ABSTRACT

Vũ Đức Minh. Improvement of traffic management efficiency in transport zones of a city. – Qualifying scientific work on the rights of the manuscript.

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The dissertation is devoted to the solution of the applied scientific problem of the estimation of the influence of complicated traffic conditions on vehicle speed and determination of the distribution of the vehicle speed on urban street networks.

To solve the problem, the existing methods to model transport flows and estimate vehicle speed on an urban street network as well as estimate vehicle delays caused by traffic management were analysed. It allowed defining that most of the existing approaches to predict vehicle speed implies determining its average value at some point or a short road section in any traffic conditions. The same approach is applied in modern transport modelling software, but it is obvious that the speed of a vehicle at a specific place and time is random. In addition, vehicle speed in urban traffic conditions is influenced by the intersections, especially signalized ones, and other obstructions of traffic causing speed decreasing. It points to the need for the study of vehicle speed in a city as the random variable and, correspondingly, the determination of its distribution law.

One of the data sources for this speed study was the traffic flows macro-modelling for relatively small but loaded areas which are the road networks in the centres of Kharkiv and Hanoi. To adequately represent the speed of traffic flows between the transport attractors located along the streets in the city centres, a new approach to traffic assignment based on vehicle delays at intersections was developed. This approach made it possible to represent traffic flow parameters more precisely compared to the existing most widespread traffic assignment method based on the road network link capacities and take into account private transport delays at signalized intersections during estimation of the travel speed between transport

attractors. Modelling of the traffic flows and a comparative assessment of the mentioned urban traffic assignment methods was carried out in the PTV® VISUM software since it provides tools that best reveal the features of each calculation method. At the same time, the comparison of alternative methods with the use of the real transport models provided the possibility to compare calculated traffic volumes with actual ones and brought the scientific problem under the study close to the problems arising in modelling practice.

Further study of the speed as a random variable made it possible to define that under the most difficult driving conditions, normal vehicle speed distribution changes to an exponential one. The gamma distribution was used as a connecting link in the transformation of the normal distribution into an exponential one under traffic conditions complication since the exponential distribution is the special case of gamma distribution with the shape parameter equal to 1, and the normal distribution is the limiting case of gamma distribution with the shape parameter tending to infinity.

To experimentally confirm the possibility of the use of the gamma distribution, the car speed influenced by the narrow carriageway was studied. This type of traffic conditions complication can be considered a kind of transition from a free flow to the complicated conditions caused by signalized intersections. It leads to a decrease in vehicle speed. However, it is not an extreme case of speed decreasing since it does not require a mandatory full stop of a vehicle– most drivers only need to reduce the speed without a full stop.

As for testing the possibility to use the exponential distribution when describing the speed under a significant traffic conditions complication, this hypothesis was confirmed during observations in the most difficult conditions in terms of speed – in the zones of influence of signalized intersections. The zone before the stop-line of signalized intersection causes traffic conditions that are a priori more complicated compared to carriageway narrowing because at this zone some drivers must stop and wait for the green signal.

During the study of the vehicle speed before the stop line of the intersection,

it was necessary to take into account the possible vehicles delays caused by waiting for the green. To take these waiting times into account during the speed measurement, a new methodology was developed. According to this methodology, the speed was measured in the cross-section at 1.5 m before the stop-line. It allowed the body of the first car in a queue to always be in the cross-section during waiting for the green signal. Upon that, the distance for which the time of passing the cross-section was measured was a car length. To make these measurements, two points of time was being recorded – when the considered cross-section was crossed by the front and rear points of a car. Also, a car length was being recorded – it was the distance between these points.

The analysis of measurements made according to the presented methodology allowed defining that the signalized intersection complicates the traffic conditions significantly compared to the narrow carriageway. This was reflected in a decrease in the average vehicle speed and an increase in speed standard deviation. In total, it causes a decrease in the shape parameter of the gamma distribution and, as a result, it tends to one. Based on the processed measurement results, the possibility to describe the random variable of the vehicle speed using an exponential distribution was confirmed.

