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Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

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Faculty of Civil Engineering
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IMPACT OF NEW BUILT ROUNDABOUTS ON ENVIRONMENTAL IN CITY OF VINKOVCI

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Abstract

By development of road traffic and all increasing demand for transport, new requirements to meet that same transport demands emerge. Many roads and intersections fail to meet the increasing demands of traffic and thus contribute to an unstable and inefficient traffic flow, increased number of traffic accidents, environmental pollution and the resulting adverse impact on the economy. Among many solutions, roundabouts have proved themselves in many cases to be one of the most successful. In this study the research was conducted on newly built roundabouts that replaced traffic light signalized and unsignalized intersections at two locations in the town of Vinkovci. Collected traffic and project data were analyzed and processed with the help of aaSIDRA analytic deterministic model in order to obtain comparison results for fuel consumption, waiting time and harmful exhaust emissions of CO_2, NOx, CO and HC for the past and present state of the intersection. After comparing the results, it was concluded that the new roundabouts have proved themselves as the best solution for reducing adverse effects of traffic and, as such, represent the future of further construction.

Keywords: roundabouts, simulation, waiting time, fuel consumption, emissions of harmful gases,CO_2, NOx, CO, HC

1 Introduction

The traffic is highly valued and necessary part of modern society, but its rapid expansion has been identified as a major cause of unwanted side effects. Traffic congestion makes cities less pleasant place to live in and reduces transport efficiency, thus increasing travel time, fuel consumption and driver stress. Organizing traffic represents an environmental, economic and political problem. It is important to establish an economical and efficient transport network while causing as little negative consequences as possible, particularly the negative influence of traffic on man and the environment. However, due to vehicle exhaust gases the traffic heavily influences the environment, thus representing one of the tasks that traffic engineers and technologists need to solve. Exhaust emissions from motor vehicles contain a wide range of pollutants, of which the most important are carbon monoxide (CO), nitrogen oxides (NOx), carbon dioxide (CO_2), sulfur oxides (SOx), hydrocarbons (CH) or volatile organic compounds (VOC) and particulate matter (PM) which, through their chemical composition, significantly affect air quality and human health. The amount of emissions of harmful exhaust gases vary depending on the total frequency of traffic, type of intersection control, behavior of participants and the characteristics of the vehicle .
The road intersections are places of deceleration and unnecessary traffic flow stops, resulting in an increased fuel consumption, lost time and creation of a certain amount of harmful exha-

ust gases. The roundabouts have appeared as a positive solution to reducing the negative traffic effects. When compared to other classical intersections, the intersections with roundabouts enable a steady stream of vehicles moving through without unnecessary stopping, unlike other types of leveled intersections where the flow of vehicles must stop and wait to be allowed free entry into the intersection. This problem mainly occurs at intersections containing traffic lights with an enforced traffic flow stops and changes in the signal plan. To check the effects of roundabouts on the environment in this study, we have analyzed the two newly constructed roundabouts that have replaced both the signalized and unsignalized intersection in the town of Vinkovci. For a comparison of the present and past state of the intersection we have used all of the important efficiency indicators such as fuel consumption, waiting-time and harmful exhaust emissions of CO_2, NOx, CO and HC, obtained by using aaSIDRA analytic deterministic model based on collected traffic and project data on the observed intersections. The research results obtained will serve as an answer to the question of which intersection type has more favorable environmental impact and represents the optimal solution for the future planning and organization of traffic.

2 An overview of previous researches

Previous studies directly related to the topic of the impact of an existing roundabouts on the environment and the economy are based on mutual comparison of leveled intersections via environmental (fuel consumption, harmful exhaust gases emissions) and traffic (waiting time, the number of unnecessary stops) criteria.

