ISSN 1822-427X print
ISSN 1822-4288 online

THE BALTIC JOURNAL
OF ROAD AND BRIDGE ENGINEERING

http://www.bjrbe.vgtu.lt

2006, Vol I, No 2, 83–92

IMPROVEMENT OF ROAD TRAFFIC SAFETY ON THE BASIS OF FORECASTING A POTENTIAL DANGER IN PLACES OF CONFLICT SITUATIONS

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Abstract. The paper gives the results of perfecting of the method for forecasting accident rate susceptibility on the controlled crossroads of potential danger. The program allowing to reduce the labour expenditures in forecasting the accident rate probability is developed. Some recommendations for reducing the accident rate probability are worked out. Also recommendations for the road traffic safety improvement at the conflict objects (pedestrian crossings and crossroads) are given. Measures aimed to the improvement of traffic safety at the controlled crossroads are singled out.

Keywords: accident rate probability, methods of forecasting, potential danger, actions for reducing the accident rate probability.

1. Introduction

Every year in the Republic of Belarus more than 100 000 accidents take place, in which nearly 1700 people die and about 10 000 are injured. Only in 11 months of 2005 (data of 06 12 2005), 68 532 accidents occurred, of which 7062 crashes involved victims (1550 people were killed and 7263 injured). Total losses, caused by the accident rate, including the social component, amount to $200 mln annually. Besides, with the growth in the amount of vehicles, this kind of losses will be constantly increasing [1].

Incidentally, the majority of accidents with the injured or killed are committed at uncontrolled pedestrian crossings and crossroads. However, in the statistic report no differences are made between the accidents in or out the residential area (elements of the plan and the profile of roads of general use and urban streets are classified together). Roads are divided into 6 categories, of which I to V are included into the list of main categories, and category VI, as an additional one. In its turn, the network of streets and urban roads is represented by the system of hierarchically coordinated streets and roads of different functional use, classified according to SNB–3.03.02-97 [2]. They are divided into the main roads and streets (with a continuous traffic – category M, of city significance – *A*, of district significance – *Б*, of medium and small cities – *В*, main streets of settlements and villages – Г, urban streets – *Д*) and the streets and roads of local significance (streets in industrial, municipal and storage zones, village roads – *E*, main residential streets – *Ж*, secondary residential streets – *3,* and thoroughfares – *П*). Accidents with the heaviest consequences are committed at the objects controlled by traffic lights (crossroads and pedestrian crossings). According to the data at the end of 2005, more than 1200 traffic light objects (TLO) were installed in the street and road network (SRN) of 86 residential areas of the Republic of Belarus. More than 75 % of TLO are erected at the crossings of SRN, the other 25 % – at the pedestrian crossings, situated out of crossroads (at the sections of streets and roads). Traffic light control is mostly spread in Minsk, in the largest cities of the Republic of Belarus due to a high concentration of transport flows on the SRN of these residential areas. Nearly 78 % of TLO are installed in the street and road network of 16 cities with the total population more than 100 000 people. Besides, only in 7 largest cities (Minsk, regional centres and Bobruysk) the central control offices of regulation (CRO or CCO) have been established to ensure the coordinated work of all or a part of traffic light objects situated in the territory of town and the centralised collection of information about the condition of TLO in the outlying areas. About 400 traffic light objects are distributed in other 82 residential areas of the country (from 1 to 30 objects in each) and operating off-line. Therefore, it is necessary to

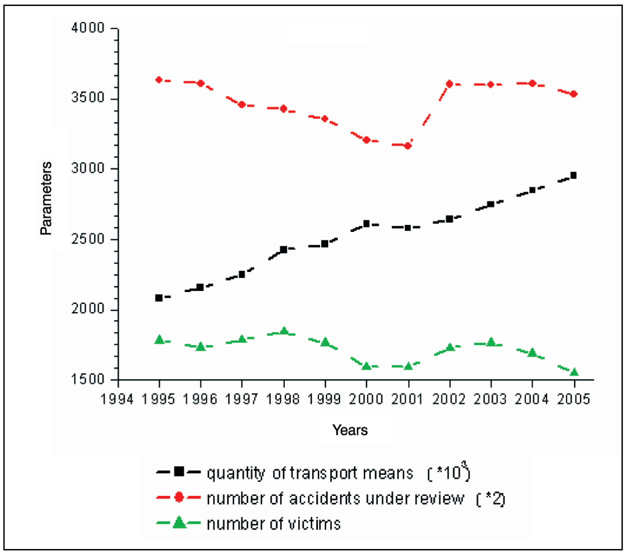

Fig 1. Dynamics of accident rate and the quantity of transport means [1]

reduce the accident rate losses at these objects, too [3].

Total accident losses, including the social component, amount to $200 mln annually. Besides, with the growth in the amount of vehicles, this kind of losses will be constantly increase [Fig 1].

Reduction of accident rate losses is restrained to a great extent by the lack of effective methods of accident rate forecasting. Existing methods of the accident rate forecast are not suitable for practical work in optimising decisions in the field of traffic organization at the stage of their elaboration or planning the transport junctions.

It is necessary to significantly increase the precision of forecasting in order to make an objective evaluation of every decision in traffic organization and to optimise it according to the safety criterion already at the stage of elaboration and planning. This will allow a substantial reduction of accident rate, especially at the conflict objects: pedestrian crossings and crossroads. This is what the article is about.

