

Usage of Video Analysis of Traffic Conflicts for the Evaluation of Inappropriately Designed Building Elements on Intersections

Vladislav Krivda¹, Jan Petru¹

¹ Department of Transport Constructions, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875, 708 33 Ostrava-Poruba, Czech Republic

Abstract. Human society is constantly evolving in all areas. The transport is no exception – especially development of road transport is considerable and visible on all levels. However, it is necessary to look for tools that can harmonize economic and social progress with the full preservation of the environment for future generations. The so-called sustainable development of road transport is also closely related to the issue of creating safe transport infrastructure. For example, roads must be in compliance with technical rules on one hand and on the other one they have to be clearly understandable for all road participants (drivers, pedestrians, etc.). Unfortunately, even if the designer of transport construction meets the technical requirements, the result is a dangerous place where very frequently the accidents or traffic conflicts take place. There exist statistics of accidents, but on the contrary, there are not any statistics of traffic conflicts. And simply monitoring the traffic conflicts can lead to early detection of problematic places in road infrastructure and thus increasing the safety in the road traffic. There are many methods used for monitoring traffic conflicts. The method used in the Czech Republic is described in the submitted paper. The original method, which monitored mainly and only the behaviour of drivers and their mistakes, was innovated, so that it could be used also for evaluation of inappropriately designed building elements of road constructions. Therefore, the paper deals with the description of so-called Innovated Video Analysis of Traffic Conflicts (IVATC) and with the usage of this method for one particular example of intersection, where larger vehicles (buses, trucks, etc.) had problems with passing through it. It points out to the fact that even a relatively small change can lead to the increase of the road safety.

1. Introduction

Each road transport construction, within its sustainability, must meet strict criteria for maintaining road safety. The reliability of such construction is influenced, inter alia, by the load which is caused by car weight (e.g. damage of roads, curbs, etc.) or by the sc. traffic load, i.e. the volume of traffic flows (high traffic volume can cause non-standard behaviour of road transport participants and hence increased number of dangerous situations or accidents). The most problematic places are intersections.

For the right design of intersections there are many sophisticated procedures and solutions based on legislation, standards, technical conditions, etc. Unfortunately, the issue of analysis of traffic conflicts is often omitted.

These analyses are generally referred to as Traffic Conflict Techniques (TCT). Amundsen and Hyden [1] defined traffic conflict as an observable situation in which two or more drivers approach



each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged. In the Czech Republic Folprecht dealt with this problematic and he called the traffic conflicts “conflict situations”. According to Folprecht [2] the traffic conflict (conflict situation) is a moment or a situation in road traffic in which a higher than usual degree of risk arises or can arise for some traffic participants. A traffic conflict naturally precedes each accident. On the contrary, it can be stated that each accident is a result of such traffic conflict when the risk of collision was impossible to be averted. Thus, traffic conflicts are potential accident situations and their types then predetermine the types of accidents.

Drivers’ behaviour is influenced by many factors which could have direct effect on the safety of road traffic. Generally, these three factors are the most significant: vehicles, human factors and the road and its surroundings. These factors also affect speeding which is one of the most common causes of an accident. For example, Atombo, Wu, Zhong and Zhang [3] describe other aspects that affect speeding (age, gender or nationality of drivers, differences between professional and non-professional drivers, etc.). This fact is also confirmed by other studies dealing with so-called working memory which changes with the driver’s age and affects driver’s behaviour (e.g. [4] or [5]).

However, it is necessary to realize that traffic conflicts can be caused also by the influence of some hidden factors, such as operating, construction, meteorological ones or others. These hidden factors can be revealed by the analysis of traffic conflicts. In other words, the designers of the transport construction can never consider their transport solution absolutely safe and satisfactory [6]. Using the analysis of traffic conflicts the doubts about their harmlessness can be avoided.

At present, a number of specialists deals with traffic conflicts in the Czech Republic (e.g. Krivda, Petru, [7]; Ambros, Kocourek [8], etc.). Based on their experience and knowledge the methodology for monitoring and evaluating traffic conflicts [8] was created. However, this methodology primarily deals with the analysis of traffic conflicts caused by drivers alone (as in the past Folprecht). This paper deals with the use of video analysis of traffic conflicts for the evaluation of inappropriately designed building elements on intersections, this is based on the original Folprecht’s procedures.

