TRAFFIC SAFETY ASSESSMENT BY USING MICRO-SIMULATION MODELLING AND TRAFFIC CONFLICTS AT LARGE ROUNDABOUTS

Pavel Lopour[1]

Abstract: Recent research has shown that traffic conflicts provide useful insight into the failure mechanism that leads to road collision between vehicles while being more frequent than accidents and without social cost. This paper provides proactive quantitative evaluation of traffic safety on three design layouts of large roundabouts by using microscopic traffic simulation approach. Combination of VISSIM and Surrogate Safety Assessment Model (SSAM) were used to model variant roundabouts with atypical layouts and assess traffic safety. The roundabouts were assessed by two approaches: (1) surrogate safety indicators - Time to Collision (TTC) and Post encroachment time (PET) and (2) safety assessment methods (reflecting severity of conflicts and potential collisions). Based on comparison of the results achieved by both methods and generally accepted safety principles were submitted proposals and recommendations for practical use of the proactive traffic safety assessment methods with surrogate safety indicators.

Key words: traffic conflicts, safety, roundabouts, surrogate safety indicators, SSAM, VISSIM

1 Introduction

The current trend of road safety development is uniform at national and international level and aims to minimize the occurrence of road accidents i.e. zero fatalities or serious injuries on the roads.

The road designers and planners are choosing safety measures and design layouts based mainly on general principles of safe road design, experiences and own intuition. The choice of intersection design according to the principles of safe intersection design could be define as “maximum road safety for all users of road

[1] Ing. Pavel Lopour, Ph.D., Univerzita Pardubice, Dopravní fakulta Jana Pernera, Katedra dopravního stavitelství, Studentská 95, 532 10 Pardubice, Česká republika, tel.: +420 466 036 397, E-mail: pavel.lopour@upce.cz

traffic and also maximum fluency of the traffic flow (capacity and traffic level quality). The research and developing of useful methods/tools is needed.

2 Current state of art

Road safety assessment can be divided into traditional methods of analyzing traffic accidents records or traffic accidents deep analysis (reactive methods) and methods based on surrogate safety measures investigation by the theory of conflict situations (proactive methods).

2.1 Traffic Conflict Technique (TCT)

The concept of traffic conflicts was first proposed by Perkins and Harris who defined a traffic conflict as any potential accident situation leading to the occurrence of evasive actions such as braking or swerving. This definition was further modified and an internationally accepted definition is now “an observable situation in which two or more rad users approach each other in space and time for such an extent that there is a risk of collision if their movements remain unchanged”.

The TCT model of traffic safety could be expressed by the traffic safety continuum, which shows two extremes in traffic flow (undisturbed passages and accidents). [1]

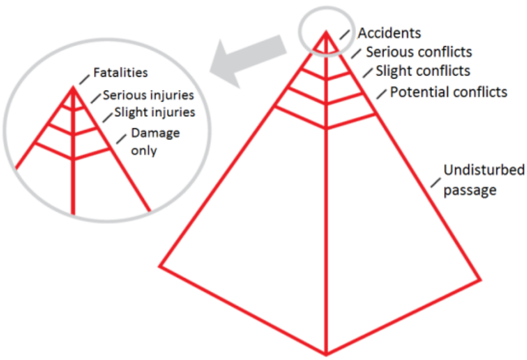

Figure 1 – The traffic safety continuum (The pyramid of safety)

Several studies have demonstrated the feasibility of collecting conflict data using: field observers, simulation models and videocamera. Each of these approaches has its own pros/cons. Field observers are most practical solutions, but are too expensive and the variability of observers make results repeatability and consistency very difficult. On the other hand the adjusting of simulation models can account for this limitation even on new design layouts. However, models don´t account with diverse and less predictable driver behavior in real traffic. Automated video camera analysis is useful for both ways (observers and simulations), but is applicable only on real layouts.[2]

The main quantitative surrogate safety indicators are Time to Collision (TTC) and Post-encroachment time (PET). TTC is defined as the time difference between the complete leaving of the collision point / area by followed vehicle and entering to the theoretical conflict point (no evasive maneuver).[3]