2. Methods and possible solutions of problems

There are four basic methods for accident rate forecast: statistic, of conflict situations, of potential danger, and expert method [4, 5].

Statistic method uses an accumulated experience of influence of different measures on the accident rate, forecasts on the basis of statistics of accident rates during the last period and requires the existence of real object. On the whole, this method uses the preliminary valuation of efficiency of a measure in implemented at real objects in the street and road network.

The method of conflict situations consists in a conversion of the measured quantity of conflict (visible, very dangerous) situations into a probable quantity of accidents and also requires the existence of a real object which is to be measured. This method enables to quickly, in several hours, discover deficiencies in the traffic organization, causing accidents and to elaborate appropriate means for their elimination [4, 6]. As a rule, it is used at newly built or reconstructed objects aiming at timely correction of decisions of traffic organization.

Expert method is based on the use of experience of highly skilled specialists (experts) for the valuation of accident rate and forecasting the accident probability. These are the people who, due to the gained experience or inborn qualities, can forecast accident risk at the given object with which they get acquainted by their own eyes or by drawings. In peculiar situations several experts are invited who forecast the accident rate together. It should be mentioned that forecasting accidents is an extremely difficult, exquisite and rather approximate task. What concerns the experts who "guess" the accident rate, unfortunately, there are only few of them and the majority of experts are worthless to accomplish this task [4, 7].

The method of potential danger requires neither a real object nor the statistics of accidents and forecasts on the basis of total combination of factors, affecting the accidents, and which could be measured at the real object or set in any combination during planning. Potential danger is considered as an invisible, hidden danger, being a complicated, coded function of many factors and a multitude of their combinations, such as traffic volume speed, traffic control, conditions of traffic etc. As far as this function still cannot be decoded, the task is limited to the selection of simple dependences that give an acceptable forecast by its precision. That's why this method is applied to the optimization of decisions for a real object as well as at the stage of elaboration or planning. Unfortunately, at present this method, like all others, still remains insufficiently precise for forecasting.

There are three modifications of the method of potential danger: the method of linear graphs, the method of conflict points and the method of deceleration.

The method of linear graphs is used for forecasting accidents on the out-of-town roads and in practice results in two kinds of methodologies [8]. The method of linear graphs of the ratio of accidents lies in the following: the road under examination is divided into sections of the same length. For each section a particular ratio of accidents characterising the effect of separate factors – the width of the traffic lane, radius of the turn, slippery rate etc – is chosen out of special tables. By multiplying these ratios, about 20 of them, the final ratio is gained, based on which the approximate quantity of accidents on the road examined is determined. In the method of linear graphs of safety ratio, the points of the speed alteration are identified, from a higher one to the lower: the bigger the alteration, the more dangerous the road section is.

The method of deceleration provides forecasting the passing car crashes and is based on determination of the parameters, the so-called the zone in which drivers can take two mutually exclusive decisions with an equal possibility to continue driving or to stop. The possibility of a car crash depends on the scale of the zone, the distance of the zone to the impediment, pending of the impediment, the speed, density of the flow etc. The method of forecasting the passing car crashes at the crossroads was proposed by Y. A. Vrubel (the Republic of Belarus) [4].

The method of conflict points was introduced by G. Rappoport (Germany), the essence of which lies in estimation of the potential danger at every conflict point together with the summation within the crossroad limits. The method can be applied in conflict objects – crossroads, pedestrian crossings etc. Initially, in the first method an estimation of the potential danger was carried out only by the number of a conflict points and the angle of trajectory of conflict area. Later the estimation model included the traffic volume flows in the conflict and its irregularity.

At the Belarussian National Technical University zone other factors were included (about 80 of them) into the model of estimation of the potential danger and this increased the forecast precision. Y. A. Vrubel has worked out the basic methods of accident rate forecasting at the regulated and non-regulated crossroads and pedestrian crossings. These methods were subjected to further improvement [9].

To test the accuracy of these methodologies a comparison of forecast and actual accident rate was carried out for selecting the conflict objects, including the crossroads with two-phase cycle traffic lights and non-regulated crossings of a moderate loading. It became clear that the dependence of traffic accidents on a potential danger is statically significant; however, the accuracy of the forecast is still unacceptably low – a relative mistake amounts to ±120 %. This fact shows the necessity of improving the method.

3. Improving the methodologies of accident rate forecasting on roads

The improvement of accident rate forecasting method was carried out with the help of a special computer program for searching the optimal dependences between the accident rate and a potential danger by any estimation model for any selection of analysis. The program takes into consideration different data, necessary for determining a potential danger at an object. The final dependence of accident rates on the potential danger was found out with the help of the method of the least squares. In case when it was difficult to reject one of the dependencies with the help of formal methods and to choose the best one, the conclusion on the suitability of one or another model was made by the calculator, proceeding from the physical essence of the proposed dependence between the accident rate and the potential danger. The program allows making any kind of changes in calculation formulas, to organise the selection of possible variants and to control the significance of the obtained dependences each time.

According to the given volume and the given consistency, the programmed changes were introduced into the estimation model and by means of examination of variants the best dependence between the accident rate and the obtained value of potential danger was defined. An examination of conversion was carried out according to the criteria of Fisher (F – criteria), the ratio of plural correlation (R) and to the ratio of linear error of approximation (E). Then, another change was introduced into the estimation model and the procedure was repeated. Besides, each time the examination of variants was performed for the previous changes, too.

