THE EFFECTS OF TRAFFIC FLOW ON THE CAPACITY OF A ROUTE TRANSPORT STOP

Abstract. This article is based on theoretical and experimental studies of the effects of traffic flow on the capacity of a public route transport stop. Using the data gathered, we examined the distribution of vehicles by traffic lanes in the vicinity of the stop.

We found out how vehicles interacting with each other and public transportation affect the amount of time traffic spends at the stop.

The presence of an entry pocket at a public transport stop influenced the distribution of traffic flow along traffic lanes on the main streets of the city.

Key words: street-road network of the city, capacity of a route transport stop, vehicles, traffic flow, entry pocket.

Introduction. The theory of traffic flows, especially the features and regularities of the movement of vehicles on the street-road network (SRN), should be given special attention in cities, considering the losses caused by mutual obstacles between transport. The increase in the duration of time that vehicles spend on urban roads is attributed to the escalating number of traffic jams, which are mainly caused by an increase in traffic flow (TF) and the inadequate capacity of SRN elements.

It’s worth noting that traffic jams, as a pause in vehicle movement, result in financial burdens (decrease in the effectiveness of cargo transportation, loss of time for vehicles, passengers, and drivers, increased fuel prices, environmental contamination, etc.) A traffic jam is characterized by its duration, the length of the line, and the number of vehicles in it. The mechanisms underlying the emergence of traffic jams, owing to the interaction of external and internal factors in the transportation process, which result in traffic delays, have been extensively examined by both domestic and foreign specialists [1, 2, 3, 4, 5, 6, 7].

Materials and the method. When solving traffic management problems involving the patterns of movement of vehicles on city streets, the dependence of the characteristics of the traffic flow is always used, namely the dependence between speed, intensity, and density [7]. The
specified characteristics cannot fully represent all the processes that occur in the traffic flow and are related to its composition, the technical condition of the roadway, the environment, and other factors.

In this article, particular emphasis is given to the determination of time expenses, which are attributed to the interconnectedness of transportation near the stop where the significant impact of public route transportation (PRT) on traffic flow is observable.

The main factors that influence the time spent by public transport are the intensity of traffic, the density, flow composition and density, the number of traffic lanes and their width, the presence or absence of a public transport lane, and weather conditions. In order to understand the time spent by vehicles on the city’s SRN in the area where the route transport stop (RTS) is located, it is necessary to consider the peculiarities of the distribution of vehicles along traffic lanes.

The distribution of vehicles by traffic lanes is highly uneven across all types of urban main streets within the city. Traffic intensity, composition of traffic flow, number of traffic lanes in one direction, current traffic rules, methods of arranging left and right turns at intersections, and placement of RTS are some of the factors that influence the distribution of vehicles along city streets [2, 8].

A distinctive characteristic of the traffic flow in urban environments is the presence of a substantial proportion of public transportation, which is obligated to make stops after a distance of 300–800 meters, as well as a significant number of intersections at the same level, where it is permissible to make left and right turns [8].

On-site surveys of traffic flows at the locations of RTS were conducted to establish the regularities of the distribution of vehicles by traffic lanes on the main streets of Kyiv.

The purpose of the conducted experiment was to establish the regularities in the distribution of vehicles by traffic lanes in the zone, where RTS has an influence, considering the number of traffic lanes along the carriageway.

The conducted research made it possible to establish the coefficients of the distribution of vehicles across the width of the carriageway (lane loading) for the relevant city main streets where the RTS is located. The coefficients depend on the number of traffic lanes on the carriageway. The loading of traffic lanes on the carriageway part of the street is determined as a percentage of the total traffic intensity in one direction. The influence of PRT on the distribution of traffic lanes is also determined.

The main streets of Kyiv with four, three, and two lanes of traffic (in one direction) have been examined. They were surveyed to see if there was an entry pocket at RTS where more than five routes pass. The main street’s free or closely linked traffic flow was one of the requirements for observing traffic.

The observations show how public traffic affects the RTS and general traffic flow moving down the street.

On the main streets of Kyiv with two lanes of traffic in one direction and an entry pocket, the distribution of vehicles by lanes is as follows: the first (right) lane was occupied by 37.53% of the total amount of traffic, the second (left) lane by 62.47%. Considering the types of vehicles, the distribution had the following values: light vehicles moving in the first lane accounted for 34.66%, 65.34% in the second lane; freight vehicles were distributed as follows: 44.74% in the first lane, 55.26% in the second lane; the distribution of public passenger transport for the first lane was 100%, there was no public transport traffic in the second lane (Fig. 1). The TF composition is: light vehicles make up 90.13%, public transport makes up 3.40%, and freight transport makes up 6.47%.
The main streets of Kyiv with two lanes of traffic in one direction and have not an entry pocket, have the following distribution of vehicles by lanes: the first (right) lane has 13.69% of the total amount of traffic flow, the second (left) lane has 86.31%. Considering the types of vehicles, the distribution had the following values: light vehicles moving in the first lane accounted for 6.47%, in the second lane – 93.53%; freight vehicles were distributed as follows: 23.47% in the first lane, 76.53% in the second lane; the distribution of public passenger transport in the first lane was 100%, there was no public transport traffic in the second lane (Fig. 2). The TF composition is: light vehicles make up 81.19%, public transport makes up 5.26%, and freight transport makes up 13.55%.

