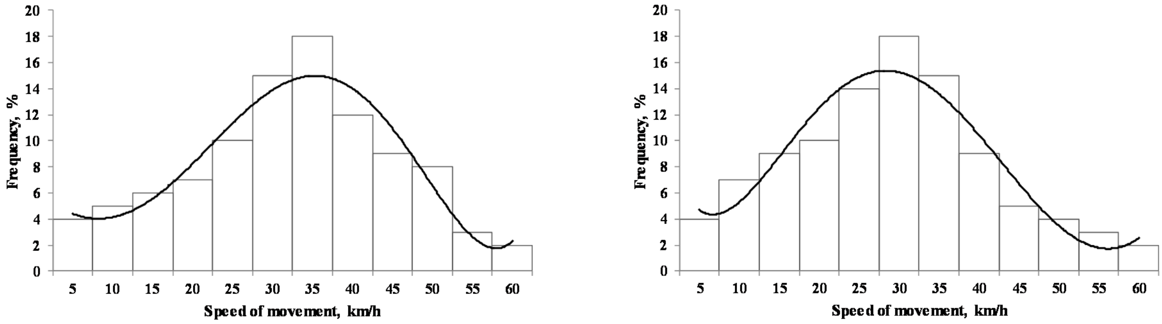


a *b*

Fig. 3. Research on the instantaneous speed at Type No. 2 intersection:
a – for private transport; b – for public transport

From the analysis of the information presented in Fig. 3, it can be seen that most private car drivers (15 %) choose speeds in the range of 23–25 km/h. In turn, among public transport drivers, 16 % choose a speed of 21–23 km/h. At the same time, the average speed for private cars on this section is 27 km/h, while for public transport, this value is 22 km/h.

The main results of a detailed analysis of instantaneous speeds for private and public transport at the Type No. 3 test site are presented in Fig. 4. It provides a better understanding of the characteristics of traffic flows and their impact on traffic efficiency within this part of the city.



a *b*

Fig. 4. Research on the instantaneous speed at Type No. 3 intersection:
a – for private transport; b – for public transport

From the analysis of the data presented in Fig. 4, it can be seen that the largest share of private car drivers (19 %) drive at speeds between 32 and 34 km/h. It indicates that most drivers maintain a moderate speed. In turn, 18 % of public transport drivers choose speeds between 28 and 32 km/h, which indicates that public transport may have a slightly higher average speed than private cars on this section. The average speed for private cars on this section is 32 km/h, indicating a high level of mobility for this type of transport in conditions without significant delays. For public transport, the average speed is 31 km/h. These data indicate that the speed of vehicles varies depending on the type of transport and the specific street, which is an essential factor for further analysis and improvement of transport infrastructure.

From the analysis of Fig. 2 (*b*) – 4 (*b*), we can see that public transport has an unstable movement pattern due to constant disturbances in traffic flow. One of the key factors is stops, where downtime depends on the number of passengers and the speed of their boarding and alighting. In addition, traffic is complicated by traffic light cycles, which create uneven delays along the route. Road conditions also have a significant impact, as traffic jams, accidents, or conflicts with private vehicles change traffic speed. Another important cause of instability is the variability of passenger flow, which makes stop times unpredictable. As a result, an unstable traffic flow is formed, leading to deviations from the schedule and disruptions in the regularity of transportation.

When assessing the priority of public transport, it is important to consider not only speed but also the time spent on delays. Delays include periods associated with passing through controlled intersections, pedestrian crosswalks, and stops in traffic jams or at stopping points to board and alight passengers. Such time expenditures are characteristic of transport moving in mixed traffic, where interaction with other road users can significantly affect the overall efficiency and timeliness of transportation.