Structural formula for determining the potential danger in the conflict "transport means – transport means" in the basic methodologies has a form of product of six ratios, each of which represents a pseudo-independent group of factors, affecting accident rates, and is determined by the dependences of different levels of complexity:

$$P_o = P_{oH} \times K_B \times K_H \times K_Y \times K_\nu \times K_\rho, \qquad (1)$$

where P_o – potential danger at the conflict point; P_{oH} – initial probability of the conflict (depends on the intensity of traffic flows in conflict); K_B – ratio of type of conflict, characterising the size of conflict areas and possibility to undertake the deviations to avoid collision; K_H – ratio of violations, characterising the probability of appearance of conflict situation and its outgrowing into the collision due to rough violations of traffic regulations; K_ν – ratio of speeds; K_ρ – ratio of density of flows in conflict; K_Y – ratio of conditions (visibility, surface of the carriage-way, presence of pedestrians etc).

The potential danger is defined for three regimes of conflict traffic: uncontrolled, when traffic lights are on under the regime of blinking of yellow light; inter-phase, when the conflict traffic takes place inside one-phase cycle of the traffic lights, for example, at the left conflict turning; intra-phase, when the conflict traffic occurs at the moment of phase changing – the transport means of previous direction are still at the conflict point and the transport means of next direction already come to this point; moreover, all of them ostensibly move to the green light. Then, the potential danger of conflict points is added under the limits of the crossroad and, based on this sum, a probable number of accidents for each regime is defined.

In order to increase the precision of forecasting, the authors made some changes in the existing model. Their interpretation consists in the following.

The first change. Some of the calculation dependencies inside the groups of factors were defined; more precisely, those which are mainly related to the inter-phase regime of traffic and are the result of the logical analysis of connections between single factors inside the pseudo-independent groups of factors.

The second change. The ratio of time, characterising the duration of operation of the object in each of three traffic regimes, was introduced into the structural formula.

The third change. The definition of conflict zone was introduced, which represents the group of nearby and interacting conflict points, the borders of which cross each other. The conflict zones differ for each traffic regime and can consist either of a separate conflict point, the borders of which are determined by the size of the conflict area, or of the compact group of conflict points. In certain cases at small objects, this area can be represented by all conflict points within the crossroad.

At the conflict object one can always notice special points of the carriage-way, to which the different conflicting traffic participants have pretensions at the same time. They are called conflict points. They may include: points of junction, points of intersection and points of deviation (Fig 2) [4, 10].

In the above-mentioned figure, the conflict points are presented in the form of measureless points of the axes of trajectories of the conflicting traffic participants. As the matter of fact, a "conflict point" has its borders and occupies some territory on the carriage-way, determined by the size of conflicting transport means and the deviation of the trajectory of their movement from the ideal trajectory (by the centre of the occupied lane).

The calculation formula of the size of the conflicting transport means is defined by the size of the so-called reduced car with the clearances $L_a = 4,6\,m$ and $B_a = 1,75\,m$, taking into account the dynamic ratio of the reduced traffic K_{nH} (m) [4]. As a result, taking into account the deviation of the trajectory of traffic of conflicting participants from the ideal trajectory, the size of the conflict car is identified. The borders of the conflict point of intersection are determined by the size of the conflict car, disposed in a free direction in such a way that a geometrical centre of its total area of projection coincides with the conflict point. In this case the borders of the conflict point will have a shape of a circle drawn through the conflict point with the radius:

$$r_a = 0,5\sqrt{\left(L_a \times K_{nH}\right)^2 + \left(B_a \times \sqrt{K_{nH}}\right)^2} \approx 2,65 K_{nH}. \quad (2)$$

The borders of the conflict point of the junction are also determined by the size of the calculated conflict car having the contact with the conflict point by the centre of the front side and occupying the special sector of 60°.

Fig 3 gives the scheme of the conflict points, their borders and the total area they occupy on the carriage-way.

Nearby laying conflict points interact between each other. As the result of this interaction, at the crossroad several relatively independent centres of danger are formed. The potential danger of each of these centers cannot be regarded as a pure sum of dangers of all conflict points included. As a result, the total danger of the crossroad cannot be regarded as a sum of dangers of all conflict points included into it, but as a sum of conflict zones included into it. On the basis of the above information, an assumption was made that it is not the conflict point, but the conflict zone, consisting of the nearby laying and interacting conflict points, which is the solitary, indivisible centre of danger at the crossroad. Here, the necessity to clearly define the borders of the conflict zone appears. The scheme of formation of the conflict zone is given in Fig 4.

It is essential to examine the conflict zones for each regime of the conflict traffic. At the crossroad with two-phase cycle regulation, there are three of them: non-regulated, inter-phase and intra-phase.

