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INFLUENCE OF PASSENGER ROUTE TRANSPORT ON TRAFFIC SAFETY ON THE STREET AND ROAD NETWORK

ВПЛИВ ПАСАЖИРСЬКОГО МАРШРУТНОГО ТРАНСПОРТУ НА БЕЗПЕКУ ДОРОЖНЬОГО РУХУ НА ВУЛИЧНО-ДОРОЖНІЙ МЕРЕЖІ

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Abstract. The public transport comprises homogeneous vehicle movement. The motion of public transport passing through a road section exhibits signs of stationarity, hence formulating the stated scientific task. The paper proposes to assess the safety level of passenger public transport movement by deviations of the movement characteristics of public transport vehicles from the characteristics of the flow vehicles. The analysis conducted by the authors and the corresponding synthesis of the general conditions of passenger public transport movement in traffic flow on public roads allowed formulating a system of interaction between three elements: traffic flow, passenger transport vehicles, and road conditions. The provided criteria for deviation of the movement characteristics of passenger public transport vehicles from the characteristics of the traffic flow subsequently enable the evaluation of the danger level on the route. The proposed overall characteristic indirectly allows evaluating the safety level of passenger public transport movement on roads according to the provisions of traffic flow theory.

To formulate general characteristics regarding the consideration of road safety at sections and nodes of the street-road network through which the route passes in the methodology of calculating urban bus transportation routes.

Key words: traffic flow characteristics, accident rates, intersection analysis, street network, traffic safety, bus route planning.

Discussion

Under current conditions of passenger transportation organization in Ukraine, a significant number of road traffic accidents (RTAs) involving public transport vehicles are recorded, with not only an increase in the number of RTAs noted, but also their severity [1, 10, 15, 17]. The majority of RTAs involving public transport vehicles occur with the participation of buses operating on urban routes. Among the main reasons for these RTAs, the following are officially recognized by statistics: driver indiscipline, expressed in their violation of basic rules of the road such as speeding, overtaking rules violations, stopping the bus at unauthorized locations along the route; non-compliance with the technical condition requirements of the rolling stock of public transport vehicles, which primarily involves the operation of buses beyond their service life without major repairs, malfunctioning of instruments on the driver's dashboard (especially speedometers); non-compliance with the requirements of road conditions and traffic conditions at the location of the RTA occurrence. When analyzing the stated reasons for RTAs, the fact that buses move along the street-road network strictly according to the designated route (without the possibility of bypassing complex road sections) and in conditions of variable traffic flows is not taken into account. Additionally, it is necessary to note that the route passport takes into account the presence of RTA concentration points and their number along the route length, but this data does not affect route calculations. Also, the fact that during the bus route journey, it sequentially passes a certain number of these specified locations for each trip is not considered [2]. Thus, the safety of public transportation should be considered as including not only the safety of the vehicle's movement directly on the route but also the safety of movement on sections and nodes of the street-road network through which the route passes. The stated generalized scientific problem allows formulating a more specific task to be addressed in this work within the following objective.

Research design and methods

Road conditions at intersections and sections of the street-road network through which the respective bus route is planned or passes are the same for both traffic flows moving through the area and for the corresponding bus transportation vehicles. This characteristic reveals the absence of the need for detailed research into the impact of road conditions on the safety of bus transportation because it operates practically under the same conditions as the general traffic flow. Therefore, this impact has already been studied in the context of analyzing the overall impact of road conditions on road safety [3, 4]. It is important to emphasize that under the conditions of a specific traffic flow on a corresponding road section, a separate system of "traffic flow - road conditions" is formed [5, 6]. It has its own operating regularities, its level of traffic convenience [7, 8], and, consequently, its level of traffic safety, which can be quantitatively assessed based on road traffic accident (RTA) statistics on the specified road section. When introducing the considered road section into the composition of a specific route, additional transportation vehicles enter the formed traffic flow [9]. Bus transportation vehicles enter the traffic flow not as separate additional vehicles but as a separate traffic flow, which, unlike the flow formed on the road section, has significant differences, including: the traffic flow of bus transportation vehicles includes a fairly defined uniform composition, which also has significant geometric dimensions; the speeds of transportation vehicles in the traffic flow of bus transportation vehicles are close to each other and to the speed specified during the route development in the schedule, which according to traffic flow theory can be considered as the speed of the indicated traffic flow; the density of the traffic flow of bus transportation vehicles is also fairly defined because it is properly predicted by the schedule. The degree of influence of bus transportation on the traffic flow on the street section can be quantitatively assessed by the

following main characteristics: the proportion of bus transportation vehicles in the traffic flow per hour during peak traffic intensity; the difference between the speed of bus transportation vehicles (according to the schedule) and the speed of the traffic flow per hour during peak traffic intensity; the degree of change in traffic flow intensity when introducing bus transportation vehicles into the traffic flow per hour during peak traffic intensity; the degree of change in traffic flow density when introducing bus transportation vehicles into the traffic flow per hour during peak traffic intensity [10]. According to the proposed characteristics for assessing the degree of influence of bus transportation on the traffic flow on the street section, the following formulas for their calculation are suggested: the proportion of bus transportation vehicles in the traffic flow:

$$\Delta_1 = \frac{n_M}{n_\Sigma}, \tag{1}$$

n_M - the number of bus transportation vehicles observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, expressed in units;

n_Σ - the total number of vehicles observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, expressed in units;

- the difference between the speed of bus transportation vehicles (according to the schedule) and the speed of the traffic flow per hour during peak traffic intensity:

$$\Delta_2 = \frac{\frac{1}{n_M}\sum_{i=1}^{n_M} V_i}{\frac{1}{n_\Sigma}\sum_{j=1}^{n_\Sigma} V_j}, \tag{2}$$

