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Forecasting the hazards of transport flows

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Abstract. The analysis of the indicators of the danger of conflict points on the equivalent intersections of roads along two directions of traffic of cars is considered: directly and to the left. Information is provided on the calculation of the forecast characteristics of the danger formed at the intersection of conflicting points in the current time mode by the input values of the speed of cars moving straight and to the left. Variations in the intensity of movement of cars moving in these two directions along the hour intervals are taken into account. Using the proposed methodology allows you to make decisions about the limitations of speed regimes and directions of traffic along the lanes of the carriageway.

1 Introduction

When reconstructing existing road crossings of motor vehicle traffic, as well as in the design of new sections of the road network of settlements, designers often do not have information about the possible danger of conflict points in places where traffic intersections occur. The purpose of this paper is the calculation of predictive estimates of the probability of occurrence of road accidents, depending on the traffic flow pattern, traffic intensity of cars and their speed. Assessment of the danger of a crossroads or pedestrian crossing is usually made on the average, based on the number of traffic accidents that have occurred over a specific period of time, for example, a month, six months or a year. Such an approach cannot accurately reflect the monitoring of the danger of a conflict point, which can change during the day in a wide range. According to the authors, at present there is a need to assess the risk of conflict points that are formed at the intersections of courses followed by traffic participants, which will allow monitoring of this indicator for short time intervals.

2 Material and methods

Each intersection of the road network, primarily in settlements, contains a certain number of conflict points, characterized by an indicator of the risk of traffic accidents. In the content of such conflict points, two types of conflict subjects can be identified: "car - car" and "car - pedestrian".

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The definition of the assessment of the danger of certain sections of the road network is usually made according to the safety index K_a [1], taking into account the annual number of road accidents, the traffic intensity and the number of conflict points,

$$K_a = \frac{10^7 G K_g}{(M+N)25}, \tag{1}$$

where M and N are the total traffic intensities of vehicles on intersecting directions of motion; 25 - the average number of working days in a month; K_g is the coefficient of annual non-uniformity of motion; G is the total annual number of road accidents at a given intersection, determined by formula

$$G = \sum_{i=1}^{n} q_i , \tag{2}$$

where q_i is the number of traffic accidents at one conflict point; n is the number of conflict points at the intersection.

The calculated road traffic hazard indicators for these formulas can be used as a starting material in the development of measures to reduce the accident rate at the intersection by changing the direction of traffic, or the reconstruction of this intersection. However, this technique can not be used to calculate the operational indicator of the danger of crossing in the current time mode, because it is based on statistics for the year.

The danger of one conflict point $q_{ia\text{-a}}$ at the intersection, where the conflict is only cars, is determined by the formula [7]

$$q_{ia-a} = K_i M_i N_i 10^{-2} , \tag{3}$$

where K_i is the danger of the conflict point; M_i and N_i - the hourly intensity of traffic of vehicles in the intersecting directions.

The danger of the conflict point at the intersection, where the conflict is cars and pedestrians, is determined year by year in the statistical record of road accidents of this type, and in the absence of such data in the forecast value by the formula [7]

$$G_P = 0{,}0025 + 10^{-3} 0{,}92 \sum (N_a N_n^{0,25}) , \tag{4}$$

where N_a and N_n are the hourly intensity of traffic of cars and pedestrians at the given conflict point.

The danger of the conflict point at the intersection, where the conflict is cars and pedestrians, is determined year by year in the statistical record of road accidents of this type, and in the absence of such data in the forecast value by the formula [7]

$$G_P = 0{,}0025 + 10^{-3} 0{,}92 \sum (N_a N_n^{0,25}) , \tag{5}$$

where N_a and N_n are the hourly intensity of traffic of cars and pedestrians at the given conflict point.