Simulation modeling in the PTV VISSIM software environment is used for a detailed analysis of the impact of the dedicated lane for public transport on traffic flow indicators. This approach allows for evaluating key indicators, such as the average and maximum queue length, and determining the duration of traffic and delays caused by various factors, particularly at intersections and stopping points. Considering various traffic conditions, modeling can provide accurate data to assess the effectiveness of dedicated lanes and their impact on general traffic flow. Based on the developed simulation model reflecting existing traffic conditions, the average speed of traffic flow was determined on several essential sections of city streets under observation. It includes a 350 m section before a Type No. 1 intersection, a 300 m section before a Type No. 2 intersection, and a 400 m section before a Type No. 3 intersection. Determining these indicators allows us to assess the impact of dedicated lanes on traffic speed, delays, and the overall state of the transport infrastructure in these sections.

Measuring points were installed at the study sites to determine traffic flow speed, allowing accurate data to be obtained at different stages of traffic movement. The study segment is a section of road on which traffic parameters are recorded in detail. It is divided into 25 m intervals to increase the accuracy of the analysis. Observation points located every 25 m make it possible to track even minor changes in traffic flow speed on different road sections and identify areas of slowdown, traffic accumulation, or the influence of external factors. The collected data became the basis for further analysis and modeling, which made it possible to evaluate the effectiveness of allocating the dedicated lanes for public transport. The summarized modeling results for the three types of studies are shown in Fig. 5–7, allowing for a visual comparison of traffic speeds and determining the effectiveness of changes on each studied section.

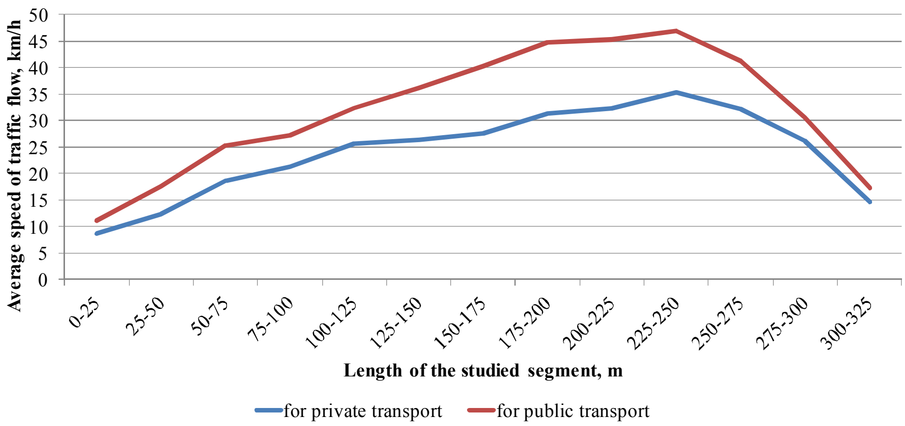


Fig. 5. Influence of the length of the studied segment on the change in the average speed of traffic flow before Type No. 1 intersection

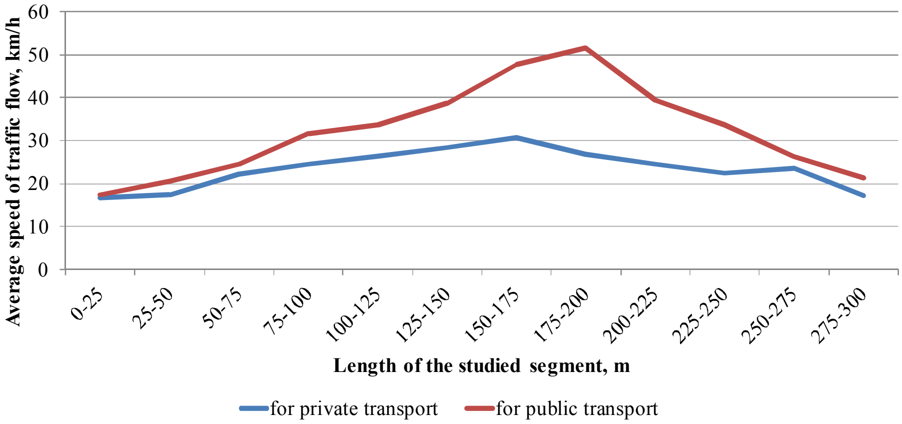


Fig. 6. Influence of the length of the studied segment on the change in the average speed of traffic flow before Type No. 2 intersections