2. Original Folprecht’s methodology

Monitoring the traffic conflicts was introduced in the Czech Republic (or then in Czechoslovakia) by the associate professor Jan Folprecht, Ph.D. in the 1970s. In 1998 the cooperation with Mr. Folprecht started and the method of video analysis of traffic conflicts was further developed. At present, we keep using and developing this method within the professional activity of the Department of Transport Constructions (VSB –the Technical University of Ostrava, the Faculty of Civil Engineering). It is impossible to describe the whole methodology in this paper, so the text below is limited only to the essential facts (for details see [9]).

Folprecht based his methodology on the then studies (e.g. [10], [11], [12], [13] and [14]) and he began to use a video apparatus for recording the road traffic which was then analysed. This methodology is called Video Analysis of Traffic Conflicts (VATC). Folprecht marked each traffic conflict (TC) by a classification symbol exactly describing the given situation. The symbol has 3 parts [9]:

- number - description of participants of the traffic conflict, e.g. 1 = pedestrian, 2 = car, 4 = pedestrian and car, 6 = two or more cars, 9 = other (one cyclist, cyclist and car, etc.),
- one or more letters - description of the way of the traffic conflict, e.g. n = violation of the rule "Give way", f_p = influence of the pedestrian crossing, f_k = influence of the near intersection, jc = wrong ride of a cyclist, a = aggression, g = giving priority against rule, o = restriction or danger in driving by changing the lane or exiting the roundabout, D = danger of the collision from the rear, etc.
- number (1 - 4) - description of seriousness of the traffic conflict (1 - 4).

The seriousness of traffic conflict is described as follows [2]:

- 1st level - potential traffic conflict,
- 2nd level - traffic conflict when one or more participants are restricted in driving,
- 3rd level - traffic conflict when one or more participants are endangered,
- 4th level - accident.

For example the symbol 6a3 means aggression (a) between two drivers of cars (6) and 3rd level of seriousness (3).

The resulting numbers of traffic conflicts were recalculated to sc. relative conflict rate c_R [TC/100 veh]:

$$c_R = \frac{N_{TC}}{V} \cdot 100 \quad (1)$$

Where N_{TC} is the number of traffic conflicts (TC) per hour [TC/h] and V is an hour traffic volume [veh/h].

3. Innovated Video Analysis of Traffic Conflicts (IVATC)

Innovated Video Analysis of Conflict Situations allows the evaluation of inappropriately designed building elements. The main change in comparison with the original Folprecht's method is the addition of the classification symbol by other features that represent a new division of conflict situations (see 'Figure 1').

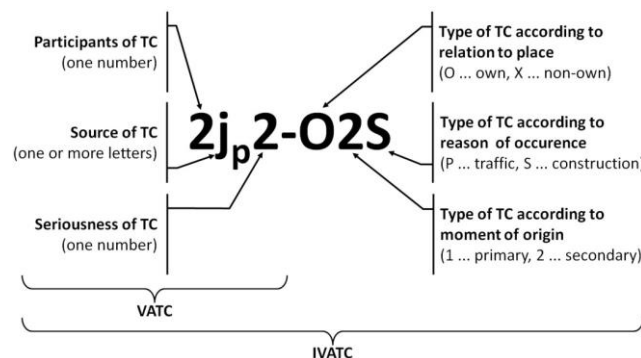


Figure 1. Innovated classification symbol of traffic conflicts (TC)

Some traffic conflicts were not caused by traffic on the intersection or by the intersection itself (i.e. its construction, traffic control, etc.). It can be e.g. a result of an action on a nearby intersection, which influences the traffic on the observed intersection (see video <https://youtu.be/2CkoyNf9EFM> - traffic jam on roundabout due to a queue of vehicles on nearby intersection with traffic lights /on the left out of the focus/), influence of a nearby parking area, etc. These are conflicts that are caused by external influences.

