ISBN 978-93-84422-22-6
Proceedings of 2015 International Conference on Innovation in Civil and Structural Engineering (ICICSE 2015)
Istanbul (Turkey), June 3-4, 2015 pp. 127-133

Proposal of a Methodology for the Calculation of Mini-Roundabouts' Level of Service on Urban Areas

PhD. Alma AFEZOLLI[1], PhD. Elfrida SHEHU[1], and PhD. Igli KONDI[1]

Construction and Transport Infrastructure Department of Civil Engineering Faculty, Polytechnic University of Tirana[1]

krasniqi1@yahoo.com[1]; elfridaal@yahoo.com[1]; i.kondi@gmail.com[1]

***Abstract*:** *This paper aims to propose a survey methodology that allows the evaluation of the level of service of the mini - roundabouts. For such a definition, we will refer to the concept of the delay suffered by users when crossing an intersection. Taking into consideration that, because of the absence of real exchange areas, the "operation" of the mini - roundabouts are affected from the delays accumulated by users queued before entering the ring gyratory, due to the "block" caused by vehicles in transit on the ring. The theoretical approach shall report the application of queuing theory, while experimental approach shall provide an empirical law from the findings of delay in two mini - roundabouts located in the urban area of the Durres city. The identification of vehicle values flows play a key role, which is a goal that we want to achieve in a near future, as well.*

Keywords: *roundabout, road, flow, traffic, delay, service*

1. Introduction

The intersections are singular points for the road networks that are located on internal or outside the city on connecting roads. In these points are included different roads belonging to different contexts: focusing, therefore, on conflicts between the movements of vehicular traffic, pedestrian and cycling.

Depending from the operating speed and magnitude of pedestrian flows, it is necessary to provide a series of actions, in order to ensure a certain level of service, as an indicator of performance in terms of safety and comfort, offered to road consumers.

There are chosen three types of interventions to adjust the intersections:

- interventions to the circulation regulations (signals of priority or obligation of stopping);
- installation of semaphores;
- radical changes in geometry, creating, for example, a one level roundabout, separating the multi-level traffic flows with different types of junctions. [1]

Currently, in urban areas, the roundabout intersections are one of the solutions relied and adopted to address the problems of road intersections. The success consists in a mix of factors: identification of the place, speed reduction, improving safety, noise reduction, ease of movement between branches with different hierarchy, flexibility of road and the possibility of reversal, simplification and reduction of road traffic lights and economics management in respect to traffic lights dynamically or manually controlled.

2. The Mini- Roundabout: An Advantage on Urban Areas

The use of a mini-roundabout, for safety reasons, is reserved exclusively to the city center, which is characterized by a reduced transit speed (30 or 50 km/h), greater attention and a good night visibility. [2]

In particular it is possible to refer to three possible schemes of mini - roundabout:

- ✓ Mini - roundabout with central island surmountable (external diameter from 14 to 20 m);
- ✓ Mini - roundabout with central island semi- surmountable or insurmountable (external diameter from 18 to 24 m);

✓ Compact mini - roundabout (outside diameter 24 to 35 m);

The advantages of a mini- roundabout allow: low speed values, especially in terms of safety; waiting and average time to stop, considerably reduced; low emission of pollutants from exhaust gases; possibility of reversing; good visual perception of movement dynamics; few maintenance issues; low implementation costs;

Conversely, the roundabouts with small radius are not recommended in the following contexts: important crossings, which allow the transition between two distinct categories of roads; roads with more than two lanes; total incoming traffic higher than 1800 vehicles/hour; angle between two arms less than 70°; heavy traffic;

3. The Delay Concept for Intersection Crossing

The evaluation of the time of crossing an intersection requires, firstly, the analysis of the different phases in which this process takes place. In particular, are distinguished four time intervals: delay approach; delay stop; control delay; start-up delay (time lost); [2]

