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COMPARATIVE ANALYSIS OF PEDERSTRIAN INFLUENCE ON ROUNDABOUTS BASED ON HCM 2010, HCM 2016 CALCULATIONS AND REAL-WORLD MEASUREMENTS

Keywords

Roundabouts
Pedestrian
Capacity
HCM 2010
HCM 2016

Abstract

Roundabouts are meant to intelligently control traffic flow at intersections without the use of stop signs or traffic lights. Roundabouts are gaining popularity due to the benefits of reducing accidents and enhancing efficiency. The capacity of a roundabout is the most important metric to consider while evaluating its performance. The presence of pedestrians utilizing the crosswalk at a roundabout approach reduces the approach's entry capacity. A roundabout's capacity is heavily reliant on pedestrians. In this paper, a comparative analysis of pedestrian influence on roundabouts capacity was performed using HCM 2010 and HCM 2016 calculations and real-world measurements.

1. INTRODUCTION

The LOS method, according to HCM 2010 [1] and HCM 2016 [2], is designed to translate complex road performance and experience factor into a single indicator that reflects the quality of service perceived by road users. The indicator is calculated using mathematical models based on various service measures and consists of a six-level evaluation system, with scores ranging from A (best conditions) to F (worst conditions). The LOS method is used by operational agencies to assess whether the performance of road facilities is satisfactory and also whether changes in the future would tend to be supported by the general public [3].

In the later versions of the HCM the LOS concept was extended to pedestrians, enabling the assessment of the quality of service provided on walkways, pedestrian crossings, and other types of pedestrian facilities, reflecting pedestrians' perceptions of the surroundings and of the traffic conditions. The relevant PLOS method, first introduced by Fruin [4] and refined thereafter, quantifies the performance based on complex factors that may influence the pedestrian movements and walking experience, and, just like VLOS, delivers a score ranging from A to F [5].

The capacity of a roundabout is heavily dependent on pedestrians, who can impede traffic anytime they enter a crosswalk. If there are a lot of pedestrians crossing, cars must stop to let them pass. They may even block the roundabout's center circle, which lowers its capacity and quality of service.

This paper gives a comparative analysis of pedestrian influence on roundabout capacity, performed using HCM 2010 and HCM 2016 calculations and real-world measurements. Using microsimulation software and drones to record roundabout footage, all assessments were performed.

2. DATA COLLECTION

Depending on the fluctuations in vehicle traffic and pedestrian volume, the performance of a road facility may vary on different days and at different times of the day. During times of low traffic flow, a roadway could function satisfactorily (LOS D or more), but during periods of high traffic volume, the quality of service might deteriorate to unacceptable levels (LOS E or F). It is obvious that the latter is a more serious situation because any design seeks to address these times of underperformance. The analyzed intersection is in the city of Nis, in the central zone. It is the intersection of Nemanjic Boulevard and Vojvode Misic Street (Figure1).

Figure 1. The appearance of the analyzed intersection

The intersection is about 1.2 km from the city center by air. The crossroads represent a more frequent crossroads in the city since they are located on location that connects attractive zones of the city. Every approach has a pedestrian crossing. At the crossroads, traffic in both directions is allowed to run in all direction. Lane widths at the zone junctions are 3.3 meters on each of the four approaches, but they are 4.6 meters in the circle-shaped center of the intersection.

3. COMPARATION

The previous counting determined the peak period of the day at the analyzed intersection, and that time was from 16:00 to 17:00 when the recording was carried out. The analyzed roundabout was filmed from the air with a drone. Figure 4 shows an analyzed intersection with traffic flow on each approach.