According to the origin of the given traffic conflicts the conflicts were newly divided into two groups (in the brackets there is a sign to be used in the classification symbol):

- own traffic conflicts (O) - traffic conflicts which are directly related to traffic on the observed intersection, to its construction, etc.,
- not-own traffic conflicts (X) - traffic conflicts which are not linked to the traffic on the observed place directly, its construction, etc. They can be originated outside the observed place.

Other traffic conflicts arise as a result of another traffic conflict. For example, the driver of the first vehicle must unexpectedly slow down (e.g. before a pedestrian crossing with careless pedestrian entering the road) and the driver of the other vehicle breaks violently in order to prevent a collision. The situation which affected the second vehicle driver, would probably not happen if it was not for the first conflict.

According to the moment of the origin of the traffic conflicts, we divide them into two groups:

- primary traffic conflicts (1) - traffic conflicts which are not caused by other traffic conflict,
- secondary (subsequent) traffic conflicts (2) - traffic conflicts which are caused by other traffic conflict.

Due to the fact that the reason of the occurrence of some traffic conflicts is not caused only by a wrong behaviour of the driver (or other road user), but e.g. building structure can be also blamed and responsible for these traffic conflicts. Therefore, it was necessary to divide the traffic conflicts according to the reason of its occurrence as follows.

- Operational traffic conflicts (P) - traffic conflicts caused only by the driver alone (or other road user),
- Construction traffic conflicts (S) - traffic conflicts caused not only by the drivers alone, but also (often primarily) by inappropriately designed building elements.

Into the group of operational traffic conflicts we can include, e.g. violation of rule "Give way", ride on red light, the risk of collision from the rear, etc. Construction traffic conflicts include, e.g. driving near curbs, moving into the opposite direction on intersection, etc., but only in case of conflict situations which are caused by inappropriately designed building elements (see video <https://youtu.be/6clxD3-nmpo-> small radius of intersection corner).

The resulting numbers of traffic conflicts are then recalculated by the new formula (weighted conflict rate c_{RW} [TC/100 veh]):

$$c_{RW} = \frac{N_{TC} \cdot C_S}{V} \cdot 100 \quad (2)$$

Where N_{TC} is a number of traffic conflicts (TC) per hour [TC/h], C_S is a coefficient of seriousness of traffic conflict and V is hour traffic volume [veh/h].

The weighted conflict rates determined by this method were used e.g. in safety study about sc. U-turns (Meel, Brannolte, Satirasetthavee and Kanitpong [15] or Meel, Vesper, Borsos and Koren [16]).

4. Example of using IVATC

IVATC was used on an intersection with inappropriately designed building elements – i.e. e.g. small radii of corners and inappropriately situated refuge island (see ‘Figure 2’). There were both operational TC and also construction TC. Attention was concentrated only on construction TC which were related to ride of buses or trucks. Measurements were made at many other intersections. The data given here is only a selection of many measurements and serves as an illustrative example of using the method described above.

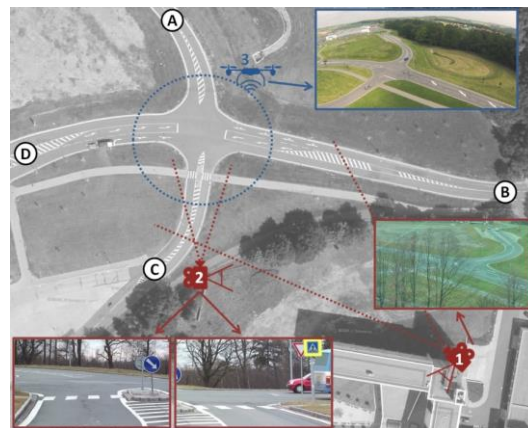


Figure 2. Monitored intersection and positions of cameras (1 and 2) and quadcopter (3) with demonstration of record views.

The first camera was situated on the sixth floor of the university building (see ‘Figure 2’– number 1) and the second camera was situated on the ground level of the intersection (see ‘Figure 2’– number 2). Camera 1 monitored general traffic on the intersection (also for measuring traffic volume) and camera 2 was used for detailed view of monitored building elements (curbs or island). The third camera was installed on quadcopter (see ‘Figure 2’– number 3). View from this camera on ‘Figure 2’ shows intersection after rebuilding (see below for more information).