If we take into account that the G_{P} index determines the forecasted value of the annual number of road accidents in this conflict point, the danger value of this conflict point per one hour of the current time for the car-pedestrian conflict can be determined by expression

$$q_{ia-n} = \frac{G_n}{365 \cdot 24} . \tag{6}$$

Assuming that the main components of the danger of the conflict points of both types $q_{ia\text{-}a}$ and $q_{i\text{-п}}$ are traffic intensity indicators of cars and pedestrians, predicted hazard estimates of each such conflict point at the intersection in the current time mode by hour intervals can be determined by these formulas.

To analyze the state of the danger of a crossroads, a scheme is drawn up, indicating the directions of traffic and the places of movement of pedestrians. Further on this scheme conflict points of two varieties are distinguished according to the composition of the participants in the conflicts.

The collection of information on the traffic intensities of cars and pedestrians can be carried out either manually or in automatic mode with hour intervals. For each conflict point, a list of observations is compiled, which records information on the intervals of observation, the intensity of traffic of cars and pedestrians, including violations of the Traffic regulations. According to the received data, the danger indicators of this conflict point are determined for each hour interval.

The probability of occurrence of road accidents in the designated conflict points can be considered as independent compatible events. hen according to the theorem of addition of probabilities [3] on the first kind of the conflict "Car-car", the forecasted risk assessment of crossing at the designated conflict points $Q_{\text{a-a}}$ can be considered in the form

$$Q_{a-a}\left(\sum_{i=1}^{n} q_i\right) = \sum_{i=1}^{n} q_i \ , \tag{7}$$

where i is the ordinal number of the conflict point of the first kind; n is the number of conflict points of the first kind; q_i is the probability of conflict at the i-th point.

Similarly, for the second type of "Car Pedestrian" conflict, the predictive hazard assessment $Q_{\text{a-n}}$ can be considered in the form

$$Q_{a-n}\left(\sum_{j=1}^{k} q_i\right) = \sum_{j=1}^{k} q_i \ , \tag{8}$$

where j is the ordinal number of the conflict point of the first kind; k is the number of conflict points of the first kind; q_j is the probability of conflict at the i-th point.

The overall probability indicator [3] of the occurrence of an accident at the intersection of two types of conflict points according to the method of induction can be expressed as the sum of the probabilities

$$Q = Q_{a-a} + Q_{a-n} \, . \tag{9}$$

The obtained forecast estimates can be used in planning the preventive work of the road patrol service or services that carry out expertise and analysis of road accidents, as well as by the road users themselves, to strengthen their control over their actions.

The danger of conflict points at road intersections depends on a large number of factors, among which a certain significant role is played by the speed mode of transport. As shown by previous studies [2-6], a significant number of road accidents are observed in collisions of cars turning to the left with cars moving in the forward direction [8].

The formula used to calculate the q_i estimate of the road crossing hazard in the current time mode is [7],

$$q_{ia-a} = K_i M_i N_i 10^{-2} \, , \tag{10}$$

where K_i is the danger of the conflict point; M_i and N_i - the hourly intensity of traffic of vehicles in the intersecting directions, does not take into account the influence of the high-speed mode of transport.

At the same time, in consideration of the influence of the speed mode of transport on the danger index of the conflict point, the factor of exceeding the actual speed of the transport unit relative to the established limit is important. In this case, in order to take into account the difference in the actual speed of the transport stream and the existing limitation,

$$K_v = \frac{V_f}{V_{ogr}}, \tag{11}$$

where V_f is the actual speed of the transport stream; V_{ogr} – the established speed limit on this section.

Then the calculation formula for determining the q_{vi} indicator of the danger of the conflict point (Figure 1) at the intersection of roads by collision of cars moving straight and turning left can be expressed in the following form

$$q_{vi} = M_r M_i V_r^2 V_i^2 K_v 10^n, \tag{12}$$

where M_r and M_i are, respectively, the hourly intensity of the movement of cars making a left turn and moving straight; V_r and V_i are, respectively, the average hourly speeds of traffic flows of cars making a left turn and moving straight; n is the exponent that takes into account the possibility of bringing the calculated data to the probability of occurrence of a road traffic accident.