A non-regulated regime at the regulated crossroad develops when the traffic volume of conflict transport flows

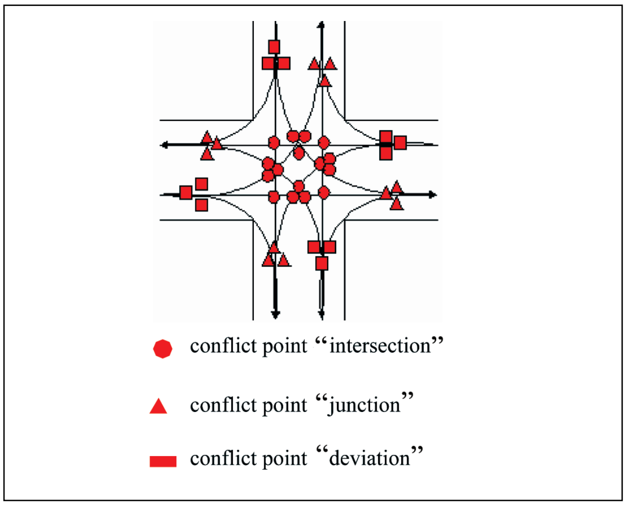

Fig 2. Crossroad conflicts [4, 10]

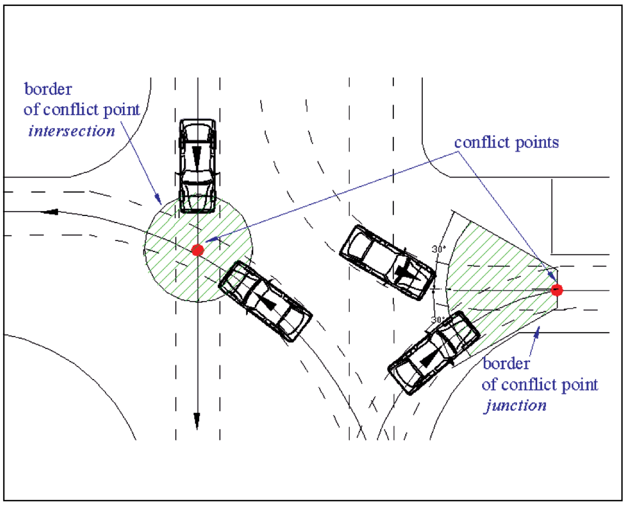

Fig 3. Borders of conflict points

falls down to the point where it does not meet the normative standards for introducing the traffic-lights regulation. It happens late in the evening, at night and early in the morning or during weekends and festive days. During these periods the cyclic regulation at the crossroad is replaced by the regime of yellow blinking, which is non-regulated (Fig 5, a).

Inter-phase regime of traffic takes place when during one phase, ie a continuous combination of signals of traffic lights, a conflict traffic of two flows is allowed. In particular, it may be the intersection of the left turning and the transit oncoming flows or the junction of the left and the right turning flows in one lane or the junction of the right turning and the passing transit flows, while the green arrow at the subordinate section of the traffic lights is on.

Intra-phase regime takes place at the moment of changing the regulation phases when the transport means of the previous direction have not still finished their movement within the conflict point and the transport means of the posterior direction have already started their movement within the same conflict point (Fig 5, b). This traffic regime is very short, often very speedy and mainly depending on a proper choice of the so-called transitional intervals, ie the moment between the turning off the green light for the previous direction and the turning on the green light for the posterior direction. There are two intra-phase traffic regimes in two-phase traffic lights cycle. During the first one the second flow goes after the first flow, during the second one the first flow goes after the second flow. Since in the traffic lights regulation it is accepted that the main is the previous direction and the secondary is the posterior one, thus in the intra-phase regime each of the flows appears to be the main for the first time and the secondary for the second time.

Obviously, all three regimes of conflict traffic differ essentially from each other by the quantity of the conflict points, the quantity and characteristics of the conflict zones, the duration of the existence, the speed of traffic, the transportation load etc. That's why the determination of potential danger and its conversion into the amount of car crashes should be carried out separately for each regime of conflict traffic. Fig 5 shows the conflict zones at the existing crossroads for different regimes of the conflict traffic.

Evidently, in some cases the conflict zones can include two or three conflict points and in separate cases – one conflict point. At the same time in small-area crossroads in non-regulated regime, the conflict zone may include all conflict points belonging to this crossroad.

A distinctive feature of the conflict zone is a compact position of conflict points and their interaction. The character of this interaction is not clear enough but we can presume that it lies in the sphere of human psychology (driver's). In order to explain the essence of this interaction we should mention that there are 3 types of danger: objective, subjec-

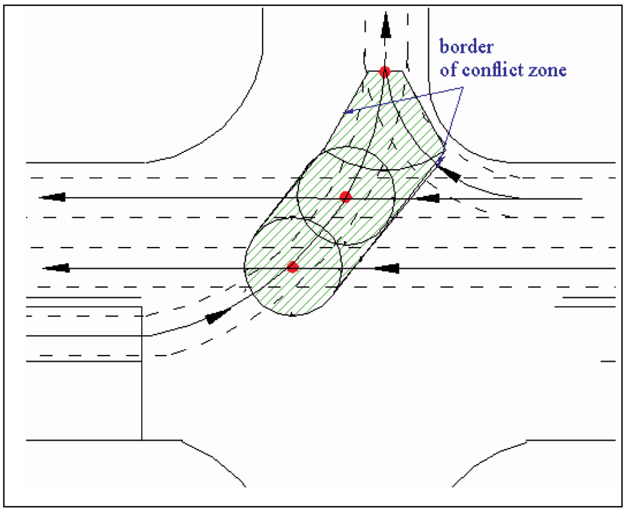

Fig 4. Scheme of formation of the conflict zone

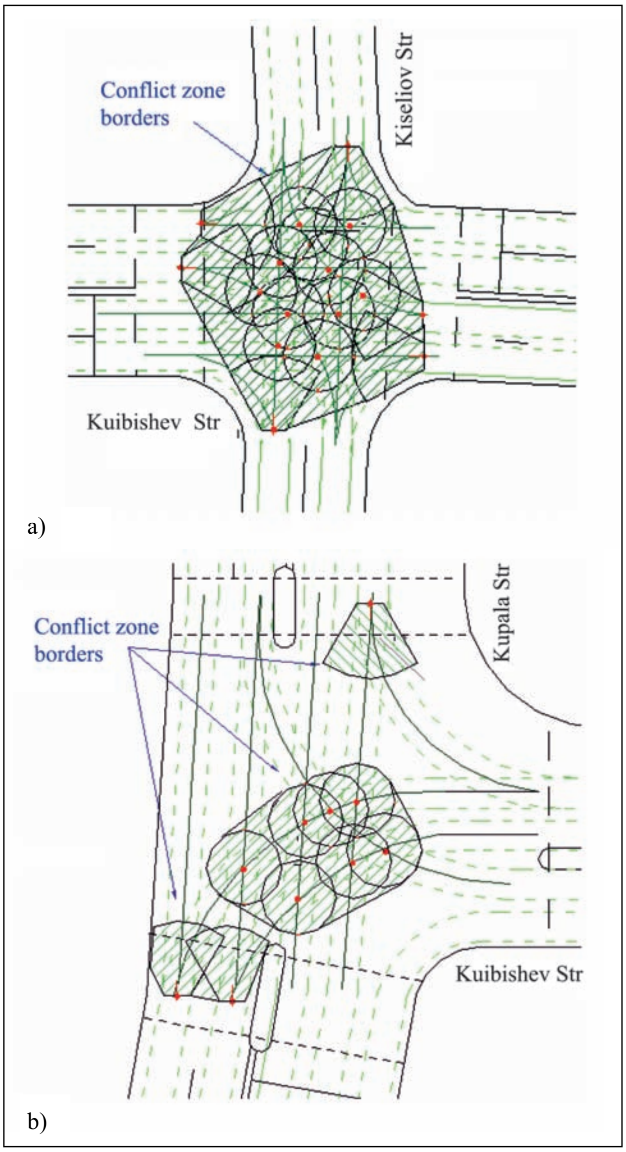

Fig 5. Character and position of the conflict zones: a – non-regulated traffic regime at the standard X-shaped crossroad of the main streets of A category; b – intra-phase traffic regime at the standard T-shaped crossroad

tive and resulting (or the real). The objective danger lies in incompatibility of the traffic conditions and traffic regimes, as a rule, in speed or direction. The subjective danger lies in the driver's perception of the objective danger and its subjective evaluation. As long as the driver's evaluation of danger, whatever subjective it may be, is real and quite objective action, resulting in taking and implementing the decision, the subjective evaluation of objective danger appeared to have a strong influence on the resulting real danger. In case when the subjective danger is a bit higher than the objective one (slight overestimation of danger), there is some reserve of safety and the possibility of accident is low. If the subjective danger is lower than the objective (underestimation of danger), the possibility of car crash is very high. It should be noted that large differences between the objective and subjective danger and vice versa are unacceptable, because they lead either to a pure underestimation of danger and, for sure, to the accident or to such reinsurance, which cannot be accepted by other participants or provokes them to commit dangerous violations.

Obviously, in the conflict zone the secondary conflict participant overcomes without stop several successively located conflict points, one of which the most "difficult" (dangerous) point becomes the "main" for him. For him the danger at this "main" conflict point is that a very objective danger that he evaluates subjectively, on which he determines psychologically and to which he compares his actions. Therefore, he overcomes without any problems the "easier" conflict points, which appear before or after the "main" conflict point. As a result, the significance of "easy" conflict points within the conflict zone is reduced and the significance of "difficult" conflict points is increased, because of the possible underestimation of danger. In this connection it can be assumed that the more conflict points are contained in the conflict zone, the less significant each of the conflict points is. If the driver overcomes several totally independent conflict zones or separate conflict points, at each of them he has to consider the biggest danger and to take adequate decisions.

This fact should be taken into consideration in an appropriate way, when the potential danger of conflict points within the conflict zone is summarised. The following dependence is proposed as the basic one:

$$P_{oz} = \left[\sum_{i=1}^{N} \left(P_{o_i}^{m} \right) \right]^{n}, \quad (3)$$

where N – quantity of conflict points in the conflict zone; m, n – indexes of degree (differ for different regimes of conflict traffic).

The fourth change. The ranging of conflict zones within the crossroad is introduced since the driver more easily overcomes the small conflict zones.

The statement on the interaction of conflict points within the conflict zone were transferred to the conflict zones connected with each other by trajectories of traffic of secondary conflict participants. Such conflict zones were ranging within the crossroad according to the formulas:

$$P_{oz}^{*} = P_{oz} \times e^{-\beta} \le P_{oz}, \quad (4)$$

$$\beta = \frac{P_o^m - P_o}{P_o^m \left(S - 5K_{nH}\right)}, \; 0 \le \beta \le 1, \quad (5)$$

where: P_{oz}^{*} – the calculation value of potential danger in the conflict zone under examination (secondary); P_{oz} – the initial value of potential danger in the conflict zone under examination; P_o^m – the maximum value of potential danger at the conflict points of the "main" conflict zone; P_o – the maximum value of potential danger at the conflict points of the conflict zone under the examination ; S – the distance between the nearest conflict points of the conflict zone under the examination and the "main" one.