Table. 1. Frequency of observed traffic conflicts (selection)

No.	Traffic conflict (TC) and direction (video on YouTube)	Time of measurement						Sum of TC	CRW^*
		13 ³⁰ – 13 ⁴⁵	13 ⁴⁵ – 14 ⁰⁰	14 ⁰⁰ – 14 ¹⁵	14 ¹⁵ – 14 ³⁰	14 ³⁰ – 14 ⁴⁵	14 ⁴⁵ – 15 ⁰⁰		
1	2j _r 1-O1S (B→C) (from it 6j _r 2-O1S) https://youtu.be/PfFuPsjrR5c	4 (1)	2 (1)	3	4	4 (1)	1	18 (3)	58.6
2	2j _r 1-O1S (D→C) (from it 6j _r 2-O1S) https://youtu.be/b2XTrIEFE3A	2	0	1	3 (2)	0	1	7 (2)	100
3	2j _p 1-O1S (C→B) https://youtu.be/se3jYzzHUxo or https://youtu.be/6clxD3-nmpo	6	4	5	4	6	4	29	100
4	2j _p 1-O1S (C→D) https://youtu.be/AITK9S_JULY	1	3	0	2	0	1	7	98.4
5	2j _p 1-O1S (A→D) https://youtu.be/6clxD3-nmpo and https://youtu.be/wloPP2dhk8A	0	0	1	0	2	0	3	88.7
6	2j _p 1-O1P (A→B) https://youtu.be/8XVShHCYVok	3	4	3	7	5	3	25	54.5
7	2j _s 1-O1S (B→A) (from it 2j _s 1-O1S + 2j _p 1-O1P) https://youtu.be/t-1zqY3YiUc or	3 (1)	1	3	3	5 (1)	7	22 (2)	94.3

https://youtu.be/zPG0Enhf--4									
8	2j _s 1-O1P(S) (D→A)	7	3	3	6	8	1	28	89.6
	(from it 2j _s 1-O1P(S) + 2j _p 1-O1P)	(1)	(1)	(1)	(2)	(2)		(7)	
https://youtu.be/KEbnTxYSf_k									
or									
https://youtu.be/A2i1xzp_7V0									

j_r = moving of the vehicle to another lane

j_p = moving of the vehicle into the opposite direction

j_s = wrong way of driving (along visual island)

*) Coefficient c_{RW} [TC/100 veh] was calculated for all the buses of the monitored direction. The value "100" means that all the vehicles caused this traffic conflict.

One of the most dangerous traffic conflicts are situations marked as 2j_p1-O1S. For example, the vehicle driving from C to B (see 'Table 1', No. 3 and 'Figure 3', blue vehicle) was using the opposite direction to prevent driving on the curb because this curb has too small radius (see 'Figure 4' or video <https://youtu.be/6clxD3-nmpo>).

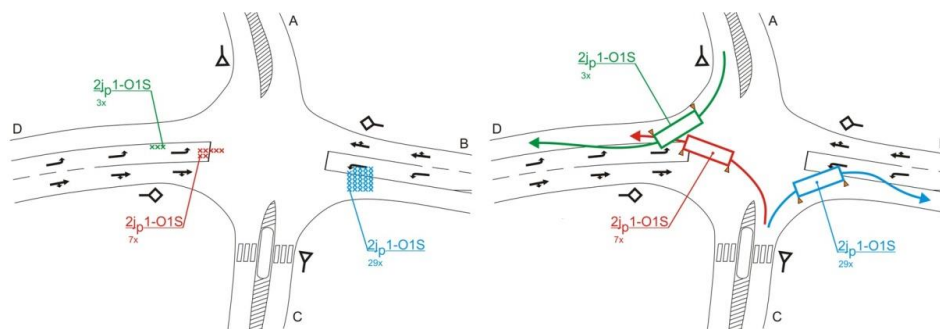


Figure 3. Scheme of location and course of traffic conflicts 2j_p1-O1S



Figure 4. Photograph of traffic conflict 2j_p1-O1S

The refuge island with pedestrian crossing (leg C) is another inappropriately designed building element of this intersection. Space between this island and curb of corner is relatively narrow for the buses exiting the intersection by this leg. For example, there was monitored traffic conflict marked as 2j_o1-O1S (j_o – driving near curb). The 'Figure 5' shows this conflict for bus which was driving from D to C (critical curbs are marked by red colour).