3 Theory

As an example, the scheme shown in Figure 1. In this case, as can be seen from the figure, in the mode of unregulated traffic, each driver, when moving either directly or to the left, has to overcome four to five conflict points. In the mode of traffic control without additional sections of traffic lights, drivers moving to the left have to overcome only the number of conflicts points equal to the number of lanes in the straight line. If for simplicity of calculation to consider the total intensity of vehicles moving in the forward direction, only one conflict point can be considered (figure 2).

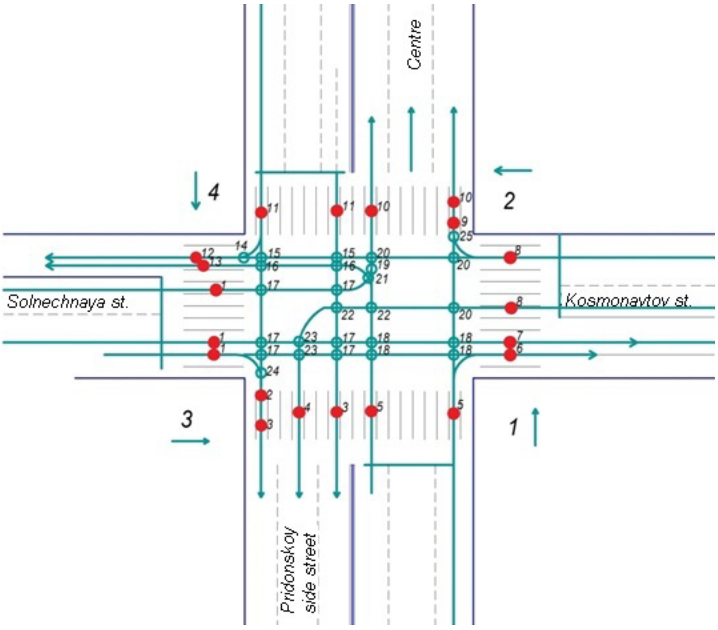

Fig. 1. Diagram of the location of conflict points at the intersection of Cosmonaut Street and Pridonsky Lane in Voronezh

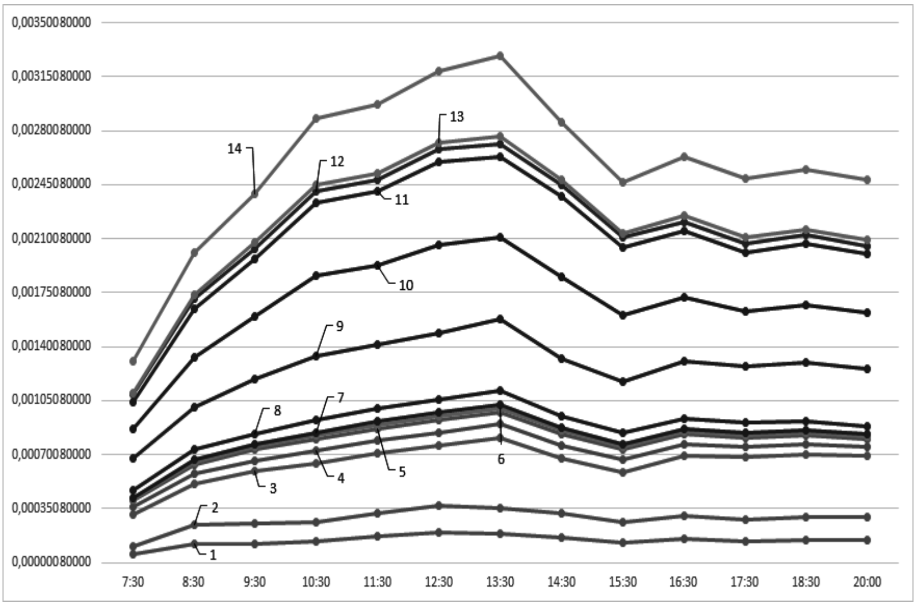

Fig. 2. Forecast estimates of the probabilities of the occurrence of road accidents at the designated conflict points

As initial data for the solution of this problem, the speed of cars turning left V_r = 10 was used; 20 and 30 km /h. At the same time, the speed of cars moving in the forward direction V_i was taken at an interval of 10 km / h in the range from 40 to 110 km / h. The intensities of the motion of M_r and M_i were taken from the results of observations and, for the present case, were considered as constant values typical for the period of the highest congestion of the intersection, M_r = 480 auto / h and M_i = 600 auto / h.