V_i - the speed of the i-th bus transportation vehicle observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, km/h.;

V_j - the speed of the j-th vehicle observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, km/h.;

- the degree of change in traffic flow intensity when introducing bus transportation into the traffic flow per hour during peak traffic intensity;

$$\Delta_3 = \frac{N_\Sigma - N_M}{N_\Sigma} = \frac{n_\Sigma - n_M}{n_\Sigma}, \tag{3}$$

N_M - the traffic intensity of bus transportation vehicles observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, vehicles/hour;

N_{Σ} - The total traffic intensity of vehicles observed during field observations of the traffic flow at the road intersection on the corresponding street section per hour during peak traffic intensity, vehicles per hour;

- the degree of change in traffic flow density upon the introduction of bus transportation into the traffic flow per hour during peak traffic intensity;

$$\Delta 4 = \frac{q_{\Sigma} - q_{м}}{q_{\Sigma}} = \frac{\frac{N_{\Sigma}}{\frac{1}{n_{\Sigma}}\sum_{j=1}^{n_{\Sigma}} V_j} - \frac{N_{м}}{\frac{1}{n_{м}}\sum_{i=1}^{n_{м}} V_i}}{\frac{N_{\Sigma}}{\frac{1}{n_{\Sigma}}\sum_{j=1}^{n_{\Sigma}} V_j}} = 1 - \frac{n_{м}}{n_{\Sigma}} \cdot \frac{\frac{1}{n_{\Sigma}}\sum_{j=1}^{n_{\Sigma}} V_j}{\frac{1}{n_{м}}\sum_{i=1}^{n_{м}} V_i} = 1 - \left(\frac{n_{м}}{n_{\Sigma}}\right)^2 \cdot \frac{\sum_{j=1}^{n_{\Sigma}} V_j}{\sum_{i=1}^{n_{м}} V_i}, \quad (4)$$

$q_{м}$ - the traffic density of bus transportation vehicles observed during field observations of the traffic flow on the segment of the corresponding street section per hour during peak traffic intensity, vehicles per kilometer;

q_{Σ} - the total traffic density of vehicles observed during field observations of the traffic flow on the segment of the corresponding street section per hour during peak traffic intensity, vehicles per kilometer;

The proposed characteristics (1)...(4) enable a quantitative assessment of the impact of bus transportation on the main characteristics of traffic flow on the street segment. Moreover, these characteristics can be relatively easily determined and calculated experimentally [11]. Evaluating these characteristics is also straightforward: minimal impact - the characteristics approach unity; significant impact - the characteristics approach zero.

As a general characteristic of the impact of bus transportation on traffic flow on the respective street segment, the following dependence can be proposed:

$$\Delta_{\partial} = \frac{1}{4}\left(\Delta 1 + \Delta 2 + \Delta 3 + \Delta 4\right). \quad (5)$$

To incorporate characteristic (5) into the methodology for calculating urban bus routes, it is necessary to conduct research on the relationship between characteristic (5) and accident rates on the corresponding street segment, considering the differentiation between accidents involving buses and accidents involving vehicles in the existing traffic flow [12, 13]. This can be accomplished through correlation analysis.

The discussed characteristics only apply to specific intersections along the middle of street segments included in the corresponding traffic routes. Additionally, it is necessary to consider the impact of the presence of bus traffic within the flow of vehicles through street intersections. In the theory of traffic flow, there are not enough well-founded characteristics that adequately reveal the state of traffic at road intersections (moreover, it still needs to be proven that the movement of vehicles, in terms of traffic safety, at road intersections can be considered as traffic flows, which should be characterized not only by intensity but also by speed and density!) [14].

Thus, it is proposed to take into account the influence of bus transport on vehicle movement at road intersections from the perspective of traffic safety in the form of the following characteristic:

$$\Delta_n = \frac{N^{\Sigma}_{ДТП} - N^{м}_{ДТП}}{N^{\Sigma}_{ДТП}}, \quad (6)$$

$N^{м}_{ДТП}$ - the average annual number of accidents involving buses at road intersections, units;

$N^{\Sigma}_{ДТП}$ - the total average annual number of accidents involving vehicles at road intersections, units.

Using characteristics (5) and (6) (with further appropriate experimental justification), it is expedient to assess the safety of bus traffic along the entire route with the necessary division into homogeneous sections of streets and road intersections, which can be symbolically expressed as the following characteristic:

$$\Delta_м = \frac{1}{D+P}\left[\sum_{f=1}^{D}(\Delta_д \cdot k)_f + \sum_{s=1}^{P}(\Delta_n)_s\right], \quad (7)$$

D - The total number of homogeneous sections along the route, units;

P - The total number of road intersections along the route, units;

k - The correction coefficient of the impact characteristic of route transport on traffic flow on the respective street section, taking into account the correlation with accident statistics, units.

Characteristic (7) serves as a kind of "safety coefficient for traffic on the route" of buses along the respective sections of the road network [15, 16]. The values of the characteristics range from 0 to 1, where 0 is the lower limit of the safety level of traffic, and 1 corresponds to the upper limit.

Conclusion. Thus, the goal of formulating general characteristics for considering the existing traffic safety on sections and intersections of the road network traversed by bus routes has been achieved in this study. The proposed characteristics enable the assessment of traffic safety on sections, road intersections, and streets as a whole.

Further research should primarily focus on identifying the correlation between the overall characteristic of the impact of bus routes on traffic flow on the corresponding street section and existing accident rates on that section. Additionally, experimental data should be gathered to determine the values of the characteristic of bus traffic safety through road intersections.

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