ROAD SAFETY EVALUATION USING TRAFFIC CONFLICTS: PILOT COMPARISON OF MICRO-SIMULATION AND OBSERVATION

Jiří Ambros[1], Richard Turek[2], Jiří Paukrt[3]
[1, 2] Centrum dopravního výzkumu, v.v.i., Líšeňská 33a, 636 00 Brno, Czech Republic
[3] SIAS Limited, Opletalova 55, 110 00 Prague, Czech Republic

Abstract: For local road safety evaluations traffic accident frequency has been traditionally used; however it has been also known that accident occurrence is statistically rare and thus their data collection is time consuming. To this end various other means have been investigated, including observation of traffic conflicts (near-accidents). Traffic conflict happens when two road users approach each other to such extent that, if no action is taken, a collision occurs. These surrogate measures may enable collection of larger samples and quicker safety assessment.
There have been various traffic conflict techniques developed around the world, using different approaches to assessing the conflict types and severity levels. For example Czech traffic conflict technique uses assessment based on the severity of evasive manoeuvre assessed by observers on the site.
However using evaluations by human observers has been criticized as subjective and potentially biased. Among others the use of microscopic traffic simulation was thus attempted. Micro-simulations are usually used to estimate the operational performance of road networks; their traffic safety applications have appeared more recently.
The paper presents the pilot study whose objective was to compare the results of simulated traffic conflict data with the observation using Czech traffic conflict technique. A busy signalized junction in Brno was chosen for this purpose. Software S-Paramics was used for the micro-simulation, employing the severity indicator of time-to-conflict, in which two vehicles will collide if no actions are taken. To test the results reliability, traffic conflicts were both observed and simulated in two terms with different traffic volumes (summer and autumn 2013). The paper presents the study approach and results, as well as discussion of pros and cons and practical conclusions.

Keywords: road safety, traffic conflict, micro-simulation.

1. Introduction

Traffic has been necessary part of everyday life, however its negative outcomes include traffic accidents. According to European Road Safety Observatory, each year over 1 million people are killed and 50 million injured on roads around the world. In the European Union, road accidents comprise over 90% of all transport deaths and accident costs and are the leading cause of death and hospital admission for people younger than 50 years (ERSO, 2009).

This toll includes huge socio-economical losses as well. The annual number of people dying on the European roads equals the number of inhabitants of a medium town (EC, 2010). The first step in managing the mentioned issue is the evaluation of current situation. In this paper the focus is on local road safety evaluations. As a measure traffic accident frequency has been traditionally used; however it has been also known that accident occurrence is statistically rare and thus their data collection is time consuming. To this end various other means have been investigated, including observation of traffic conflicts. Traffic conflict is internationally defined as 'an observable situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged' (Amundsen and Hydén, 1977). The frequency of conflicts, considering their severity and types, may serve as an indirect safety performance indicator (surrogate safety measure). Compared to traditional indicators based on traffic accidents, conflicts are more frequent and thus enable collection of larger samples and quicker safety assessment. There have been various traffic conflict techniques (TCTs) developed around the world, using different approaches to assessing the conflict types and severity levels. Some of them use qualitative definitions, some are more quantitative; for example Older and Shippey (1980) presented more than 10 different techniques.

Nevertheless TCTs have been usually dependent on human observers; they have thus been criticized as subjective and potentially biased, with unproven or insufficient reliability and validity (Williams, 1981; Hauer and Gårder, 1986; Chin and Quek, 1997). One way of circumventing this issue has been using computer microscopic traffic simulations (micro-simulations). Traffic simulation models utilise stochastic sampling of the distributions of driver behaviour to replicate the interactions between vehicles in a traffic stream to determine the consequences of their actions (Young et al., 2014). Micro-simulations have thus been used to estimate the operational performance of road networks – they can provide estimates of traffic system capacity, delay and general flow conditions.
Their traffic safety applications – modelling the stochastic process involving driver behaviour and vehicle movement on transport infrastructure – have appeared more recently. Notwithstanding the progress in software capabilities and computing power, according to recent state-of-the-art review, road safety simulation models are still in an early stage of development. Vehicle behaviour is based on the family of car-following, lane-changing and gap acceptance models (Huguenin et al., 2005). It is also important that simulations have still focused primarily on vehicular traffic (Young et al., 2014).

