CAR20111160

THE EFFECT OF CONVERTING A SIGNALIZED INTERSECTION INTO A ROUNDABOUT - A CASE STUDY

Dinu Covaciu*, Daniela Florea, Ion Preda, Janos Timar

Transilvania University of Brasov, Romania

KEYWORDS - road traffic, urban driving, data collection, roundabout, signalized intersection

ABSTRACT – It is generally considered that modern roundabouts reduce vehicle crashes, because traffic speeds in roundabouts are lower than in other signalized intersections. It is also considered that there are less conflict points in roundabouts. On the other hand, modern roundabouts are less expensive than the traffic signals. These obvious advantages led many local authorities to the conslusion that it is a good option to convert the existing signalized intersections into roundabouts. Having the opportunity to record driving data before and after converting some signalized intersection to roundabout, our team made an analysis of the differences in driving parameters before and after.

INTRODUCTION

The road traffic flows consist in vehicles interacting each others and also with the road and environment. A traffic flow on an artery has certain characteristics that vary with time and distance. These characteristics are grouped in macroscopic and microscopic parameters (5), (8). The macroscopic parameters describe the behaviour of vehicle groups, as assembly, on a road segment, at a given time or during a period of time. The microscopic parameters describe the position of the individual vehicle, as an entity moving on road and analysed through the driving particularities.

The analysis of driving inside the city can be made globally but also on individual roads or intersections. In case of an intersection it should be considered also the space needed for entering and exiting the intersection, to include the braking and acceleration sequences and all the conflict points (2), (4).

Basically, the analysis of traffic flow through an intersection (signalized or roundabout) starts from the individual vehicle motion, taking into account the speed versus time variation and the acceleration, which allow the rigurous determination of the vehicle dynamics. Then, combining the records of multiple tracks (multiple vehicle passings) can be ascertained the velocity field (the unique velocity $v(x,t)$ associated to each time t, for a point x located on the road) (5). Other macroscopic parameters that can be ascertained and used in the analysis of the traffic flow through an intersection are v_{50} and v_{85} (4).

The median speed v_{50} is the speed achieved or exceeded by 50% of the vehicles, and the speed v_{85} is the speed not reached by 85% of vehicles (or the speed achieved or exceeded by 15% of vehicles). The speed v_{85} is recommended as legal speed limit for the analyzed roads (4).

These parameters are used to compare the *below* and *after* vehicle motion through the monitored intersections.

The method used for collecting data is the instrumented vehicle method. The instrumented vehicle is a vehicle road user with data acquisition equipment installed (6). In this paper it is considered that the equipment installed on vehicle records only those data related to his behaviour, not also for other vehicles (4).

It is important that the instrumented vehicle to have a similar behaviour of the majority of vehicles in traffic, so that the recorded data to be representative as possible. Data are taken from GPS receivers and basically are: position, time and velocity (1), (7).

FIRST INTERSECTION – DRIVING AHEAD

The first analysed intersection was covered going forward (*Fig. 1*). The intersection was originally signalized with traffic lights and was converted to a roundabout. The monitored direction was the main road.