Figure 5. Scheme and photograph of traffic conflict 2j₀1-O1S

These traffic conflicts were monitored by both the camera 1 (from the building) and by camera 2 (for detailed monitoring). ‘Figure 6’ describes important items for detailed video analysis of TC, i.e. the position of wheels and profile to guide strip (“a”+“b”) and curb (“c”). Guide strip is divided into 2 parts – the line of horizontal marking (“a”) and a part between the line and the curb (“b”). The recording was also divided into 2 parts (left and right) for more simplified and transparent analysis (see ‘Table 2’).

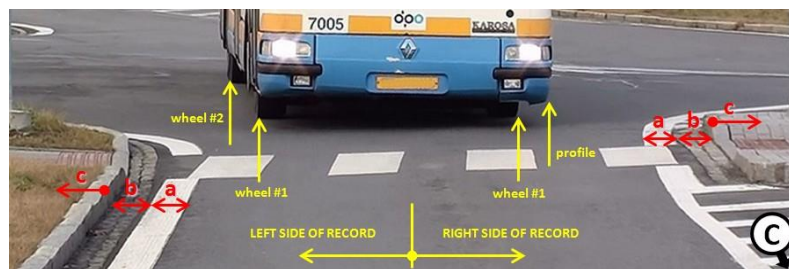


Figure 6. Description of monitored items for detailed analysis of traffic conflicts (camera 2)

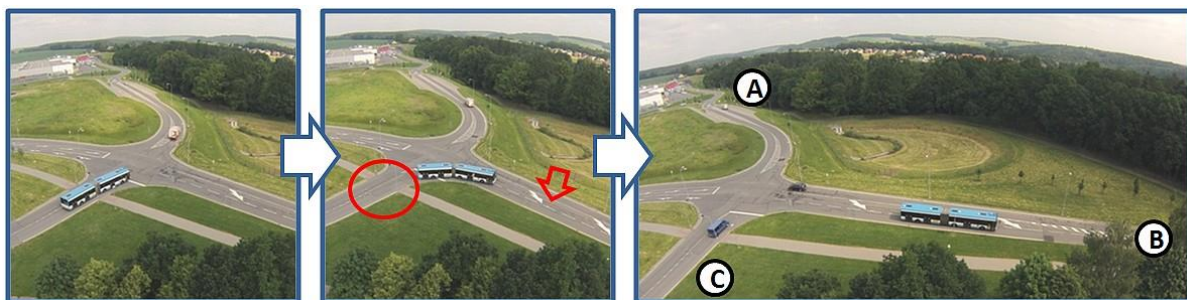
‘Table 2’ shows selected vehicles and their movement through the intersection. The type of the vehicle (bus or truck, or car brand) is marked by colour. Red colour means traffic conflict j_r (moving of the vehicle to another lane) and blue colour means traffic conflict j_p (moving of the vehicle into the opposite direction). Some fields of the table are filled with red or orange colour. Red colour (in the “profile” column) means that the vehicle drove by profile (more than 50 %) above the guide strip (part “a” or “b”) or above the curb (part “c” – see ‘Figure 6’). Red colour (in the “wheel” column) means that the vehicle drove by the wheel (more than 50 %) the guide strip (part “a” or “b”) or the curb (part “c”). Orange colour (in the “profile” column) means that the vehicle drove by profile (less than 50 %) above the guide strip (part “a” or “b”) or above the curb (part “c”). Orange colour (in the “wheel” column) means that the vehicle drove by wheel (less than 50 %) over the guide strip (part “a” or “b”) or the curb (part “c”).