In a study conducted by the author Mustafa et.al (1993) it was concluded that there exists a direct relationship between the quantity of exhaust gases and the frequency of traffic at intersections regardless of the type of signaling installed. Conducted simulations have showed that both signalized and unsignalized intersections produce up to 50 % higher amounts of toxic emissions than the ones with roundabouts [1]. Várhelyi (2002) has examined the effects of small roundabouts that have replaced signalized and unsignalized intersections, on harmful exhaust emissions, fuel consumption, vehicle waiting time and the number of unnecessary vehicle stops. Roundabouts that have replaced signalized intersections have effectuated results in reducing vehicle waiting time for 11 seconds per vehicle as well as in the number of unnecessary stops, which declined from 63 % to 26 % of the total number of vehicles at the intersection. Emission of carbon monoxide (CO) was reduced by 29 %, nitrogen oxide (NOx) decreased by 21 % and fuel consumption per car has been reduced by 28 %. Roundabouts that have replaced unsignalized intersections haven't effectuated results with respect to reducing the quantity of harmful exhaust gases. Emission of carbon monoxide (CO) increased by 6 %, nitrogen oxide (NOx) increased by 4 %, and fuel consumption per car increased by 3 % [2]. Retting et.al. (2002) has conducted a survey in which he concluded that roundabouts that have replaced three unsignalized intersections have reduced waiting times by 13-23%, and the number of unnecessary stops by 14-37% [3]. On three unsignalized intersections remodeled into roundabout ones, Mandavilli et.al (2003) has proven a reduction in the harmful exhaust gases emission of carbon monoxide (CO) of up to 32 %, nitrogen oxide (NOx) of up to 34 %, carbon dioxide (CO2) of up to 37% and hydrocarbons (CH) of up to 42 % [4]. Sides et.al (2005) has proved that six classic types of intersections (three signalized and three unsignalized) refurbished into roundabouts, on an annual basis enables fuel savings of 67,142 liters and reductions of harmful exhaust emissions of CO_2, NOx, CO and HC by 179,440 kg [5]. The research conducted according to Bergh (2005) estimated that savings in waiting time of 62-72 % would be achieved should five out of ten signalized intersections get reconstructed in the roundabout ones, which represents the approximate equivalent of 325 000 hours of waiting time in reduced delays at the annual level [6].

3 Collecting, processing and display of traffic data

For a comparison of fuel consumption, waiting time and harmful exhaust emissions of CO_2, NOx, CO and HC for the past and present states of the selected intersections, we chose two intersections with roundabouts that have replaced one signalized and one unsignalized intersection in the town of Vinkovci. The intersection with roundabout which has replaced the signalized intersection (V2) is located on the corner of Kneza Mislava street – Lapovačka street – Ivana Gorana Kovačića street and Ljudevita Gaja street, while the unsignalized intersection (V1) which was replaced by the intersection with roundabout is located on the corner of Hrvoja Vukčića Hrvatinića street and Hansa-Dietricha Genschera street. Figure 1. shows the present and past state of the intersection at the observed locations.

Past state at the V_1 location

Past state at the V_2 location

Present situation at the V_1 location

Present state at the V_2 location

Figure 1 Display of the present and past state at the intersection on V_1 and V_2 locations

To collect traffic data via video recording on mentioned V1 and V2 roundabouts sites, we used sports video camera Prestigio RoadRunner 700x for its technical characteristics and simplicity (compact size, wide angle coverage, autonomy of use, high resolution of full HD recording and easy video processing on the PC). Video recording of traffic at roundabouts was carried out during the working day on December 22nd 2013, over a four hour peak period (6:00 AM to 8:00 AM and 3:00 PM to 5:00 PM). Videos were reviewed manually and traffic data was collected on the type of vehicles (flow structure) and the number of vehicles flowing through the roundabout and approach (due to low frequency, the pedestrian traffic was not analyzed). The collected traffic data from morning and afternoon peak loads are reduced to one peak hour. At the V1 location, the peak hour for the morning period from 6:00 AM to 8:00 AM is located in the time interval between 6:30 AM and 7:30 AM, and on the V2 location in the time interval between 7:00 AM and 8:00 AM. The peak hour for the afternoon period from 3:00 PM to 5:00 PM is located in the time interval between 4:00 PM and 5:00 PM for the V1 location, and for the V2 location in the time interval between 3:00 PM and 4:00 PM. Table 2 shows the peak hour for the morning and afternoon period at the V1 location and Table 3 shows the peak hour for the morning and afternoon period at the V2 location. The collected traffic data are implemented in the aaSidra analytic deterministic model for simulating the present situation, and the same traffic data were used to simulate the past state at the intersections.