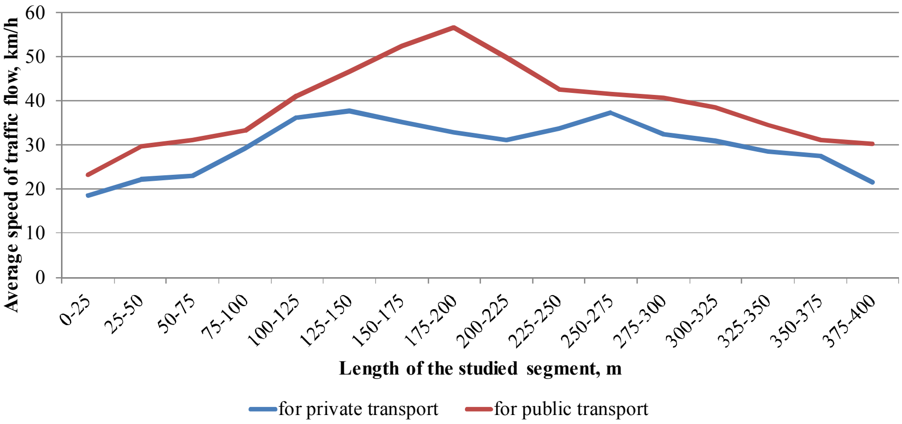


Fig. 7. Influence of the length of the studied segment on the change in the average speed of traffic flow before Type No. 3 intersections

Having analyzed Fig. 5–7, we can conclude that there are practically no significant traffic delays on sections of streets with dedicated lanes for public transport. It means that public transport can move along these lanes unhindered, even in cases of high traffic volume, which is typical for urban conditions. A decrease in traffic flow speed for the three studied objects is observed mainly near intersections, pedestrian crosswalks, parked cars, and other possible obstacles affecting overall traffic flow. This speed reduction may be due to the need to comply with traffic rules and natural delays associated with pedestrian behavior or delays before intersections. These trends are characteristic of both peak hours, when traffic volume increases significantly, and off-peak periods, when traffic volume decreases but the influence of external factors remains significant.

It is also worth noting that the minimum speeds on lanes for private transport and dedicated ones for public transport are almost the same – the difference in speed does not exceed 10 km/h. This indicates that, despite the dedicated lanes, the overall traffic flow remains similar under certain conditions. The maximum speed on such lanes ranges from 30 to 45 km/h, which indicates a stable traffic mode within the city. The weighted average speed indicators on these lanes also show similar values, which can be explained by the high traffic volume in these areas, which affects all types of transport. It is important to note that on dedicated lanes for public transport, minimum speeds do not fall below 10 km/h, which indicates their effectiveness.

When calculating the average speed of vehicles, the length of the section, i.e., the distance between the stop lines of adjacent controlled intersections or controlled pedestrian crosswalks, plays a key role.

Theoretical studies have shown that as this distance increases, the average speed of vehicles in traffic also increases. It can be explained by the fact that on longer road sections, there are fewer situations when vehicles are forced to accelerate or decelerate due to traffic lights. Under such conditions, traffic flow can move more smoothly, with fewer interruptions in the form of stops or accelerations. Thus, as the length of the section increases, vehicles have more opportunities to maintain a stable speed, which positively affects the overall speed of traffic flow.

Therefore, it can be concluded that dedicated lanes for public transport significantly improve traffic flow in cities. They help reduce delays in these areas and allow public transport to serve passengers faster at stops, providing a more efficient and reliable transport service for residents.