[1] Corresponding author: jiri.ambros@cdv.cz

In the context of safety the idea has been to use the micro-simulation to estimate the number and the location of conflicts predicted by the model. These estimates should then be validated against observed conflicts and/or recorded accidents. One of first example applications was reported by McDowell et al. (1983): their study focused on rural T-junctions in UK. Using gap acceptance as safety indicator proved to yield the results comparable to 5-year injury accident history. Sayed et al. (1994) tested their simulation on a sample of 4-arm urban junctions in Canada and also found correlation between observed and simulated conflicts. Further studies were conducted for example by Archer (2005) on Swedish urban T-junctions, by Cunto and Saccomanno (2008) in California or by Astarita et al. (2012) in Italy.

These authors used various safety indicators to define potential conflicts: e.g. gap acceptance, time-to-conflict (TTC), post-encroachment time (PET) or deceleration rate (DR). The most common measures (TTC and PET) indicate the likelihood of accidents, while the other class of measures is more indicative of the severity of accidents (Gettman and Head, 2003).

Important step in progress of safety micro-simulations was development of Surrogate Safety Assessment Model (SSAM). This software is able to derive surrogate measures from data output (vehicle trajectories) through several compatible traffic simulation models (Gettman et al., 2008). One of them is S-Paramics software from SIAS Limited, UK. It has been used for example by Pirdavani et al. (2010) or Dijkstra (2013).

To sum up there have been several applications of using simulated conflicts to assess local safety conditions. However they used different conflict indicators and also conflicts observed with different techniques. Specifically with Czech traffic conflict technique, which uses assessment based on the severity of evasive manoeuvre assessed by observers on the site, no micro-simulation has been attempted. The pilot study reported in the paper aimed to fill this gap. Its objective was to compare the results of micro-simulation traffic conflict data with the observation using Czech traffic conflict technique. A busy signalized junction in Brno was chosen for this purpose. Software S-Paramics was used for the micro-simulation, employing the severity indicator of time-to-conflict. To test the results reliability, traffic conflicts were both observed and simulated in two terms with different traffic volumes (summer and autumn 2013). The paper presents the study approach and results, as well as discussion of pros and cons and practical conclusions.

2. Methodology

The study aim was to compare observed and simulated conflict frequency. A busy signalized 4-arm junction in Brno (local name ‘Nové Sady’) was selected. In order to test the results reliability two terms were chosen – summer and autumn week-day (July and September 2013). The methodology behind the two indicators is described in following sections.

2.1 Observed conflicts

Traffic conflicts were observed according to the Czech technique (Ambros and Kocourek, 2013). It is based on physical observation on-site or video observation in the office. Observers detect conflicts and assign them conflict types (turning, rear, front, etc.) and severity grades. The severity grades (0, 1, 2, 3, 4) are based on conflict evolution scheme – see Fig. 1.