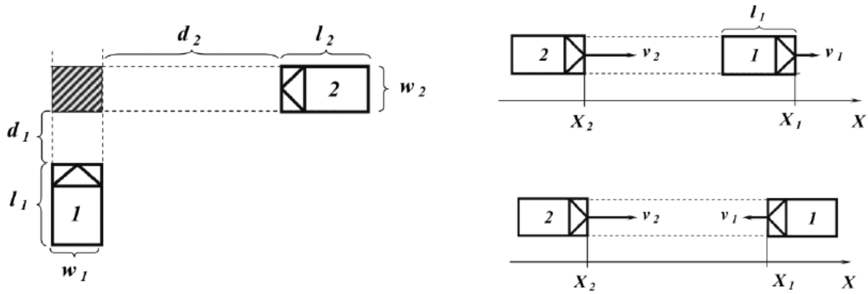

Figure 2 – TTC definition for three possible collisions (crossing, rear-end, lane change)

PET is defined as the time difference between the complete leaving of the collision point / area and the actual passing through the theoretical conflict point.

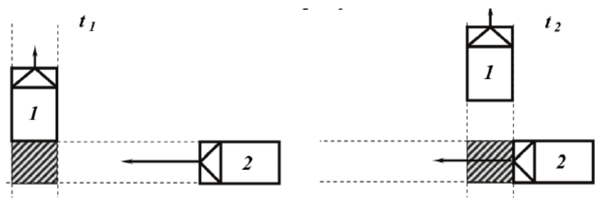

Figure 3 – PET definition

2.2 Safety assessment methods

It was the use selected methods for determining the safety of using TCT reflecting the severity of conflicts and potential collisions large roundabouts. Among the selected methods belong:

- USZ (Uniform Severity Zone) by Hydén

This method evaluates the severity of the conflict using the time to collision (TTC) and severity of the collision using the maximum speed of the vehicle when determining the collision (MaxSpeed). [4]

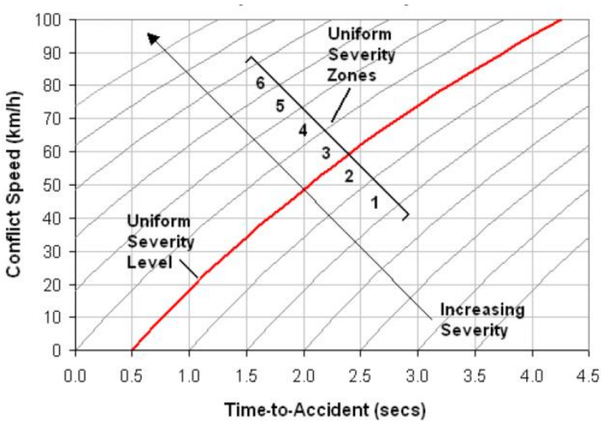

Figure 4 – Uniform severity level and severity zones developer by Hydén

TCS Score (Total conflict severity score) - method evaluates the severity of the conflict using the time to collision (TTC) and severity of the collision using the maximum difference of the speed of vehicles after the theoretical collision (MaxDeltaV).[5]

TTC and ROC Score	TTC (sec)	ROC
1 (Potential)	$1.5 < TTC \leq 2.0$	Low Risk
2 (Slight)	$1.0 \leq TTC \leq 1.5$	Moderate Risk
3 (Serious)	< 1.0 second	High Risk

Figure 5 – TCS Score method by Sayed

3 Methodology

3.1 Traffic microscopic simulator - PTV VISSIM

This case study use technique of microscopic traffic simulation in VISSIM version 5.4. This simulation software is a discrete, stochastic, time step based, microscopic model with driver-vehicle-units as single entities. It works on sub-models of psycho-physical car-following logic and rule-based lane-changing logic to determine the longitudinal and lateral vehicle movements.[6]

3.2 Surrogate safety assessment model – SSAM

The Surrogate Safety Assessment Model (SSAM) is a software application designed to perform statistical analysis of vehicle trajectory data output from microscopic traffic simulation models. The software computes a number of surrogate measures of safety for each conflict that is identified in the trajectory data and then computes summaries of each surrogate measure. [7]

3.3 Description of the simulated roundabouts

The chosen urban large roundabout is located on the road III/32224 near shopping center Globus in Pardubice. The findings were obtained on three design layouts of real roundabout (changed through the lifetime of selected intersection): roundabout with one circular lane, with two circular lanes and atypical spiral arrangement of lanes. The case study of variant roundabout design was performed to verify the findings about traffic safety assessment with use of proximal surrogate indicators.

