Optimization of traffic flows to increase the capacity of urban unsignalized junctions

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Abstract. Regular studies of traffic flows allow obtaining the actual parameters of the vehicle movement. Field observations using unmanned aerial vehicles help to optimize the research due to the wide capture field of the video camera, which allows comprehensively assessing traffic flows simultaneously utilizing all approaches to the intersection. When designing a road network, it is necessary to determine the capacity of all its elements. The characteristic elements are unsignalized intersections and junctions, the capacity of which largely depends on the intensity of the main and secondary directions, the behavior of drivers and the adoption by drivers of intervals between cars of the main traffic flow when entering the intersection.

1. Introduction
When designing the elements of the road network, it is necessary to ensure reliability and safety of traffic, as well as comfortable driving conditions for drivers characterized by the level of service.

A characteristic indicator of the intersection efficiency is its capacity during the design process.

Many factors affect the capacity values. Russian [2, 9, 10] and foreign researchers [4, 5, 6, 11, 12] note high influence of the traffic stream mix, traffic conditions, geometric parameters of intersections, as well as the difference in driver behavior on rural and urban roads.

The traffic stream mix and the dynamic characteristics of cars are fundamental factors that determine the capacity using the load equivalency factors [1, 3, 10]. The study of traffic flows on the example of Moscow space intervals [8] confirmed a decrease in the intervals between different types of cars in conditions of free movement compared to the study results of 1970s conducted for rural roads [10].

Foreign research [11, 12] also confirms that regular studies of traffic flows are necessary for a more accurate determination of road capability in modern traffic conditions. For example, the study of regulated intersections in Japan [12] is characterized by a systematic approach to the assessment of traffic flows by observing the same vehicles annually and by an integrated comparison after several years.

The issue of determining the boundary interval and the capacity of unsignalized intersections and junctions is relevant for a number of northern European countries [5], due to the fact that unsignalized intersections and junctions are one of the most common elements of the road network.

As a rule, the movement at unsignalized intersections and border intersections is determined by priority traffic signs for the adjacent direction. If there is no interference for drivers moving in the forward direction, except for cars moving in front of them, then the drivers of the secondary direction...
are forced to stop before intersection waiting for a sufficient interval in the main flow of vehicles to perform a safe left, right or forward maneuver.

The present study was conducted to determine the traffic stream mix in modern conditions and confirm changes in driver behavior using the example of boundary intervals.

2. Methods to determine the capacity of unsignalized intersections

The approach to determine the capacity of unsignalized intersections in Russia [2, 3] and abroad [1] is based on the probability that the drivers accept the secondary direction of intervals between cars of the main direction of movement (boundary intervals). Many authors [2, 4–6] note a high degree of influence of the drivers’ behavior on the boundary interval.

There are two models of behavior of drivers depending on the traffic intensity at the intersection. The classic model of acceptance of the boundary interval by drivers in the conditions of a continuous queue of secondary direction is the basis for the method to determine the capacity in Russia, which is used in the current regulatory documents [2, 3] and in the guide for determining the traffic flow capacity [1].

The second model of behavior of drivers while turning is caused by a high tension in a situation of high congestion in the intersection. At the same time, the drivers of the secondary direction take smaller boundary intervals, and the drivers of the main direction are forced to reduce speed and give way to drivers of the secondary direction. A number of European studies [4–6] focus on the analytical comparison of the capacity values of unsignalized intersections depending on the adopted model of behavior of drivers by comparing experimental data and computer simulations.

The approach to determining the boundary interval accepted by the drivers of the secondary direction is based on the comparison of the probabilities of acceptance and deviation by the drivers of the intervals available for integration into the main stream and safe maneuver.

Due to the fact that it is impossible to constantly observe the continuous queue of cars at unsignalized intersections and junctions, the Raff method is adopted as a method for determining the boundary interval in this work [7].

3. Results

A number of unsignalized intersections in Moscow were chosen as the subject of the study. The observations were made under conditions close to favorable. Time periods of measurements are picked with good illumination, no precipitation and dry pavement. Traffic at all facilities is organized by priority signs for drivers.

Field observations were made using a quadcopter. Video shooting was performed near the intersection, while the drone hovered at the height from 50 to 100 m, which made it possible to record the simultaneous movement of all traffic flows when approaching the intersection [8]. The shooting lasted 15 minutes.

The data were collected during laboratory processing of video material, which made it possible to obtain the following database: the traffic stream mix, the intensity of traffic in the main and secondary directions of movement, the intervals between cars of the main and secondary directions of movement.

The study of the traffic stream mix showed a predominantly high proportion of motor vehicles – 80-90%. The results are shown in Figure 1.

Subsequent statistical processing of the database was carried out in order to determine the values and the probability of intervals between cars of the main direction of movement. The nature of the secondary direction is determined by the average distance between cars. The boundary intervals are also defined.

Figure 2 shows an example of comparison of distribution functions of cumulative frequency of received and rejected intervals according to Raff method [7].

A comparative analysis of the boundary intervals obtained by field observations and theoretical values currently used in Russia is given in Figure 3.
Traffic stream mix

- Trolleybuses
- Road trains
- Motor lorries with the loading capacity over 8 tons
- Minivans
- Motor lorries with the loading capacity from 2 to 8 tons
- Motor lorries with the loading capacity up to 2 tons
- Articulate trolleybuses and buses
- Buses
- Motor cars

Share of vehicles in the traffic stream mix, %

Figure 1. Traffic flow in Moscow

Figure 2. Definition of the boundary interval of a pair of directions for unsignalized left-turn junction
Fig. 3. Dependence of the boundary interval on the intensity of the main direction when turning left

4. **Conclusion**

The capacity of unsignalized intersections depends on the composition of the flow, the intensity of the traffic stream mix and the probability of the drivers accepting boundary intervals of the secondary direction of movement.

During the study, the traffic stream mix, traffic intensity and the intervals between the cars of the main and secondary directions were determined. The values of the boundary intervals accepted by the drivers of the secondary direction at the entrance to the intersection are determined.

The values of boundary intervals for various planning solutions of unsignalized intersections will make it possible to clarify the capacity of unsignalized intersections and optimize the parameters of the road network.

The value of the boundary interval is influenced by a significant number of factors: geometric parameters of the intersection, number of lanes, intensity of the main and secondary directions, behavior of drivers at the entrance to the intersection, weather conditions, time of day, state of the road surface, equipment of intersections and organization of traffic, movement of pedestrians and cyclists.

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