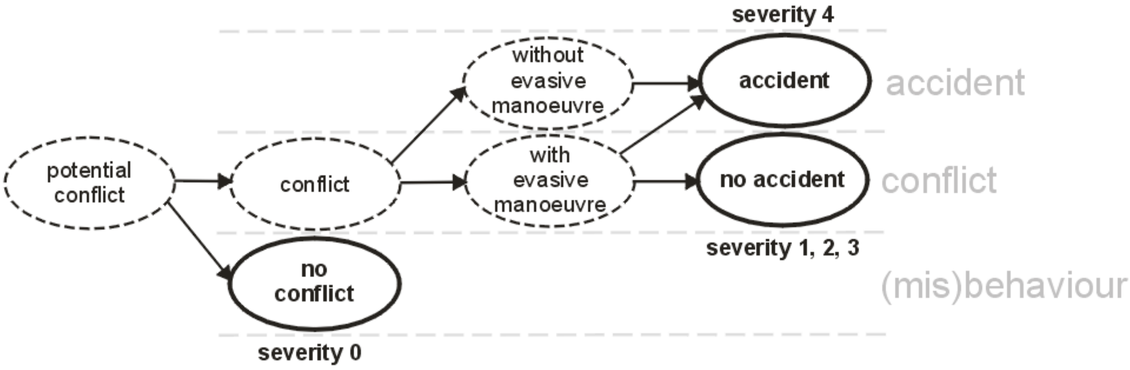

Fig. 1.
Definition of severity grades in the Czech TCT within the conflict evolution scheme

Table 1 shows the characteristics of severity grades which are assigned to observed conflict situations based on severity of an evasive manoeuvre. Situations of specific behaviour or misbehaviour have severity grade 0, since they are situations of one user only and thus do not conform to a conflict definition.

Severity grades 1, 2, 3 (highlighted in the Table 1) are assigned to conflict according to the observed evasive manoeuvre severity, together with physical reactions and other characteristics. Obstruction and endangerment, used to distinguish between 2nd and 3rd severity grade, is defined according to the Czech law (Road Act No. 361/2000 Coll.). Severity grade 4 belongs to a traffic accident with property-damage-only and/or injury consequences.

Table 1
Characteristics of severity grades according to the Czech TCT (traffic conflicts are highlighted)

Severity grade and description	Severity	Physical reactions	Events	
			Related to vehicles	Related to pedestrians
0 – (mis)behaviour	none	none	breaking the rules without consequences, misbehaviour of road users	breaking the rules, e.g. crossing outside of crossing
1 – slight conflict	low	common	fluent, controlled, predictable manoeuvres	change of walking course, e.g. overtaking
2 – medium conflict	obstruction	sudden	pronounced, sudden, unpredictable manoeuvres	change of walking speed, sudden entering the crossing
3 – severe conflict	endan-germent	sharp	critical, emergency manoeuvres	shocking manoeuvres
4 – accident	various levels (property damage only or injury consequences)			

Video camera was used, recording time was between 2 and 4 hours. In the office video record was observed in order to detect conflicts and assess their severity using the above mentioned definitions.

Traffic volume data (in terms of total number of entering vehicles) were also detected from video records. Since the first term occurred in summer vacation time, traffic volumes were lower, compared to the autumn term (see Table 2).

Table 2
Overview of observation and simulation parameters

Term	Date	Approximate hourly number of entering vehicles	Observation period	Simulation period
summer	Tuesday (July 9, 2013)	1800	4 hours (7:00 – 11:00)	1 hour (8:00 – 9:00)
autumn	Wednesday (September 18, 2013)	2100	2 hours (7:30 – 9:30)	

2.2 Simulated conflicts

Micro-simulation in S-Paramics was based on following input data: junction geometry, categorized directional traffic count, signal plans and queue lengths. This data was obtained during above mentioned conflict observation (on-site and from video). The model was calibrated using the observed and modelled queue lengths according to recommendations in UK Design Manual for Roads and Bridges (Highways Agency, 1996).

S-Paramics generated trajectory files for each simulated vehicle, including its position, speed, acceleration, direction and other information such as category or dimensions (defaultly twice per second). Some indicators (position, speed and direction) were used to calculate time-to-conflict (TTC). The process used was inspired by SSAM approach (Gettman et al., 2008) and Dijkstra (2010) and developed into internal S-Paramics module (Paukrt, 2010). Its functioning may be shortly described as follows:

- All combinations of modelled vehicle pairs were created. Their distances were calculated.
- Calculated distances were compared with threshold value (multiplied by 1.5), which was set as potential distance travelled in 2 seconds (critical TTC), based on speed and acceleration of involved vehicles. Distant vehicles (i.e. above threshold value) were discarded.
- Potential collision course of selected vehicle pair trajectories was determined, based on speed and size of collision area (given by vehicle dimensions). Should the vehicles trajectories intersect with TTC below 2 seconds, situation was considered a conflict.
- Conflict positions were stored and their counts summed up.