In the main streets with three lanes of traffic in one direction and no entry pocket, the distribution of vehicles by lanes is as follows: the first (right) lane has 10.69% of the total flow, the second (left) lane has 41.17%, the third lane has 48.14%. Considering the distribution of vehicles by traffic lanes, according to their composition, the indicators were distributed as follows: 7.27% of light vehicles traveled in the first lane, 41.42% in the second lane, and 51.31% in the third lane; freight vehicles moved as follows: 19.26% in the first lane, 51.64% in the second lane and 29.10% in the third lane; public transport (trolley buses, buses, shuttle taxis): 96.55% moved in the first lane, 3.45% in the second lane (public transport bypassing another vehicle at the stop), there was no public transport in the third lane (Fig. 4).

The TF composition is: light vehicles make up 89.40% of the total amount of transport, public transport makes up 2.79%, and freight transport makes up 7.81%.

In the main streets with three lanes of traffic in one direction and an entry pocket, the distribution of vehicles by lanes is as follows: the first (right) lane has 26.61% of the total traffic flow, the second (left) lane has 36.08%, and the third lane has 37.31%. Considering the distribution of vehicles by traffic lanes, according to their composition, the indicators were distributed as follows: for light vehicles, 22.93% of vehicles traveled in the first lane, 35.67% in the second lane, and 41.40% in the third lane; freight transport moved as follows: 20.21% in the first lane, 56.48% in the second lane, and 23.32% in the third lane; public transport (trolley buses, buses, shuttle taxis): 100% moved in the first lane, no public transport was observed in the second and third lanes (Fig. 3).

The TF composition is: light vehicles make up 84.30%, public transport makes up 3.13%, and freight transport makes up 12.57%.

Fig. 2. The diagram of the distribution of vehicles by traffic lanes (two lanes) on streets that have not an entry pocket on the RTS

Fig. 3. The diagram of the distribution of vehicles by traffic lanes (three lanes) on streets with an entry pocket on the RTS

Fig. 4. The diagram of the distribution of vehicles by traffic lanes (three lanes) on streets with no entry pocket on the RTS
On the four-lane main street of citywide significance of continuous traffic with an entry pocket arranged at the RTS, vehicles were distributed by traffic lanes as follows: 16.37% of traffic moved in the first lane, 25.53% in the second lane, 29.74% in the third lane, and 28.36% of the entire amount in the fourth lane.

The distribution by types of vehicles was as follows: 11.19% of light cars moved in the first lane, 26.32% in the second lane, 29.68% in the third, and 32.82% of all light cars moved in the fourth lane; 15.69% of freight vehicles movement was observed in the first lane, 27.45% in the second lane, 38.56% in the third lane, 18.30% in the fourth lane; the distribution of public transport was as follows: 92.42% in the first lane, 7.58% in the second lane, the movement of public transport vehicles was completely absent in the third and the fourth lanes (Fig. 5).

The TF composition is: light vehicles make up 76.05% of the total amount of transport, public transport makes up 5.35%, and freight transport makes up 18.60%.

![Fig. 5. The diagram of the distribution of vehicles by traffic lanes (four lanes) on main streets of citywide significance with continuous traffic, which have an arranged entry pocket on the RTS](image)

On the street with four traffic lanes, which do not have an arranged entry pocket at the RTS, vehicles were distributed by traffic lanes as follows: 5.88% drove in the first lane, 29.23% in the second lane, 33.80% in the third lane, and the largest number of vehicles – 31.09% of the entire number – moved along the fourth lane. Based on the obtained indicators, it is possible to determine the actual intensity distribution in the traffic lanes.

The distribution of vehicles by traffic lanes was established: 0.75% of light vehicles moved in the first lane, 28.10% in the second lane, 33.88% in the third lane, 37.27% of all light vehicles moved in the fourth lane; 1.96% of freight traffic was observed in the first lane, 32.35% in the second lane, 48.04% in the third lane, 17.65% in the fourth lane; the distribution of public transport traffic was as follows: 71.21% traveled in the first lane, 28.79% in the second lane, the movement of public passenger transport was completely absent in the third and fourth lanes (Fig. 6).

The TF composition is: light vehicles make up 75.24% of the total amount of transport, public transport makes up 7.46%, and freight transport makes up 17.30%.