Figure 6 – Roundabout with spiral arrangement of lanes in PTV VISSIM

The three roundabout designs including bypass were each modelled in VISSIM and examined with SSAM. Total traffic volume at roundabout was over 2300 veh/h. Driving characteristics were verified by experimental measurement with “fifth wheel cart”.

Each model was simulated 2 hours in VISSIM (first hour served as warm up and second hour was examined). Each alternative model was run 25 times with 25 different random seeds causing vary the arriving traffic and the results (stochastic variation of input flow arrival times).

3.4 Examination of the simulated roundabouts

To identify potential conflicts from simulated trajectories was used maximum TTC threshold 4,5 s and maximum PET threshold 6,3 s. These limits were chosen due higher speeds of vehicles (intersection is close to road I/37) and heavy goods traffic. TTC value 1,5 s was derived from previous research at urban low-speed intersections and representing uniform severity level between serious and non-serious conflict.

4 Results and discuss

4.1 Surrogate safety indicators TTC and PET

All results were filtered by simulated time and then examined. Table 1 summorizes summa of identified conflicts by SSAM during 25 simulated „second“ hours, average hourly conflict (AHC) and type of the conflict by conflict angle.

Table 1 – Results of conflict frequency comparison for large roundabouts design alternatives identified by SSAM

	OK 1lane	AHC	OK 2lanes	AHC	OK s	AHC
Summa conflicts	***63856.0***	***2554.2***	***32567.0***	***1302.7***	***48464.0***	***1938.6***
rear-end	*58182.0*	***2327.3***	*25018.0*	*1000.7*	*43029.0*	*1721.2*
lane change	*5598.0*	***223.9***	*7341.0*	*293.6*	*5183.0*	*207.3*
crossing	*76.0*	***3.0***	*208.0*	*8.3*	*252.0*	*10.1*
rear-end	*91.11%*		*76.82%*		*88.79%*	
lane change	*8.77%*		*22.54%*		*10.69%*	
crossing	*0.12%*		*0.64%*		*0.52%*	

As is shown above the most conflicts were identified at 1 lane roundabout and the fewest at 2 lanes roundabout. As is shown below the most of the conflicts are rear-end (green) identified at the approach lanes (waiting queues). The lane change and crossing conflicts are mostly identified at the roundabout lanes. And according these types looks spiral roundabout as the safest and 2 lanes roundabout as the most danger.

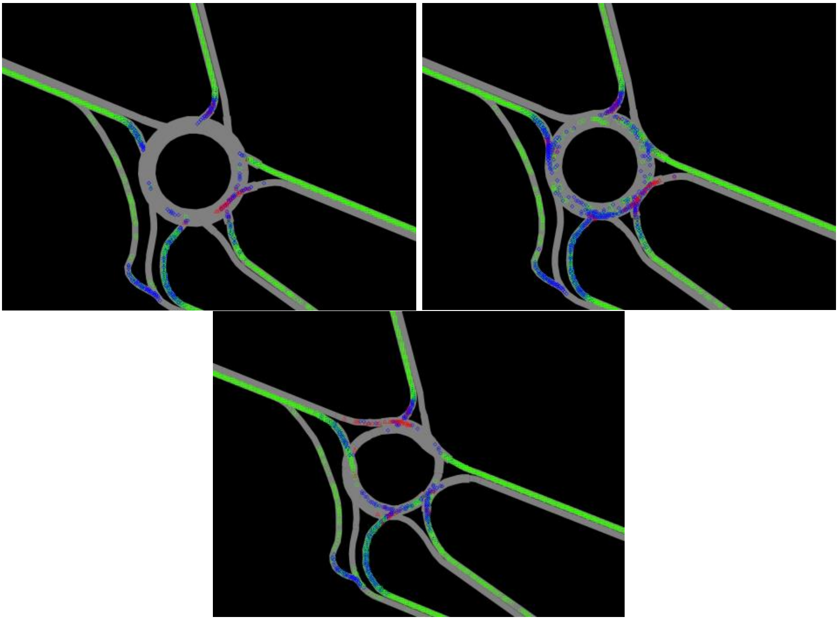

Figure 7 – Roundabouts design alternatives (1 lane, 2 lanes and spiral) with SSAM conflicts

Table 2 shows the main statistical characteristic of safety indicators TTC/PET (mean and median) are very similar for all three design alternatives, making it difficult to tell which alternative is the safest design. These results are not including important assessing parameter of conflict severity by TTC threshold.