2.3 Comparison

Results of traffic volume survey showed the most pronounced streams. These are the two direct streams depicted in Fig. 2: they involve 16% and 20% of all entering vehicles. Since left turns are typically the most critical, the combinations A and B were chosen for the comparison.

Given the fact that micro-simulations focus on vehicles, observed conflicts including pedestrians were not used in comparison.

Only conflicts of severity grade 1, 2, 3 were used in comparison.

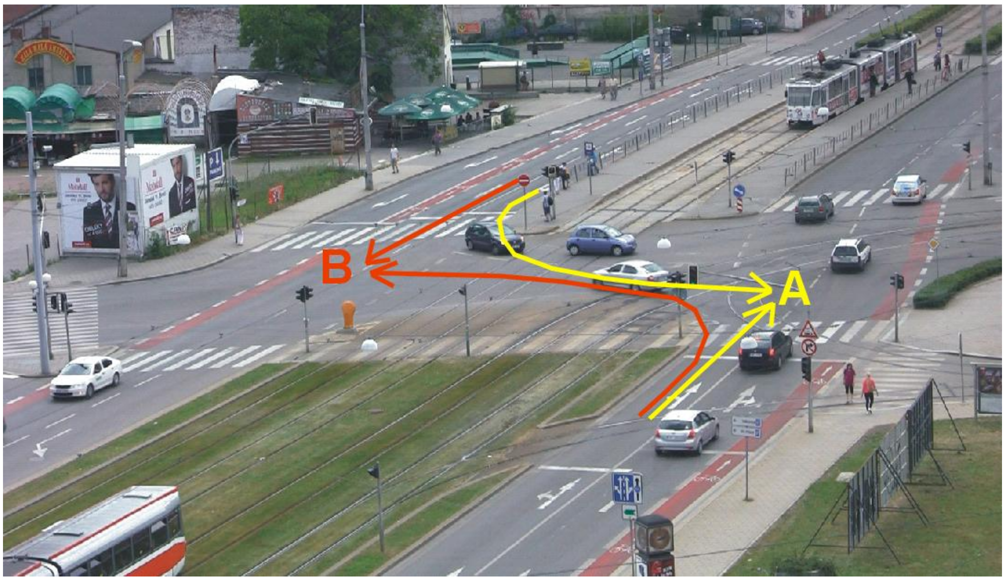

Fig. 2.
View of the junction, with studied combinations of traffic streams A and B

3. Results and discussion

Table 3 reports the results for summer and autumn term:

- Total observed conflict frequency and hourly value (divided by number of hours) (*O*)
- Hourly simulated conflict frequency (*S*)
- Ratio of hourly simulated conflict frequency to hourly observed conflict frequency (*S/O*)

Table 3
Results of observed and simulated conflicts

Left turns	Summer term				Autumn term			
	Observed conflicts (*O*)		Simulated conflicts (*S*)	Ratio *S/O*	Observed conflicts (*O*)		Simulated conflicts (*S*)	Ratio *S/O*
	4 hours	1 hour	1 hour		2 hours	1 hour	1 hour	
A	8	2.00	7	3.5	4	2.00	8	4.0
B	3	0.75	3	4.0	2	1.00	4	4.0

All but one ratio have value 4, which means there were 4 times more simulated conflicts compared to observed conflicts.

In addition to investigate the relation between observed/simulated conflicts and accidents, Police accident records from studied junction were retrieved. In total 20 accidents happened in junction in available time period 2009 – 2012 (4 years). However accidents and conflicts should be compared in comparable conditions (Older and Spicer, 1976), thus accidents which happened on weekends, at night, in wet conditions or with pedestrians, were excluded. In further step only accidents from time period 8 – 9 AM and studied left turns were selected. After this filtering the sample contained only 1 accident: it was an accident with left turn B.

It would be ideal to prove the validity by quantifying the relation between conflicts (both observed and simulated) and accidents (Fig. 3) in so called ‘two-stage validation process’, where firstly modelled conflicts are related to observed conflicts and secondly observed conflicts are related to accidents (Darzentas et al., 1980).

