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Research of accepted headways and visibility conditions on intersections

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Abstract

Studies conducted in the preparation of a new standard for designing intersections in Russia are presented in this article. The studies were carried out using unmanned aerial vehicles in accordance with generally accepted scientific methods. Using statistical processing of measurement results, data were obtained about the headways accepted by drivers when making right and left turns from a minor road, and the distance from the edge of the main road to the driver's eyes, waiting an interval in the main flow on the minor road. Acceleration and deceleration on the turn lanes were also measured.

Keywords: accepted intervals, visibility, intersections, traffic safety

1. Research task

1.1. Visibility

When designing intersections, it is necessary to ensure minimum visibility distances for various types of intersections, sufficient for the driver to identify the traffic situation, make decisions and perform a safe maneuver, as well as ensure the availability of time required by another car that creates a risk of a traffic accident, completion of the maneuver begun by him [Montella 2011, Arndt 2004, NCHRP 2018, Road Safety 2010, Kimberly 2018, Road safety report 2009].

In case of an intersection from a secondary (minor) road without traffic lights, it is necessary to provide a visual field in the form of a triangle (Figure 1).

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At intersections with a STOP sign on a minor road, the driver of a vehicle on a secondary road must see the main road at a distance equal to the visibility distance to stop on the main road.

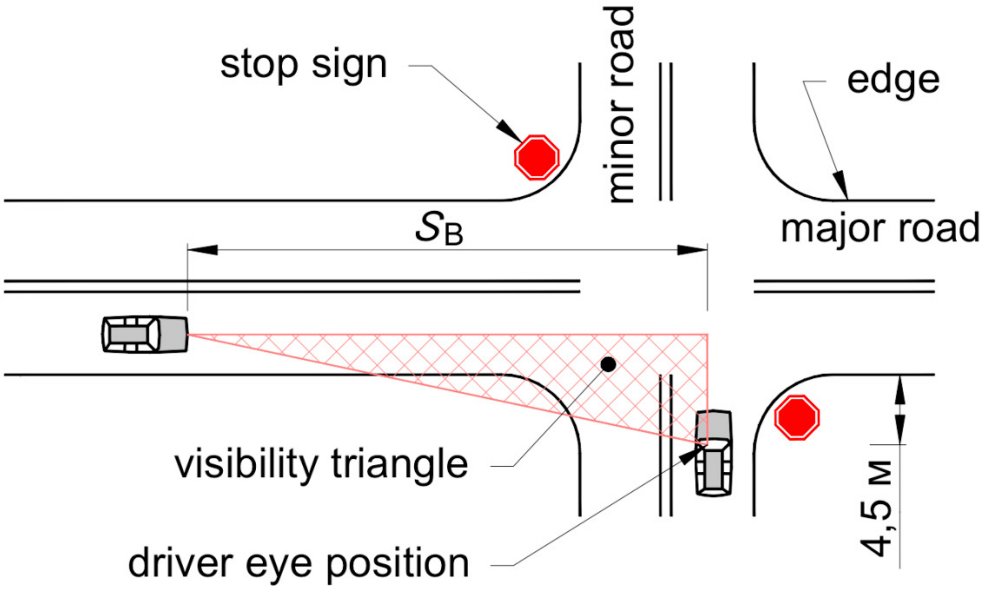


Fig. 1 - Scheme for determining the minimum distance of visibility to stop S at an un-signalized intersection.

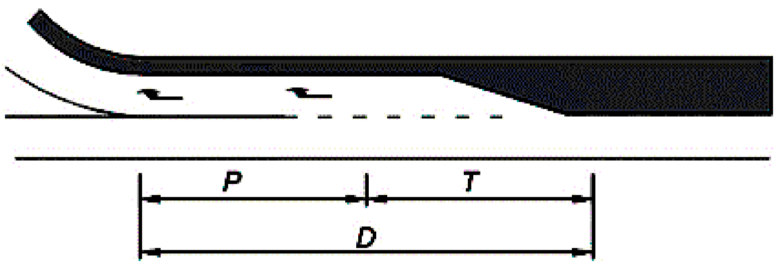
At intersections with a STOP sign on a minor road, the driver of a car who stopped on a minor road, at a certain distance from the edge of the main road carriageway, should be able to see the approaching car at a distance, allowing the car on minor to safely exit the main road. This distance is provided by the time of the maneuver or the interval taken for the maneuver, which is considered safe by drivers.