Using simulation modeling to study the speed mode of vehicles in dedicated lanes is appropriate. It allows for a detailed examination of changes in traffic flow characteristics under various conditions. Simulation modeling methods make it possible to assess how multiple factors affect key indicators such as speed, traffic volume, and the road network's capacity. For example, modeling can monitor how these parameters change depending on changes in traffic composition (the ratio of private and public transport), driver behavior, road conditions, or the optimization of traffic lights.

Such studies are beneficial for analyzing the effectiveness of transport systems, as they allow for predicting the possible consequences of implementing new solutions in traffic management. For example, modeling allows for identifying how the capacity of dedicated lanes for public transport changes with increasing traffic volume or how variations in traffic light programming affect idle time and delays. Because of such modeling, it is possible to identify the most critical points for improving traffic management, reducing delays, and increasing the transport infrastructure's overall efficiency.

Simulation modeling also makes it possible to consider various scenarios and their impact on traffic flow stability, which is essential for long-term planning and making justified decisions regarding the development of the transport network. It provides a flexible tool for predicting changes in the transport environment and improving the level of convenience for transport system users.

We will conduct simulation modeling for the analyzed sections of the road network using the results of field studies, in particular, data on traffic flow composition, actual traffic volume, and traffic light timing parameters. This modeling will allow us to recreate the real traffic conditions on these sections and examine how traffic volume, traffic light phase duration, and driver and pedestrian behavior interact.

The desired speed for different types of vehicles was determined, in particular: 40 km/h for cars, 30 km/h for trucks, 25 km/h for buses and trolleybuses, and 15 km/h for trams. These speeds are guidelines for each type of transport and consider their specific characteristics and traffic safety requirements in urban infrastructure conditions.

Initial traffic flows were established based on actual data on traffic volume in the analyzed areas. The first section has 749 veh./h., the second section has 827 veh./h., and the third section has 924 veh./h.. This variation in traffic volume reflects the different conditions in these sections, including the nature of the road infrastructure, the level of congestion, and possible traffic restrictions.

During the first five stages of simulation modeling, the volume of incoming traffic gradually increases by 10 %, 20 %, 30 %, 40 %, and 50 % of the initial values for each of the analyzed sections. It allows us to investigate how an increase in the number of vehicles will affect key traffic indicators, such as the duration of travel through the section under study, average speed, and maximum length of the vehicle queue. At each stage, changes in traffic flow characteristics are observed, allowing us to assess road infrastructure stability and performance under increased load conditions. The results of the simulation modeling are presented in Table 1.

Having analyzed the results of simulation modeling presented in Table 1, several important conclusions can be drawn regarding travel time, speed, and queue length on different sections of the road:

– On Type No. 1 section: there is a sharp increase in travel time when traffic volume increases by 10 % and 40 %, indicating potential delays or reduced road network capacity under such conditions. There is a significant increase in queue length (up to 159.6 m) with an increase in traffic volume, confirming an increase in delays.

- On Type No. 2 section: travel time remains almost constant as traffic volume increases, indicating sufficient reserve capacity on this section. There is only a moderate decrease in average traffic speed, which may indicate a minor impact of increased volume on these sections. The absence of significant traffic queues may indicate that traffic volume does not reach critical values for this part of the route.
- On Type No. 3 section: travel time remains stable when traffic volume increases; there is a 10 % decrease in average speed when traffic volume increases. An increase in queue length with a 20 % increase in volume may indicate a critical capacity threshold for this section, which needs to be considered when planning future changes.