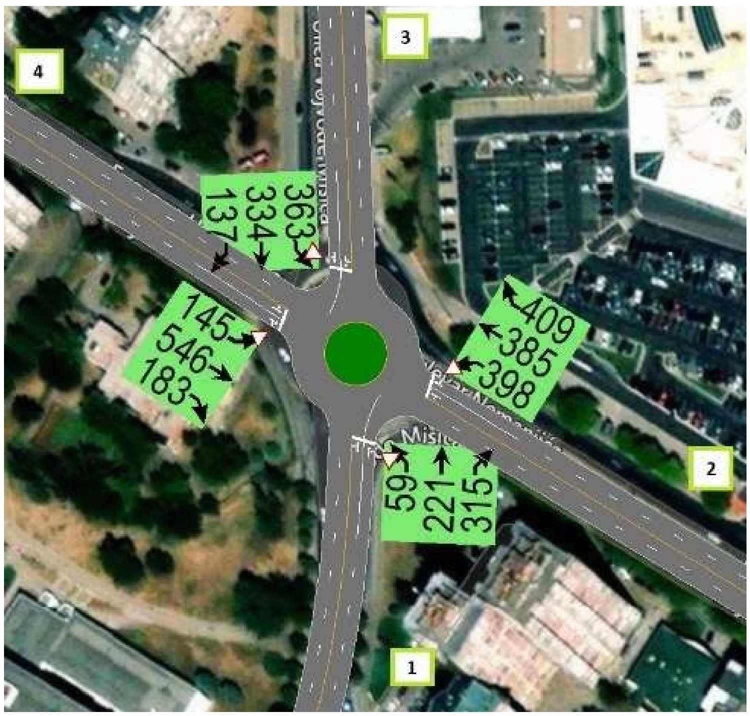

Figure 4. Analyzed intersection

Traffic and pedestrian counting were made for peak hour at all approaches. Results are given in the following tables. (Table 1, Table 2).

Table 1. Values of traffic flow at the roundabout

	Total number of vehicles on approaches by directions (15 min)							
	15min		15min		15min		15min	
	Ve	**Vex**	**Ve**	**Vex**	**Ve**	**Vex**	**Ve**	**Vex**
Approach 1	179	156	171	154	178	150	159	145
Approach 2	158	107	152	104	157	114	153	94
Approach 3	159	195	158	190	159	190	153	198
Approach 4	227	265	222	255	223	264	128	236

Table 2. Values of pedestrians at the roundabout

Number of pedestrians				
	15min	15min	15min	15min
Approach 1	85	72	83	89
Approach 2	97	89	85	103
Approach 3	109	112	102	116
Approach 4	127	131	124	125

Real-world measurements show the level of service H at the intersection without counting pedestrians and intersection capacity utilization of 129.7%.

HCM Unsignalized Intersection Capacity Analysis
3:

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Right Turn Channelized									MOYes			MOYes
Traffic Volume (veh/h)	145	546	183	398	385	409	59	221	315	363	334	137
Future Volume (veh/h)	145	546	183	398	385	409	59	221	315	363	334	137
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	158	593	199	433	418	445	64	240	342	395	363	149
Approach Volume (veh/h)		950			1296			304			758	
Crossing Volume (veh/h)		1191			462			1146			915	
High Capacity (veh/h)		532			962			552			667	
High v/c (veh/h)		1.79			1.35			0.55			1.14	
Low Capacity (veh/h)		405			780			422			521	
Low v/c (veh/h)		2.34			1.66			0.72			1.45	

Intersection Summary			
Maximum v/c High	1.79		
Maximum v/c Low	2.34		
Intersection Capacity Utilization	129.7%	ICU Level of Service	H

The HCM methods are based on empirical and theoretical models that describe the relationships between traffic demand, capacity, speed, density, and level of service. [6]

3.1. HCM 2010 findings

In contrast to the real-world measurements, HCM 2010 considers the number of pedestrians when determining an intersection's capacity. After calculation, the level of service F is obtained on all approaches. Although there is an unfavorable level of service F in all approaches, HCM 2010 displays a significantly better level of service compared to the real-world measurements 2010 quantifies the impact of pedestrians on entry capacity through an adjustment factor $f_{ped.}$ [7]

$$c_e = f_{ped} * c_{e,cir} \tag{1}$$

Table 3. Pedestrian adjustment factor in HCM 2010

Case	f_{ped}	
If $q_c > 881$	$f_{ped} = 1$	(a)
Else if, $n_{ped} < 101$	$f_{ped} = 1 - 0.000137\, n_{ped}$	(b)
Else	$f_{ped} = \frac{1119.5 - 0.715 q_c - 0.644 n_{ped} + 0.00073 q_c n_{ped}}{1068.6 - 0.654 q_c}$	(c)

n_{ped}: number of pedestrians per hour (ped/h), q_c: circulating flow (pc/h)

Intersection	
Intersection Delay, s/veh	119.0
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	950	1296	646	907
Demand Flow Rate, veh/h	993	1335	664	936
Vehicles Circulating, veh/h	1226	476	1193	946
Vehicles Exiting, veh/h	504	1032	1026	865
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	665	782	564	757
Ped Cap Adj	0.787	0.706	0.834	0.729
Approach Delay, s/veh	208.9	126.0	59.4	57.2
Approach LOS	F	F	F	F