Table 1 The peak hour for morning and afternoon period at V_1 location

LOCATION V1																					
		APPROACH 1 (NORTI				APPROACH 2 (EAST)					APPROACH 3(S					APPROACH 4(WEST)					
	1-2	1-3	1-4	1-1	∑	2-3	2-4	2-1	2-2	∑	3-4	3-1	3-2	3-3	∑	4-1	4-2	4-3	4-4	∑	∑
6:30-6:45	2	79	18	2	101	5	5	2	0	12	35	59	4	0	98	24	4	20	0	48	259
6:45-7:00	4	89	18	1	112	1	5	1	0	7	43	80	5	1	129	19	4	35	0	58	306
7:00-7:15	6	55	12	2	75	4	3	3	0	10	36	31	11	4	82	20	3	31	0	54	221
7:15-7:30	3	59	22	2	86	2	3	2	0	7	32	43	1	3	79	11	3	33	0	47	219
ukupno	15	282	70	7	374	12	16	8	0	36	146	213	21	8	388	74	14	119	0	207	1005
%	4.01	75	19	88	0	33	44.4	22	0	0	38	55	5.4	2.1	0	36	6.76	57	0	0	0
phf	0.63	0.79	0.80	0.88	0.83	0.60	0.80	0.67	0.00	0.75	0.85	0.67	0.48	0.50	0.75	0.77	0.88	0.85	0.00	0.89	0.82
car	15	239	55	6	315	12	15	8	0	35	127	174	20	8	329	62	13	97	0	172	851
%cars	100	85	79	86	84.2	100	93.8	100	0	97.2	87	82	95	100	85	84	92.9	82	0	83.1	84.7
heavy v.	0	30	15	1	46	0	1	0	0	1	15	18	0	0	33	10	0	17	0	27	107
%heavy v.	0	11	21	14	12.3	0	6.25	0	0	2.78	10	8.5	0	0	8.5	14	0	14	0	13	10.6
motorcycle	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	0	0	0	1	3
%motor.	0	0	0	0	0	0	0	0	0	0	0.7	0.5	0	0	0.5	1.4	0	0	0	0.48	0.3
bus	0	11	0	0	11	0	0	0	0	0	3	8	0	0	11	0	0	5	0	5	27
%buses	0	3.9	0	0	2.94	0	0	0	0	0	2.1	3.8	0	0	2.8	0	0	4.2	0	2.42	2.69
bicycles	0	2	0	0	2	0	0	0	0	0	0	12	1	0	13	1	1	0	0	2	17
%bic.	0	0.7	0	0	0.53	0	0	0	0	0	0	5.6	4.8	0	3.4	1.4	7.14	0	0	0.97	1.69
LOCATION V1																					
		APPROACH 1 (NORTI				APPROACH 2 (EAST)					APPROACH 3(SOUTI					APPROACH 4(WEST)					
	1-2	1-3	1-4	1-1	∑	2-3	2-4	2-1	2-2	∑	3-4	3-1	3-2	3-3	∑	4-1	4-2	4-3	4-4	∑	∑
16:00-16:15	3	71	13	2	89	6	1	4	0	11	43	84	6	1	134	20	4	58	0	82	316
16:15-16:30	1	39	13	0	53	4	1	2	0	7	25	70	6	0	101	13	6	37	0	56	217
16:30-16:45	4	61	8	1	74	8	7	5	0	20	33	67	5	0	105	7	6	41	0	54	253
16:45-17:00	4	66	15	2	87	5	2	2	0	9	33	57	1	1	92	13	4	40	0	57	245
ukupno	12	237	49	5	303	23	11	13	0	47	134	278	18	2	432	53	20	176	0	249	1031
%	3.96	78	16	38	0	49	23.4	28	0	0	31	64	4.2	0.5	0	21	8.03	71	0	0	0
phf	0.75	0.8	0.8	0.6	0.85	0.7	0.39	0.7	0	0.59	0.8	0.8	0.8	0.5	0.8	0.7	0.83	0.8	0	0.76	0.82
car	11	212	44	4	271	22	10	13	0	45	123	235	16	1	375	47	18	154	0	219	910
%cars	91.7	89	90	80	89.4	96	90.9	100	0	95.7	92	85	89	50	87	89	90	88	0	88	88.3
heavy v.	0	12	5	0	17	0	1	0	0	1	7	17	0	1	25	5	0	10	0	15	58
%heavy v.	0	5.1	10	0	5.61	0	9.09	0	0	2.13	5.2	6.1	0	50	5.8	9.4	0	5.7	0	6.02	5.63
motorcycle	1	6	0	1	8	1	0	0	0	1	2	6	1	0	9	1	0	4	0	5	23
%motor.	8.33	2.5	0	20	2.64	4.3	0	0	0	2.13	1.5	2.2	5.6	0	2.1	1.9	0	2.3	0	2.01	2.23
bus	0	3	0	0	3	0	0	0	0	0	1	9	0	0	10	0	1	3	0	4	17
%buses	0	1.3	0	0	0.99	0	0	0	0	0	0.7	3.2	0	0	2.3	0	5	1.7	0	1.61	1.65
bicycle	0	4	0	0	4	0	0	0	0	0	1	11	1	0	13	0	1	5	0	6	23
%bic.	0	1.7	0	0	1.32	0	0	0	0	0	0.7	4	5.6	0	3	0	5	2.8	0	2.41	2.23