Fig. 1: The first intersection on map, with some recorded tracks

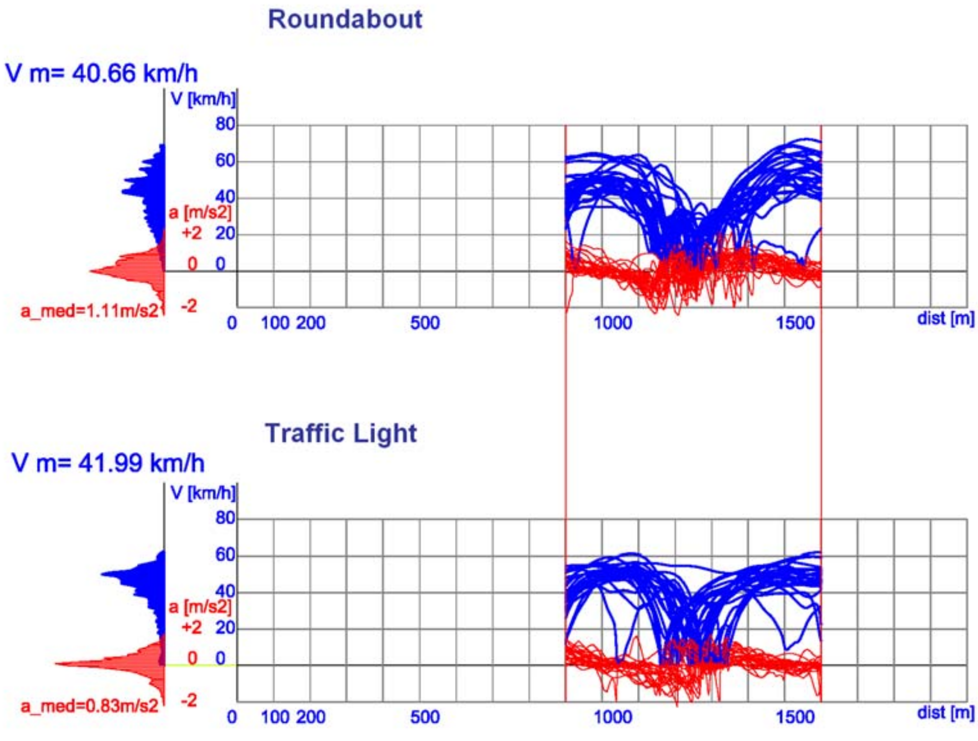

Fig. 2: Comparison between roundabout and signalized intersection, 700 m

The comparative analysis was done for a road segment with a length of 700 meters, so that the measured values are not influenced by the previous and next intersections (Fig. 2).

It was observed a decrease of the distance-mean speed, after changing into roundabout, with less than 5% (41.99 km/h to 40.66 km/h), but also an increase of the mean acceleration with more than 25% (from 0.83 m/s^2 to 1.11 m/s^2).

The cause of the increase of the mean acceleration can be seen in the detail shown in *Fig. 3*. In case of the original signalized intersection there is only one stop, when entering in the intersection (red color of the traffic light), then a portion with acceleration, weighted by the vehicles flow (since there are many vehicles starting together). In case of roundabout, there are two or even three stops, because beside the stop when entering in roundabout there are also two pedestrian crossings – before and after the roundabout. Exiting the roundabout is accelerated, and since the distance to the vehicle in front is higher than when starting in a intersection signalized with traffic lights, the acceleration may be higher.

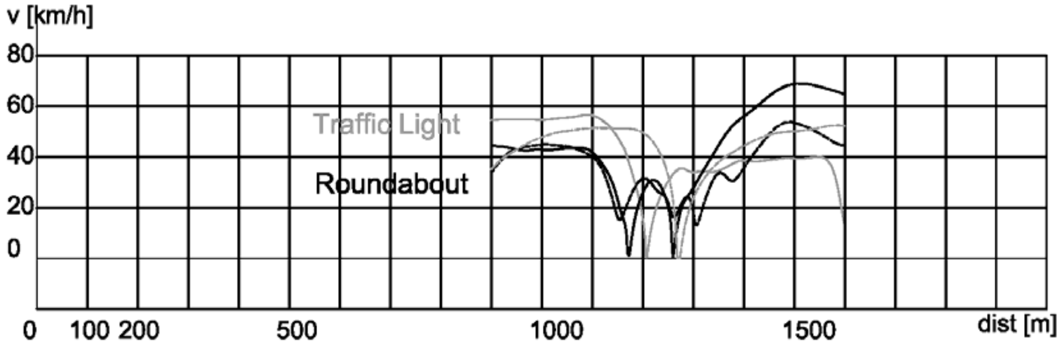

Fig. 3: Comparison between roundabout and signalized intersection, detail

For this road segment were calculated the speeds v_{50} and v_{85}, for both cases. The results are shown in *Fig. 4*. The median speed v_{50} is lower in case of roundabout, and v_{85} is higher.