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	TR	LT	TR	LT	TR	R	LT	TR	R
Assumed Moves	LT	TR	LT	TR	LT	TR	R	L	TR	R
RT Channelized							Yield			Yield
Lane Util	0.470	0.530	0.470	0.530	0.470	0.530		0.514	0.486	
Critical Headway, s	4.293	4.113	4.293	4.113	4.293	4.113		4.293	4.113	
Entry Flow, veh/h	467	526	627	708	148	167	349	403	381	152
Cap Entry Lane, veh/h	451	479	791	810	462	490	403	556	583	683
Entry HV Adj Factor	0.957	0.958	0.972	0.970	0.967	0.966	0.980	0.980	0.952	0.980
Flow Entry, veh/h	447	504	609	687	143	161	342	395	363	149
Cap Entry, veh/h	339	361	542	555	372	395	329	397	404	488
V/C Ratio	1.317	1.395	1.123	1.239	0.384	0.409	1.039	0.995	0.897	0.306
Control Delay, s/veh	193.4	222.7	103.7	145.9	17.5	17.3	96.9	76.6	54.5	12.1
LOS	F	F	F	F	C	C	F	F	F	B
95th %tile Queue, veh	21	25	20	26	2	2	12	12	9	1

3.2. HCM 2016 findings

According to HCM 2016, pedestrian impedance for roundabouts which are analyzed using values of the counted number of vehicles per hour, is calculated using eq (2)

$$f_{ped} = \frac{1119.5 - 0.715 v_{c,pce} - 0.644 n_{ped} + 0.00073 v_{c,pce} n_{ped}}{1068.6 - 0.654 v_{c,pce}} \tag{2}$$

The results obtained by the HCM 2016 methodology show the level of service F at the intersection. Compared to the HCM 2010 methodology, the intersection delay is 21.7% lower. HCM 2010 methodology at the NB approach shows an approach delay of 59.4 and a level of service of F on the other side. HCM 2016 methodology shows an approach delay of 34.8 and a level of service of D. This shows a significant difference, which is a 70% higher approach delay.

Intersection	
Intersection Delay, s/veh	93.2
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	950	1296	646	907
Demand Flow Rate, veh/h	993	1335	664	936
Vehicles Circulating, veh/h	1226	476	1193	946
Vehicles Exiting, veh/h	504	1032	1026	865
Ped Vol Crossing Leg, #/h	665	782	564	757
Ped Cap Adj	0.787	0.706	0.834	0.729
Approach Delay, s/veh	203.2	72.8	34.8	48.9
Approach LOS	F	F	D	E

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	TR	LT	TR	LT	TR	R	LT	TR	R
Assumed Moves	LT	TR	LT	TR	LT	TR	R	L	TR	R
RT Channelized							Yield			Yield
Lane Util	0.470	0.530	0.470	0.530	0.470	0.530		0.514	0.486	
Follow-Up Headway, s	2.667	2.535	2.667	2.535	2.667	2.535		2.667	2.535	
Critical Headway, s	4.645	4.328	4.645	4.328	4.645	4.328	349	4.645	4.328	152
Entry Flow, veh/h	467	526	627	708	148	167	482	403	381	825
Cap Entry Lane, veh/h	437	501	871	948	450	515	0.980	565	635	0.980
Entry HV Adj Factor	0.957	0.958	0.972	0.970	0.967	0.966	342	0.980	0.952	149
Flow Entry, veh/h	447	504	609	687	143	161	394	395	363	590
Cap Entry, veh/h	329	378	597	649	363	415	0.869	404	441	0.253
V/C Ratio	1.357	1.334	1.020	1.059	0.394	0.389	50.6	0.978	0.823	9.4
Control Delay, s/veh	211.0	196.3	68.2	76.8	18.2	16.0	F	71.7	40.3	A
LOS	F	F	F	F	C	C	9	F	E	1
95th %tile Queue, veh	22	24	16	19	2	2		12	8	

4. CONCLUSIONS

Roundabout capacity is significantly impacted by pedestrians since they are not subject to traffic lights or regulations. Specifically, in roundabouts, pedestrians have the right of way, and if possible, vehicles are required to stop for them to cross the street. HCM provides models and formulas for analyzing the capacity of pedestrian influence for entering roundabout lanes; however, the theoretical values obtained do not match the real values recorded on the field. This study compares the effects of pedestrians on roundabout capacity using observations from the real world and estimates from HCM 2010 and HCM 2016. All analyses were carried out using microsimulation software and drones to record roundabout visuals.

Values measured on-field indicate the level of service H, while the values obtained by the methodologies HCM 2010 and HCM 2016 show the level of service F. Entering the capacity adjustment factor for pedestrians into the HCM methodology results in better traffic conditions within the intersection because vehicles must stop to let pedestrians pass. The pedestrian impedance for roundabout, which is analyzed using values of the counted number of vehicles per hour by HCM 2016 methodology, shows considerable differences in approach delays compared to HCM 2010.

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