In urban conditions, when the speed limit V_{orp} = 60 km / h was limited, the excess speed K_v ratio ranged from 0.6 to 1.8.

As can be seen from Figures 3 and 4, at a speed of turning cars V_r = 10 km/h in the speed range of cars moving straight from 40 to 110 km/h, the danger of crossing the q_{vi} increases by no more than 8%.At the same time, if the speed of cars making a turn increases to V_r = 20 km/h, the q_{vi} indicator increases by 2.5 times. In the same situation, at a speed of V_r = 30 km/h, the crossing hazard indicator increases by more than 5 times.

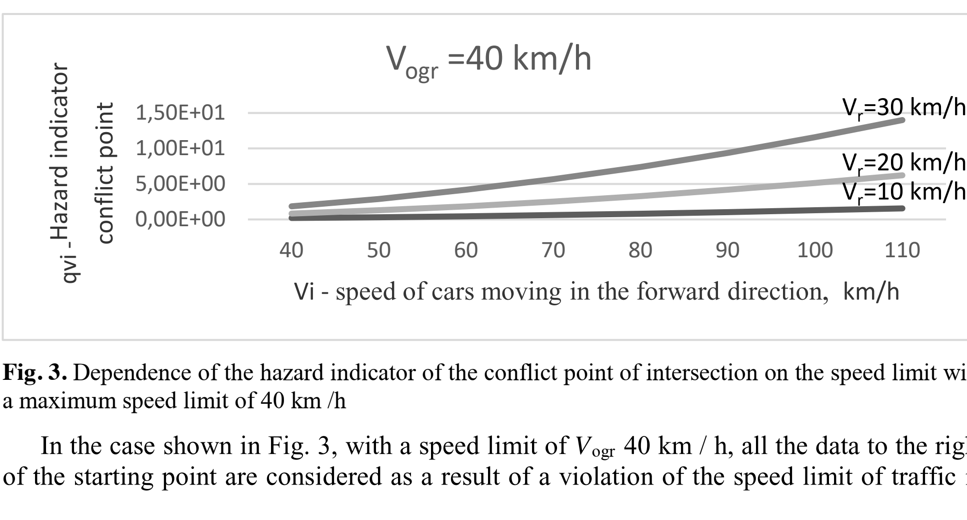

Fig. 3. Dependence of the hazard indicator of the conflict point of intersection on the speed limit with a maximum speed limit of 40 km /h

In the case shown in Fig. 3, with a speed limit of V_{ogr} 40 km / h, all the data to the right of the starting point are considered as a result of a violation of the speed limit of traffic in this section and, an increase in the danger index of the conflict point depending on the speed mode of interaction of the two intersecting automobile flows, is most significant.

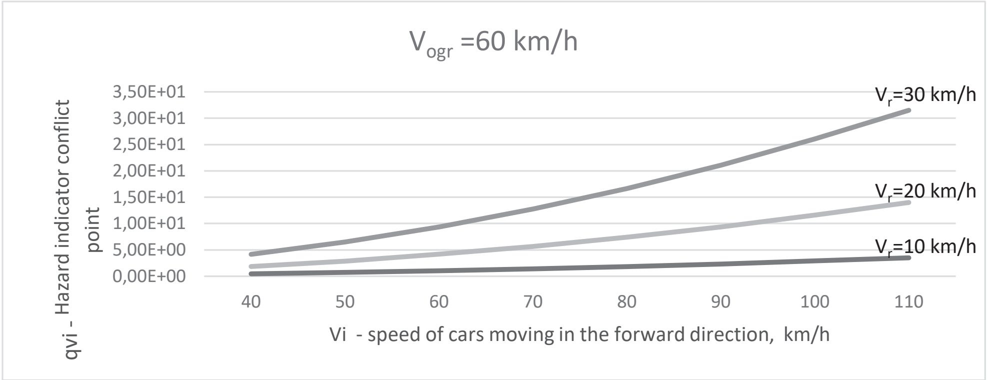

Fig. 4. Dependence of the hazard indicator of the conflict point of intersection on the speed limit with a maximum speed limit of 60 km /h

