Improving the Method of Conflict Situations

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Abstract. The paper presents the results of research to develop methodology for a rapid assessment of the effect of measures used to improve road safety. The research includes the improvement of the method of determining traffic conflict situations and the development of accident prediction in conflict situations. A method of conflict situations is one of the most advanced and effective methods for predicting accidents at conflict sites since this method is based on the dependency of the number of accidents on the number of conflict situations. Having determined at the study site the number of conflict situations it is possible to calculate a predictable annual number of accidents at that site. The research implemented gave a possibility to increase the accuracy of accident prediction according to the method of conflict situations making it suitable to be used in practice for assessing the quality of road safety measures at the conflict sites – signalized intersections and pedestrian crossings, in the zone of which the artificial speed humps have been installed, such as a “sleeping policeman”.

Keywords: road traffic, traffic conflicts, road accidents, accident prediction, forecasting methods.

1. Introduction

Road traffic has safety, environmental, economic and social threats. For road users the most crucial of all the threats is the accident rate, since it directly affects their lives, health and welfare. Much attention has been paid to a reduction of the number of accidents, despite this, accidents still happen – in the world annually more than 1 million people are killed on the roads and about 50 mln people are injured (Coelingh et al. 2007).

The selection and evaluation of decisions on road traffic management – one of the most accessible, timely, capital and yet effective methods of improving traffic safety in the urban centers (Kapski 2008). Traffic organization measures must be assessed by a safety criterion as soon as they are implemented (realized). It is necessary to develop methodology for a rapid assessment of the effect of implemented actions. It is also necessary to find and eliminate any errors in the decision-making process or during the design or implementation of the measures. Its creation required improvement in terms of the accuracy of the existing method of predicting road accidents in conflict situations (a new mathematical model was developed for determining the accident in conflict situations) which is built on the basis of the said method.

The application of traffic conflict techniques in assessing the safety of a road entity (intersection, road segment, etc.) has gained continuous attention among safety researchers and practitioners. Several studies have demonstrated the feasibility of collecting conflict data using field observers, simulation models, and video-camera to assess the safety of a particular road entity (Autey et al. 2012; El-Basyounya, Sayed 2013).

The method of conflict situations is one of the most modern and effective methods for predicting accidents at sites of conflict. It is based on the existence of fairly strong dependence of the number of accidents on the number of conflicts in each individual conflict. They are divided into light (very dangerous), medium (a miracle had passed) and heavy (or almost miraculously survived the accident). Conflict situations are thousands and sometimes tens of thousands times more than road accidents. By counting conflict situations of the given type of conflict having occurred in a relatively short period of time at the site under investigation nCFS, by expressing it in the average annual number and multiplying it by the reduction coefficient nCFS the projected annual number of road accidents is determined Pa by the formula (Kapski 2008; Vrubel et al. 2006):
$P_a = N_{cfs} \eta_{cfs}$  \hspace{1cm} (1)

where $P_a$ – projected annual number of road accidents, acc./year; $N_{cfs}$ – number of conflict situations, cfs/year; $\eta_{cfs}$ – the reduction coefficient of different type of conflict (Table 1).

This is the method of conflict situations proposed by the Swedish researcher C. Hyden (Hyden 1983).

Unfortunately, the current method is not sufficiently accurate for the particular site because it does not take into account several factors related to the road accident rate, especially for a relatively small number of road accidents. In addition, various authors give different coefficients of reduction that are associated with some national characteristics of the road. In particular, (Kot 2006) proved that the gravity of the conflict and severity of accidents

