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U-TURN CAPACITY AT SIGNALIZED INTERSECTIONS

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Abstract

The article presents the results of a study of the intersections capacity, at which the U-turn lane is organized, depending on the traffic flow volume and its organization. Signalized intersection capacity depends on traffic flow, geometry, traffic organization type, driver's behaviour and headways between drivers in each traffic lane. To analyse signalized intersection capacity it is necessary to determine traffic lanes saturation flow. The study presents field observation analyses of headways between drivers and saturation flow on U-turn lanes at signalised intersections in Moscow. To conduct research and identify patterns, intersections in Moscow were chosen with different conditions and different organization of the U-turns.

Keywords: intersection, critical headway, U-turn, capacity

1 Introduction

U-turn at the intersection is performed from the left lane, which can be designed for a left turn or be a shared lane for through and left-turn movements.

U-turn from the left lane can be carried out at the intersection itself, the queue to the left turn and the U-turn is accumulated before (downstream) the stop line. In this case, the U-turn is made through the upstream traffic or using a separate phase for left-turn traffic. The critical headway required for a U-turn exceeds the critical headway for a left turn, hence the presence of U-turn cars in the queue reduces the capacity of left-turn movement through the upstream traffic. U-turns can also be allowed before intersection from a left turn lane or a special lane for a U-turn. In the second case, the U-turn is made during the prohibition of the upstream traffic at the nearest signalized intersection.

At the selected intersections and sections of streets, surveys were carried out of the number of cars making a U-turn at different volume of the traffic flow, the percentage of cars making a U-turn, the delay before performing the manoeuvre and critical headway required for a U-turn.

This study aims to compare the saturation flow values of U-turn lanes at controlled intersections with different traffic arrangements. The types of the studied U-turn lanes are shown in Fig. 1

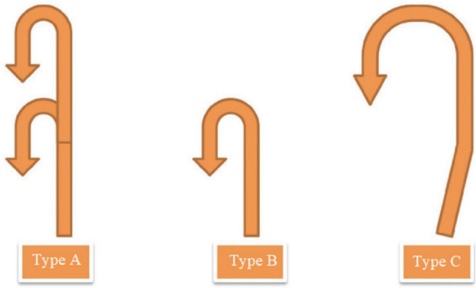

Figure 1 U-turn lanes traffic arrangements types at signalized intersections

The first type of arrangements for the allocated U-turn lane (type A in Fig. 1) allows drivers to make a U-turn in two flows.
The second type (type B in Fig. 1) allows drivers to make a U-turn in one flow.
The third type (type C in Fig. 1) suggests the following way of drivers movement. At first, drivers go along the lane allocated for the right turn, then cross the oncoming traffic flow and complete the maneuver, moving along the lanes allocated for the left turn.
Section 2 presents the research capacity and traffic flow methods. Section 3 presents data collecting and field observation process. Section 4 presents the research conclusions.

2 Research methods

Russian studies [3, 4] and guidelines [1] determine the capacity of the traffic lane at a signalized intersection depending on the saturation flow and the duration of the green phase as part of the traffic signal regulation cycle. The lane capacity P is determined by the formula (1):

$$P = S \cdot \frac{t_{green}}{T_c} \tag{1}$$

where
S - the saturation flow,
t_{green} - green signal duration, s,
T_c - cycle length, s.

The basic saturation flow corresponds to the number of vehicles moving freely in the forward direction, provided that the duration of the permissive traffic signal is one hour. This does not take into account the effects of longitudinal gradients, parking, bus stops, multi-lane roadways, pedestrians and cyclists. [1, 2]. The recommended value of a basic saturation flow with a lane width of 3.50-3.60 m is 1900 veh/hour [1]. The same value is adopted in the USA HCM 2016 Guidelines for cities with a population of more than 250,000 [2].
Reduction factors are applied for the turn lanes. In the Russian Guidelines [1], with a lane width of 3.50-3.60 m, the following factors are used: for turning left 1/1.75 or 0.571, for turning right 1/1.20 or 0.833. The US Guidelines for turn lanes management recommends using the value of 1.00 for an individual separate lane; if it is included in a group of lanes: to the left turn lane - 0.971, to the right turn lane - 0.885 [2].
Russian and foreign studies were conducted to saturation flow and capacity values determent at signalized intersections. The question of surface type and conditions were observed in Russia [10]. Saturation flow modelling at signalized intersections for modern traffic conditions was developed in India [7, 8]. A huge work was done in Japan [5], the values of modern and last decade saturation flow were compared with USA HCM 2016 [2] values and saturation flow reduction factors were established. The questions of queue length and left turn capacity