With a speed limit of V_{ogr} = 60 km / h, as shown in Fig. 4, the danger indicator of the conflict point, typical for cars making a left turn at a speed of V_r = 10 km / h, remains practically unchanged. A certain increase in this indicator is observed with an increase in the speed V_r of turning cars, but in the range up to the established limit of 60 km / h it is insignificant. If the cars driving directly, this speed limit are exceeded, there is a sharp increase in the danger indicator of the conflict point.

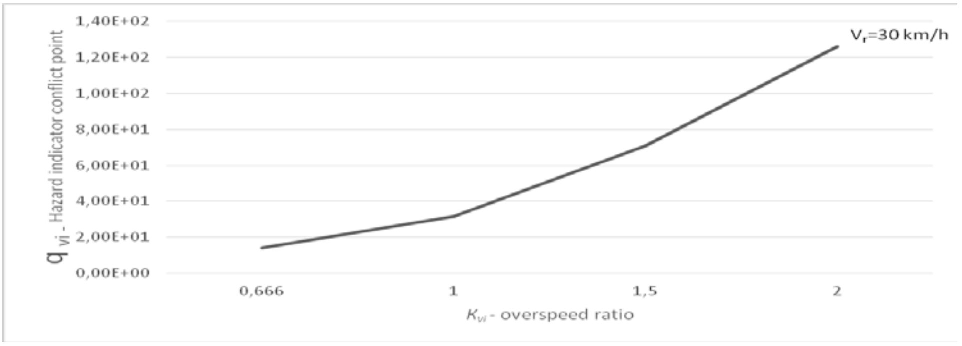

Fig. 5. Dependence of the indicator of the danger of a conflict point on the excess rate

A certain influence on the change in the value of the danger indicator of the conflict point at the intersection is exerted by the speeding ratio relative to the established speed limit. As it was established, the value of the danger indicator of the conflict point increases sharply with the increase of the coefficient K_{vi} more than one, that is, as shown in Fig. 5, when the speed of the transport stream moving straight exceeds the value of the established limit.

4 Results and Discussion

Using the above methodology and having information on the traffic intensities along the directions of traffic flows, it is possible to obtain predictive estimates of the danger index of the conflict point at the intersections of roads. As a result of this, appropriate decisions can be made about the limitations of speed regimes and the directions of traffic along the lanes of the carriageway. When designing a route of traffic that passes through a large number of conflict points located at many road intersections, you can calculate the hazard index of such a route. With a significant level of danger of the projected route, you can change the trajectory of its path in order to achieve its least danger. In addition, in order to reduce the risk of conflict points at road intersections, appropriate organizational measures may be taken to change the pattern of movement of participants in traffic at intersections.

However, as noted by experts when considering the proposed method, it was pointed out that in many cases, changing the projected route of public transport in order to reduce its danger, contradicts the wishes of passengers who prefer to use this route. To solve such questions, the proposed method can serve as a basis for finding dangerous areas along the length of the transport route and searching for a compromise solution based on logical analysis.

5 Conclusions

Calculation models have been developed for determining the probability of accidents at pedestrian crossings and intersections, allowing for specific factors to determine dangerous time periods, on the basis of which it is possible to make appropriate management decisions on localizing the hazard level of an object.

It has been established that the main factor forming a sharp increase in the danger of any conflict point is the excess of the speed limit by individual drivers of automobiles relative to the established speed limit.

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