Table 2. An example of results of detailed video analysis of traffic conflicts

DIRECTION	RECORD	TRAFFIC CONFLICT	TIME	VEHICLE TYPE	STOPPED	LEFT SIDE OF RECORD												RIGHT SIDE OF RECORD											
						PROFILE			WHEEL 1			WHEEL 2			WHEEL 3			PROFILE			WHEEL 1			WHEEL 2			WHEEL 3		
						a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
D→C	1	1	00:38	KAR																									
		27	13:36	JSP																									
	2	51	00:21	REN																									
		89	22:03	REN																									
		100	27:19	SOR																									
		107	29:57	KAR																									
	3	164	29:21	KAR																									
C→B	1	4	01:51	KAR																									
		6	03:13	K-KAR																									
		7	03:33	KAR																									
		12	07:09	KAR																									
		24	11:39	KAR																									
		26	12:43	KAR																									

*) last wheel

It is evident the drivers were driving into the opposite direction (j_p) or in the wrong lane (j_r) to prevent driving on the curb (j_o). On the basis of this analysis the monitored intersection was rebuilt (see 'Figure 7'). The pedestrian crossing and refuge island were demolished (see the red circle) and the turning lane for left turning (leg B) was rebuilt to connection lane for connection from the left (see the red arrow).

**Figure 7. Monitored intersection after rebuilding**

'Figure 7' shows a situation when the bus is turning from C to B and it is driving into a new connection lane. This movement is correct and safe. During the analysis (IVATC) on this rebuilt intersection no buses (which were driving from or to leg C) caused the traffic conflict of type j_p or j_r or j_o .

5. Conclusion

The results of the video analysis of traffic conflicts point only to selected situations at monitored intersection and which are at least partially related to inappropriately designed building elements. These are the conflicts where the drivers drive into the opposite direction, use a wrong lane, drive near the curbs or drive on them, etc. Analyses have shown that the causes of these conflicts are small radii of corners and an inappropriately situated refuge island with pedestrian crossing.

The buses which used leg C, where the mentioned pedestrian crossing was situated, were monitored in the first place. The monitored traffic conflicts show relatively high values of weighted conflict rate c_{RW} – it was often maximum, i.e. 100 TC/100 veh. As parameter V, the volume of all monitored vehicles (i.e. buses or trucks) was taken for each traffic conflict. This means that in the case of $c_{RW} = 100$ TC/100 veh, all vehicles created the particular traffic conflict. For all the traffic conflicts their seriousness was marked with a symbol 1 (potential traffic conflict) – this means that no other vehicle was affected at the time. The reason is that the bus drivers were aware that they will cause the

traffic conflict (they will drive into the opposite direction, etc.). Therefore, they waited for an empty intersection without any other vehicles. This was also possible due to low traffic volume.

After the reconstruction of this intersection (demolition of refuge island and pedestrian crossing, and change of the turning lane to the connection lane), the previous traffic conflicts were not monitored anymore. To this is related the size of c_{RW} which equals zero. It can be said that the implemented changes contribute to the increase of the traffic safety at this intersection. However, it is always necessary to keep in mind that whichever change (even a positive one) can lead to another problem or several problems (which are often much more serious). For example, demolished pedestrian crossing can cause a traffic conflict with crossing pedestrian on leg C.

The conclusions of these analyses of traffic conflicts confirm the hypothesis that Innovated Video Analysis of Traffic Conflicts (IVATC) is the ideal tool for monitoring and evaluation of inappropriately designed building elements on intersections and this process has certainly its well-founded importance. It is always better to prevent problems (i.e. traffic accidents), than to handle their consequences later, when they can be (and usually are) of relatively serious character (death, injury, damage).