Table 1

Results of simulation modeling of changes in traffic flow parameters with an increase in traffic volume on a lane for private transport

The analyzed section of the street or road network	Increase in the number of vehicles in traffic by a certain percentage, assuming a constant composition of vehicles in the studied section					
	0 %	by 10 %	by 20 %	by 30 %	by 40 %	by 50 %
Duration of passage through the analyzed section, s						
Type No. 1 section	28.4	36.5	38.4	42.1	45.9	47.5
Type No. 2 section	24.5	25.6	26.9	28.4	29.2	30.6
Type No. 3 section	27.2	28.9	29.7	30.8	31.6	31.8
Average speed of vehicles on the analyzed section, km/h						
Type No. 1 section	32.6	31.5	28.4	26.8	25.1	21.1
Type No. 2 section	36.8	36.0	35.1	34.6	32.7	28.5
Type No. 3 section	32.9	30.5	29.4	27.5	26.5	25.4
Maximum queue length of vehicles, m						
Type No. 1 section	65.2	78.9	85.9	106.4	124.8	159.6
Type No. 2 section	31.6	33.6	38.8	48.5	62.7	82.4
Type No. 3 section	45.7	51.5	74.6	90.5	102.4	116.5

In the following five stages of modeling, there is a gradual increase in the share of public transport by 5 %, 10 %, 15 %, 20 %, and 25 %. This approach allows us to assess the impact of the increase in the number of buses, trolleybuses, and trams on the overall efficiency of the transport system. Analysis of these stages allows us to understand how effective dedicated lanes for public transport are. The results of the simulation modeling are presented in Table 2.

Table 2

Results of modeling the changes in traffic flow parameters with an increase in the share of public transport

The analyzed section of the street or road network	Increase in the number of public transport vehicles in traffic by a certain percentage at the current traffic volume					
	0 %	by 5 %	by 10 %	by 15 %	by 20 %	by 25 %
Duration of passage through the analyzed section, s						
Type No. 1 section	34.2	38.5	39.1	40.6	41.1	43.8
Type No. 2 section	26.3	27.4	27.9	28.3	30.2	31.2
Type No. 3 section	28.3	29.6	31.3	33.7	34.9	35.3
Average speed of vehicles on the analyzed section, km/h						
Type No. 1 section	35.2	30.2	29.2	28.6	26.3	22.5
Type No. 2 section	41.2	40.2	39.5	38.6	37.4	35.5
Type No. 3 section	36.5	35.2	34.1	33.2	32.1	32
Maximum queue length of vehicles, m						
Type No. 1 section	86.2	97.5	125.4	135.4	195.6	215.6
Type No. 2 section	68.4	74.5	91.2	93.2	105.6	126.2
Type No. 3 section	78.5	84.2	102.6	116.3	124.8	145.3

Having assessed the simulation modeling results, the following conclusions can be drawn. In Type No. 1 section, when the share of public transport increases from 5 % to 15 %, there is a sharp increase in travel time. It can be explained by the fact that an increase in the number of public transport vehicles reduces the available space for private cars, reducing their speed. However, with a further increase in the share of public transport from 15 % to 25 %, the increase in travel time becomes much more moderate, indicating that traffic flow is gradually adapting to changes in the flow composition. In Type No. 2 and No. 3 sections, there is a direct relationship between the share of public transport and travel time. As the number of public transport vehicles increases, travel time increases evenly, without sharp fluctuations. It may result from better adaptation of the road infrastructure to such changes and the even distribution of vehicles.

It is also worth noting a significant decrease in average traffic speed with an increase in the share of public transport from 5 % to 20 % on the Type No. 1 section. It can be explained by the fact that many public transport vehicles take up significantly more space on the road. At the same time, in the Type No. 2 and No. 3 sections, the average speed remained virtually stable, indicating that an increase in the share of public transport has no significant impact on traffic speed. This is due to better traffic management and larger capacity in these sections, which allows public transport to travel at optimal speeds without significant obstacles.

Based on the results of simulation modeling, it can be noted that there are no significant changes in the dependence of the maximum queue length on the increase in the share of public transport in Types No. 2 and No. 3 sections. It indicates that changes in traffic flow composition in these sections do not significantly impact queue formation, probably due to effective traffic management and sufficient capacity. At the same time, in Type No. 1 section, there is a sharp increase in queue length when the share of public transport increases from 10 % to 25 %. This phenomenon can be explained by the poor condition of the road surface in the studied section, which limits traffic speed. The maximum queue length in Type No. 1 section reaches 215.6 m when the share of public transport increases to 25 %, which indicates a significant impact of this factor on queue formation and the overall state of traffic. It may also indicate the need to improve infrastructure, particularly road surface, and optimization of priorities for public transport to avoid a negative impact on private car traffic.