This condition is provided by the triangles of visibility (Figure 1), the sides of which are:

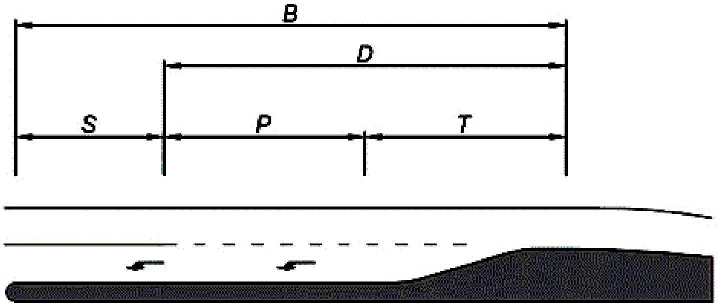
- along the minor road - the distance from the position of the driver's eyes at the right turn to the axis of the near lane of the main road, and at the left turn - to the axis of the main road.
- along the main road - the minimum distance of visibility for a vehicle moving on a main road.

1.2. Deceleration lane length

When arranging the right- and left-turn strips, an important question is the assignment of its minimum length (Lpsp, Fig.2).



a) Right-turn lane



a) Left-turn lane

Fig. 2 - scheme to determine the length of the transition-speed band

B = D + S;
D = P + T;

Where:

B is the length of the right turn lane, m;
D is the length of the deceleration section (L_t), m;
T is the length of taper, m;
P is the length of the parallel strip, m;
S is the length of the zone for accumulating a queue of cars, m.

In the framework of this work, the calculation of the length of the deceleration section (D) of the right- and left-turn lanes was carried out in accordance with the general theoretical principles for calculating the length of deceleration or acceleration lanes [MRWA 2017] using formulas (1):

For the right turn of the main direction of movement of the unsignalized intersection:

$$L_t = \frac{V^2 - V_0^2}{2a}; \qquad (1)$$

Where:

V - vehicle speed at the time of the start of braking, taken 0.7 - 1.0 of the design speed on the road, m / s;
V_0 - is the speed of the car at the moment of the end of deceleration, the design speed of the exit is taken, m / s;
a - is the calculated deceleration.

For the all turn lanes of the secondary road and the left-turn lane of the main road of the unsignalized intersection (a stop is required and a queue may accumulate while waiting for the possibility of maneuver):

$$L_t = \frac{V^2}{2a}; \qquad (2)$$

Accelerations of deceleration on left-turn lanes taken according to the data of various researchers and standards are presented in Table 1 [Thomas 2016].

Table 1 - Accelerations of deceleration on left-turn lanes, taken according to the data of various researchers and standards [Thomas 2016]

Source	Design Speed, km/h	Deceleration, m/s^2
AASHTO	50	2,5
	comfortable	1,5
	Unexpected situation	3,4
Austroroads	comfortable	2,5
	maximum	3,5
Trieber et al. (2008)	comfortable	1,67
Maurya and Bokare (2012)	Car	1,71

	Truck	0,88
Iowa State-Wide Urban Design	comfortable	2,74
Ong and Fwa (2010)	Depends on the condition of the road surface	
Benett and Dunn (1995)	60-70	1,39
	70-80	1,79
	80-90	2,22
	90-100	2,34
Whereas Wang et al. (2005)	60-90	2,67-2,55
Akcelik and Busley (2001)	≥60	3,09
	40-60	2,4-2,39
Qi et al. (2012)	85%	2,71-2,77

2. Research methodology

The method of determining the values of the critical headway Lt consists in measuring the values of practically observable intervals at which drivers of secondary road vehicles take to make a maneuver with their subsequent processing by mathematical statistics methods — by constructing curves of the accumulated frequency.

Given that the road conditions when making the right and left turn are different, the study of the values of the critical intervals must be conducted for each type of maneuver: making the right turn, making the left turn.

Considering that the composition of the traffic flow significantly affects the measurement results, the observations were organized in traffic conditions on two-lane highways, located in not built-up areas.

To carry out the observations, pre-sampling sites were selected and the data was collected.

The preliminary selection of measurement sites was carried out using the system for providing cartographic information, taking into account the following provisions:

1. The proposed intersection of roads to research must be located in not built-up areas.
2. The intersection of roads supposed to be researched must be located at the intersection of highways with two lanes (total in both directions).
3. The main direction of movement should be arranged on a straight line in the plan or a curve with a radius of more than 2000m.
4. The intersection of roads supposed to be researched must be equipped with technical means of road traffic in accordance with standard GOST 52289.