The fifth change. The definition of the threshold of sensitivity of potential danger at the conflict point (below which this sensitivity does not cause any accidents and this is why it should be not included in summarising), was introduced. The thresholds of sensitivity appeared to be different for different traffic regimes.

Special researches were carried out to prove the existence of the sensitivity threshold, and the calculation values of the threshold of sensibility were determined for each of traffic regimes. As a result, if the value of potential danger in the conflict point is under the threshold of sensitivity, it is not included in the summarisation within the conflict zone. This is especially important for forecasting the accident rate at the crossroads of low traffic volume and this was confirmed during the test forecast of accident rates.

The sixth change. The dependence of generalization of sequences on potential danger was carried out. Since the factors influencing the accident probability and the generalization of consequences (such as speed) participate in the definition of potential danger, it is obvious that an equal potential danger can cause a greater number of accidents with "easy" consequences, or a smaller number of accidents with "heavy" consequences. It was determined that one car crash with injury is relatively equal to two car crashes causing material damage within an inter-phase regime, three car crashes within a non-regulated regime and four car crashes within an intra-phase regime. Thus, not only the number of accidents may be forecast, but also a generalised number of car crashes, ie car crashes with material losses.

The seventh change. The ranging of the structural formula ratios (1) for determining a potential danger was introduced and the formula now looks like this:

$$P_o = P_{он}^{a_1} \cdot K_v^{a_2} \cdot K_в^{a_3} \cdot K_ρ^{a_4} \cdot K_н^{a_5} \cdot K_у^{a_6} \cdot K_t^{a_7}. \quad (6)$$

The value of indexes of the degree $a_1 \div a_7$ for each regime, which lies within the bounds of 0,9–1,2, were determined. This ranging to some extent enables to compensate those errors which lie in accepted dependences of defining each index of structural formula representing the single group of factors. Besides, such kind of ranging enables us to easily and quickly "build" the calculation model for forecasting traffic accidents in other regions which differ from Belarus in climate, economy, ethnics and other characteristics.

The improvement of calculation model led to positive results. The exactness of the forecast has grown for all 3 regimes of conflict traffic and became acceptable for practical works in optimising decisions in the field of traffic organization (Figs 6–8).

4. Practice of using the method and some recommendations

Based on the results of research and using the acquired experience, it is possible to point out the following trends in reducing the traffic accidents.

The separation of the flows regulates the traffic, simplifies the process of its regulation. The space separation is carried out by the Traffic Regulations, the road signs and marking (barriers and traffic islands), the dividing lines, the kerbs as well as by the crossroads and pedestrian crossings on different levels. The time separation is carried out by the priority, giving the traffic advantage to one of the conflict participants by the lights regulation.

The reduction of conflicts by:

- the reduction of the quantity by reducing of the number of non-obligatory, allowed and forced manoeuvres which are usually carried out on the run, including the change of the lane, the overtaking, the run and the braking. This manoeuvres are conditioned by the heterogeneous transport flow, the uncertainty of traffic situation;
- improving the traffic conditions in the conflict zone is firstly reached by insuring the visibility of conflict participants (about 5–6 sec, but not less than 3 sec before arrival to the conflict point), a good condition of carriage-way, the clarity and the logic of the priority allocated, presentation of the preliminary information;
- reduction of the traffic speed in the conflict zone helps to fulfill conflict manoeuvre safely. Besides, it is important to reduce the relative speed of participants and this can be carried out by reducing the speed of the main participant as well as in-

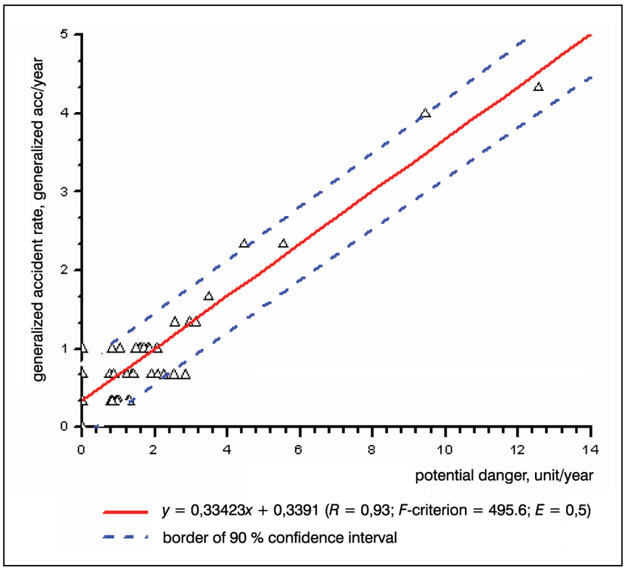

Fig 6. Dependence of the generalised accident rate on potential danger in the inter-phase regime