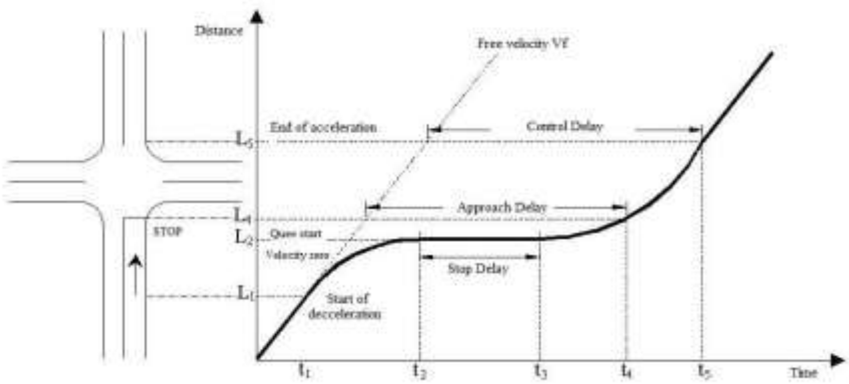


Fig. 1: Schematic of the delays by the user in the early stages of crossing an intersection

It is important to note that, the extent of the delay in the various stages of crossing is considered in the literature as a reliable indicator of the level of service offered by the intersections. The same methodology provided by HCM for the determination of the level of service, both in the case of non-signalized intersections and signalized intersections, is based precisely on the determination of the cumulative delay. [3]

3.1. Level of Service for Signalized Intersections

Based upon the Highway Capacity Manual, the level of service for signalized intersections is defined in terms of delay, which is the measure of the discomfort and frustration of the driver, the fuel consumption and travel time lost. In particular, the LOS is measured in terms of the average delay of the stop for the vehicle for a period of 15 minutes. The assessment of the delay is a complex measure and depends on a number of variables which include: the quality of progression; cycle length; the relationship between flow and capacity for a given group of lanes. [5]

TABLE 1: Levels of service for signalized intersections based on HCM

Level of service	Average total delay (seconds / vehicle)
A	U 5.0
B	>5.0 e U 15.0
C	>15.0 e U 25.0
D	>25.0 e U 40.0
E	>40.0 e U 60.0
F	> 60.0

1. LOS A: is representative of a very short delay, to below 5 seconds to vehicle.
2. LOS B describes operations characterized by delays between 5 and 15 seconds.
3. LOS C is indicative of delays of between 15 and 25 seconds per vehicle.
4. LOS D: the delays associated with this level of service are between 25 and 40 seconds per vehicle.
5. LOS E describes operations with delays between 40 and 60 seconds to vehicle.

6. LOS F describes operations with delay greater than 60 seconds to vehicle.

3.2. Level of service for not signalized intersections

The limit values of the delay in the case of not signalized intersections, according to HCM, are summarized in Table 2. It is reiterated as, similarly in the case of intersections regulated by semaphores, the level of service is directly associated with the delay. [4]

TABLE II: Levels of service for no signalized intersections based on HCM

Level of service	Average total delay (seconds/vehicle)
A	U
B	>5.0 e U 10.0
C	>10.0 e U 20.0
D	>20.0 e U 30.0
E	>30.0 e U 45.0
F	>45.

The total delay is defined as the total time elapsed, when a vehicle is stopped at the end of the queue up to the moment, when it starts again from the same line stop; this time includes the time required by the vehicle to move from the last position in the queue to the first position in the queue. The average total delay for a particular secondary maneuver is a function of the capacity and the degree of saturation. [1]

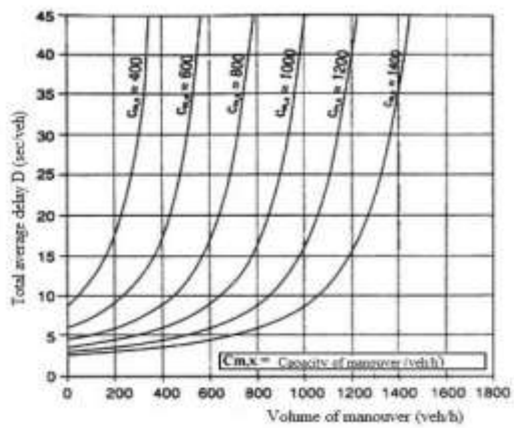


Fig. 2: Schedule to calculate the average waiting time (D) (analysis period =15 minutes)