Table 2 The peak hour for morning and afternoon period at V_2 location

LOCATION V_2																					
	APPROACH 1 (N)					APPROACH 2 (E)					APPROACH 3(S)					APPROACH 4(W)					
	1-2	1-3	1-4	1-1	∑	2-3	2-4	2-1	2-2	∑	3-4	3-1	3-2	3-3	∑	4-1	4-2	4-3	4-4	∑	∑
7:00-7:15	29	34	11	0	74	11	18	10	0	39	5	27	25	0	57	11	51	12	0	74	244
7:15-7:30	32	41	16	0	89	22	29	9	0	60	10	28	27	2	67	14	60	15	1	90	306
7:30-7:45	19	32	13	0	64	16	27	12	0	55	15	39	23	0	77	13	49	20	0	82	278
7:45-8:00	23	23	16	0	62	13	21	11	0	45	16	28	17	0	61	14	55	7	0	76	244
sum	103	130	56	0	289	62	95	42	0	199	46	122	92	2	262	52	215	54	1	322	1072
%	36	45	19	0	0	31	47.7	21	0	0	17.6	47	35.1	0.76	0	16	66.8	17	0.311	0	0
phf	0.80	0.79	0.88	0.00	0.81	0.70	0.82	0.88	0.00	0.83	0.72	0.78	0.85	0.25	0.85	0.93	0.90	0.68	0.25	0.89	0.88
car	85	110	46	0	241	57	76	32	0	165	41	98	79	2	220	38	188	47	1	274	900
%cars	83	85	82	0	83	92	80	76	0	83	89.1	80	85.9	100	84	73	87.4	87	100	85.1	83.96
heavy v.	10	14	7	0	31	5	18	4	0	27	5	16	10	0	31	11	21	6	0	38	127
%heavy v.	9.7	11	13	0	11	8.1	18.9	9.5	0	14	10.9	13	10.9	0	11.8	21	9.77	11	0	11.8	11.85
motorcycle	1	1	0	0	2	0	1	0	0	1	0	0	0	0	0	2	2	1	0	5	8
%motor.	1	0.8	0	0	0.7	0	1.05	0	0	0.5	0	0	0	0	0	3.8	0.93	1.9	0	1.55	0.746
bus	5	2	3	0	10	0	0	6	0	6	0	6	0	0	6	1	0	0	0	1	23
%buses	4.9	1.5	5.4	0	3.5	0	0	14	0	3	0	4.9	0	0	2.29	1.9	0	0	0	0.31	2.146
bicycle	2	3	0	0	5	0	0	0	0	0	0	2	3	0	5	0	4	0	0	4	14
%bic.	1.9	2.3	0	0	1.7	0	0	0	0	0	0	1.6	3.26	0	1.91	0	1.86	0	0	1.24	1.306