at signalized intersections were observed in China [6]. The questions of saturation flow regression at rainy weather conditions were observed in Shanghai [9].
When determining the saturation flow by field observations, Russian [1, 3, 4] and foreign methods [2, 5] suggest calculating the saturation flow by the formula (2). Provided that the mean value of the headway between vehicles takes into account the start delays of the first 4 cars when they are leaving the queue.

$$S = \frac{3600}{\Delta t_{cp}} \tag{2}$$

where
S - the saturation flow, veh/hour
Δt_{cp} - headway when the vehicles are leaving the queue, s.

3 Data collecting and field observation process

Signalized intersections in Moscow were selected as the object of research. The selected intersections are located on arterial roads with multi-lane carriageways. The width of the traffic lanes is 3.50 m. The intersections are equipped with traffic signals with different cycle lengths.
At the same time, traffic signal synchronization assumes a separate phase for the left turn and making a U-turn, thus there is no influence of the oncoming traffic flow on the drivers making a U-turn. During the study, the duration of the traffic signal control cycle and the duration of the green signal for turning left were determined.
Diagrams of typical intersections with allocated traffic lanes for a U-turn (types A, B, C) with indication of the traffic directions are shown in Fig. 2.
The theoretic cross-section for recording the vehicle passage is set along the left edge of the U-turn lane where the allowing changing lane road markings are applied.
For crossing the U-turn lane of type A, the cross-section length is 35.00 m, for type B - 25.00 m. For type C, the cross-section is set along the stop line of the allocated traffic lane for turning right, the section width is 7.00-12.00 m for two traffic lanes.
Field observations were carried out during daylight hours when the road surface was dry. The observations were carried out by video filming the traffic flow using stationary surveillance cameras located near intersections at a height of 6-10 m.
The video analysis allows obtaining the following database used in the study: lane traffic flow, headway between drivers, percentage of trucks in the traffic flow.

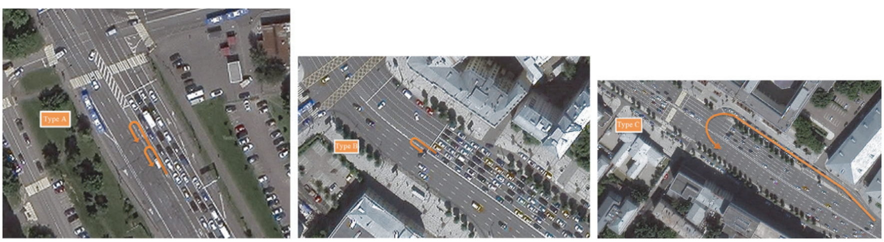

Figure 2 Layouts of the observation objects in Moscow. Type A - intersection of Lipetskaya St. and Lebedyanskaya St. Type B - intersection of Zubovskiy Boulevard and Prechistenka St. Type C - intersection of Zubovsky Boulevard and Zubovsky Proezd.

4 Conclusions

The result of the study is a comparative analysis of traffic flow parameters for three types of the U-turn lanes. The percentage of heavy vehicles is less than 15 %. Fig. 3 shows mean values of the headway between drivers when they are leaving the queue. Fig. 4 shows the actual values of hourly U-turn lanes traffic intensity. Fig. 5 provides a comparative analysis of the saturation flow of the U-turn lanes.