| Object | Conflict Characteristics of conflict interaction | $\eta_{cfs} \times 10^{-5}$ | Country |
|--------|--------------------------------------------------|-----------------------------|---------|
| Unidentified | T–T $V \leq 30$ km/h | 2.4 | Sweden |
| Unidentified | T–T $V > 30$ km/h | 9.6 | |
| Unidentified | T–P $V_0 \leq 30$ km/h | 11.9 | |
| Unidentified | T–P $V_0 > 30$ km/h | 34.0 | |
| Unidentified | T–T $V > 30$ km/h | 53.3 | Denmark |
| Unidentified | T–T $V_0 > 30$ km/h | 60.0 | USA |
| Non-signalized intersection | T–T | - | Germany |
| Unidentified | T–T $V \leq 30$ km/h | 2.2 | |
| Unidentified | T–T $V > 30$ km/h | 24.2 | |
| Unidentified | T–P $V_0 \leq 30$ km/h | 15.4 | |
| Unidentified | T–P $V_0 > 30$ km/h | 55.1 | |
| Crossroads | T–T | - | Republic of South Africa (SAR) |
| Unidentified | T–P $V_0 > 30$ km/h | 5.1 | |
| Unidentified | T–P $V_0 > 30$ km/h | 5.1 | |
| Unidentified | T–P $V_0 > 30$ km/h | 11.9 | |
| Unidentified | T–P $V_0 > 30$ km/h | 3.0 | |
| Unidentified | T–P $V_0 > 30$ km/h | 0.4 | |
| Unidentified | T–P $V_0 > 30$ km/h | 13.0 | |
| Unidentified | T–P $V_0 > 30$ km/h | 2.0 | |
| Unidentified | T–P $V_0 > 30$ km/h | 0.7 | |
| Unidentified | T–P $V_0 > 30$ km/h | 7.0 | |
| Unidentified | T–P $V_0 > 30$ km/h | 25.0 | Estonia |
| Signalized intersection (SI) | T–P | - | Germany |
| Signalized intersection | T–T | - | |
| Roundabout | T–T | - | Belarus (Vrubel 2006) |
| Unregulated crosswalk | T–P | - | |
| Unmarked crosswalk | T–P | - | |
| Stop of passenger transport | T–P | - | |
| Signalized intersection (SI) | T–P | - | |
| Signalized intersection (SI) | T–P | - | |
| Signalized intersection (SI) | T–T | - | |
| Signalized intersection (SI) | T–T | - | |
significant increase the accuracy of the forecast. It was therefore considered appropriate to improve the method of conflict situations by gradually supplementing it with the model of calculating a degree of the danger of conflict situations, the severity of road accidents, the threshold sensitivity of the conflict and the function of converting the number of reduced conflicts to the number of reduced road accidents.

Monitoring of conflict situations is carried out as a rule at the stationary posts. During a certain period of time (approx 5 h) the observers register conflict situations, also a driving scheme of road users, development of the situation, its severity, conditions, etc. As a result, the number of conflict situations at the certain site within 5 h is counted. These figures are further calculated to the number of conflicts per year, then it is multiplied by the appropriate factor. The process of evaluation of the situation directly observed is rather individual and quite subjective. One and the same conflict estimated differently. Moreover, one and the same observer in different periods of time and in different state evaluate the identical conflicts differently. The absence of conventionally accepted standards leads to the situation when the variance of the evaluations of conflict situation is large. Today the method is making progress. The process of evaluation of the situation directly observed is rather individual and quite subjective. One and the same conflict estimated differently. Moreover, one and the same observer in different periods of time and in different state evaluate the identical conflicts differently. The absence of conventionally accepted standards leads to the situation when the variance of the evaluations of conflict situation is large. Today the method is making progress.

The authors in (Eremen, Korolev 2007; Hatakenaka et al. 2003; Ismail et al. 2009; Klunder et al. 2006; Uno et al. 2010) investigated possibilities for simulating conflict situations. Vehicle deceleration rate is taken as a danger degree of a conflict situation, and as an accident risk the number of conflicts is taken. Some simulation models (Eresov, Rjabec 2001) consider the geometry of crossroads, the composition of traffic flow and some characteristics of traffic signalization; reduction of conflicts according to the value of longitudinal and transverse accelerations, conflict participants and other. In research (Malkhamah et al. 2005) the model also includes the number of decisions taken by the drivers in typical situations.

The major disadvantage of conflict simulation modeling is considerable discrepancy between the model and reality because of many assumptions and simplifications while modeling. Nevertheless, this approach is making progress and improvement of the forecast quality.

Dynamic reduction of the average and heavy conflict situations to the easy one is introduced. The dynamic reduction coefficient \( K_{\text{cfs}} \) is defined as the relation of conditional danger (Accident Risk \( R_a \)) of average or Heavy Conflict Situations to conditional danger of easy conflict situation:

\[
K_{\text{cfs}} = \frac{R_a}{R_a_{\text{e}}} = \frac{cfs}{cfs_{\text{e}}}
\]
where $K_{cfs}^{w}, K_{cfs}^{d}$ - dynamic reduction coefficients of conflict situations by a degree of their danger for the average and serious conflict situations, respectively; $R_{a}^{w}, R_{a}^{d}$ - conditional danger (Accident Risk) of light, average and serious conflict situations, respectively.

The average annual number of the reduced conflict situations $n_{cfs}^{+}$ is defined by the formula (4):

$$n_{cfs}^{+} = \frac{n_{cfs}^{l} + n_{cfs}^{w} K_{cfs}^{w} + n_{cfs}^{d} K_{cfs}^{d}}{t_{mss}}, \text{ red. cfs/year},$$

where $n_{cfs}^{l}, n_{cfs}^{w}, n_{cfs}^{d}$ - number of light, average and serious conflict situations fixed during measurements, respectively; $F_{l}$ - annual fund of time, h/year; $t_{mss}$ - time of measurements, h.

In a similar way the dynamic reduction of road accidents based on the severity of their consequences was carried out. The dynamic reduction coefficient of road accidents $K_{acc}$ is defined as a relation of conditional severity of injury or fatal accident to conditional severity of damage-only accident:

$$K_{acc} = \frac{E_{a}^{inj}}{E_{a}^{d}},$$

where $E_{a}^{inj}, E_{a}^{d}$ - dynamic reduction coefficients of injury and fatal accidents, respectively; $K_{cfs}^{inj}, K_{cfs}^{d}$ - conditional severity of damage-only, injury and fatal accident, respectively.

The average annual number of reduced accidents $n_{a}^{+}$ is defined by the formula:

$$n_{a}^{+} = n_{a}^{l} + n_{a}^{inj} K_{acc}^{inj} + n_{a}^{d} K_{acc}^{d}, \text{ red. acc./year},$$

where $n_{a}^{l}, n_{a}^{inj}, n_{a}^{d}$ - number of damage-only, injury and fatal accidents, respectively, acc./year.

The intermediate formula for calculating the predicted number of reduced road accidents $P_{a}^{+}$ has taken the following form:

$$P_{a}^{+} = n_{cfs}^{+} n_{cfs}^{+} \text{ red. acc./year,}$$

where $f(n_{cfs}^{+})$ - function of recalculation of the number of reduced conflict situations into the number of reduced accidents, different for each kind of the conflict.

The concept of threshold sensitivity of the conflict $d_{cfs}$ is the greatest number of reduced conflict situations in the given conflict point which cause no accidents in it (i.e. the absence of at least one reduced accident in three years). The threshold sensitivity differs for each kind of conflict and is subtracted from the sum of reduced conflict situations of each conflict point. Calculation of the number of reduced road accidents is made according to the number of reduced conflict situations $n_{cfs}^{+}$:

$$n_{cfs}^{+} = n_{cfs}^{+} - \left( k d_{cfs} \right) F_{l}, \text{ red. cfs/year},$$

where $k$ - number of conflict points of the given kind of conflict in the study object in which conflict situations took place; $d_{cfs}$ - threshold sensitivity of the conflict in the given type of the conflict, cfs/h.

Formula for the definition of predicted number of reduced road accidents looks like that:

$$P_{a}^{+} = f\left(n_{cfs}^{+} \cdot 10^{-3}\right), \text{ red. acc./year.}$$

The number of non-reduced accidents with $i^{th}$ severity $P_{a}^{+}$ is defined by the formula:

$$P_{a}^{+} = \frac{P_{a}^{+} \delta_{a}}{K_{acc}^{+}}, \text{ a/year},$$

where $\delta_{a}$ - part of accidents with $i^{th}$ severity in the study $k$ conflict. It is defined from accident statistics for each kind of the conflict; $K_{acc}^{+}$ - the total dynamic reduction coefficient of accidents by their severity (Table 5).

For the realization of a new calculation model it is necessary to define numerical values of dynamic reduction coefficients $K_{cfs}^{w}, K_{cfs}^{d}, K_{acc}^{inj}, K_{acc}^{d}$; threshold sensitivity $d_{cfs}$; conversion functions of the calculated reduced conflict situations to the reduced road accidents $f(n_{cfs}^{+})$ and a part of accidents of $i^{th}$ severity $\delta_{a}$ for each type of the conflict. For that purpose, experimental researches have been executed, including receiving and processing of statistical sample of road accidents, experimental measurements of conflict situations and processing of the received sample, and also the search for the best dependences of reduced accidents from the reduced conflict situations.

Researches were realized at 100 signal-controlled junctions and 80 humps. Dependences between the road accidents and conflict situations were investigated in 6 kinds of conflicts (Table 2) (the sample of the frontal (oncoming) collisions was inconsiderable and was not taken into consideration).

The study sample of accident rate covered 3360 accidents in three years, including 2946 damage-only accidents, 395 injury accidents and 19 fatal accidents. The
study sample of conflict situations covered 19,995 events in 5 h, including 19,019 light ones, 871 average and 105 serious. Investigations were carried out in towns and large cities, as well as Minsk. The further research of conflicts will be more detailed considering the number of traffic lanes, the number of traffic-light phases and the schemes of phase-by-phase traffic, the intensity of vehicle and pedestrian traffic by the traffic lane, the direction of pedestrian traffic while crossing a carriageway, etc. In this research work, however, the main task was to adapt the conflict situations method to the traffic conditions in the Republic of Belarus and at the same time to obtain the accuracy of accident forecasting sufficient enough for its practical use.

3. Experimental research and results

The accident rate analysis was executed for three years separately for each study object and for the sample as a whole. For each kind of conflict the total number of accidents and separately the average annual number of damage-only, injury and fatal accidents was defined. The results of the analysis are shown in Table 3.

The required size of the study samples was defined according to the formula

\[ n = \frac{t^2}{K^2} \left(1 + bK + cK^2\right), \]

where \( t^\beta \) – reliability index; \( K \) – accuracy indicator; \( b \) and \( c \) – factors (indexes).

The reliability level in the given research is \( \beta = 0.95 \), that corresponds to \( t^\beta = 1.96 \), where \( b = 0.022 \) and \( c = 0.69 \).

The accuracy indicator is calculated by the formula:

\[ K = \frac{\Delta}{\sigma}, \]

Table 2. Types and kinds of conflicts

| Type | Number \( N_j \) | Kind | Scheme |
|------|------------------|------|--------|
| 1    | Lateral collision |      |        |
| 2    | Rotary collision  |      |        |
| 3    | Passing (manoeuvring) collision |      |        |
| 4    | Collision with impact behind |      |        |
| 5a   | Impact, transit transport–pedestrian (\( V \leq 30 \text{ km/h} \)) |      |        |
| 5b   | Impact, transit transport–pedestrian (\( V > 30 \text{ km/h} \)) |      |        |
| 6    | Impact, turning transport–pedestrian |      |        |

Table 3. The study sample of road accidents

| Conflict | Average annual number of accidents \( n_a \) and their part \( \delta_{ak} \) in the sample \( \frac{n_a}{\delta_{ak}} \) | Damage-Only | Injury | Fatal | \( \frac{n_a\delta_{ak}}{\Delta_{aj}} \) |
|----------|---------------------------------------------------------------------------------------------------------------------------------|-------------|--------|-------|---------------------------------|
| Number \( (N_j) \) | Scheme | Damage-Only | Injury | Fatal | |
| 1        |        | 115.333/0.867 | 16.000/0.120 | 1.667/0.013 | 133.000/0.119 |
| 2        |        | 189.000/0.904 | 19.333/0.093 | 0.667/0.003 | 209.000/0.187 |
| 3        |        | 188.000/0.981 | 3.333/0.017 | 0.333/0.002 | 191.667/0.171 |
| 4        |        | 479.333/0.970 | 13.667/0.028 | 1.333/0.002 | 494.333/0.441 |
| 5a       |        | 2.000/0.118 | 14.667/0.862 | 0.333/0.020 | 17.000/0.015 |
| 5b       |        | 6.000/0.103 | 50.333/0.868 | 1.667/0.029 | 58.000/0.052 |
| 6        |        | 2.33/0.137 | 14.333/0.843 | 0.333/0.020 | 17.000/0.015 |
| Total    |        | 982.000/0.877 | 131.667/0.117 | 6.333/0.006 | 1120.000/1.000 |
where $\Delta$ – measurement error; $\sigma$ – standard deviation.

The quantity of measurements of a conflict interaction between 2 road users should be at least 764.

Experimental researches were carried out for the purpose to define the quantity and the level of risk of conflict situations. The researchers, who have passed special instruction, have been monitoring the study object within 5 h of the light time of the day (approx from 13.00 p.m. till 18.00 p.m.).

In case of a conflict situation they recorded time and place of the conflict, the kind and the level of risk of the conflict situation. Then the average annual number of conflict situations for each kind of the conflict and each level of risk as a whole (Table 4) was defined.

Figs 1–4 give the accident rate dependences on the conflicts of two typical types, received by using the existing and advanced methods. The Table 5 and Figs 1–4 show that the dependences, received by using the advanced method, statistically are more significant and very accurate.

The conducted researches have shown that possibilities for the further perfection of the method are not exhausted yet. In particular, a detailed elaboration of the

| Table 4. The study sample of conflict situations (during 5 h measurements) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| The level of risk           | The number of conflict situations |
| Nj                          | 1       | 2       | 3       | 4       | 5a      | 5b      | 6       |
| Light                       | 915     | 1712    | 5575    | 7686    | 823     | 1041    | 1267    |
| Average                     | 143     | 137     | 108     | 240     | 28      | 170     | 45      |
| Serious                     | 35      | 19      | 14      | 14      | 1       | 19      | 3       |
| Total                       | 1093    | 1868    | 5697    | 7940    | 852     | 1230    | 1315    |

Fig. 1. The accident rate dependence on conflict situations (conflict No. 1, the existing method)

Fig. 2. The reduced accident rate dependence on the reduced conflict situations (conflict No. 1, the advanced method)

Fig. 3. The accident rate dependence on conflict situations (conflict No. 3, the existing method)

Fig. 4. The reduced accident rate dependence on the reduced conflict situations (conflict No. 3, the advanced method)
kinds of conflict and introduction in the calculation model the factor of speed and conflict zones is possible. Also, as a result of researches the reduction coefficients $\eta_{cfs}$ were received. They were adapted for Belarusian conditions.

4. Methodology for the rapid assessment of the efficiency of road traffic management

Methodology for the rapid assessment of efficiency included the following. The measurements of conflict situations were carried out in a really existing object in a period of 5 h of the light time of the day (approx from 13.00 p.m. till 18.00 p.m) on a working day of the week (on new or reconstructed objects – every 5–7 days) after introduction of the measure. At large four-leg intersections the measurement are taken by two observers, at three-leg intersections, small four-leg intersections and humps the measurements are taken by one observer. The observers are disposed at a 15–25 m distance to the study object to have the view of their own sector or of the whole object (Fig. 5).

The observers receive a special instruction with video display, so they confidently identified conflict situations and divided them into light, average and serious. In case of the conflict situation the observer marks its place on the object plan, indicates the kind of conflict, the level of risk and the time of its occurrence. Both observers are in a constant contact, as it allows to discuss the conflict situation and to come to a consensus.

The predicted road accidents are calculated in the following sequence. For each kind of the conflict within all crossroads the number of conflict situations and the average annual number of the reduced conflict situations $n_{cfs}$ are defined. The probable number of the reduced accidents $P_a$ is defined for each kind of conflicts, which then is translated to the probable number of non-reduced accidents $P_a^*$ for each kind of the conflict by the total dynamic reduction coefficient according to the severity of consequences.

In summary, all the road accidents for each kind of conflicts within the study object are summarized.

The results are verified with the data received by the method “Conflict zones”. The control calculations are repeated in case of significant divergences and if the results prove to be true the measure to be introduced is corrected.

Moreover, apart from safety, the observers also take into consideration other aspects of the object observed. Such as occurrence of traffic jams, violation by both drivers and pedestrians of road traffic regulations, etc. In case of revealing these facts they fixed an analyzed in detail with the possible corrections of the measures introduced.

In some cases, when there is no necessity to carry out the accident control forecast of the whole object, one restrict oneself to the forecast of one separate conflict zone or of one separate type of conflict.

5. Conclusions

1. The aim of the research was to develop methodology for the rapid assessment of the effect of implemented measures to improve road safety based on the accident prediction method for conflict situations which allows evaluating and if necessary to correct measures directly during their implementation.

2. The improved method provides a higher (4 times on average) forecasting accuracy for each type of conflicts
as well as for each study object. They are used in road traffic organization. As for its adaptation to Belarusian conditions it showed no significant results, since the calculated change in the forecast accuracy (on average from -1% to +7%) meet the limits of calculation error.

3. A new mathematical model for forecasting accidents in the conflicts “transport-transport” and “transport-pedestrian” was developed which uses dynamic reduction of conflict situations according to a degree of danger, dynamic reduction of accidents according to the severity of consequences, the threshold sensitivity of the conflict, also new non-linear dependencies between the dynamically reduced accidents and dynamically reduced conflict situations, makes it possible to increase the forecasting accuracy 4 times on average compared to the existing method and to use it in practice for determining the effect of implemented road safety measures. The developed model allows forecasting not only an adequate number of accidents but also the severity of their impact on existing facilities, to evaluate the designed technical solutions for transport planning facilities, schemes of movement and traffic light control modes implemented in the street network of the Republic of Belarus. It is possible to further improve the prediction of accidents in conflict situations by more detailed classification of types of conflicts and the introduction of computational model predictions for new factors affecting the accident rate, in particular, speed.

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