To carry out the observations of the stopping distances taken by drivers on the secondary road before the intersection, the preliminary selection of measurement sites was carried out using the system for providing cartographic information taking into account the following provisions:

1. The proposed intersection of roads to research must be located in not built-up areas.
2. The intersection of roads supposed to be researched must be located at the intersection on two lane highways.
3. The main direction of movement should be arranged on a straight line in the plan or a curve with a radius more than 2000m.
4. The intersection of roads supposed to be researched must be equipped with technical means of road traffic in accordance with standard GOST 52289.
5. To achieve the objectives of the study, surveys were conducted at the intersections of country roads. To determine the intervals between the cars, the values of the accepted critical intervals and the trajectories of movement in the intersection zone, intersections were chosen on some roads of Moscow and other regions. The intersections to be examined were located outside of the settlements. To record mainly used quadrocopter equipped with a video camera and recorders, followed by video processing. Also, to measure the speed mode, we used speed and range meters.
6. For the measurements, the locations, the optimal period for the saturation factor (more than 0.7, but less than 1), the number and duration of the sessions were determined.
7. Data about the volumes and density of traffic flows from video recording was obtained manually or with the help of special software.

8. The speed of vehicles and headways were fixed on the basis of the reference segments of known length, transferred to the video image of the road (between two lighting poles, etc.) and the travel time of the vehicle of such a segment. These data were also selectively compared with the data of the velocities obtained by direct measurement with the help of speed meters in order to control the accuracy of the measurements.

9. When processing video files, headways were recorded. To fix the time of approach to the target, critical headways and other indicators of interest, we used online stopwatches that allow you to simultaneously take into account several time characteristics.

10. The accuracy of such measurements is high and the error is determined only by the human factor, which can be minimized by the technology of performance of work. One video was processed by at least two accountants on two different online programs to improve measurement accuracy.

The best place to install the equipment is considered to be a curb or pavement near the entry point to the intersection, provided that they do not interfere with traffic, and observers are not visible to drivers. The recorders were installed in such a way as to ensure the possibility of shooting the main stream and the stream moving along the secondary road at a sufficient length. Also in parallel with the shooting of DVRs, a survey was conducted from a quadcopter, which was located at an altitude of about 100-300 meters above the intersection. In this way, it was possible to shoot all incoming flows and the intersection itself by tracing the trajectory of all vehicles along the whole route.

3. The location of the driver's eyes on a secondary road unsignalized intersection

To construct a triangle of visibility it is necessary to define the legs of such a triangle. And if the length of the leg along the main road depends on the estimated speed, driver response time and deceleration rates (the standard formula for calculating the distance of visibility), the leg length along the minor road will be determined by the distance of the driver's eyes from the edge of the secondary road. It depends on the size of the car, the location of the driver inside the car (in the car the driver is located between the axles, the head is often close to the middle of the car's length car, in truck or bus - in front of the front axle), the place of application of the stop line (determined some factors, including the presence of a pedestrian crossing).

Based on the results of the studied un-signalized intersections, a graph of the likelihood of the driver's eyes being located on the secondary road from the edge of the main road has been build (Figure 3). The study did not take into account pedestrian crossings due to their performance at un-signalized intersection outside built-up areas.

The distance from a stopped car on a secondary road to the edge of the main road is shown in Figure 1. For the case of 85% security, the distance is about 4 m, 100% security is 5 m. But increasing this distance leads to an increase in the restriction of the adjacent territory or additional requirements for cutting down of green plantings.

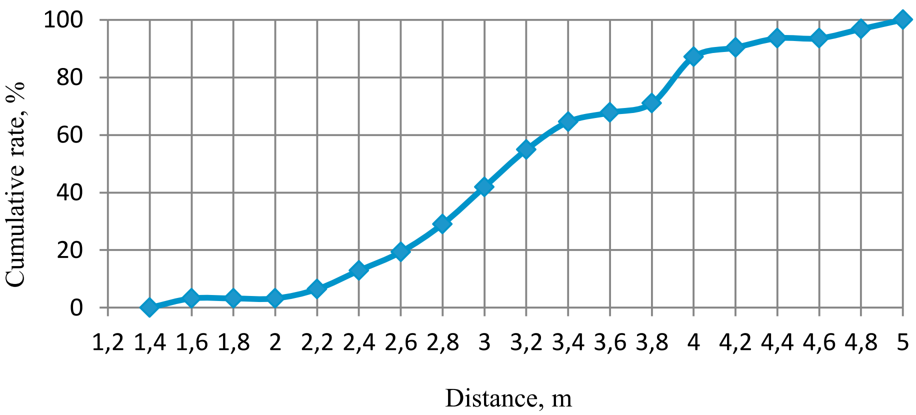


Fig. 3 - Distance from a stopped car on the secondary road to the red line (roadway) of the main road