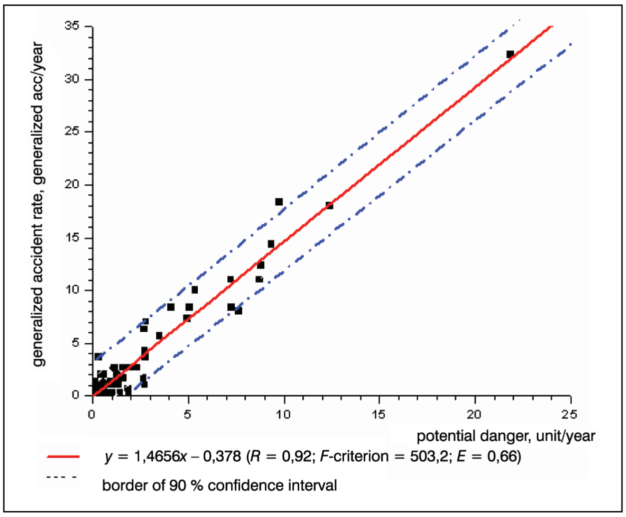

Fig 7. Dependence of the generalised accident rate on the potential danger in the intra-phase regime

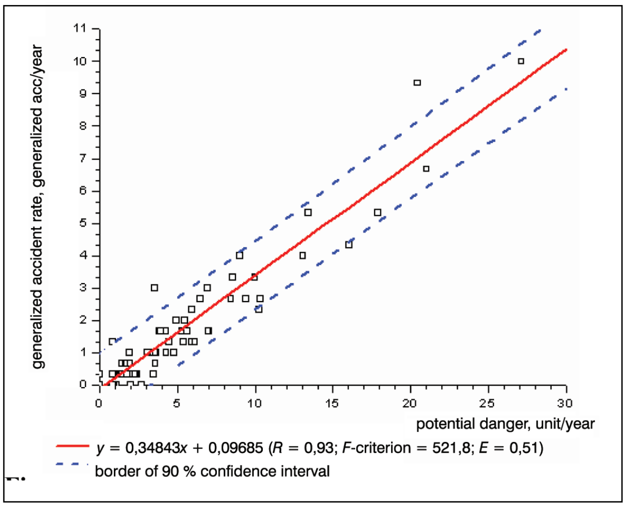

Fig 8. Dependence of the generalised accident rate on the potential danger in the non-regulated regime

creasing the speed of the secondary participant, for instance, construction of acceleration lane, increasing the radius of the turning at the entrance to the ring crossroads and other measures (they got the name "Traffic calming").

It should be pointed out that in many Belarussian cities the increase in the capacity of the crossroad with the help of construction of ring junctions, basically, is not used in practice (as the exception – Mogilev region). Just in this region many of the ring junctions are built. They let almost totally reduce the necessity of complete stopping of transport means. Vivid examples of the organization of the optimal ring junctions are presented by Mogilev; the by-passes of Bobruysk (Fig 9), Kostukovichi.

The construction of ring crossings can be recommended: for non-regulated crossroads with a great number of accidents (as the canalization of movement of transport and pedestrians); to attract drivers' attention to the changing character of traffic (at the entrance to a city or settlement, to a dwelling zone, when a general use road crosses a settlement); on crossroads, which initially had a complicated non-standard configuration; on crossroads where significant left-turn flows exist and as an alternative to the traffic lights regulation with a proper choice of parameters (example of such crossing is the Victory square in Minsk having already significant transport flows (more than 11 000 cars/h) but still with a capacity reserve). Thus, the speed of transport flow on a flyover can be regulated: by diameter of a ring; by the width of carriage-way; by radiuses of adjunctions of roads to a ring; by a general lay-out of a flyover.

In certain cases where we consider that it is necessary to develop a more complete technique of application of the so-called artificial roughnesses or hampers. Their correct application gives the accident decrease up to 60 % [6]. Only in Minsk there are more than 250 of such roughnesses, however, in the authors' opinion, it will not likely lead to the decrease of safety on city streets; in fact, they are situated even on the highly loaded highways of the city! Depending on purpose and locations, as well as on a general visual perception, hampers can have round, dome-shaped, sine wave or trapezoid forms. Application of hollow form roughnesses on road pavement has not found a practical application because of decrease in efficiency during winter time and necessity to erect a drainage system.

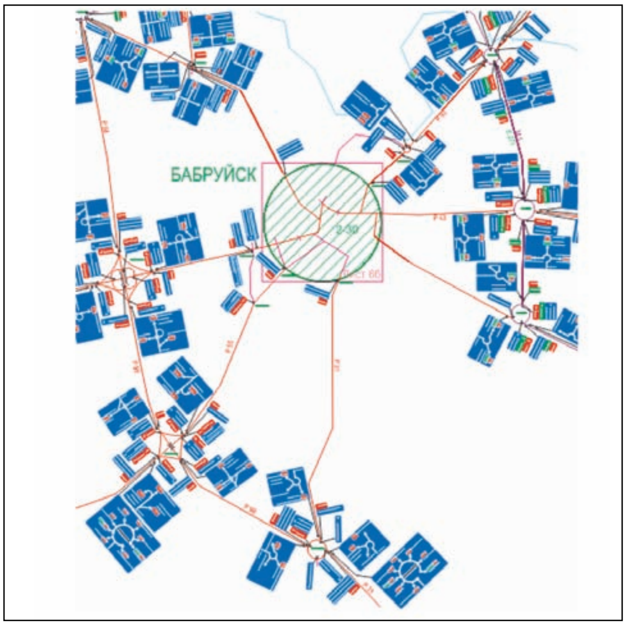

Fig 9. Scheme of the junctions on the by-pass of Bobruysk

It is necessary to note that the application of artificial roughnesses and other actions for restriction of traffic speed have also essential negative moments. Excess quantity of speed restriction elements reduces the traffic speed (accident rate of one or another type of accident), but they raise the other traffic losses (ecological, economic, social and sometimes accident rates in passing flows). Within a zone of their application not optimum actions, such as artificial roughnesses etc reduce the capacity of roads and streets, increase operational costs of road and street system; they demand additional technical maintenance for prevention of by-effects (increase of noise, pollution etc). Therefore it is recommended to prove carefully the necessity of application of speed restriction measures.