![Fig. 6. The diagram of the distribution of vehicles by traffic lanes (four lanes) on main streets of citywide significance with continuous traffic, which have an arranged entry pocket on the RTS](image)

As it has been already stated in scientific works [8, 9, 10, 11, 12], one of the important characteristics of the operation of highways and main streets is the loading of traffic lanes by vehicles. The loading of the traffic lanes has a significant impact on vehicle maneuverability and is influenced by the characteristics and distribution of vehicles in each lane. The distribution of vehicles on traffic lanes is very uneven for all categories of roads and city streets. It depends, to a greater extent, on the intensity of traffic and the composition of the traffic flow. In the central and middle zones of the city, it also depends on the number of public transport routes and the distance between intersections and route transport stops.

It is known that the loading of lanes on city main streets significantly affects the speed of traffic flow in a specific lane. As the results of the survey showed, the driver tends to occupy the traffic lane that allows him to move at a higher speed.
The faster the flow moves along the lane, the more drivers of vehicles will want to get into it.

Observations on the loading of the carriageway by transport showed that the presence of public transport in the flow, which to a greater extent moves in the extreme right lane, discourages car drivers from moving into this lane. This is explained by the fact that public transport moves at a lower speed and, usually, has stops immediately after the intersection. Therefore, the first lane in the area where public transport stops are located is not fully filled with light vehicles. It should also be noted that in the presence of public transport with a traffic density of more than 6 vehicles, freight vehicles also move to the second and third lanes of traffic.

To analyze and determine the carrying capacity of streets, as well as to implement traffic management measures on main streets of citywide and regional importance, you can use the methodology suggested in works [9, 10]. These works are based on the determination of the lane coefficient for certain categories of streets and roads.

The results we obtained from our investigation of the intensity of vehicle traffic on the streets of Kyiv, where a public route transport stop influenced the traffic flow, led us to calculate the values of lane coefficients for the respective sections, which are correlated with the number of lanes of movement (Table 1).

Based on the obtained results (Table 1), it is possible to determine the actual indicators of the distribution of traffic intensity by lanes. This helps figure out the loading coefficient for each traffic lane and whether it’s necessary to have a pocket at a route transport stop.

Analyzing the obtained data, it can also be asserted that the absence of an entry pocket on the RTS leads to an increase in the number of vehicles in the second, third, and fourth lanes in relation to the area where the corresponding pocket is arranged.

**Conclusions.** Furthermore, it was established that the stops of route transport, which do not have entry pockets, significantly affect the distribution of vehicles along the traffic lanes. Especially, the loading of the first lane is characterized by an average decrease in the intensity of traffic along it. For streets with two traffic lanes, the average decrease in traffic intensity is 23%, for streets with three traffic lanes it is 12%, and for streets with four traffic lanes – 10%. But it should also be noted that with connected and dense traffic, the patterns of distribution of vehicles by lanes are significantly different from the free and partially connected mode. In such cases, most vehicles are distributed evenly across all lanes. Moving from one lane to another is observed only when the traffic in this lane is completely stopped. In a traffic jam on a four-lane main street, the average distribution of vehicles by traffic lanes is as follows: approximately 21% of vehicles move in the first lane, 23% in the second lane, 25% in the third lane, and 31% in the fourth lane. This phenomenon can be attributed to the fact that in the event of a traffic jam, the velocity of traffic decreases simultaneously across all lanes. As a result, light vehicles begin to move behind freight and public traffic, thereby filling the underloaded first and second lanes of traffic. When a traffic jam occurs, the number of vehicles in the first lane increases by an average of 13% and by 3.5% in the second lane, thereby reducing the load by 7.5% in the third lane and by 9% in the fourth lane.

After looking at the research, it can be concluded that the arrangement of the entry pocket at a route transport stop is appropriate on the main streets of the city with two, and three lanes of traffic going in one direction. This will enhance the carrying capacity of such a street and increase the load in the first lane from 15% to 25%.

**Table 1**

<table>
<thead>
<tr>
<th>Number of traffic lanes</th>
<th>Lane coefficient</th>
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<tbody>
<tr>
<td></td>
<td>1:2</td>
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<tr>
<td>2 lanes with a pocket</td>
<td>1.66</td>
</tr>
<tr>
<td>2 lanes without a pocket</td>
<td>6.30</td>
</tr>
<tr>
<td>3 lanes with a pocket</td>
<td>1.36</td>
</tr>
<tr>
<td>3 lanes without a pocket</td>
<td>3.85</td>
</tr>
<tr>
<td>4 lanes with a pocket</td>
<td>1.56</td>
</tr>
<tr>
<td>4 lanes without a pocket</td>
<td>4.65</td>
</tr>
</tbody>
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Bibliography:

1. Яковенко К.А. Містобудівні принципи та методи формування магістральної вулично-дорожньої мережі в умовах зростання рівня автомобілізації : дис. канд. : 05.23.20. Київ, 2013. 150 с.
8. Степанчук О.В. Закономірності розподілення транспортних засобів на багатосмугових магістральних вулицях. Вісник Інженерної академії України. К., 2016. Вип. 4. С. 259–263.

References:
