Computer simulation of traffic conflicts

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Introduction

The task of traffic conflicts computer simulation appeared because using traditional empirical traffic conflict methods was at some cases very difficult or impossible. There are such cases as traffic safety evaluation of new road projects, road reconstruction projects or long road sections. It is a very actual problem because safety evaluation of road projects has a key function.

At the beginning we knew that computer simulation of traffic conflicts has adventures and disadventures. The using of this method is very cheap. One computer experiment with simulation model is 10 till 1000 times cheaper comparing with empirical experiment. And this method is more objective because the identification of traffic conflicts is realized during simulation experiments according to input definition and not dependant on observer opinion But the quality of computer simulation of traffic conflicts is very dependant on the adequacy grade of the traffic flow simulation models. That is why we had to work out complicated simulation models, which describe the traffic flow as the moving and interaction of individual driver-vehicle units. This way of system description was achieved by desaggregated simulation models. We determine these models as the models built on the formal basis on the formal basis, proposed by Buslenko (1978) (partly constant aggregations), however, completed with the decision of some tasks (Siljanov, Tonkonozhenkov, 1996)

In the present article we will consider some results of the solution to these tasks related to simulation of traffic conflicts (the other results were described by Siljanov, Tonkonozhenkov, 1996) and will concentrate on two examples: for traffic flow simulation model on two-lane rural roads with oncoming traffic and for four-lane motorways which have two lanes in each direction.

Conceptual model on the interaction of drivers and conflicts in the traffic flow

The working out model on the interaction of drivers and conflicts in the traffic flow is based on the determining the special situations. We determine such situations as situations, where drivers can change their opinion on the road situation, regime or trajectory of movement. In the intervals between the special situations we assume, that all parameters presenting all drivers and vehicles on the simulated road section remain constant and the occurring of each situation corresponds to the leapingly changes of driver-vehicle units parameters, i.e. the determining of special situations is very important for the modelling. In the course of traffic conflicts simulation two groups of special situations were exposed:

Group 1. There are situations, related to the effect of vehicles moving in the same direction, same lane and road parameters on the vehicle movement (group 1); these situations are common to all mixed traffic flow simulation models in as far as they do not take into account the effects of vehicles on the neighbouring lanes and can be used as unifying unit in different models. At the first stage of investigations we assumed that these situations cannot be a main reason for the traffic conflicts because drivers can change their vehicle moving parameters as regards the moving parameters of the vehicle ahead and there are no reasons to sharp and abrupt braking (we didn't take into consideration such situation where drivers can be diverted from the road situation observation or can not "feel" the distance etc.). That is why we will not consider these special situations here.

Group 2. There are situations, modeling interaction of vehicles, situated on different lanes and (or) moving in a different (opposite) directions. These situations are connected with processes of forecasting and drivers decision making and also with mistakes during these processes, which can lead to traffic conflicts. Determining situations in this group and the reactions of drivers to them depends on concrete traffic control scheme on the lanes and that is why we use for each traffic flow simulation model the individual set of special situations. The important feature of worked out schemes on special situations for desaggregated models (fig. 1 - 2) is taking into account the characteristic features of every driver-vehicle unit. This is achieved by determining the characteristic distances (i.e. the distances which could correspond to one of the special situations), taking into account vehicle speeds (V_i, V_{i-1}; i - vehicle number for which a situation occurred, i-1 - the nearest vehicle ahead number on the same lane); vehicle types (TA_i, TA_{i-1} - passenger cars, light trucks, medium trucks, heavy trucks, trailers, buses); driver types (TD_i - mild (1), normal (2), aggressive (3)). These indexes are used below in the situations description. Another necessary attributes are determining the critical speed differences between interacting vehicles D taking into account the driver types, vehicle types, vehicle speed. This parameter is used for simulation of the choice of the speed by the movement after the vehicle ahead, for the overtaking possibility judgment etc.

Very important feature of presented schemes is taking into account the individual driver-vehicle system attributes when calculating speed value V, which could be maintained by drivers on the condition, that there are no vehicles ahead (block V, the algorithm for block V work was described by Syljanov, Tonkonozhenkov, 1996) and when checking the driver's possibility to start and complete overtaking or to change lane (block OVER; two results of the block OVER work mean: YES - driver decides to overtake; NO - driver refuses to overtake).

Group two situations for two-lane roads with oncoming traffic. The schemes for this group are presented in fig.1 (j - nearest oncoming vehicle on the neighboring lane).

Situation 1. Departure of vehicle i and nearing oncoming vehicle j ("tail & tail" position). In this situation the driver nimbler i have no more the vehicle number j as nearest oncoming vehicle and will judge, whether the new gap in the oncoming traffic flow is enough for the overtaking.

Situation 2. The appearance of the gap D' in a traffic flow of same direction before vehicle i-n which is enough for placing vehicle i on its proper lane after overtaking of the group of n vehicles. The value D' is calculated by a function:

$$D' = D_2 + L_i + D_{\min}, \quad (1)$$

where: D_2 - safety distance between vehicles i and i-n at the end of overtaking (Netzer, 1966); L_i length of vehicle i; D_{min} - minimal safety distance between vehicles i and i-n-1.

By occurring of this situation driver i have a new favorable situation for the overtaking of group of n vehicles due to the return to his lane after the overtaking and will judge whether he can overtake whether he can overtake this group due to other conditions.

Situation 3. Sight distance went up to value S', enough for making a safe overtaking, i.e. at the moment of the incident the following condition is observed:

$$a \cdot X_i + b = S', \tag{2}$$

where: a and b - constant coefficients (road section characteristics), determining the function of sight distance for driver i on vehicle's i coordinate X_i (the distance between its front edge and the start point of the simulated road, measured through the road axis). The values a and b depend on the type of vehicle i. The critical value S' is evaluated through the working of the submodel on drivers overtaking judgment (block OVER)

Situation 4. Overtaking (i) and leading in the group of overtaken vehicles (i-n) equaled ("head & head" position). Empirical investigations showed, that this point is a critical point where the overtaking driver usually make a decision about the further way of his overtaking. That is why two variants of driver's reaction on the occurring of this situation are simulated: driver i can under corresponding conditions "prolong" overtaking (new leader of the group of overtaken vehicles among the further moving vehicles is chosen) or continue overtaking on the previous (at the start of overtaking) determined overtaking scheme.

Situation 5. The overtaking driver i is convinced, that from the closeness of oncoming vehicle the continuation of overtaking is dangerous. Simulation possibility of such situation makes such provision that during the simulation of driver's checking the possibility of overtaking (block OVER, see below) inaccuracy by driver in judgment overtaking parameters (time and distance T_o, S_o, required to overtake) and speed of oncoming vehicle (V_j) is considered. In this way the driver's inaccuracy in judgment of overtaking parameters is simulated by correcting actual values T_o and S_o; driver's inaccuracy in judgment of the oncoming vehicle speed - through substitution in the resulting condition in order to determine overtaking possibility not of actual speed value of oncoming vehicle which at the moment of overtaking beginning the driver is usually not able to identify (specify due to special visual perception in respect of the objects moving apart), but the kind of speed value which the driver "expect" when making a decision to overtake - potential speed V_p (Tonkonozhenkov, 1987). This function is expressed in the form:

$$S_o' + V_p \cdot T_o' < D, \tag{3}$$

where: D - distance between vehicles i and j at the moment of the driver's judgment; S_o', T_o' - corrected values S_o and T_o.

Situation 5 could occur in a case where $V_p < V_j$ (underestimation), but the distance between the overtaking and oncoming vehicles (D) decreases to value D' determined by the following equation:

$$D' = (S_o' - s) + V_p(T_o' - t)\,, \tag{4}$$

where: s,t - respectively distance and time through which the vehicle i passed from the moment of overtaking start till situation 5 occurs.

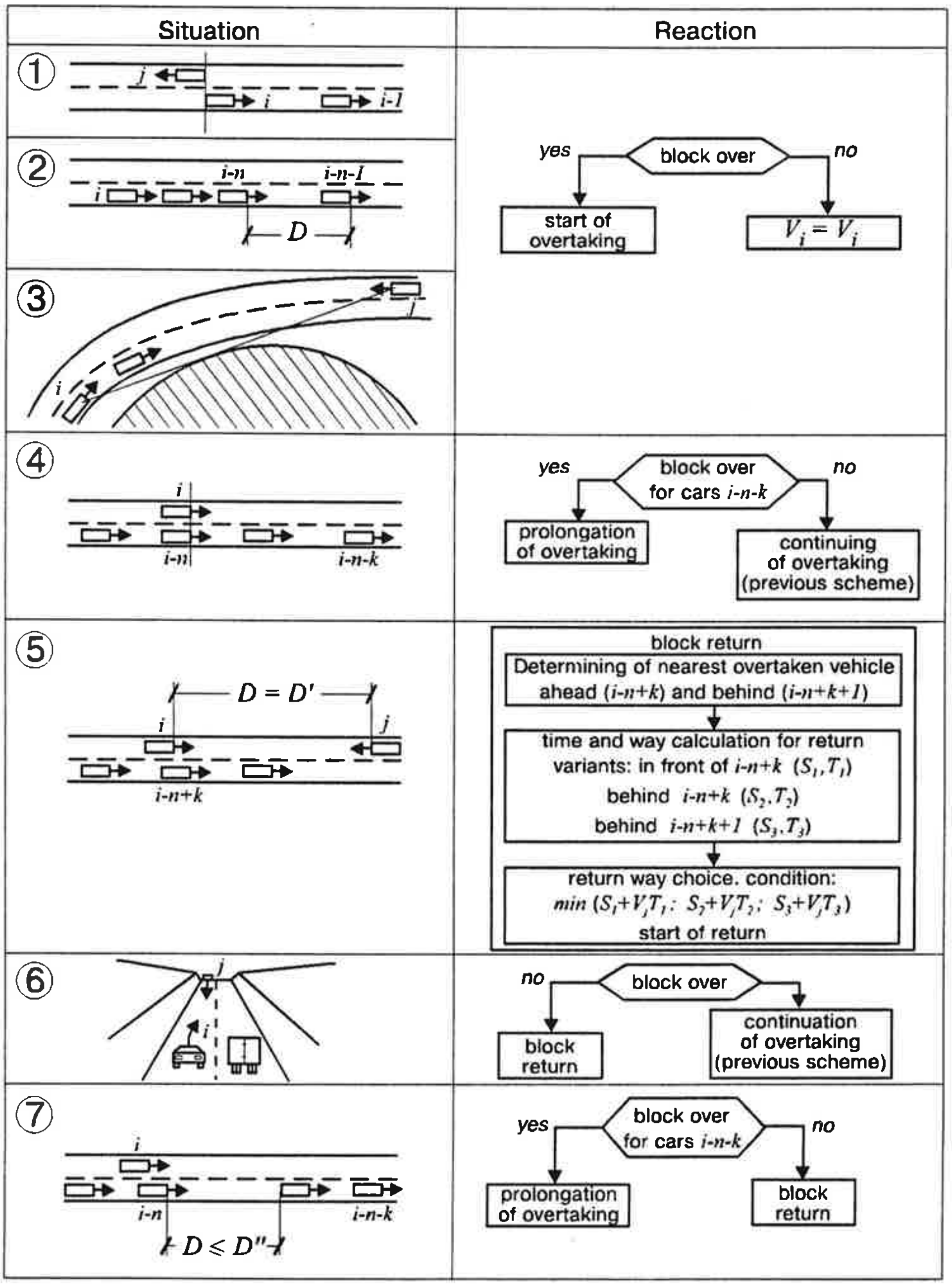

Fig. 1. Schemes on special situations in second group for two-lane roads with oncoming traffic

The occurrence of such situation calls for measures to avoid a collision, i.e. this is a conflict situation. Three possible kinds of conflicts are displayed: vehicle *i* returns to its lane in front of vehicle *i-n* (there is a reduction in safety distances between the vehicles *i*, *i-n* and *j*, however overtaking is carried up to the end); vehicle *i* returns to its lane using one of the gaps between the overtaken vehicles moving after the vehicle *i-n* and before vehicle *i*-1 (partial overtaking); vehicle *i* returns to its lane after vehicle *i-1* (a failed attempt to overtake).

Situation 6. The appearance of oncoming vehicle within the visual area of overtaking driver. A situation can occur for all those drivers who did not see the oncoming vehicle at the moment of the start of overtaking. Here the driver *i* will choose one from four possible variants dependent from the road situation: he can continue to overtake in according to his previous scheme or change his movement and trajectory parameters in according to variants described for the situation 5 (three possible variants of conflict situations)

Situation 7. Decreasing the distance between the leader of overtaken vehicles (*i-n*) and vehicle *i-n*-1 up to value $D = D''$, which is less than minimal distance required for safety return of overtaking vehicle *i* to its lane at the end of overtaking. In this situation driver *i* have to choose the safest variant: he can change his previous overtaking scheme and move further to overtake following vehicles or he can return to his lane in spite of the new distance in front of the leader in group of overtaken vehicles. Both variants can lead to the traffic conflicts, which are described above.

The block OVER has a key function for the traffic conflicts simulation. This submodel simulate the forecasting of the road situation development, the drivers evaluation of the road situation and decision making process. It works as follow (fig. 2):

- Selecting leading in the group of overtaken vehicles (number *i-n*). It is taking into account the distance between the vehicles *i* , and *i-n* and their speed values and also the speed value, at which the vehicle *i* will move at the end of overtaking. In such way is determined the potential aim of the driver *i*. Then the potential movement parameter of vehicle *i* are compared with actual movement parameters of vehicle *i-n* - as a result we determine, whether the driver *i* has a desire to overtake this vehicle group. Evidently the submodel can stop here its work (overtaking refusal).
- Calculation time and distance *To* and distance *So* required for the overtaking of the group from *n* vehicles follows. Overtaking may occur in different, among others the changing road conditions and that can influence the traveling of overtaking and overtaken vehicles during the overtaking. Because of that, the simulation of vehicles *i* and *i-n* movement forecasting during the overtaking is used. For this simulation four special situations are determined and time of occurrence of these situations is calculated. There are following situations: overtaking vehicle *i* reaches the end of the road section (change in road conditions is possible); leader in the group of overtaken vehicles (*i* - *n*) reaches the end of the road section; the vehicles *i* and *i-n* equaled (head & head position - the overtaking driver will determine the way of return to his lane); overtaking vehicle *i* completes the overtaking and returns to his lane before the vehicle *i-n*. After the occurrence of first, second and third situations the change in vehicles parameters take place according to the conceptual models on the reactions to these situations; by the occurrence of the fourth situations the parameters of potential overtaking of *n* vehicles are ready.

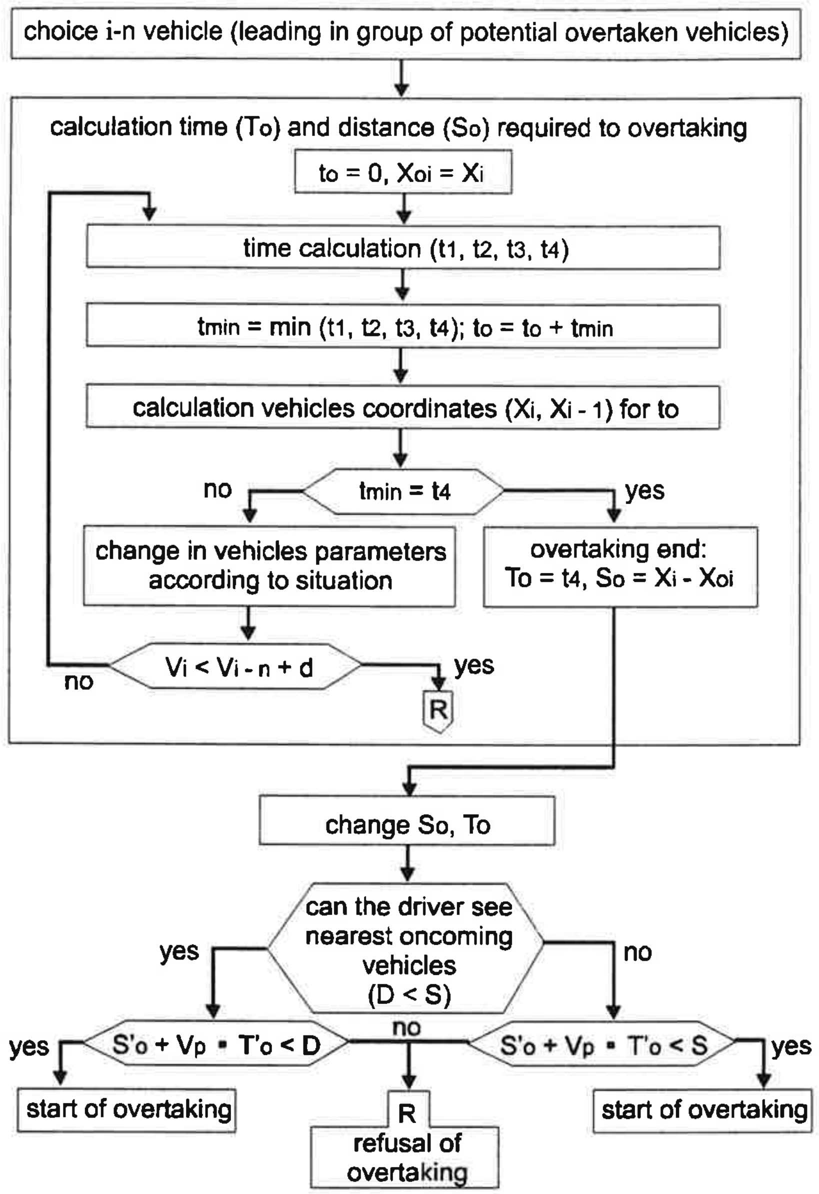

Fig. 2. General scheme for simulation of driver judgement of the overtaking possibility on two-lane roads (block OVER)

- After determining actual parameters *So* and *To* correction of their values follows in the light of inaccuracy of theses parameters, made by the overtaking driver; the grade of theses mistakes is dependent on the grade of movement parameters changing during the potential overtaking;

- The issue about starting overtaking is solved by using function 3 of two cases : for oncoming vehicle within the driver's sight distance and outside it (in both cases instead of actual oncoming speed value the potential speed value *Vp* is used; it takes into account, that the driver *i* is not able to estimate the speed value of oncoming vehicle at the start of overtaking).

Group two situations for four-lane motorways. Schemes for simulation this group of situations for four-lane motorways with median dividing lane and two lanes for traffic in every direction are shown in fig. 3. The vehicle involved in the situation is noted by number *i*; the nearest vehicle ahead in the neighboring lane is given the number *in*; the nearest one following at the back - *in+1*. The vehicle speeds are expressed as V_i, V_{jn}, V_{Jn+1}; their coordinates - as X_i, X_{jn}, X_{Jn+1}. , their lengths - as L_l, L_{jn}, L_{jn+1}.

In determining situations it was assumed, that a change in lanes with the aim of increasing speed and to overtake the vehicle(s) moving ahead on the same lane, is determined as an overtaking. A change in lanes not backed up by the aim to increase speed but freeing the lane to faster moving vehicles behind is counted as a change in lane (this maneuver can be accomplished only by the vehicle moving from the left lane to the right-hand one). Simulation of checking overtaking and change in lanes possibility is carried out by the block OVER. Following group two situations for four-lane motorways are simulated (fig. 3):

Situation 1. The distance between the vehicles (*i*) and (*in*) rose to value D_1 at which there is possible overtaking (or change in lanes) for vehicle *i*. For vehicles moving in the right lane overtaking possibility is checked for all vehicles, the speed of which is limited by the vehicle ahead (*i-1*). For vehicle *i* moving in the left lane, checking overtaking possibility is done only for some drivers ("aggressive" one, $TD_i = 3$), who allow the prohibited overtaking from the right. For drivers moving in left lane and do not belong to the type $TD_i = 3$, change in lanes possibility is checked. Here it is carried out in the following cases: if vehicle *i* is traveling out of the zone of influence (*De*) by vehicle ahead (*i-1*) or speed, which he can maintain (*V*) is less than that of vehicle *i-1*. This scheme is also used for simulation the drivers reaction to the occurrence the below described situations.

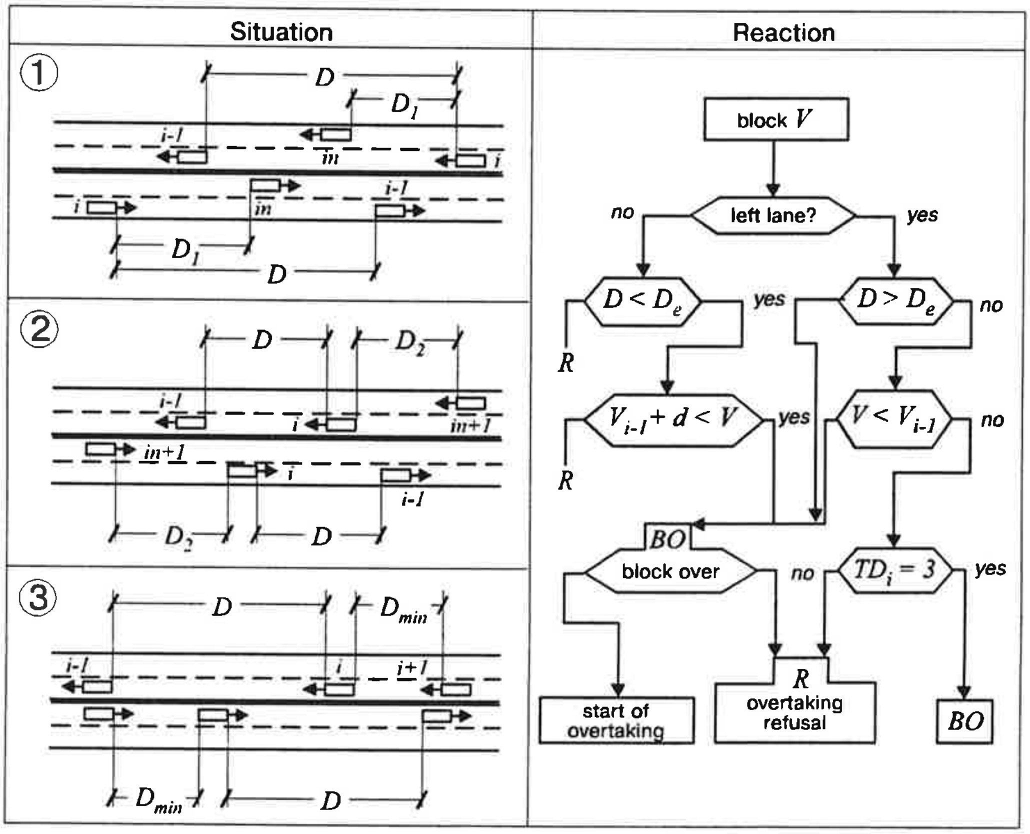

Fig. 3 Special situations schemes in second group for four lane motorways

Situation 2. The distance between vehicles (*i*) and (*in* +*1*) increased up to value D_2, at which driver *i* can begin overtaking (changing lane).

Situation 3. Driver *i*, moving in the left lane notices a fast moving vehicle behind (*i* +*1*), driving on the same lane. This situation occurs at the moment when distance between vehicles *i* and *i* +*1* decreases to the value D_{min}. It is assumed, that under definite conditions driver *i* can change to the right lane leaving way for the vehicle behind.

Block OVER which simulate drivers overtaking (change in lanes judgment) has some features comparing with the submodel OVER for two-lane rural road but the general approach is the same. To consider, that driver *i* at the moment of overtaking possibility judgment can only approximately judge the speed value of vehicle *in+1* , it is accepted, that at that moment he should compute his speed as potential value *Vp*.

$$V_p = V_{in+1} + p \qquad (5)$$

Where: *p* - value of inaccuracy of the vehicle *in+1* speed judgment from the driver *i* (random value). For the modeling the cases, where overtaking (change lane) necessitates a braking of vehicle *in+1* it is assumed, that some drivers by overtaking possibility judgment consider, that the maneuver may necessitate a braking of vehicle moving behind on the neighboring lane, but the deceleration will do not exceed the value a_p (this random value is one of the drivers characteristics) Safety condition for maneuver lies in the fact, that at the moment when the speeds of vehicles *i* and *in+1*are equaled (maximum closeness of vehicles *i* and *in+1*), the distance between them will be not less than the border-line value *Dmin.*

Adequacy test

For the adequacy judgment of the presented simulation models were employed the comparing output parameters of the real and simulated traffic flows for the same input parameters. Input parameters comprise of: traffic volume and composition by vehicle types and brands in every lane; loading distributions for different vehicle types; road parameters, traffic control scheme. This method is applied on the availability of all above mentioned input data.

As an example illustrating this method of adequacy evaluation comparison of traffic conflicts distribution for real and simulated vehicles on different sectors on 1.5 km road stretch is below described. That was a four-lane motorway which has two lanes in each direction. All the simulated road parameters and traffic control scheme, data on traffic composition by vehicle types and brands and vehicles loading distributions corresponded to the data obtained from the observation on the actual road.

Table 1

section	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
model	2	2	1	2	2	4	6	8	6	14	20	14	14	14	6	8
real	2	2	2	2	3	4	8	9	7	16	22	14	16	12	6	6
range	2.5	6.5	10.0	13.5	18.5	25.5	36.5	51.0	65.5	87.5	123.5	158.0	186.5	213.5	231.5	244.5

$Z = -0.8$ ($< Zt$)

The results of comparison of traffic conflicts distributions on the observation spots for one of time intervals which was 2 hours long is shown in table 1. Adequacy test was based on the checking up of the hypothesis - that the selection of output model and actual system data belongs to one aggregate and was carried out with the use of Monney-

Whitney criterion, described by Shannon (1978). In most given case it was seen that the calculated criterion value Z proved less than the border value Z_t, i.e. adequacy test in most cases gave a positive result.

Application examples for research into traffic conflicts distribution

The developed simulation models for traffic conflicts distributions investigations consider in detail the individual driver-vehicle characteristics, road conditions, behaviour nature of drivers and drivers interactions under different road conditions. That is why in order to carry out simulation experiments it is essential adventure to have minimum input data.

The developed models can be used for research into traffic conflicts distributions on concrete roads, taking into account their individual characteristics. This possibility is important for evaluation of new road projects, road reconstruction projects or traffic control measures on concrete roads.

The practical use of traffic conflicts simulation is demonstrated by the results of computer experiments with the traffic flow simulation model on a four-lane motorway, which has 1.5 km length and an about 1-km long upgrade with 3-4.5 percent slope (fig. 5). There were 10 % of trucks in the traffic flow. The total time of simulation experiment was 7 hours.

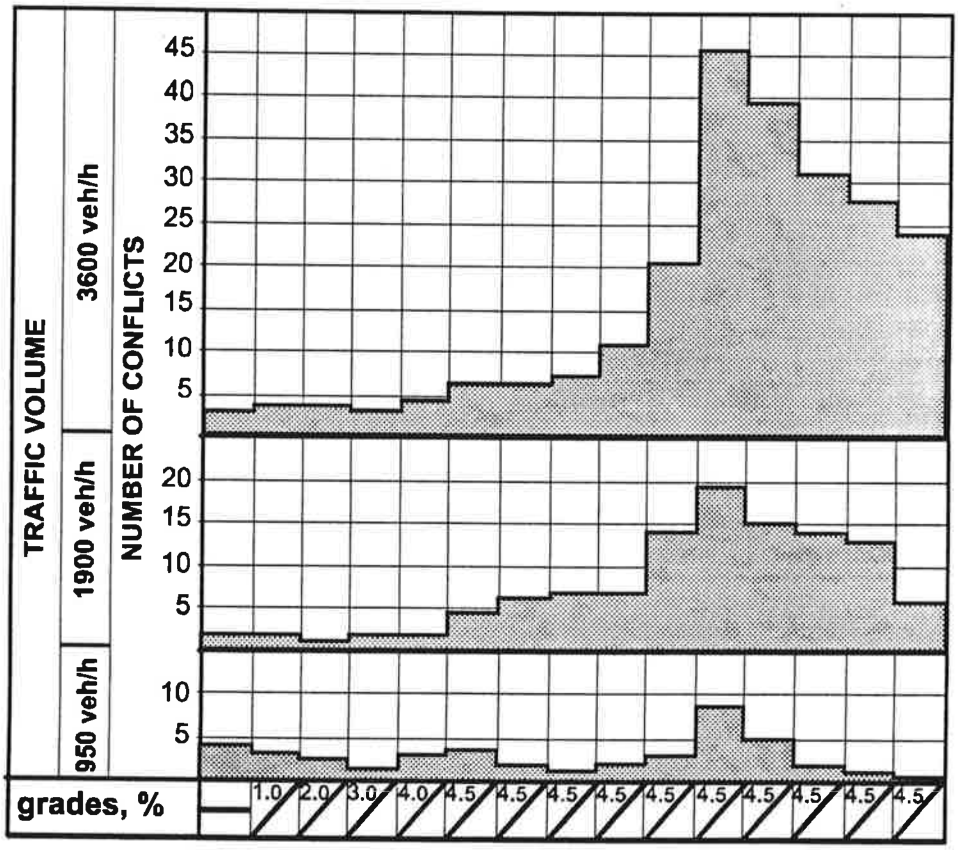

Fig. 4. Traffic conflicts distribution on an upgrade of four-lane motorway (one direction) dependent on traffic volume (total time of simulation experiment is about 7 hours)

It is interesting to see, that the sector with traffic conflicts concentration don't move by traffic volume change and is situated at the 400 - 500 m distance from the top of upgrade and the number of conflict situations increases when the traffic volume increases. The same tendencies were observed at the empirical way.

Another example demonstrates the results of computer experiments with the traffic flow simulation model on a two-lane rural road stretch, which had 1.5 km length, an about 800 m long upgrade with about 4.5 % medians slope, one horizontal curve with 300 m radius and limited sight distance. (fig. 6) There were 56 % of trucks in the traffic flow. Total time of the simulation experiment was 2 hours.

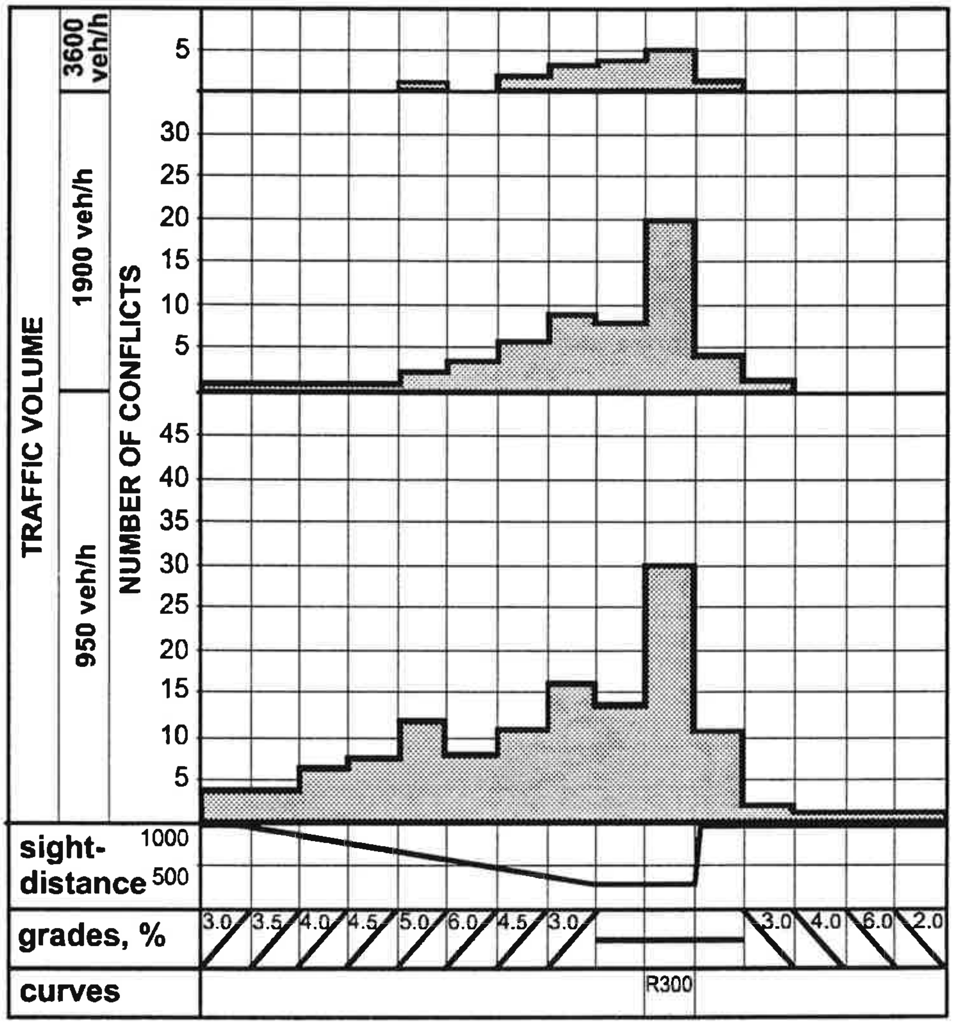

Fig. 5. Traffic conflicts distribution two-lane rural road with oncoming traffic (one direction) dependent on traffic volume and traffic volume distribution on lanes (total time of simulation experiment is about 2 hours)

It was noticed, that the road has an evident potential black spot, which is situated on the curve and the road is most dangerous by significant differences in traffic volume on lanes. Here it was the 650/280 traffic volume distribution.

Conclusion

The described method of traffic conflicts computer simulation considers in details the features of each driver-vehicle unit and their interaction in the traffic flow under different road conditions. The important result of this is the possibility to investigate the traffic conflicts distributions on the roads depending on the changes in the input parameters i.e. road parameters and traffic flow volume and composition. That gave room for such investigations, which would be very difficult to carry out by means of other methods. Using of described method proved effective for investigations into traffic conflicts distributions on concrete roads with their individual features, what is very important for the traffic safety evaluation of new road projects, road reconstruction projects or evaluation of traffic regulation measures.

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