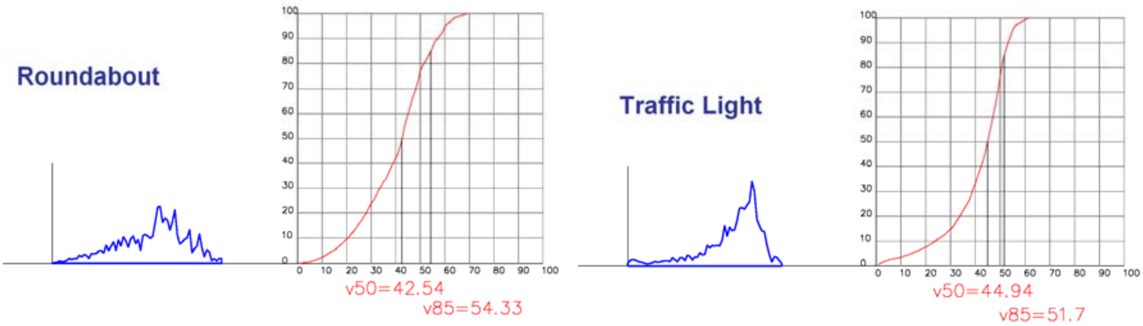

Fig. 4: Ascertaining of v_{50} and v_{85} for roundabout and traffic light

By reducing the analyzed area close to the intersection, on a 300 meters length, the weight of the intersection increase and the results are those shown in *Fig. 5* and *Fig. 6*. The mean distance-speed is decreased more (17%), and the mean acceleration is increased with about 44% in case of the roundabout.

The results of this comparative analysis of the two intersection variants (*signalized with traffic lights* versus *roundabout*), for the same intersection location, are given in *Table 1*.

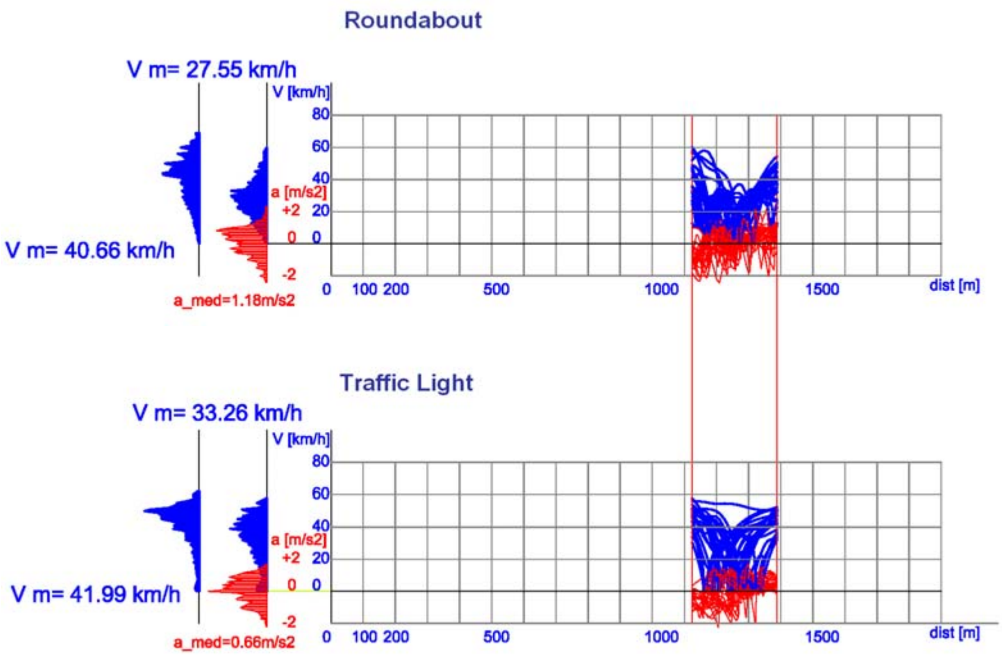

Fig. 5: Comparison between roundabout and signalized intersection, 300 m

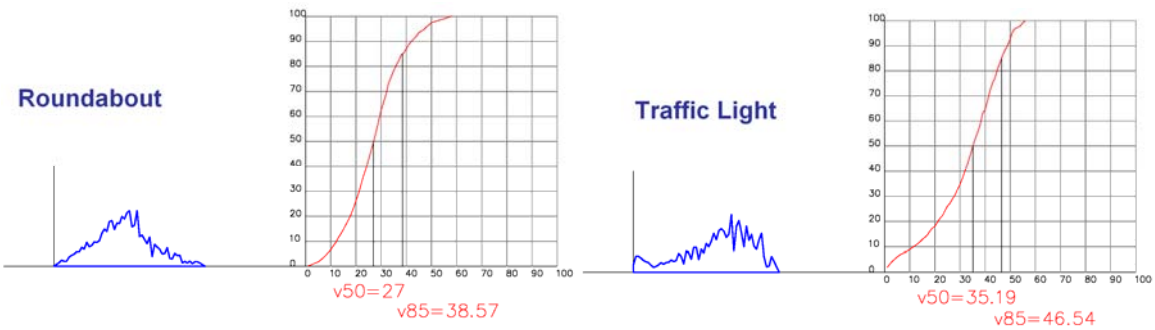

Fig. 6: Ascertaining of v_{50} and v_{85} for roundabout and signalized intersection, 300 m

Table 1 – Comparison between traffic lights and roundabout, first intersection

Road segment length	Variant	Distance-mean speed	Mean acceleration	Speed v_{50} (km/h)	Speed v_{85} (km/h)
700 m	Traffic lights	41.99 km/h	0.83 m/s^2	44.94 km/h	51.70 km/h
	Roundabout	40.66 km/h	1.11 m/s^2	42.54 km/h	54.33 km/h
	Variation %	-3.17%	**33.73%**	-5.12%	5.09%
300 m	Traffic lights	33.26 km/h	0.66 m/s^2	35.19 km/h	46.54 km/h
	Roundabout	27.55 km/h	1.18 m/s^2	27.00 km/h	38.57 km/h
	Variation %	-17.17%	**78.79%**	-23.27%	-17.13%

SECOND INTERSECTION – TURN LEFT

The second analysed intersection was covered turning left (*Fig. 7* and *Fig. 8*, left). The intersection was originally signalized with traffic lights and was converted into two successive roundabouts (*Fig. 7* and *Fig. 8*, right). The main traffic flow is on the track represented in the right side of *Fig. 7* (going ahead), since the monitored direction (turning left) has a lower traffic density.

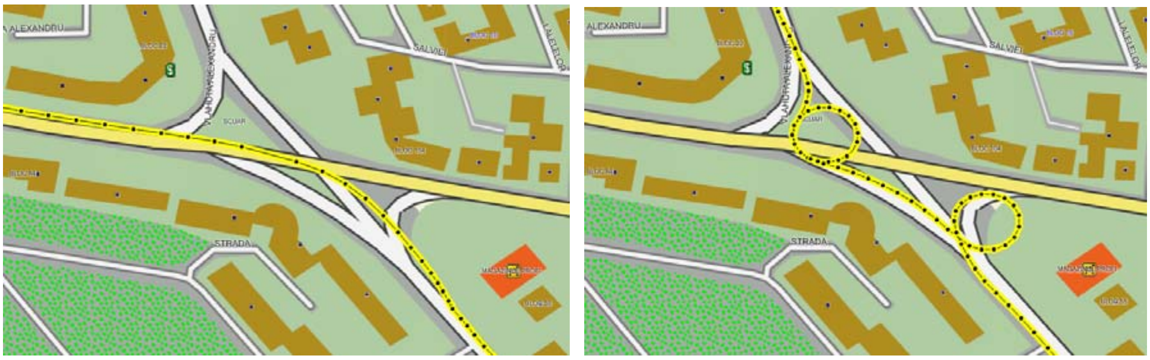

Fig. 7: The second intersection on map, with a recorded track *before* and *after*

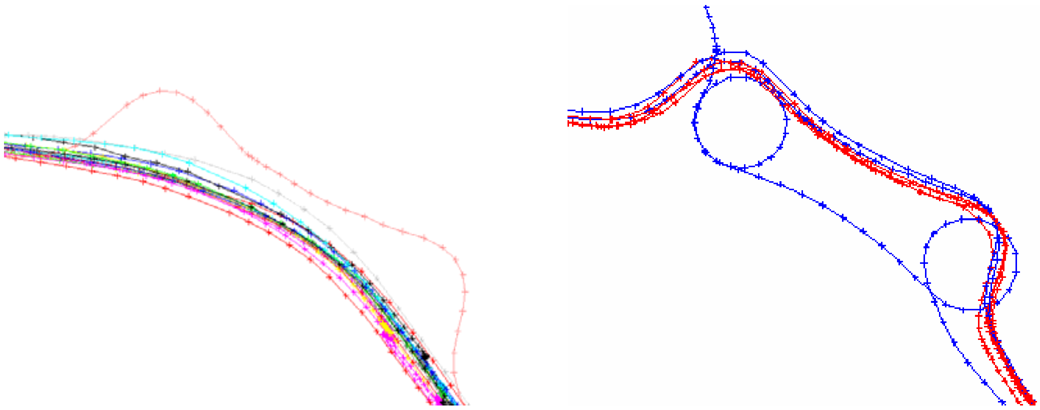

Fig. 8: Tracks recorded passing through the second intersection, represented as CAD drawing

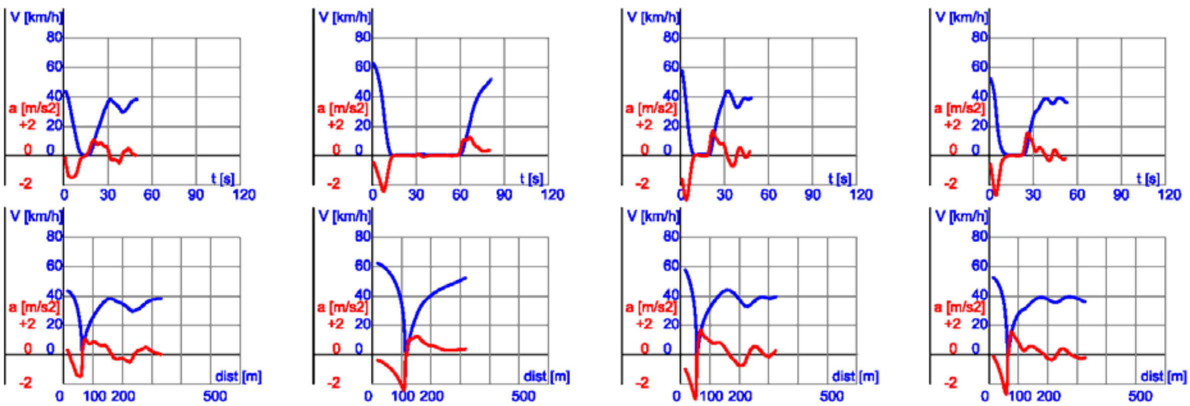

Fig. 9: Speed and acceleration as function of time (up) and distance (down), recorded for the second intersection, before converting to roundabout

In *Fig. 9* and also in *Fig. 10*, left, can be seen that before converting the intersection to roundabout, the distance traveled was shorter but the time needed to pass through the intersection was very different, in many cases longer than for roundabouts (*Fig. 10*, right).

As result of converting the signalized intersection into two successive roundabouts, when turning left (entering the intersection from south), the average time needed to pass through the intersection is shorter with 9 seconds, and the distance traveled is longer with 40 meters.