Therefore, recommendations have been developed to improve traffic flow on dedicated lanes and increase the efficiency of the transport system (Table 3). The proposed measures consider each section's specific characteristics and aim to reduce travel time, stabilize speed limits, and reduce queue lengths.

Table 3

Recommendations for improving traffic flow on dedicated lanes based on simulation modeling results

Section	Results found	Recommendations	Expected effect
Type No. 1	Increase in travel time at +10 % and +40 % volume; queue length up to 159.6 m; with an increase in the share of public transport to 25 % – queue length of 215.6 m	– road surface repairs; – introduction of public transport priority (T-signals, adaptive traffic lights); – allocation of a dedicated bus lane	Reduction in travel time by 15–20 %; reduction in queues by 30–40 %
Type No. 2	Travel time remains stable at +50 % volume; average speed decreases slightly; queues are practically non-existent.	– maintaining the existing organization; – monitoring of traffic volume	Maintaining a stable speed (no more than a 5 % decrease); preventing queues from forming
Type No. 3	At +20 % volume, queue length increases; average speed drops by 10 %	– adaptive traffic light control; – arrangement of bus bays; – widening of narrow sections	Reduction in waiting time by 10–15 %; stabilization of traffic speed
In general	With a 5–25 % increase in the share of public transport, traffic slows down on Type No. 1 section; on Types No. 2 and 3 sections, travel time increases evenly without critical delays	– implementation of GPS monitoring; – adaptive planning of the number of trips during peak hours; – information boards for passengers	Increase in traffic frequency by 10–15 %; reduction in the impact on private transport

Analysis of the modeling results showed that the most problematic section is Type No. 1, where, with an increase in the volume and share of public transport, the length of queues reaches 159.6–215.6 m. It indicates the need to repair the road surface and introduce priority for buses and trolleybuses. In Type No. 2 section, traffic remains stable even at +50 % volume, which confirms the availability of reserve capacity and allows for monitoring and local optimization only. Type No. 3 section shows a critical increase in queues at +20 % volume and a 10 % decrease in speed. Therefore, adaptive traffic light control and the arrangement of bus bays are required. In general, an increase in the share of public transport leads to a slowdown in private cars on Type No. 1 section, but does not cause significant problems on other sections. It indicates the feasibility of introducing intelligent transport systems and further infrastructure modernization.

5. CONCLUSIONS AND PERSPECTIVES FOR FURTHER RESEARCH

An analysis of vehicle speed on dedicated lanes was conducted to determine the impact of various factors, such as traffic volume and traffic flow composition, on road traffic efficiency. It was found that in areas with dedicated lanes for public transport, there is a reduction in delays and an increase in traffic capacity. Problems arising in these areas, related to increased traffic volume and changes in traffic composition, can lead to a reduction in average traffic speed and the formation of queues at intersections.

One of the main problems identified during the study is the negative impact of the increase in the share of public transport on traffic speed, particularly in areas with high traffic volumes. At the same time, increasing the number of public transport vehicles in some areas can significantly reduce travel time and improve traffic flow on arterial streets with sufficient capacity reserves. However, there is a significant increase in travel time and queue length in areas with low capacity.

It is necessary to focus on optimizing the traffic flow composition, in particular, balancing the number of public and private vehicles, as well as improving infrastructure to ensure the efficient movement of both categories of transport, to address these issues. It is recommended that measures be implemented to improve road surfaces, expand public transport lanes in high-traffic areas, and optimize traffic light control, which will reduce delays and facilitate the adaptation of traffic flow to changes.