The position of the driver on the secondary road relative to the edge of the main road also changes (Figure 4.) However, the results of the study carried out at stage 2 showed that to calculate the length of the leg of the triangle of visibility along the main road, this difference is not significant due to the insignificant value relative to the required distance of visibility.

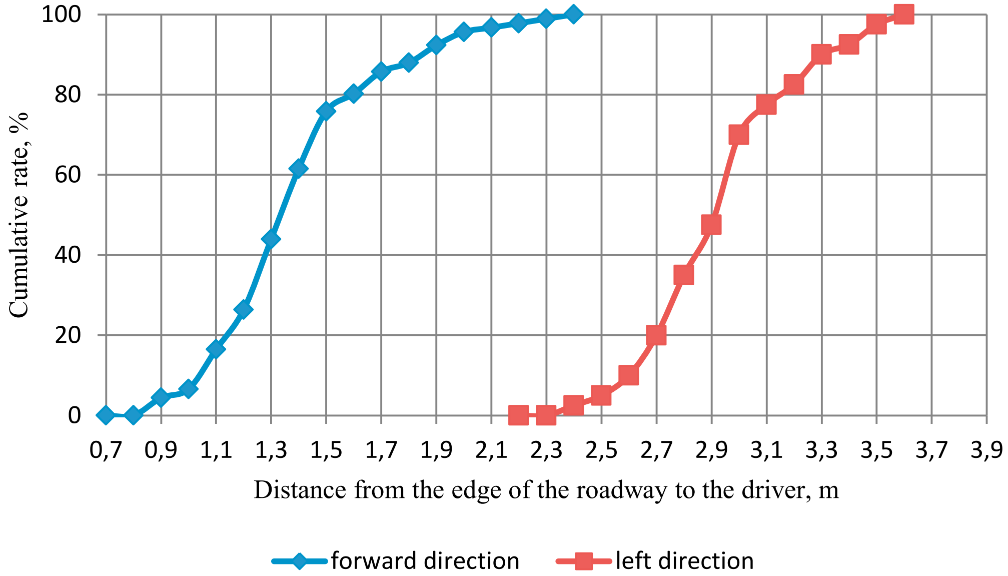


Fig. 4 - The position of the driver's eyes on the secondary road relative to the carriageway

4. The results of processing measurements of the speeds and accelerations of the transport stream

The measurements made it possible to reveal the accelerations and decelerations, which will allow to calculate the length of the acceleration section after the intersection and the length of the deceleration section of the lane for the right or left turn at the intersection. The measurement results are shown in Figures 5 and 6.

For right and left turn lanes optimal, according to foreign documents. is the deceleration of 1.5 m/s^2. According to the research conducted at the previous stage in the case of movement of buses, especially when there are standing passengers. the design deceleration shall be taken as 1.0 m /s^2.