4. Definition of a Procedure for the Calculation of Mini- Roundabouts' Level of Service

It doesn't exist in the literature a standard procedure for the calculation of the level of service of roundabouts of small radius. The aim of this paper is precisely to prepare a procedure for calculating the crossing delay in the mini-roundabouts. For this aim are offered two types of approach: a theoretical approach, based on queuing theory and an empirical approach, based on a series of experimental data conducted at several small roundabouts radius belonging to the urban area of the Durres city, Albania. [5]

4.1. Theoretical Approach: The Behavioral Model Users' Input

In order to understand better the considerations that will be carried out below, it is necessary to examine the pattern of behavior of the road users introducing on the roundabout. In figure 4 is shown a typical case of approach vehicle to a mini-roundabout. It seems how, to each input of a vehicle in the roundabout, corresponds a preliminary phase in which, each vehicle is enforced to stop, even several times consecutively, to effect of the presence of vehicles in the queue that precede it. The delay of the stop depends on the circulating flow on the ring and the gap accepted by drivers. [4]

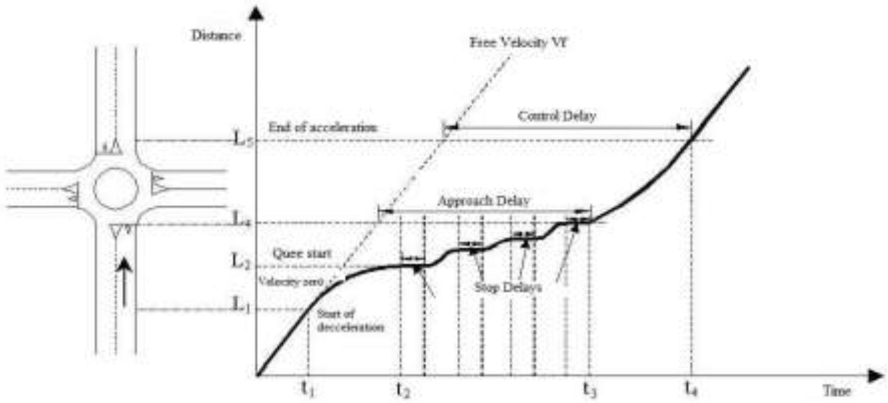
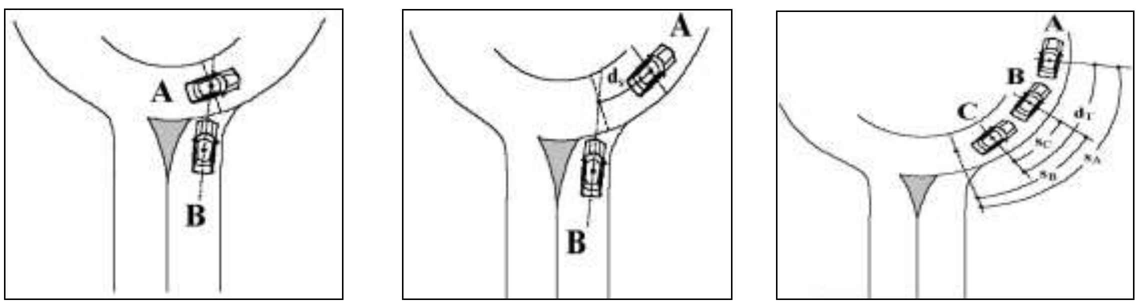


Fig. 3: Diagram of the delays by the user in the early stages of crossing a roundabout

We define the critical range the smallest time interval (T) between two vehicles traveling on the ring that allows an ideal placing. We call, therefore, d_T (critical distance) the spatial distance associated with the gap T. [2]



time t = 0

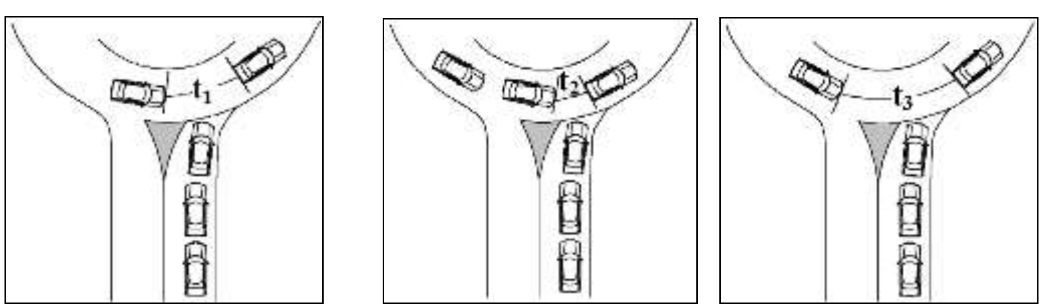
time t = δ
ds = safety distance
ds = v · δ

time t = t *

$S_A = d_s + v x\, t^* = v\, x\, (\delta + t^*)$
$S_B = ½\, a\, t^{*2}$
$S_C = d_s = v\, x\, \delta$
$d_T = S_A + S_C - S_B$

Fig. 4: Schematic of the operation of placing the crown gyratory by the first vehicle in the queue on the branch of approach.

Another important parameter for the characterization of the entry maneuver into the circulation from head vehicles to the queue, is called the service time (ts), defined as the interval of time that elapses, while the user who is at the head of the queue, is "Served". In figure 5 is shown this example of the temporal intervals that contribute to the definition of the time service, the value of **ts** is the contribution the two time periods (t_1 and t_2) individually below the critical gap (T). [3]



t_1 <T, T = critical interval t_2 <T, T = critical interval t_3<T, T = critical interval ($t_s = t_1 + t_2$)

Fig. 5: Definition of the time of service in the case of release for a urban mini-roundabout

4.2. Experimental Approach

We chose to analyze two mini- roundabouts, with features geometrically similar, both located in Durres city of Albania. The first roundabout (Fig. 7) is with four branches and the second (Fig. 8) with three ones.

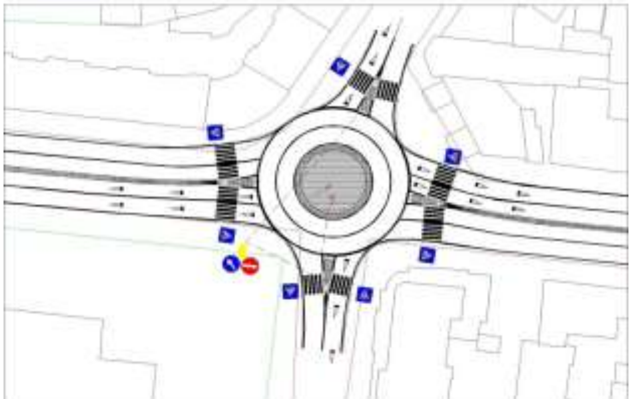


Fig. 6: Miniroundabout 1

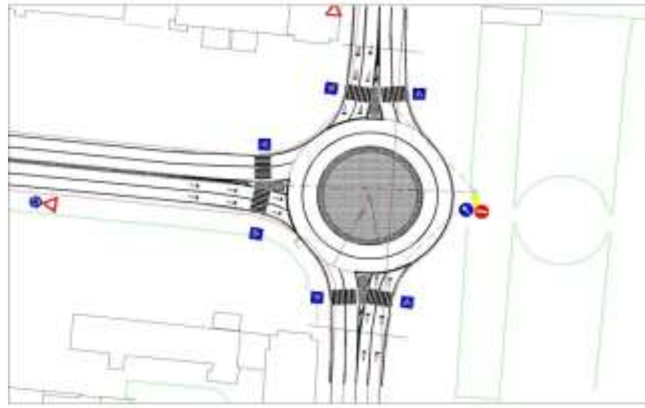


Fig. 7: Miniroundabout 2

1. The four branches of approach are not exactly inclined of about 90 °. The central island has a diameter 14 m. The branches of approach, to a single lane, have the following values for width: branch A= 4.40 m, branch B = 5.10 m, branch C = 4.50 m, D = branch 4.20 m.