Perfection of process of conflict manoeuvre includes: timely warning of all participants about the forthcoming manoeuvre; the precise and confident performance of the manoeuvre; the prevention of suddenness – all manoeuvres should be clear, expected and logical (for example, the stop at a red light of the moving coordinated group of cars is illogical by itself and consequently is often accompanied by passing collisions).

Increase of capacity of traffic assumes a decrease in all kinds of losses, first of all, economic. It is achieved by a complex of methods: improvement of the structure of transport flow; informing of participants should be perceived, sufficient, timely and confidential; improvement and decrease in a loading level; choice of an optimum speed mode.

Classification of streets and roads. It is known that the level of regulating influences should correspond to a level of road loading or danger. A classical example is the prohibition to cross the carriage-way if there is a pedestrian crossing or crossroad within the range of visibility. This rule is suitable for highly loaded highways, it is disputable for medium loaded streets and roads and it is absolutely absurd for non-loaded local streets, not to mention cart- and wood roads. In order the control influences were adequate to variety of conditions and comprehensive for traffic participants, the streets and roads should be divided into several regulated groups.

A separate trend of traffic accidents decrease is also gathering and systemisation of reliable initial data describing geometrical parameters of crossings (width of lanes, distance from stop-line up to a conflict point, radiuses of edge curve of road carriage-way, carriage-way longitudinal gradient etc), traffic loading (intensity and speed of traffic, structure of transport flow), operating modes of traffic lights object (diagram of regulation, duration of traffic lights cycle, green light, yellow light, transition interval) and conditions of traffic of transport flows (visibility of conflict point in traffic direction, lateral visibility, corner of interaction of conflict transport flows, value of friction coefficient etc). These questions are partially solved by detecting. For example, on the Minsk ring highway three measuring stations were installed, having video control and analysing the traffic speed, transport flow intensity and structure, meteorological parameters in the area under control. The whole measuring system is connected to RUP "Belavtodor" server. In total 25 such stations are installed in different places of Belarus. The perspective installations could be considered those, which allow to change traffic directions due to the worsening road conditions or in traffic-jam situations. The stations can also be connected to CRO automated traffic control system of highway, city or region by wire or wireless (mainly GSM) channels.

Some of the developed measures are related to the controlled crossroads.

Duration of transition interval, i e time from the moment of green light turning off for the previous direction till the moment of turning on a green light for the next direction, has a great importance at inter-phase traffic mode. In order to reduce the value of transition interval without decreasing traffic safety, it is necessary to reduce time of crossing the crossroads for transit (direct) flows. It is achieved by improving the quality of pavement, first of all, evenness and slipperiness, the maximum approach of stop-lines to the crossed carriage-way (within the limits of admissible norms), clear marking of carriage-ways, elimination of every possible traffic interference, especially on the right lanes. In this connection a common traffic from one lane of transit and turning conflict flows is extremely undesirable, especially in case of a moderate and high loading.

A great importance is attached to the visibility of traffic signs, defining a regime of traffic – priority, traffic direction in a lane, displacement of trajectory etc, also signals of the main traffic lights and their doublers. Clearness and timeliness of drivers' warning about the forthcoming change of traffic lights, not only green into red, but also vice versa, have a great importance. The timely and precise warning about the forthcoming change of lights allows the drivers to make the necessary decision in advance and to realise it confidently and without conflicts. That's why it is necessary to unify the duration of yellow light, a combination of yellow and red lights and a green blinking light. It is suggested to introduce a red light blinking, that is especially urgent for a coordinated regulation, when the high-speed front of coordinated group of cars cooperates with the signals of coming nearer traffic lights object. The effective control of how the Traffic Regulations are followed on the controlled crossroads has a great significance. Since it is impossible to identify temporary violations, for example, the moment of crossing stop-line, without the special equipment, many drivers use this for mercenary purposes. To eliminate it, it is necessary to equip the controlled crossroads with the control video equipment, precisely fixing all violations and violators. For a coordinated control of a great importance are signs of the permissible traffic speed, constructed on the basis of microprocessor techniques and blocked with the controllers of traffic lights object, which bring the coordinated group of cars precisely to the turning of a green light.

It is desirable to allocate for the left-turn flow a separate turn lane (at traffic volume more than 120 cars/hour), and for the right-turn flow – enough place before a pedestrian crossing, where all the turning cars could fit in. If it is possible, the movement of pedestrians should be started with some delay to permit to the majority of right-turning vehicles to make a manoeuvre without conflicts.

5. Conclusions

The following conclusions can be formulated:

- the method of estimation of accident rate probability is developed, which is comprehensible to practical application on disputed objects and allows to optimise the decisions made for the organization of movement at a stage of their acceptance by the criterion of minimisation of emergency losses;
- it is necessary to continue research on the applicability of the method for such disputed objects, as the system of crossroads and pedestrian crossings, also ring crossroads.

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Submitted 20 April, 2006; accepted 22 May, 2006