The data about vehicle speed in urban areas in different countries collected during the research made it possible to obtain the regression model reflecting the relationship between the average speed and the shape parameter of the gamma distribution suitable for describing the regularities in speed values. The obtained model has sufficient predictive capability since the multiple correlation coefficient equals 96.3%.

Based on the research results, practical recommendations to apply defined regularities in the variable of private transport speed in cities were developed. Thus, a method to calculate acceleration noise for the vehicles leaving the signalized intersection on a green signal was developed based on these regularities. It allows obtaining initial data to estimate acceleration noise as a measure of comfort and energy consumption when driving in urban traffic flows as well as traffic

management quality. Also, a methodology to calculate the volumes of exhaust emissions from vehicles was developed, and it makes it possible interval assessment of the environmental impact of traffic flows and provides the tools for a comparative analysis of the changes in urban transport systems.

The developed recommendations and methods were applied during traffic flows modelling for the Long Biên district in Hanoi city and assessing the road network performance under different traffic conditions. Two options of traffic management in the district were considered – the current network state and the state with the rational traffic signal cycles at all signalized intersections in the district. These changes relate to the most loaded part of the road network as well as make it possible to evaluate the practicability of the developed methods and the effectiveness of the proposed recommendations. If the proposed traffic signal cycles are used, then total vehicle delays at signalized intersections in the Long Bien district should decrease by 12.47%, the average vehicle speed between transport attractors should increase by 0.55%, exhaust emissions should decrease by 0.56%, acceleration noise should decrease by 5.88%. It confirms the feasibility of the use of new methods for a comprehensive assessment of urban transport networks performance.

The scientific novelty of the obtained results is as follows:

- for the first time the influence of complicated urban traffic conditions on the car speed, which allows, in contrast to known approaches, determining the type of car speed distribution for the urban street network is established;

- for the first time a new approach to estimate the parameters of car speed distribution in cities which allows obtaining these parameters based on the average speed and, in contrast to known approaches, characterizing the speed as a random variable with the distribution law suitable for its description.

Methods to estimate the vehicle speed are improved due to determining the speed on the basis of the time for passing the distance equal to vehicle length, It, in contrast to known approaches, makes it possible to directly take into account the vehicle delays at intersections during speed measurements.

The practical significance of the research results consists in the development

of the methodology to measure the vehicle speed before the stop line of an urban signalized intersection, the approach to traffic assignment for urban networks based on vehicle delays at intersections as well as the methodology to estimate acceleration noise for the vehicles leaving the intersection on the green signal.

Keywords: speed distribution, car speed, signalized intersection, narrow carriageway, traffic conditions, traffic flow, transport modelling.

List of candidate's publications

Scientific papers in which the main scientific results of the thesis are published:

1. Lobashov A.O., Vu Duc Minh. Method to predicting traffic flows behaviour in cities. *Bulletin of the Kharkiv National Automobile and Highway University*. 2002. № 18. P. 77–79.

2. Makarychev O., Horbachov P., Vũ Đức Minh, Horbachova O. Car speed distribution in front of a stop-line of urban regulated intersection. *Bulletin of the Kharkiv National Automobile and Highway University*. 2019. № 85. P. 107–116.

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5. Vũ Đức Minh. Approach to estimating acceleration noise based on average vehicle speed. *Bulletin of Kherson National Technical University*. 2021. № 3(78). P. 27–35.

Scientific works certifying the testing of the dissertation materials:

6. Vũ Đức Minh, Horbachov P., Kolii O., Svichynskyi S. An approach to urban traffic assignment based on the parameters of traffic signal cycles. *Problems and prospects of automobile transport*: materials of the VIII Int. sc. and pract. internet-conf. (April 14-15, 2020). Vinnytsya, 2020. P. 98–102.

7. Horbachov P., Vũ Đức Minh, Svichynskyi S. The research of the distribution of the car speed before the stop-line of signalized intersection. *Innovation technologies for the development of machinery and efficient functioning of transport systems*: proceedings of the II All-Ukrainian sc. and tech. internet-conf. (November 9-11, 2020). Rivne, 2020. P. 34–36.

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Scientific works which additionally reflect the scientific results of the dissertation:

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