LOCATION V_2																					
	APPROACH 1 (N)					APPROACH 2 (E)					APPROACH 3(S)					APPROACH 4(W)					
	1-2	1-3	1-4	1-1	∑	2-3	2-4	2-1	2-2	∑	3-4	3-1	3-2	3-3	∑	4-1	4-2	4-3	4-4	∑	∑
15:00-15:15	36	46	28	0	110	31	48	17	0	96	16	41	37	0	94	25	46	15	0	86	386
15:15-15:30	39	28	27	0	94	21	57	10	0	88	18	35	18	0	71	11	65	12	0	88	341
15:30-15:45	27	28	27	0	82	16	35	9	0	60	20	33	29	1	83	18	50	9	0	77	302
15:45-16:00	20	20	21	0	61	5	34	6	0	45	14	28	21	0	63	11	62	4	0	77	246
sum	122	122	103	0	347	73	174	42	0	289	68	137	105	1	311	65	223	40	0	328	1275
%	35	35	30	0	0	25	60.2	15	0	0	21.9	44	33.8	0.32	0	20	68	12	0	0	0
phf	0.8	0.7	0.9	0	0.8	0.6	0.76	0.6	0	0.8	0.85	0.8	0.71	0.25	0.83	0.7	0.86	0.7	0	0.93	0.826
car	104	101	90	0	295	68	154	36	0	258	66	122	95	1	284	55	201	35	0	291	1128
%cars	85	83	87	0	85	93	88.5	86	0	89	97.1	89	90.5	100	91.3	85	90.1	88	0	88.7	88.47
heavy v.	3	10	12	0	25	3	15	2	0	20	2	5	5	0	12	9	15	5	0	29	86
%heavy v.	2.5	8.2	12	0	7.2	4.1	8.62	4.8	0	6.9	2.94	3.6	4.76	0	3.86	14	6.73	13	0	8.84	6.745
motorcycle	5	2	0	0	7	2	3	0	0	5	0	2	2	0	4	1	4	0	0	5	21
%motor.	4.1	1.6	0	0	2	2.7	1.72	0	0	1.7	0	1.5	1.9	0	1.29	1.5	1.79	0	0	1.52	1.647
bus	8	7	1	0	16	0	0	2	0	2	0	3	1	0	4	0	0	0	0	0	22
%buses	6.6	5.7	1	0	4.6	0	0	4.8	0	0.7	0	2.2	0.95	0	1.29	0	0	0	0	0	1.725
bicycle	2	2	0	0	4	0	2	2	0	4	0	5	2	0	7	0	3	0	0	3	18
%bic.	1.6	1.6	0	0	1.2	0	1.15	4.8	0	1.4	0	3.6	1.9	0	2.25	0	1.35	0	0	0.91	1.412

From the design documentation for the observed intersections, provided to us by the Town of Vinkovci, we've gathered the project sizes of: outer radius, that is the intersection's inner radius, the width of the circular roadway, the width of the entrance and exit parts of approach , the width of the approach lane, the width of the isles or dividers in approach , the entrance angle , the entrance and exit's round off, the length of the extension, sharpness of the extension, lateral circular inclination of the track and drainage, which were implemented in the aaSIDRA analytic deterministic model.

4 aaSIDRA analytic deterministic model

In making of this study we've used aaSIDRA analytic deterministic model (signalized and unsignalized Intersection Design and Research Aid) developed by Akcelik and Associates for the design and evaluation of various forms of at-grade intersections (circular, signalized and unsignalized) [7].

On basis of certain input data, the program calculates output values and, among other things, calculates the level of service at the intersection, waiting time, fuel consumption, environmental impact, and ultimately the very viability of the intersection. Depending on the structural characteristics of the intersection it is possible to switch between the types of intersections depending on user requirements, and therefore it is possible to analyze signalized, unsignalized, circular, four-spoke and T-shaped intersections. It is as well possible to set the main ways and alternate the signaling at the intersection, and thus analyze a particular option of an intersection arrangement.

For the purposes of this study we used the input data (project- design elements intersections and traffic data) in aaSIDRA program through which we've reached the output data (waiting time, harmful exhaust emissions, fuel consumption). To estimate fuel consumption and harmful exhaust emissions, aaSIDRA program uses four basic sequences of driving through an intersection, acceleration, deceleration, idling and driving (see Figure 2) for each driving lane, while taking into account the light and heavy vehicles used to model the consumption and emissions of harmful exhaust gases.

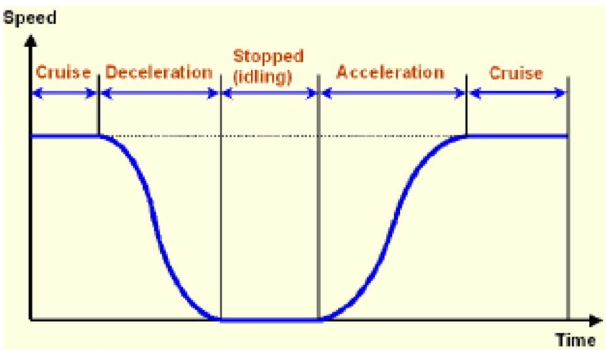

Figure 2 Four basic driving sequences

5 Output data for the present and past state of the intersection

aaSIDRA program output data for the quantities of harmful exhaust emissions of CO_2, NOx, CO and HC, the waiting time and fuel consumption for the entire circular and unsignalized intersection for morning and afternoon peak hour on the V1 location is shown in Table 3. Table 4. shows all output data for the entire circular and signalized intersection at the V2 location for morning and afternoon peak hour.