However it is obvious that accidents, being filtered according to specific conditions, are relatively infrequent. Using longer time period is a solution, however the conditions may not be stable for a longer time. This only stresses the need for surrogate safety measures using more frequent events in shorter time periods.

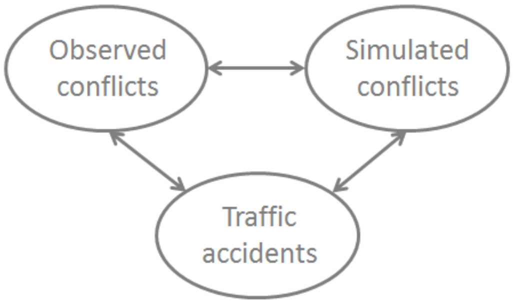

Fig. 3.
Scheme of ideal validity triangulation between conflicts and accidents

Nevertheless even the relation between observed and simulated conflicts is not definite. Some relation was found in the study (see Table 3), however probably only due to narrowing the focus to most critical left turns and excluding pedestrian conflicts.

4. Summary and conclusions

Traffic conflict studies provide surrogate safety measures which may complement or even substitute traditional safety studies based solely on traffic accidents. In order to overcome some of weaknesses of conflict studies, conflict micro-simulation applications have appeared recently. In this respect a link between Czech traffic conflict technique observations and micro-simulation results was sought. With this objective the reported pilot study compared observed and modelled conflict counts in signalized junction. To test the results reliability, two terms were modelled (summer and autumn 2013).

In results ratio between simulated and observed conflicts was around value of 4, i.e. there were 4 times more simulated conflicts compared to observed conflicts. The one exception (ratio 3.5) appeared in summer term, probably due to lower traffic volumes.

Although it was only a pilot study, the results are potentially promising and should be validated in other sites and conditions. Also other limitations should be considered:

- Calibration of micro-simulation model was done only by comparison of queue lengths. While it may be sufficient for capacity studies, models for safety purposes should be probably calibrated more thoroughly. However Yang and Ozbay (2011) noted a limited simulation calibration experience with an emphasis on safety evaluation – no recommended procedure exists.
- The method used (currently an in-house S-Paramics module) is using only several parameters of modelled vehicles; set of data parameters may be enlarged in order to better describe real driving behaviour.
- Presented micro-simulation model was only 1-hour long; an extension is necessary. The same hold for study limitation to the most critical turning movements and vehicle conflicts only.

These points are consistent with general objections towards micro-simulations: insufficient calibration and reliability of driving behaviour and dynamics (Wood, 2012). Simulation models have also been seen as ‘black boxes’, producing the conflicts different from the actual observed ones (Dijkstra, 2013). Nevertheless there has been large progress in this field in recent years and it was concluded that simulations will become a useful tool in analysing the safety of the traffic system (Young et al., 2014). In this context the authors of the paper are willing to continue in effort in order to enhance the quality of described tools with objective of practical proactive road safety assessment.

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References

Ambros, J.; Kocourek, J. 2013. *Metodika sledování a vyhodnocování dopravních konfliktů*. Transport Research Centre, Brno and Czech Technical University in Prague. Czech Republic.

Amundsen, F.H.; Hydén, C. (Eds.). 1977. *Proceedings: First workshop on traffic conflicts*. Institute of Transport Economics, Oslo. Norway.

Archer, J. 2005. *Indicators for traffic safety assessment and prediction and their application in micro-simulation modelling: A study of urban and suburban intersections*. PhD thesis. Royal Institute of Technology, Stockholm. Sweden.

Astarita, V.; Guido, G.; Vitale, A.; Giofré, V. 2012. A new microsimulation model for the evaluation of traffic safety performances, *European Transport*, (51): 1-16.

Chin, H.-C.; Quek, S.-T. 1997. Measurement of traffic conflicts, *Safety Science*, 3(26): 169-185.