Table 2 – Statistical characteristic and frequency of TTC and PET

	OK 1lane	OK 2lanes	OK s
AHC	*2554*	*1303*	*1939*
TTC Mean [s]	***3.94***	***3.78***	***3.90***
TTC Median [s]	***4.20***	***4.10***	***4.20***
PET Mean [s]	***2.47***	***2.58***	***2.51***
PET Median [s]	***2.20***	***2.40***	***2.20***

Table 3 shows only serious conflict (TTC <= 1.5 s). The results are more objective and assess roundabout by conflict severity (the proximity to the accident). According this is the order from the safest to the most danger following: spiral roundabout, 1 lane roundabout and 2 lanes roundabout.

Table 3 – Statistical characteristic and frequency of serious conflicts (TTC = 1.5 s)

TTC<=1.5 s	OK 1lane	OK 2lanes	OK s
Summa conflicts	*104*	*116*	*80*
AHC	***4.16***	***4.64***	***3.20***
%	*0.16%*	*0.36%*	*0.17%*
Mean [s]	***1.21***	***1.15***	***1.13***
Median [s]	***1.40***	***1.30***	***1.30***

4.2 Safety assessment methods

Uniform severity zones illustrated in Figure 8 were approximated by graphing MaxS (the maximum speed of either vehicle during the conflict event) versus min TTC. All conflicts were plotted and assessed by number (severity level) as shown below.

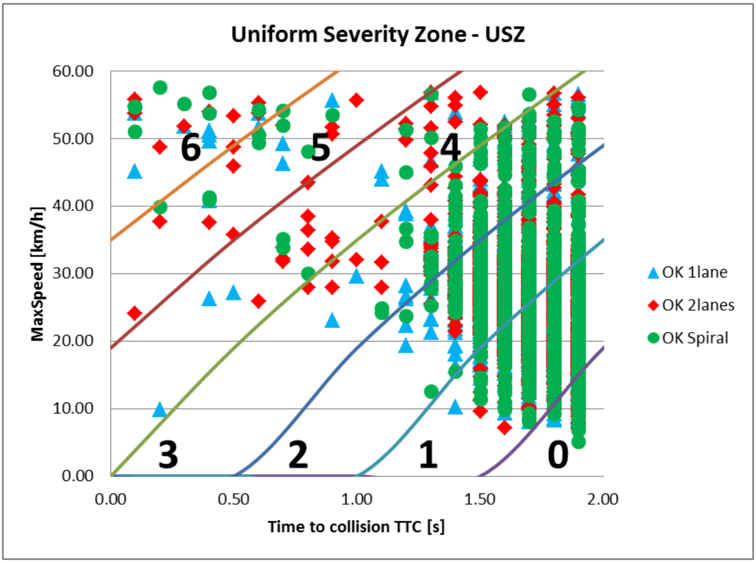

Figure 8 – Uniform severity zone for roundabout design alternatives

USZ 1+ is described as mean of conflicts with severity level at least 1. The order for safety assessment from the safest to most danger is: spiral roundabout, 1 lane roundabout and 2 lanes roundabout.

Table 4 – Conflicts frequency according USZ and USZ 1+

	Uniform Severity Zone - USZ							
	0	1	2	3	4	5	6	USZ 1+
OK 1lane	*62242*	*926*	*548*	*117*	*10*	*5*	*8*	*1.540*
OK 2lanes	*30661*	*1085*	*639*	*141*	*22*	*11*	*8*	*1.562*
OK Spiral	*46841*	*954*	*522*	*119*	*11*	*9*	*8*	*1.535*

Second approach Total Conflict Severity Score (TCS Score) is the sum of TTC score and Risk of collision score and overall severity score need to be assigned to each conflict. Higher number means higher conflict severity.

The ROC is independent from the TTC score and assigned to each conflict based on its MaxΔV value (maximum delta velocity of the two vehicles in the conflict during hypothetical collision). The thresholds were selected as the 85th percentile of MaxΔV from all roundabout design alternatives. The 2 lanes roundabout shows higher values of MaxΔV than 1 lane and spiral design (both similar distribution).. The chosen threshold values are shown below in the Table 5.

Table 5 – Assigned ROC score based on MaxΔV

ROC Score	MaxDV [km/h]	P injuries	P fatal	Sample size		Severity
1	<5	<0.0003	<0.0000	118453	81.76%	low
2	5≤maxDeltaV≤15	0.0003-0.0056	0.0000-0.0001	21168	14.61%	moderate
3	maxDeltaV>15	>0.0056	>0.0000	5266	3.63%	high

Table 6 summarized conflicts of assigned score (1 - 6). Average conflict score 1+ is described as mean of conflicts with TCS Score at least 1.