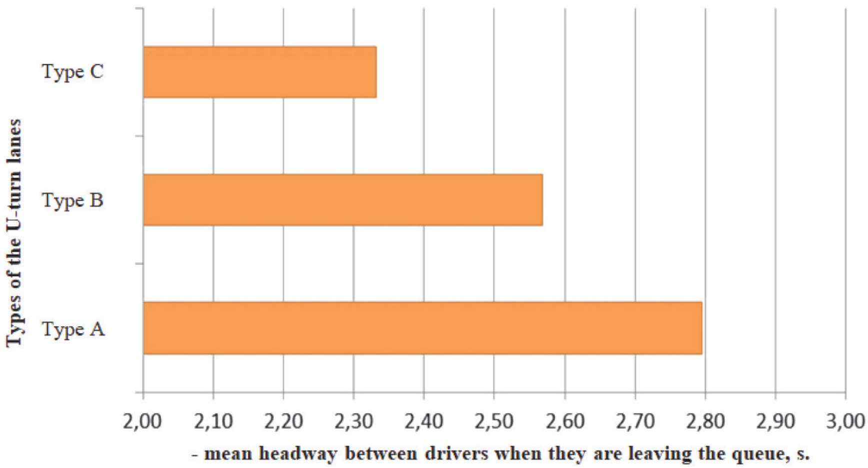

Figure 3 Mean headway between drivers

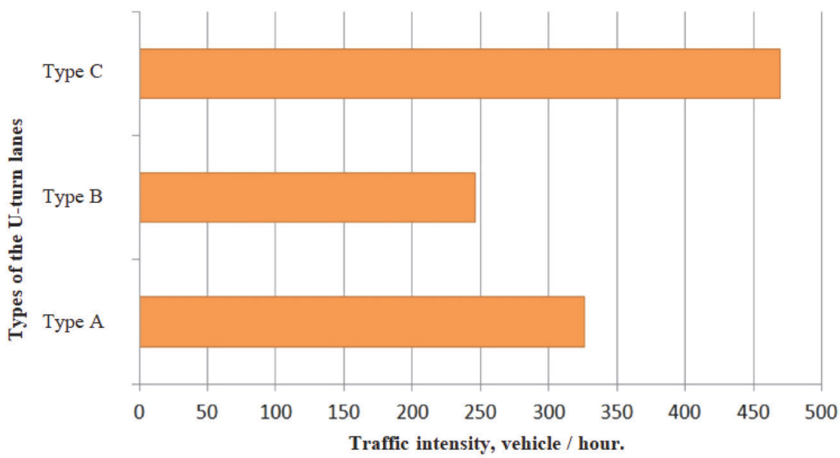

Figure 4 Traffic flow by field observations

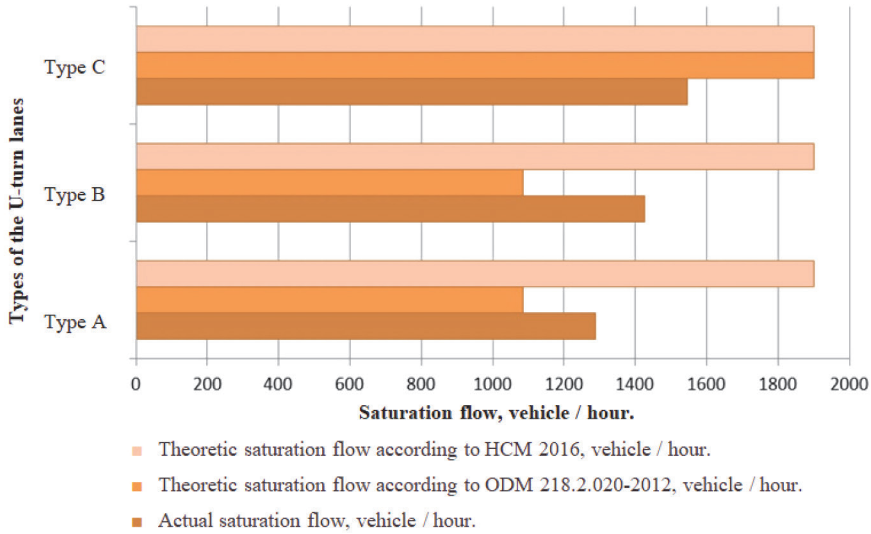

Figure 5 Comparative analysis of saturation flow values

The compare of theoretical values of saturation flow used in Russian Federation ODM [1] and used in USA HCM [2] with actual saturation flow shown the difference of 20-30 %.
The comparative analyses of average headways between leaving the queue drivers and saturation flow of different type U-turn lanes shown the more effective probability of type C U-turn lanes.

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