Therefore, the results can help improve urban transport infrastructure, reduce delays, and improve traffic efficiency on critical road sections with high traffic loads. Using simulation modeling results to plan changes in traffic flow and road infrastructure is an essential step towards the sustainable development of urban transport systems.

Prospects for further research in analyzing the speed mode of vehicles in dedicated lanes are in-depth studies of the interaction of various factors that affect the efficiency of road traffic. One direction is to expand research on the impact of changes in road infrastructure, such as widening lanes for public transport, improving traffic light control, and creating integrated traffic management systems. In particular, it is worth focusing on developing adaptive traffic light control systems that can automatically respond to changes in traffic volume and composition, thereby optimizing traffic in dedicated lanes.

Author Contributions: Oleh Hrytsun: Conceptualization, Methodology, Software, Validation, Writing-Reviewing and Editing. **Dmytro Sydorov:** Writing-Original Draft, Visualization, Investigation, Software. Authors have read and agreed to the published version of the manuscript.

Funding: This research did not receive any specific grants from funding organizations in the public, commercial, or non-commercial sectors.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Bura, R. R. (2021). Vdoskonalennia metodiv minimizatsii zatrymky transportnykh potokiv u mistakh zi shchilnoiu zabudovoiu [Improvement of minimization methods of traffic flow delays in cities with dense built-up area]. *Doctor of Philosophie's thesis*. Lviv: LPNU (in Ukrainian).

2. Fornalchyk, Y., Kernytskyy, I., Hrytsun, O., & Royko, Y. (2021). Choice of the rational regimes of traffic light control for traffic and pedestrian flows. *Scientific Review Engineering and Environmental Studies (SREES)*, 30(1), 38–50. DOI: 10.22630/PNIKS.2021.30.1.4 (in English).

3. Zhang, M., & Wang, F. (2021). Impact of Bus Lanes on Traffic Flow and Congestion in Large Cities. *Journal of Urban Transportation, 35(2)*, 89–103. DOI: 10.1007/jutr.2021.0230 (in English).

4. Lu, J., Trasatti, A., Guan, H., Dalmeijer, K., & Van Hentenryck, P. (2024). The impact of congestion and dedicated lanes on on-demand multimodal transit systems. *Travel Behaviour and Society, 27*, 100772. DOI: 10.1016/j.tbs.2024.100772 (in English).

5. Basbas, S. (2007). Sustainable urban mobility: The role of bus priority measures. *WIT Transactions on Ecology and the Environment*, *102*, 12. DOI: 10.2495/SDP070782 (in English).

6. Li, Y., & Wang, H. (2020). Modeling the effectiveness of dedicated bus lanes in reducing traffic congestion. *Transportation Research Part B: Methodological, 135*, 94–108. DOI: 10.1016/j.trb.2020.01.002 (in English).

7. Bayrak, M., & Guler, S. I. (2021). Optimization of dedicated bus lane location on a transportation network while accounting for traffic dynamics. *Public Transport, 13(2*), 325–347. DOI: 10.1007/s12469-021-00269-x (in English).

8. Madadi, B., Van Nes, R., Snelder, M., & Van Arem, B. (2021). Optimizing Road Networks for Automated Vehicles with Dedicated Links, Dedicated Lanes, and Mixed- Traffic Subnetworks. *Journal of Advanced Transportation*, *2021(1)*, 8853583. DOI: 10.1155/2021/8853583 (in English).

9. Tsitsokas, D., Kouvelas, A., & Geroliminis, N. (2021). Modeling and optimization of dedicated bus lanes space allocation in large networks with dynamic congestion. *Transportation Research Part C: Emerging Technologies*, *127,* 103082. DOI: 10.1016/j.trc.2021.103082 (in English).

10. Russo, A., Adler, M. W., & Van Ommeren, J. N. (2022). Dedicated bus lanes, bus speed and traffic congestion in Rome. *Transportation Research Part A: Policy and Practice, 160*, 298–310. DOI: 10.1016/j.tra.2022.04.001 (in English).