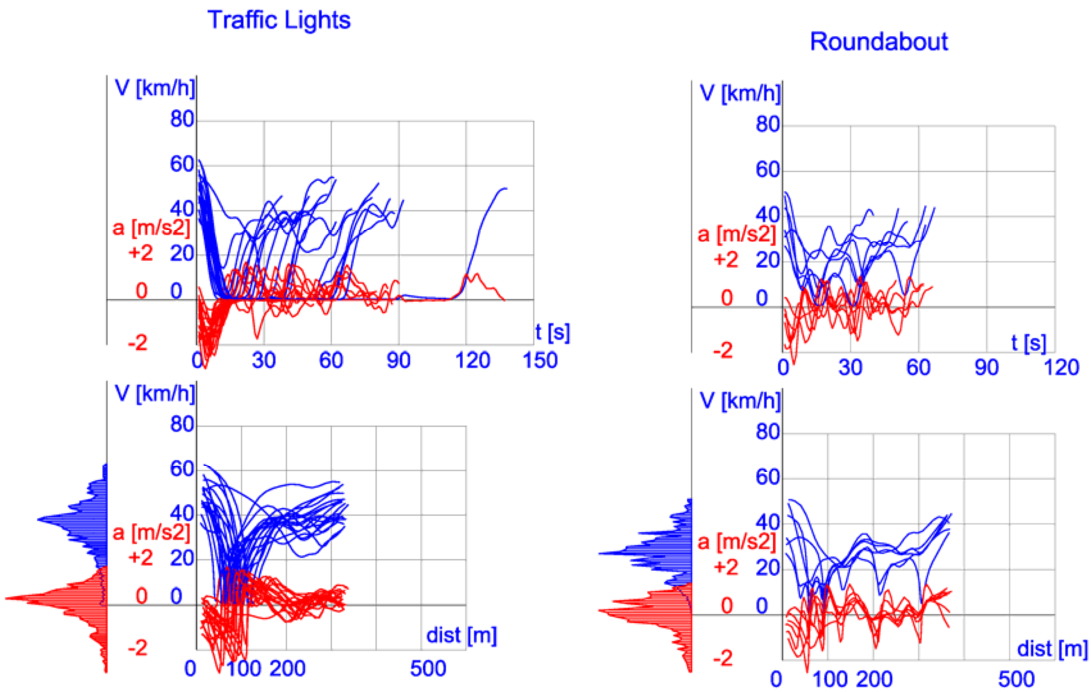

Fig. 10: Comparison between signalized intersection and roundabout (second intersection)

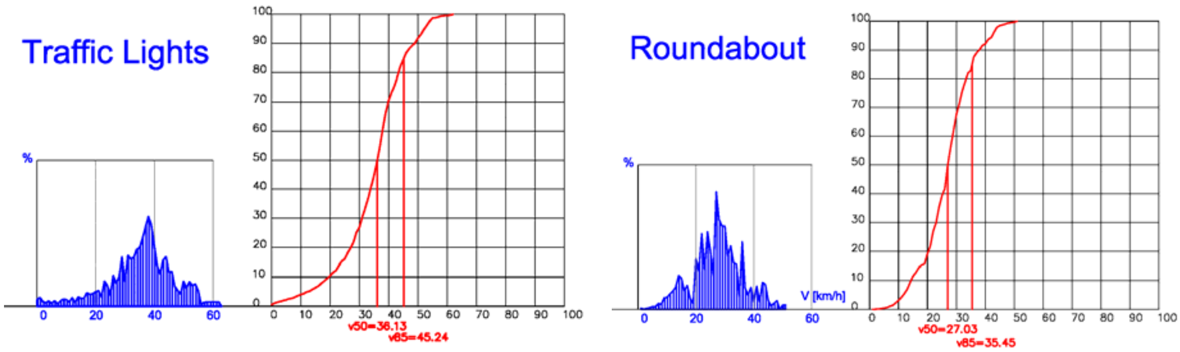

Fig. 11: Ascertaining of v_{50} and v_{85} for signalized intersection and roundabout (second intersection)

Table 2 – Comparison between traffic lights and roundabout, second intersection

Road segment length	Variant	Distance-mean speed	Mean acceleration	Speed v_{50} (km/h)	Speed v_{85} (km/h)
330 - 370 m	Traffic lights	35.20 km/h	0.40 m/s^2	36.13 km/h	45.24 km/h
	Roundabout	27.32 km/h	0.57 m/s^2	27.36 km/h	35.07 km/h
	Variation %	-22.39%	**42.50%**	-24.27%	-22.48%

The results of this comparative analysis of the two intersection variants (signalized with traffic lights versus two roundabouts), for the same intersection location, are given in *Table 2*. The mean distance-speed is decreased with about 22% and the mean acceleration is increased with 42.5% in case of the roundabout. The values of v_{50} and v_{85} are also lower in case of roundabout than in case of signalized intersection.

An important issue is to know how many passings through the roundabout are necessary to calculate the statistical parameters, to be compared with the previous variant (signalized intersection with traffic lights), for which there were already made many records. As shown in *Fig. 12*, the distance-mean speed does not change significantly as the number of records is increased (and the number of speed measuring points is increased too). The diagrams in this figure represent the probability density of speed, as function of distance, for different record numbers.