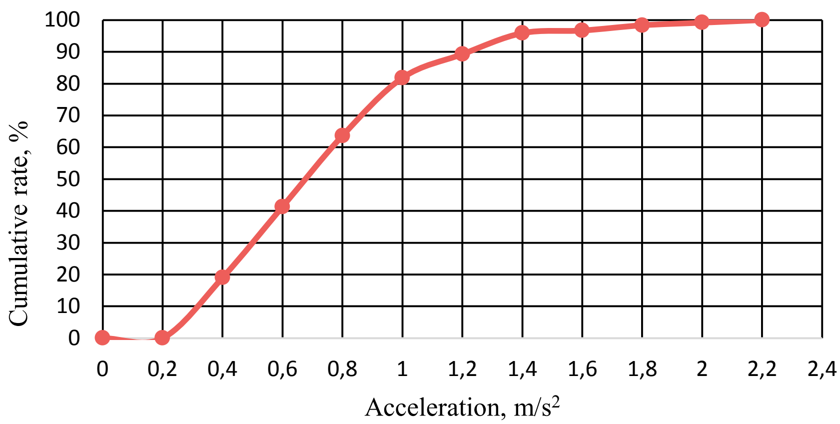


Fig. 5 – Acceleration on the turn lane of intersection

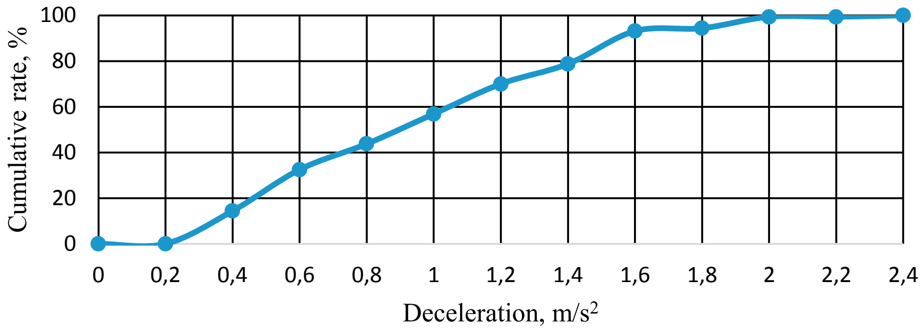


Fig. 6 – Deceleration on the turn lane of intersection

5. Critical headways

The results of studies of critical headways are presented in Figure 7 - in Moscow and in Figure 8 - in Irkutsk. The critical interval was investigated for the case of left turns from main direction on the intersection.

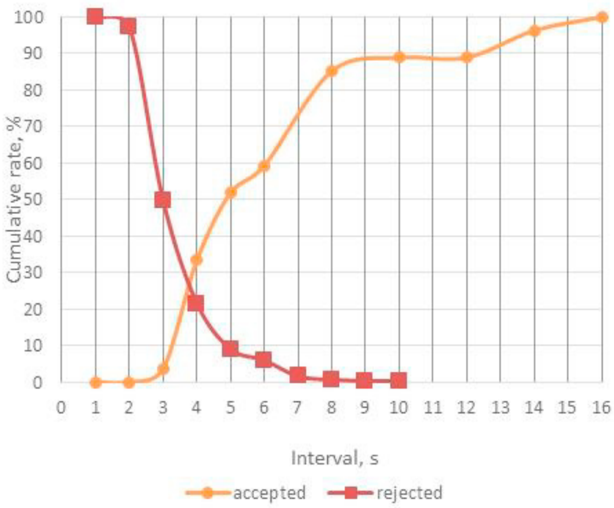


Fig. 7 – Critical headway for left turn from the central dividing line in Moscow

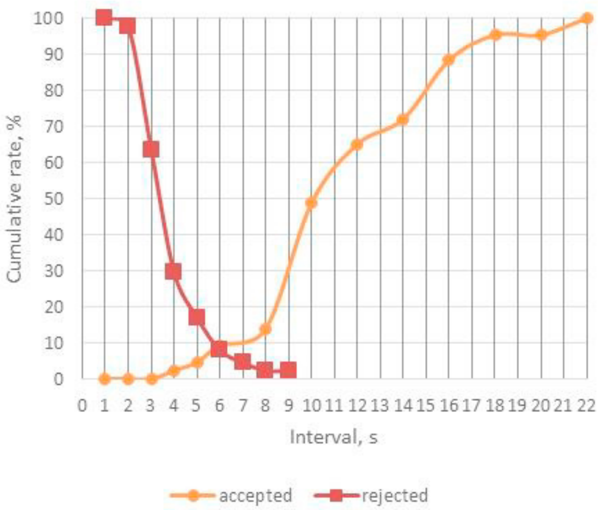


Fig. 8 – Critical interval for U- turn on expressway in Irkutsk

6. Conclusion

The results of the study will clarify the requirements for the geometric design of intersections of different types. The new design manual will include revised visibility requirements at the intersections, as well as revised parameters of braking and acceleration lanes length calculations. The new Russian standard with intersection requirements will be approved this year.

The conducted studies allowed to formulate requirements for the length of the deceleration and acceleration lanes, based on the design speed at the approach to the intersection. This allows you to reduce the required space for acceleration and deceleration lanes by speed management at the approach to the intersection on the main road.

Results of the critical intervals study allows to provide safe maneuvers from the secondary road by speed management at the approach to the intersection on the main road, when visibility at the intersection is limited.

The position of the driver on the secondary road relative to the edge of the main road make it possible to set requirements for roadside widths that are free from obstructed visibility.

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