6. References

- [1] Amundsen F and Hyden C 1977 *Proceedings of first workshop on traffic conflicts* (Oslo, Institute of Economics)
- [2] Folprecht J 1995 Method for Monitoring and Analysis of Conflict Situations in Road Traffic and influence for road safety. In *International scientific conference on occasion of the 50th anniversary of VSB in Ostrava*. Ostrava: VSB – Technical University of Ostrava. pp 227-231. Czech
- [3] Atombo C, WU C, ZHONG M and ZHANG H 2016 Investigating the Motivational Factors Influencing Drivers Intentions to Unsafe Driving Behaviours: Speeding and Overtaking Violations. In: *Transportation Research Part F: Traffic Psychology and Behaviour*. Elsevier Limited. Volume 43, 1 November 2016, Pages 104-121. ISSN 1369-8478. DOI: 10.1016/j.trf.2016.09.029
- [4] Ross V, Jongen E M M, Brijs T, Ruiter R A C, Brijs K and Wets G 2015 The relation between cognitive control and risky driving in young novice drivers. In: *Applied Neuropsychology:Adult*. Volume 22, Issue 1, 2 January 2015, Pages 61-72. ISSN 23279095. DOI: 10.1080/23279095.2013.838958
- [5] Cuenen A, Jongen E M M, Brijs T, Brijs K, Houben K and Wets G 2016 Effect of a working memory training on aspects of cognitive ability and driving ability of older drivers: Merits of an adaptive training over a non-adaptive training. In: *Transportation Research Part F: Traffic Psychology and Behaviour*, Volume 42, 1 October 2016, Pages 15-27. ISSN 13698478. DOI: 10.1016/j.trf.2016.06.012
- [6] Folprecht J 2000 Current Developments and Perspectives of the Method of Monitoring of Conflict Situations on Road Traffic. *Silnicni Obzor*, Pages 39-44. ISSN 0322-7154. Czech
- [7] Krivda V, Petru J, Mahdalova I and Zitnikova K 2016 *Evaluation Intersection Building Elements Using Video Analysis*. Ostrava: VSB - Technical University of Ostrava, Czech Republic, 184 p. Monograph. ISBN 978-80-248-3995-0. Czech
- [8] Ambros J and Kocourek J 2013 *Methodology of Monitoring and analysis of Traffic Conflict*. Brno: CDV Brno, ISBN 978-80-86502-62-5. Czech
- [9] Krivda V 2013 Analysis of Conflict Situations in Road Traffic on Roundabouts. In: *PrometTraffic&Transportation: Scientific Journal on Traffic and Transportation Research*. Zagreb: University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia, Volume 25, Issue 3, Pages 295-303. ISSN 0353-5320 (print), ISSN 1848-4069 (on-line). DOI: 10.7307/ptt.v25i3.296.
- [10] Baker W T 1972 An Evaluation the Traffic Conflicts Technique. *Highway Research Record*. Washington, No 384

- [11] Bennet C T 1971 Accident at Urban Junctions. In: *The Journal of the Institution of Highway Engineers*
- [12] Hayward J C 1972 Near-miss Determination through Use of a Scale of Danger. *Highway Research Record*. Washington
- [13] Perkins S R and Harris J I 1968 Traffic Conflicts Characteristics – Accident Potential at Intersections. *Highway Research Record*. Washington
- [14] Rustam K and Sabey B E 1972 Accident and Traffic Conflicts at Junction. *TRRL Report*. Crowthorne, Bereshire
- [15] Meel I P, Vesper A, Borsos A and Koren C 2017 Evaluation of the Effects of Auxiliary Lanes on Road Traffic Safety at Downstream of U-turns. In: *Transportation Research Procedia*. Elsevier B.V. Volume 25, 2017, Pages 1936-1950. ISSN 23521457. Conference Paper, In: *World Conference on Transport Research - WCTR 2016 Shanghai*, 10-15. DOI: 10.1016/j.trpro.2017.05.186
- [16] Meel I P, Brannolte U, Satirasetthavee D and Kanitpong K 2017 Safety Impact of Application of Auxiliary Lanes at Downstream Locations of Thai U-Turns. In: *IATSS Research. International Association of Traffic and Safety Sciences*. Elsevier B.V. Volume 41, Issue 1, April 2017, Pages 1-11. ISSN 03861112. DOI: 10.1016/j.iatssr.2016.06.002

Acknowledgement

The work was supported from sources for conceptual development of research, development and innovations for 2017 at the VSB-Technical University of Ostrava which were granted by the Ministry of Education, Youths and Sports of the Czech Republic.