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Using Intersection Conflict Index in Urban Traffic Risk Evaluation

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Abstract

This paper presents part of the research on traffic risk estimation for Bucharest City area. The aim of our research is to develop complex models as tools of urban traffic risk assessment in planning phase. In this way, several urban planning alternatives could be analysed and evaluate before important transport infrastructure investment are made. The first part of the paper analyses the state of road accidents recorded in Bucharest. The second part of the paper demonstrates how the intersection conflict index can be used in traffic micro-simulation models to assess measures of traffic risk reducing.

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Keywords: Urban road accidents; traffic safety; traffic risk; traffic micro-simulation; intersection conflict points.

1. Introduction

Because road accidents have important social and economic consequences, road safety represents a constant objective of the transportation development measurers and regulation [1]. The complexity of the numerous factors which contribute to accidents occurrence (from land use and urban planning, design and management of road infrastructure, traffic management system, design and state of vehicles, traffic management system to education level and behaviour of road users) implies the necessity of pluri- and inter-disciplinary research to evaluate the effects of the measures applied for road safety improvement, but also to assess the traffic risk and to identify actions needed to traffic risk reducing since planning phase [2]. In this ample research frame, this paper presents a study on traffic risk assessment in urban area.

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In the last 20 years, the Romanian major cities are characterized by continuous concern of urban population on accessibility enhancement, which finally has led to congestion, increased travel time and high rate of traffic accidents. Consequently, actions need to be taken to improve of the urban road safety. Therefore we have started a study on traffic risk assessment for Bucharest, a large city where around 10% of population of Romania is concentrated. The main goal of our study is to provide analysis tools to local decision makers for ex-ante assessment of the different urban planning alternative consequences, in terms of traffic flow increasing and associated accident risk. In our research we define the risk associated to road traffic as the probability of accidents occurring with consequences on users of traffic infrastructure and also on community of the surrounding area.

2. Research methodology

In the first step of our study we used Geographic Information System (GIS) facilities to develop a complex project for:

- Modelling the urban area,
- Modelling the road network and
- Analysing the available recorded data on road accidents in Bucharest in period of 2008 - 2012 (Fig. 1).

The developed geo-database allowed us to process and to obtain data sets of characteristics of the road sections and intersections with low safety performances.

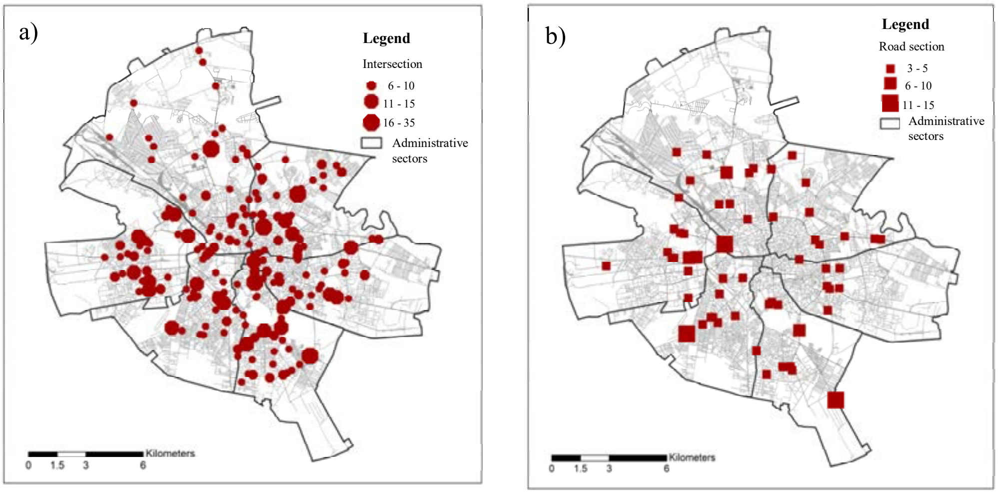

Fig. 1. Location of road accidents in Bucharest City recorded in 2008 - 2012 (a) intersection; (b) road section.

Further, the resulted data sets are used to define and to calibrate accident prediction functions [3]. We managed to define accident prediction functions for some categories of road section with low safety performances [4], but difficulties have been encountered for intersections. Statistical data on road accidents located in intersections (Fig. 2) reveals that:

- 66 % are vehicle – pedestrian accidents;
- 70 % of vehicle-vehicle accidents are located in intersections with complex configuration;
- 45 % of vehicle-vehicle accidents are located in intersections with tram facilities.

Several studies present accident prediction functions [5 - 8], but the equations defined for intersections are not appropriate in the most cases in Bucharest because they take into account only simple intersection configurations and road traffic. Therefore we have decided to assess the traffic risk for intersections on microscopic level, based on traffic conflicts, which allow us to take into consideration also pedestrian flow. A traffic conflict is defined as a traffic event involving two or more road users where evasive maneuvers are taken to avoid a collision [9].

It was demonstrated that traffic conflict could be used as surrogate safety measures [10 - 14]. Initial, the traffic conflict technique was applied based on observations and counting of conflicts in intersections [15]. In the last years, traffic simulation models are used to compute traffic conflicts for different design alternative and to estimate safety [11, 13].

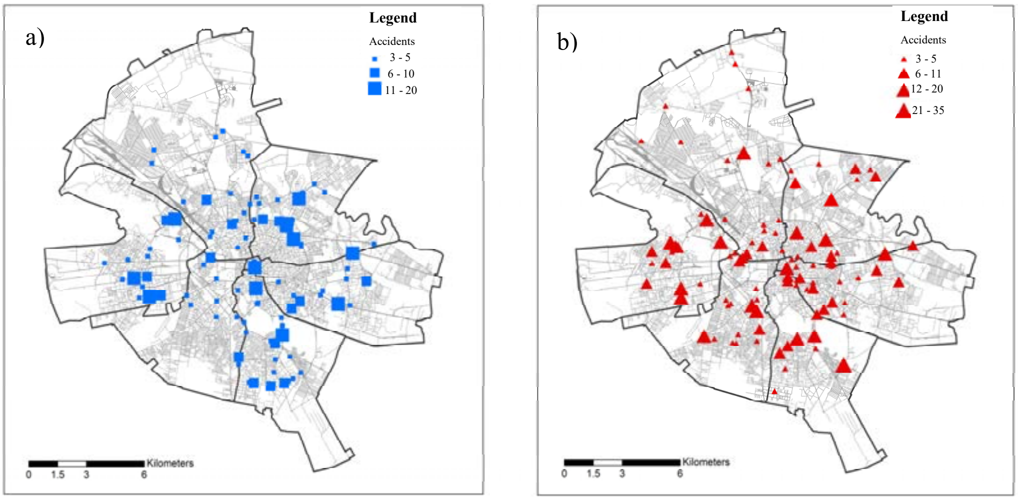

Fig. 2. Accidents recorded in intersections in Bucharest, in 2008 -2012 (a) vehicle – pedestrian accidents; (b) vehicle – vehicle accidents.

Hence, in order to obtain a tool to estimate traffic risk in intersection in our study on Bucharest area, we decided to develop a simulation model to compute traffic conflict index defined by:

$$I_C = \sum_{i \in \{X_C\}} \overline{q_{ij}} \cdot \overline{q_{ik}} \quad (1)$$

where $\overline{q_{ij}}$, $\overline{q_{ik}}$ are average traffic flows (PCE/h) on movement $i - j$ and $i - k$ respectively, traffic flows that interact in conflict point i;

$\{X_C\}$ – the set of conflict points.

In this stage of our research we propose to use indices for vehicle-vehicle conflicts and vehicle-pedestrian conflicts as measures of traffic risk. Data on pedestrian flows are not available for all selected intersections with low safety performances; consequently we compute the traffic conflict indices on peculiar complex intersections, where detailed vehicle and pedestrian flow measurements are made. The obtained data are used in development and calibration of the traffic simulation model. For the case study presented in this paper we selected the intersection Spl. Independentei – Sos. Grozavesti, with incorporated tram facilities and crossed by significant pedestrian flow generated and attracted by the University Campus and the large commercial centre located in the neighbourhood (15 severe road accidents are recorded in this intersection in 2008 – 2012).

3. Simulation model

In order to build the microsimulation model using AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks), the following input data are required [16]:

- Network layout in the studied area (Fig. 3) – is used as reference for geometry configuration and network coding, details of the number of lanes, possible turning movements in intersections (*a, b, c, d, f, g, k*), speed limits for all sections (one-way links);

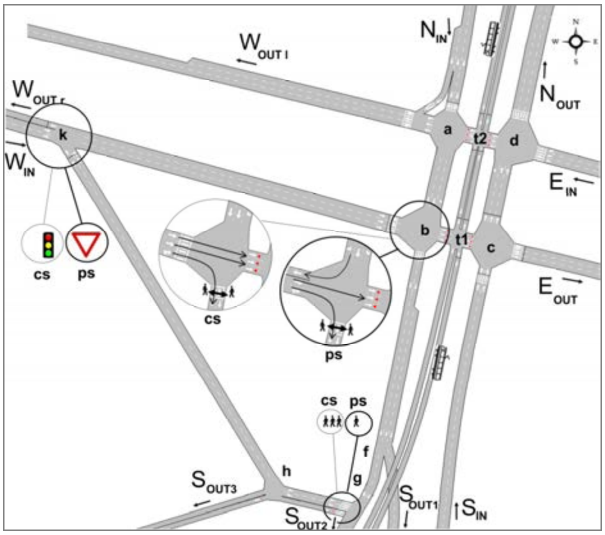

Fig. 3. Network layout with details of current situation (*cs*) and proposed situation (*ps*).

- Traffic demand data provided by an O/D matrix – includes the number of trips going from every origin (N_{in}, W_{in}, S_{in}, E_{in}) to any destination (N_{OUT}, $W_{OUT\ l}$, $W_{OUT\ r}$, S_{OUT1}, S_{OUT2}, S_{OUT3}, E_{OUT}). The traffic volume counts were conducted for two hours in peak period on two days. The results are summarized in Table 1. The tram flows are simulated accordingly to the schedule supplied by the urban transit operator.

Table 1. Origin/Destination matrix from traffic counts (PCE/h).

	E_{OUT}	S_{OUT1}	$W_{OUT\ l}$	N_{OUT}	S_{OUT2}	S_{OUT3}	$W_{OUT\ r}$	**Total**
S_{IN}	122	22	48	895	10	3	32	**1132**
N_{IN}	128	282	154	69	122	37	405	**1197**
E_{IN}	77	170	371	217	74	22	243	**1174**
W_{IN}	658	41	19	355	18	5	13	**1109**
Total	**985**	**515**	**592**	**1536**	**224**	**67**	**693**	**4612**

- Traffic control scheme – describes the location of signals, the signal groups *S1, S2, S3* into which turning movements are grouped (Fig. 4), the sequence of the phases and, for each one, the signal groups that have right of way and duration of each phase (Fig. 5). As shown in Figure 4, in first phase the vehicles movement are protected on North-South direction and permitted for straight and left turning in node *a* and *c*. The conflict points arising between protected and permitted traffic flows are denoted by n_x, where *n* is the node (*a, c*) and *x* is the type of the conflict: *m* (merging) or *c* (crossing). For example, a_c is the conflict point between traffic flows on North-South direction, *aNS* and traffic flows on East-West direction, *aEW*; a_{m0} is the conflict point between traffic flows on North-South direction, *aNS* and traffic flows on East-South direction, *aES*. The second and fifth phases are identical, allowing for existing vehicles between nodes *a* and *b* to release this section for the left turning vehicles from East-West direction on third phase. In fourth phase all vehicle and pedestrian signals are red and trams may be in conflict (*t1*, *t2*) with vehicles from section between nodes *b* and *a*.

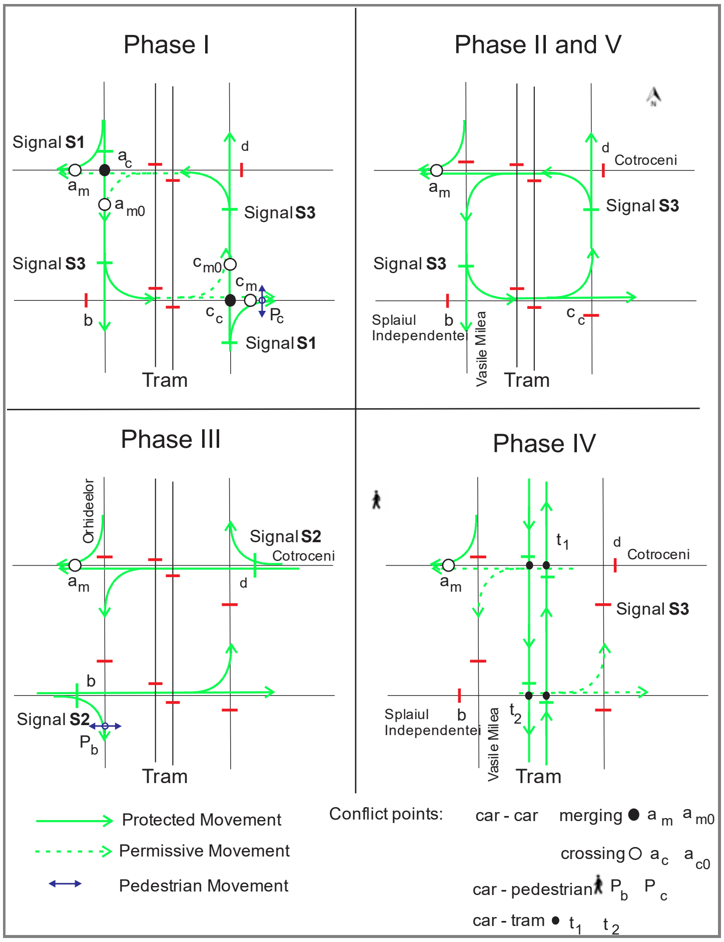

Fig. 4. The current phasing and the signal groups (with right of way on each phase).

- Modelling parameters such as: PCE vehicle attributes: 4.3m length; 1.7m width; maximum desired speed: 50 km/h; global network parameters: warm-up period is one hour considered adequately to limit the effects of initial state and to achieve steady state [17].

In the current network layout (*cs* – current situation), right turning manoeuvre in node *b* from node *a* is forbidden (Fig. 3 - *cs* detail) and a detour to nodes *g, h, k* is needed to reach the destination $W_{OUT\,r}$. In the proposed situation (*ps*), we consider that right turning maneuver to be allowed in node *b* from node *a* and also elimination of pedestrian crossing on section *b-k* (Fig. 3 – *ps* details). The present detour in the current situation has some drawbacks compared with proposed right turning directly in node *b*, such as:

- larger distance travel through *b-g-h-k* vs. directly *b-k* (450 m vs. 210 m) and thus greater time travel, pollution etc;
- more conflicts between vehicles and pedestrians in node *g*;
- larger traffic delay imposed to vehicles travelling from W_{in} to node *b* which must wait at traffic light in node *k* to pass vehicles from detour *b-g-h-k*.

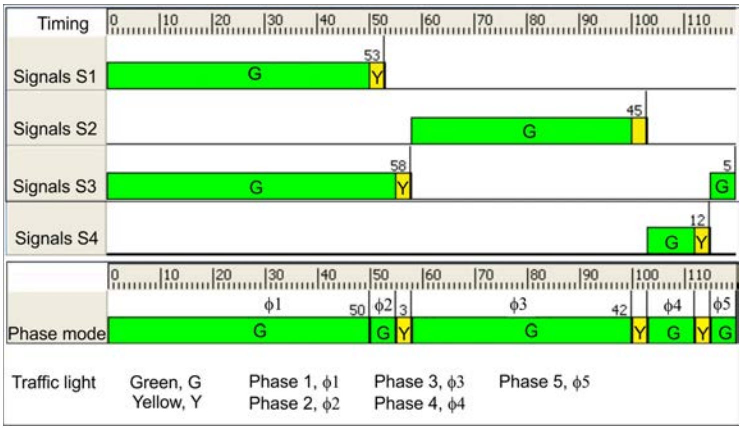

Fig. 5. The sequence of the phases and duration of each phase (cycle time of 120s).

We compare the two situations (current and proposed) for the systematization of vehicle and pedestrians movement through micro-simulation in AIMSUN. The statistics provided at the stream level are the following:

- *Average Flow*: average number of vehicles per hour which traverse the stream during the simulation period.
- *Travel Time*: average time per vehicle, needed to traverse the stream.
- *Delay Time*: average delay time per vehicle: the difference between the expected travel time (time it would take to traverse the stream under ideal conditions) and the experienced travel time.

The micro-simulation model was applied for the current situation and then for the proposed systematization scheme (Table 2).

Table 2. Simulation results in current and proposed situations.

	Stream	
	b-g-h-k-W_{out}	*b-k-*W_{out}
Average flow (veh/h)	362	590
Travel time (s)	71,17	22,16
Delay time (s)	29,6	1,57

The values of intersection conflict points indices (besides available data on average daily road traffic and tram flows estimated on public transport schedules) are shown in Table 3. The difference between intersection conflict point indices in the current (*cs*) and proposed situation (*ps*) are shaded in grey in Table 3.

For the proposed situation, no changes are obtained for vehicle – vehicle conflict indices, but significant decrease of vehicle – pedestrian index is obtained (about 80 %). Consequently, traffic conflict index could be used to assess different configurations and systematization schemes of intersections, but further research are needed to establish and to calibrate the relationships between the conflict index and accidents number.

4. Conclusion

Generally, the most urban transport and traffic studies focus on travel time, congestion delays, environmental impact, without taking into account the traffic risk estimation. Although traffic safety is considered an important social and environmental issue, the traffic safety performances quantification are made after designing, construction and using of transport infrastructure. Black spots are identified only after traffic and accidents data gathering and analysis. After that, correcting measures are applied. The aim of our research is to develop tools which allow urban traffic risk estimation and, further, assessment of proposed measures to traffic risk reducing.

Table 3. Conflict indices in current and proposed situations.

Type of conflict		Conflict point	Stream j	Traffic Flow q_j (PCE/h)	Stream *k*	Traffic Flow q_k (PCE/h)	$q_j \cdot q_k$	Conflict index $\Sigma(q_j \cdot q_k)$
Vehicle - Vehicle	cs/ps	**Phase I**						
		ac	*aNS*	2050	*aEW*	111	227550	
		am0	*aNS*	2050	*aES*	565	1158250	
		am	*aNW*	165	*aEW*	111	18315	**2015549**
		cc	*cSN*	2229	*cWE*	91	202839	
		cm0	*cSN*	2229	*cWN*	172	383388	
		cm	*cSE*	277	*cWE*	91	25207	
		ac	*aNS*	2050	*aEW*	111	227550	
	cs/ps	**Phase II**						
		am	*aNW*	96	*aEW*	432	41472	**41472**
	cs/ps	**Phase III**						
		am	*aNW*	128	*aEW*	1032	132096	**132096**
	cs/ps	**Phase IV**						
		actram	*t1NS*	180	*t1EW*	600	108000	
		bctram	*t2NS*	180	*t2WE*	252	45360	**306720**
		cctram	*t2SN*	180	*t2WE*	252	45360	
		dctram	*t1SN*	180	*t1EW*	600	108000	
	cs/ps	**Phase V**						
		am	*aN-aW*	24	*aE-aW*	240	5760	**5760**
Vehicle - Pedestrian	cs/ps	**Phase I**						
		Pa	*aNW*	165	*apNS*	924	152460	
		Pa	*aEW*	111	*apNS*	924	102564	**334922**
		Pc	*cWE*	91	*cpNS*	878	79898	
		Phase III						
	cs	*Pb*	*bWS*	176	*bpEW*	523	92048	92048
	ps	***Pb***	***bWS***	**176**	***bpEW***	**248**	**43648**	**43648**
		all phases						
	cs	*Pg*	*gNW*	362	*gpNS*	483	174846	174846
	ps	***Pg***	***gNW***	**71**	***gpNS***	**483**	**34293**	**34293**

The available models to traffic risk estimation are recognized being deficiently. Especially for urban intersections, the models are developed for simple configuration and take into account only road traffic flows. Because these models are inappropriate for many cases in our research area (Bucharest City), detailed analysis on each complex intersection are necessary. We propose to use intersection traffic conflict indices to assess traffic risk at urban network level.

We demonstrated that traffic conflict index can be used as a useful measure to compare different configuration and systematization schemes. Supplementary detailed analysis and calibration are still necessary to quantify the relationships between traffic conflict index and accident number for different intersection configuration in order to obtain an accurate measure of traffic risk.

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