Cunto, F.; Saccomanno, F.F. 2008. Calibration and validation of simulated vehicle safety performance at signalized intersections, *Accident Analysis and Prevention*, 3(40): 1171-1179.

Darzentas, J.; Cooper, D.F.; Storr, P.A.; McDowell, M.R.C. 1980. Simulation of road traffic conflicts at T-junctions, *Simulation*, 5(34): 155-164.

Dijkstra, A. 2010. Do calculated conflicts relate to observed crashes? Retrieving conflicts from S-Paramics. In *The 10th Annual S-Paramics User Group Meeting & Conference*.

Dijkstra, A. 2013. Assessing the safety of routes in a regional network, *Transportation Research Part C*, (32): 103-115.

European Comission (EC) 2010. Towards a European road safety area: policy orientations on road safety 2011-2020. Available from Internet: <http://ec.europa.eu/transport/road_safety/pdf/com_20072010_en.pdf>.

European Road Safety Observatory (ERSO) 2009. Road Safety Management. Available from Internet: <http://ec.europa.eu/transport/road_safety/specialist/knowledge/pdf/road_safety_management.pdf>.

Gettman, D.; Head, L. 2003. *Surrogate Safety Measures from Traffic Simulation Models: Final Report*. Publication No. FHWA-RD-03-050. Federal Highway Administration, McLean. USA.

Gettman, D.; Pu, L.; Sayed, T.; Shelby, S. 2008. *Surrogate safety assessment model and validation: Final report.* Report No. FHWA-HRT-08-051. Federal Highway Administration, McLean. USA.

Hauer, E.; Gårder, P. 1986. Research into the validity of the traffic conflicts technique, *Accident Analysis and Prevention*, 6(18): 471-481.

Highways Agency 1996. Design Manual for Roads and Bridges. Volume 12: Traffic Appraisal of Roads Schemes. Part 1: Traffic Appraisal in Urban Areas. Available from Internet: <http://www.dft.gov.uk/ha/standards/dmrb/vol12/section2/12s2p1.pdf>.

Huguenin, F.; Torday, A.; Dumont, A.-G. 2005. Evaluation of traffic safety using microsimulation. In *Proceedings of the 5th Swiss Transport Research Conference*.

McDowell, M.R.C.; Wennell, J.; Storr, P.A.; Darzentas, J. 1983. *Gap acceptance and traffic conflict simulation as a measure of risk.* Supplementary Report 776. Transport and Road Research Laboratory, Crowthorne. UK.

Older, S.J.; Shippey, J. (Eds.) 1980. *Proceedings of the Second International Traffic Conflicts Technique Workshop*. Supplementary Report 557. Transport and Road Research Laboratory, Crowthorne. UK.

Older, S.J.; Spicer, B.R. 1976. Traffic Conflicts – A Development in Accident Research, *Human Factors*, 4(18): 335-350.

Paukrt, J. 2010. *Road Safety Assessment*. SIAS Technical Note.

Pirdavani, A.; Brijs, T.; Bellemans, T.; Wets, G. 2010. A simulation-based traffic safety evaluation of signalized and un-signalized intersections. In *Road Safety on Four Continents*.

Sayed, T.; Brown, G.; Navin, F. 1994. Simulation of traffic conflicts at unsignalized intersections with TSC-Sim, *Accident Analysis and Prevention*, 5(26): 593-607.

Williams, M.J. 1981. Validity of the traffic conflicts technique, *Accident Analysis and Prevention*, 2(13): 133-145.

Wood, S. 2012. Traffic microsimulation – dispelling the myths, *TEC Magazine*, October 2012: 339-344.

Yang, H.; Ozbay, K. 2011. Calibration of Micro-Simulation Models to Account for Safety and Operation Factors for Traffic Conflict Risk Analysis. In *3rd International Conference on Road Safety and Simulation (RSS2011)*.

Young, W.; Sobhani, A.; Lenné, M.G.; Sarvi, M. 2014. Simulation of safety: A review of the state of the art in road safety simulation modelling, *Accident Analysis and Prevention*, (66): 89-103.