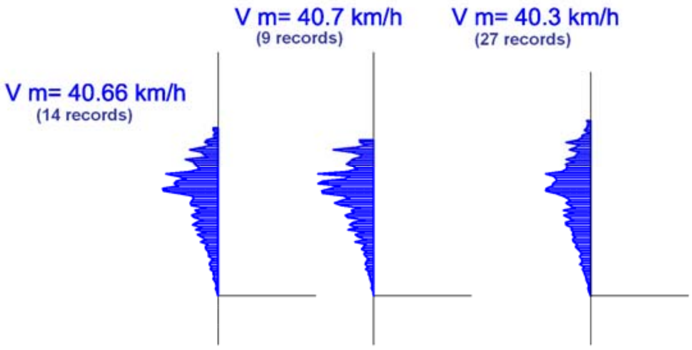

Fig. 12: The influence of the measurements numbers on the calculated average speed

In order to know the effect of each type of intersection on the environment it can be calculated the level of emissions. It is known that the emission levels (NO_x, CO and HC) depend by speed and acceleration. Using a custom software function implemented in Lisp language, it was ascertained the average level of hydrocarbons (2). For the first intersection, the average level of instantaneous HC emission was 1.54 mg/s in case of signalised intersection and 2.45 mg/s in case of roundabout. Of course, these values are approximate only and the real pollution level depends also by the emissions of the individual vehicles. For this study it was considered a theoretical vehicle.

For the second intersection, the average level of instantaneous HC emission was 1.18 mg/s in case of signalised intersection and 1.19 mg/s in case of roundabout. These values are very close and it is obvious that if the vehicle needs a shorter time to pass through the intersection the total emission level will be lower.

CONCLUSIONS

Since the travel speed is lower in case of roundabout than in case of the same intersection signalized with traffic lights, it may be considered that the roundabout is safer (9). But the speed is not the only factor of risk. The roundabouts analysed above have three lanes, so there are much more conflict points than in case of a single lane. Before converting the intersection into roundabout the move of pedestrians was coordinated by dedicated traffic lights. In case of roundabout, the pedestrians are more exposed. So, the roundabouts are not safer than signalized intersections, except the simple case of the roads with a single lane.

An important conclusion resulted from this comparative analysis is the significant increase of acceleration in case of roundabout. This will lead to an increase of the noise level in that intersection, and this means that it is not recommended to change an intersection into roundabout, as a noise reduction measure. This conclusion applies for intersections located inside cities, with intense traffic flow.

Regarding the chemical pollution, the acceleration influences also the emission level in a higher measure than the speed. In the first case, when going ahead through intersection, the average emission level was ingreased significantly after converting to roundabout; in the second case (left turn) the average emission level is almost the same for signalized intersection and roundabout, and since the time is shorter, it is expected a decrease in the total amount of pollutants.

However, this study is only a part of a larger analysis and the main goal of the paper is to present the working method and to show the first results.

REFERENCES

(1) Covaciu, D.; Florea, D.; Preda, I.; Timar, J.: *Using GPS Devices for Collecting Traffic Data*. SMAT2008 International Conference, Craiova, 2008.

(2) Covaciu, D.: *Solutions on the Study Of Dynamic and In-Traffic Behaviour of Automotive Vehicles Through CAD/PLM and GPS Integration*, PhD Thesis, Transilvania University of Brasov, 2010.

(3) Covaciu, D.; Preda, I.; Florea, D.; Timar, J.; Câmpian, V.: *Analysis of a Driving Cycle Proposed for Brasov City*. CONAT2010 International Congress, Braşov, 2010.

(4) Covaciu, D.: *Use of GPS and CAD in Vehicle Dynamics Study*. VDM Verlag, Saarbruecken, ISBN: 978-3-639-35589-5, 2011.

(5) Filip, N.: *Ingineria Traficului Rutier (Road Traffic Engineering)*. Editura Mediamira, Cluj-Napoca, 2010.

(6) Florea, D.; Cofaru, C.; Covaciu, D.; Timar, J.: *Data Acquisition Methods for Estimate the Noise Generated by the Road Traffic*. 3rd WSEAS Conference on Urban Planning and Transportation UPT 2010, Corfu, Greece, 2010.

(7) Preda, I.; Ciolan, Gh.; Covaciu, D.: *Systems Based on GPS Devices Used for Vehicles Dynamic-Behaviour Study*. "Intelligent Transportation Systems ITS-Romania-2009" International Conference, Bucuresti. ISBN 978-606-501-026-0, 2009.

(8) Timar, J.: *Studies and Researches Regarding the Optimization of Urban Traffic Flows*, PhD Thesis, Transilvania University of Brasov, 2010.

(9) ***, *Myths & Facts about Roundabouts*, http://www.alaskaroundabouts.com/

ACKNOWLEDGEMENT

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU POSTDOC-DD, ID59323.