2. The second roundabout has a central island is perfectly circular (diameter 12 m). The road widths that flow in the roundabout are almost identical for the branches A, B , (respectively 6.60 m, 6.70 m), while the branch C has a width equal to 13.00 m . The widths of lanes in the entry are the following: Branch A = 6.40 m, B = 3.00 m branch, branch C = 5.90 m.

The traffic data were obtained with recovery directs camera intersections and next vehicle count. In order to determine the time of service which, as said, is the average time of waiting for the first vehicle in the queue, it is adopted the criterion to measure the time of entry of vehicles in the head to the queue, for each of the different branches of approach, with reference to 58 hours of relief overall (30 for the first roundabout and 28 for the second one). The survey was conducted in 30 days (on September and November of 2013). The days of the week in which they were pads were always on Tuesdays, Wednesdays and Thursdays. For each day was performed a maximum number of three hours of video footage.

The Tables 3 and 4 summarize the results obtained through the significant experimental whose mode of execution are just been exposed.

TABLE III: Cash in circulation and service times for the first roundabout

Branch	Hour Interval	Day of the week	Circular flow Q_C [veh/h]	Service time t_S [s]
A	16.00 – 17.00	Thursday	1073	3,81
A	17.00 – 18.00	Wednesday	1171	5,08
A	9.00 –10.00	Thursday	1194	4,72
A	12.00 – 13.00	Tuesday	1208	5,38
A	8.00 – 9.00	Tuesday	1490	5,36
A	18.00 – 19.00	Thursday	1930	5,94
B	9.00 – 10.00	Tuesday	459	3,64
B	17.00 – 18.00	Wednesday	480	3,50
B	16.00 – 17.00	Thursday	885	3,88
B	11.00 –12.00	Wednesday	889	4,42
B	12.00 – 13.00	Wednesday	1223	4,54

B	8.00 – 9.00	Thursday	1510	4,71
B	18.00 – 19.00	Tuesday	1557	5,66
B	18.00 –19.00	Tuesday	1865	6,35
C	16.00 – 17.00	Tuesday	804	4,36
C	18.00 – 19.00	Wednesday	1219	5,12
C	8.00 – 9.00	Thursday	1398	4,91
C	9.00 – 10.00	Tuesday	1529	5,55
C	8.00 – 9.00	Thursday	1602	5,22
C	18.00 – 19.00	Thursday	1636	5,38
D	18.00 – 19.00	Tuesday	238	3,52
D	17.00 – 18.00	Wednesday	307	3,54
D	18.00 – 19.00	Tuesday	326	3,64
D	8.00 – 9.00	Wednesday	335	3,65
D	9.00 – 10.00	Thursday	383	3,37
D	10.00 – 11.00	Tuesday	402	3,74
D	10.00 – 11.00	Wednesday	471	3,56
D	17.00 – 18.00	Wednesday	477	3,52

TABLE IV: Cash in circulation and service times for the second roundabout

Branch	**Hour Interval**	**Day of the week**	**Circular flow Q_C [veh/h]**	**Service time t_S [s]**
A	16.00 – 17.00	Tuesday	453	3,68
A	11.00 – 12.00	Thursday	529	3,22
A	17.00 –18.00	Wednesday	576	3,24
A	18.00 – 19.00	Wednesday	588	3,44
A	8.00 – 9.00	Tuesday	682	3,63
B	9.00 – 10.00	Thursday	444	3,67
B	9.00 – 10.00	Tuesday	713	4,21
B	16.00 – 17.00	Thursday	725	3,81
B	18.00 – 19.00	Wednesday	735	3,61
B	18.00 –19.00	Wednesday	845	4,37
B	8.00 – 9.00	Tuesday	912	4,42
B	9.00 – 10.00	Tuesday	988	4,71
B	8.00 – 9.00	Thursday	1229	5,03
C	17.00 – 18.00	Wednesday	318	3,11
C	16.00 – 17.00	Tuesday	400	2,99
C	18.00 – 19.00	Wednesday	1535	5,19
C	8.00 – 9.00	Thursday	1625	5,76
C	9.00 – 10.00	Tuesday	1650	5,21
C	8.00 – 9.00	Wednesday	1680	6,05

5. Application of Developed Procedure

This paragraph intends to expose the results of the methodology explained in the preceding paragraph to a real situation. In particular, it was decided to assess the level of service two miniroundabouts, in the context of the redevelopment project the urban road network of the city of Durres, Albania.

TABLE V: Vehicular flows in the MiniRoundabout 1

MINIROUNDABOUT 1		
Entrance	Entrant flows (veh/h)	Circular flows (veh/h)
A	480	1264
B	1504	548
C	560	1528
D	896	656

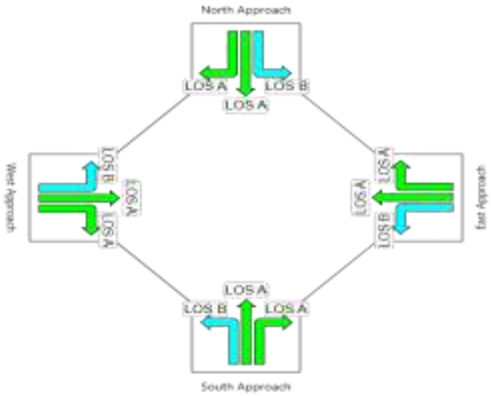


TABLE VII: LOS in the MiniRoundabout 1

	South	East	North	West	Intersection
Delay (Average)	8.8	8.3	8.5	8.8	8.6
LOS	A	A	A	A	A

TABLE VI: Vehicular flows in the MiniRoundabout 2

MINIROUNDABOUT 2		
Entrance	Entrant flows (veh/h)	Circular flows (veh/h)
A	2176	20
B	1204	2100
C	916	1728

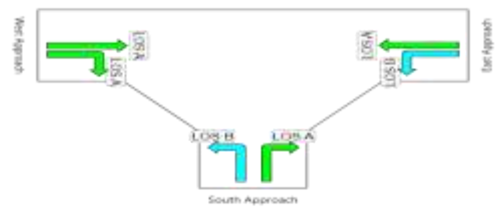


TABLE VIII: LOS in the MiniRoundabout 2

	South	East	West	Intersection
Delay (Average)	9.7	8.2	7.3	8.3
LOS	A	A	A	A

6. Conclusions

Miniroundabouts represent a solution for the redevelopment of intersections that, mainly in urban areas, are already much diffused. With this contribution we wanted to propose an original approach to the quantification of delays by users who, before entering into the circulation, would require spending a considerable time queued on entrances intersection branches. The scientific support studies on queuing theory and the empirical findings of the in situ experimental allowed the formulation of a methodology of a general validity, applicable, for each possible flow vehicular, to those that follow roundabouts quite closely to the typical geometrical standards as mini – roundabouts. The application of the procedure developed in some mini-roundabouts of the city of Durres, Albania, has finally created the conditions for incrementing the research in order to quantify the outflow vehicular characteristics, within a range of adequate variability, to guide the designers towards the best choice of one or other type of intersection (regulated by stop sign or give way, signalized intersections, interchanges roundabouts), as a function of predetermined service levels. In this regard, it is necessary to emphasize that, the concept of level of service and capacity are closely related, in the case of evaluating the performance of intersections, to the crossing delay. [5]

7. References

[1] Road planning and design Manual – Queensland Government (Department of Main Roads) – Agosto/Settembre 2000. 22;

[2] Roundabouts an information guide – U. S. Department of Transportation – Federal Highway Administration – Giugno 2000.

[3] S. Canale, S. Leonardi, F. Nicosia – Le intersezioni stradali – Quaderno n°2 – Febbraio 1999 – AIIT (Associazione Italiana per l’Ingegneria del Traffico e dei Trasporti).

[4] S. Canale, S. Leonardi, G. Pappalardo – Mini–rotatorie urbane ingressi a rischio –Rivista Onda Verde– Novembre/Dicembre 2001.

[5] R. Mauro – Su alcune recenti acquisizioni in tema di incroci a rotatoria – Trasporti e trazione – Febbraio 1995.