From Table 3. it can be concluded that there are several significant changes in relation to the comparison of the past and present state of the intersection. Quantities of carbon monoxide (CO) have been reduced by 6% to 10%, nitrogen oxide (NOx) by 6.7%, while the amount of hydrocarbons (HC) increased by 1.5% to 3.3%, and the waiting time for 17% to 33%. According to Table 4., it can be concluded the roundabout that has replaced the signalized intersection, has in all output parameters significantly reduced the waiting time at the intersection, as well as the amount of harmful exhaust emissions and unnecessary fuel consumption.

Table 3 Display of output dana for morning and afternoon peak hour on the V_1 location

Location V1 morning results 6:30 AM – 7:30 AM				
Pollutant	Roundabout	Unsignalized intersection	Difference	Percentage (%)
Carbon dioxide (CO2) (kg/h)	212,7	214,7	-2 (kg/h)	-0,93
Carbon monoxide (CO) (kg/h)	12,3	13,2	-0.9 (kg/h)	-6,82
Hydrocarbons (HC) (kg/h)	0,273	0,269	0.004 (kg/h)	1,49
Nitrogen oxide (NOX) (kg/h)	0,471	0,505	-0.034 (kg/h)	-6,73
Fuel consumption (l/h)	84,8	85,4	-0.6 (l/h)	-0,70
Waiting time (s)	9,9	8,4	1.5 (s)	17,86
Location V1 afternoon results 3:00 PM – 4:00 PM				
Pollutant	Roundabout	Unsignalized intersection	Difference	Percentage (%)
Carbon dioxide (CO2) (kg/h)	180,2	175	5.2 (kg/h)	2,97
Carbon monoxide (CO) (kg/h)	8,72	9,66	-0.94 (kg/h)	-9,73
Hydrocarbons (HC) (kg/h)	0,248	0,24	0.01 (kg/h)	3,33
Nitrogen oxide (NOX) (kg/h)	0,367	0,367	0.00 (kg/)	0,00
Fuel consumption (l/h)	71,8	69,8	2 (l/h)	2,87
Waiting time (s)	8,8	6,6	2.2 (s)	33,33

Table 4 Display of output dana for morning and afternoon peak hour on the V_2 location

Location V1 morning results 6:30 AM – 7:30 AM				
Pollutant	Roundabout	Unsignalized intersection	Difference	Percentage (%)
Carbon dioxide (CO2) (kg/h)	252,8	264,6	-11.8 (kg/h)	-4,46
Carbon monoxide (CO) (kg/h)	16,64	18,55	-1.91 (kg/h)	-10,30
Hydrocarbons (HC) (kg/h)	0,32	0,347	-0.027 (kg/h)	-7,78
Nitrogen oxide (NOX) (kg/h)	0,615	0,666	-0.051 (kg/h)	-7,66
Fuel consumption (l/h)	100,5	105,2	-4.7 (l/h)	-4,94
Waiting time (s)	12,2	14,6	-2.4 (s)	-16,44
Location V1 afternoon results 3:00 PM – 4:00 PM				
Pollutant	Roundabout	Unsignalized intersection	Difference	Percentage (%)
Carbon dioxide (CO2) (kg/h)	260	267,5	-7.5 (kg/h)	-2,80
Carbon monoxide (CO) (kg/h)	16,12	17,04	-0.92 (kg/h)	-5,40
Hydrocarbons (HC) (kg/h)	0,363	0,383	-0.02 (kg/h)	-5,22
Nitrogen oxide (NOX) (kg/h)	0,585	0,605	-0.02 (kg/h)	-3,31
Fuel consumption (l/h)	103,6	106,6	-3 (l/h)	-2,81
Waiting time (s)	14,1	17,9	-3.8 (s)	-21,23

6 Conclusion

According to the stated in this study, it can be concluded that the newly built circular intersection replacing the unsignalized one has partly contributed to the reduction of exhaust emissions, fuel consumption and waiting time. Circular intersection that replaced the signalized intersection has significantly contributed to the reduction of exhaust emissions, fuel consumption and waiting time. It is therefore necessary to undertake additional research related to the reconstruction of the existing unsignalized intersections into signalized or circular ones, that is it is necessary to develop a scientific methodology for justification of reconstructing the existing unsignalized and signalized intersections into circular intersections.

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