11. Szarata, M., Olszewski, P., & Bichajło, L. (2021). *Simulation study of dynamic bus lane concept. Sustainability*, *13(3)*, 1302. DOI: /10.3390/su13031302 (in English).

12. 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).

13. 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).

14. Ahmad, F., Ansari, M. Z., Hamid, S., & Saad, M. (2023). A Computer Vision based Vehicle Counting and Speed Detection System. In *2023 International Conference on Recent Advances in Electrical, Electronics & Digital Healthcare Technologies (REEDCON)* (pp. 487–492). IEEE. DOI: 10.1109/reedcon57544.2023.10151423 (in English).

15. Polischuk, V. P., Vygovska, I. A., Nahrebelna, L. P. & Korchevska, A. A. (2023). Modeliuvannia rozpodilu transportnykh potokiv na merezhi avtomobilnykh dorih [Modeling of traffic flow distribution on the road network]. *Zbirnyk naukovykh prats "Dorohy i mosty" [The Collection of scientific papers "Roads and Bridges"], 27*(2023), 253–266. DOI: 10.36100/dorogimosti2023.27.253 (in Ukrainian).

Received date 28.08.2025; Accepted date: 10.11.2025; Published date: 09.12.2025.

ДОСЛІДЖЕННЯ ШВИДКІСНОГО РЕЖИМУ ТРАНСПОРТНИХ ЗАСОБІВ НА ВИДІЛЕНИХ СМУГАХ РУХУ

Анотація. *У роботі розглянуто питання зміни швидкісного режиму транспортних засобів на виділених смугах руху для громадського транспорту. Для аналізу цього явища було вибрано кілька основних магістральних вулиць Львова. Дослідження спрямоване на оцінювання впливу різних чинників, таких як інтенсивність руху та склад транспортного потоку, на ефективність дорожнього руху. Виявлено, що на ділянках із виділеними смугами для громадського транспорту відзначається зменшення затримок і підвищення пропускної здатності. Додатково встановлено, що впровадження виділених смуг сприяє підвищенню регулярності руху автобусів і тролейбусів, що позитивно впливає на дотримання графіків перевезень. Результати показали, що на вулицях із виділеними смугами для громадського транспорту істотні затримки в русі практично відсутні. Це забезпечує безперешкодний рух громадського транспорту навіть за умов високої транспортної інтенсивності, типової для міського середовища. Зниження швидкості транспортного потоку виявлено переважно в зонах, розташованих біля перехресть, пішохідних переходів, запаркованих автомобілів та інших об'єктів, які можуть впливати на загальну динаміку руху. Встановлено, що мінімальні швидкості на смугах для приватного та громадського транспорту практично не відрізняються – розбіжність не перевищує 10 км/год. Отримані дані підтверджують доцільність розширення мережі виділених смуг у межах міста, особливо на ділянках із високим пасажиропотоком.*

За допомогою програмного комплексу PTV VISSIM здійснено імітаційне моделювання для кожної із досліджуваних ділянок. Під час експерименту поступово збільшували інтенсивність транспортного потоку на 10 %, 20 %, 30 %, 40 % і 50 % від початкових значень. Це дало змогу оцінити, як зростання кількості транспортних засобів впливає на ключові параметри руху, зокрема на час проїзду досліджуваної ділянки, середню швидкість та максимальну довжину черги.

Отримані результати порівняно із реальними польовими спостереженнями, що дало змогу підтвердити достовірність моделі та її придатність для подальших досліджень транспортних процесів. Ці результати можуть сприяти вдосконаленню міської транспортної інфраструктури, що, своєю чергою, допоможе зменшити затримки та підвищити ефективність руху на ділянках із підвищеним навантаженням.

Ключові слова: *вулично-дорожня мережа, транспортний потік, інтенсивність руху, швидкість руху, пропускна здатність, рівень завантаження, моделювання руху, натурні дослідження, громадський транспорт.*