Table 6 – TCS Score and ACS1+

TCS Score (Total Conflict Severity Score)							
	1	*2*	*3*	*4*	*5*	*6*	ACS1 1+
OK 1 lane	*55887*	*5895*	*1774*	*269*	*28*	*3*	*1.163*
OK 2 lanes	*23023*	*6822*	*2379*	*288*	*45*	*10*	*1.389*
OK spiral	*39294*	*6470*	*2416*	*260*	*22*	*2*	*1.251*

The order for safety assessment by TCS Score from the safest to most danger is: 1 lane roundabout, spiral roundabout and 2 lanes roundabout.

Both methods have pros/cons. USZ is very simple to use, but does not count with severity of potential collisions (only with severity of conflict). TCS Score method count with severity of conflicts and potential collisions, but ROC score severity thresholds (MaxΔV) could be different for design alternatives and slightly affect results.

For right choice of design is needed to include both principles of safe road design: road safety and fluency of traffic flow (capacity with adequate level of traffic quality).

5 Conclusion

This report examined the use of SSAM and microsimulation models for performing a conflict analysis and safety assessment of roundabout design alternatives.

The safety assessment by surrogate safety indicators and safety assessment methods confirms general opinion about safer 1 lane roundabout than 2 lanes roundabout with equal traffic volume.

The spiral roundabout confirms partially better solution than both standard roundabout designs. The low severity of potential collisions (against 2 lanes roundabout) and higher capacity could be significant reason to be chosen by road designers.

The safety assessment using the Traffic Conflict Theory and safety analysis of the modeled surrogate indicators has great potential in these nowadays problem cases.

- Safety diagnosis of designs of existing intersections reconstruction. Especially in the case of under registration of accident records (accident reports may be unavailable, the information may be insufficient or unreliable).
- The evaluation of the impact of designed measures on traffic safety

Literature

[1] AMBROS, Jiří a Josef KOCOUREK. *Metodika sledování a vyhodnocování dopravních konfliktů* [online]. Brno: Centrum dopravního výzkumu, v.v.i., nedatováno. ISBN ISBN 978-80-86502-62-5. Dostupné z: http://konflikt.cdvinfo.cz/file/certifikovana-metodika/

[2] HUANG, Fei, Pan LIU, Hao YU a Wei WANG. Identifying if VISSIM simulation model and SSAM provide reasonable estimates for field measured traffic conflicts at signalized intersections. *Accident Analysis & Prevention* [online]. 2013, roč. 50, s. 1014–1024 [vid. 26. listopad 2013]. ISSN 00014575. Dostupné z: doi:10.1016/j.aap.2012.08.018

[3] SAUNIER, Nicolas. Introduction to Surrogate Analysis in Non-Motorized Safety [online]. 2013 [vid. 17. leden 2014]. Dostupné z:

http://grimes.mcgill.ca/content/documents/workshop/Lectures/Nicolas%20Saunier%20-%20lecture.pdf

[4] HYDÉN, C. *The Development of a Method for Traffic Safety Evaluation: The Swedish Traffic Conflicts*. bulletin 70. University of Lund: University of Lund, 1987.

[5] SAYED, Tarek a Sany ZEIN. Traffic conflict standards for intersections. *Transportation Planning and Technology* [online]. 1999, roč. 22, č. 4, s. 309–323 [vid. 5. leden 2014]. ISSN 0308-1060. Dostupné z: doi:10.1080/03081069908717634

[6] AG, PTV Planung Transport Verkehr. *VISSIM 5.40 User Manual*. B.m.: epubli, 2012. ISBN 9783844214017.

[7] FHWA. *SSAM - Surrogate Safety Assesment Model*. english. 2013.

Summary: Application of traffic safety assessment at urban large roundabouts by micro-simulations (VISSIM) and Traffic Conflict Technique (TCT). The first approach use simply surrogate safety indicators from simulated trajectories (SSAM). The second approach use assessment methods with severity of conflicts and potential collisions. Both approaches of safety assessment were performed at three design roundabout alternatives (1 lane roundabout, 2 lanes roundabout and atypical spiral roundabout) and appropriate conclusions were summarized.