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Capacity analysis of branches and geometric parameters of existing roundabouts

XHEVAHIR ALIU
Faculty of Civil Engineering
Tirana, Albania
MENTOR BALILAJ
Faculty of Civil Engineering
Tirana, Albania
FLONARD HALILAJ
Freelance Engineer, Tirana, Albania

Abstract:

The infrastructure system plays a fundamental role in the development of the economical and social activity of every industrialized country. More than ever is determined that one of the most problematic element in the infrastructure system are the road intersections. Designing such elements requires a commitment not only from the economic perspective but also technical-engineering, from the initial conception phase to the design project phase. From monitoring these parts, were observed problematic phenomena related to its inefficiency, this in regard to problems of traffic blocking or creating big traffic flow near these areas. The technical solution and its efficiency have a close relationship to the professional training, such connected to experience or undertaking the right studies prior to making any decision. So that each intersection to be effective, all its geometrical parameters must be conform the technical conditions and also to meet the capacity criteria for its branches.

In this article, it will be presented the standard analysis procedure for the conditions of an existing roundabout, in connection to its geometrical parameters and the capacity analysis of its branches. Throughout these analysis of the above mentioned parameters are *drawn the conclusions on the roundabout state and recommendations for possible solutions.*

Key words: roundabout, circulating flow, branch, capacity, traffic.

1. INTRODUCTION

The starting point of this article was the excising traffic condition in one of the country most important intersection, at the entrance of Tirana city known as the roundabout of the square "Shqiponja" ("Eagle" square). In the last few years, more than ever priority has been given to the development of the country infrastructure, but in several cases, these investments have been inefficient and not provided the adequate technical-engineering solutions.

In this article it is presented the study assessment on the existing conditions of the intersection, on its geometrical parameters, traffic flow, and corresponding performances for each branch.

2. SCOPE OF STUDY

The object of this study is the roundabout "Shqiponja", located on the north-west of the city Tirana. This intersection is very important serving as the principal gate of the city, since though it passes 70% of the traffic entering and leaving the city. The heavy traffic created near the roundabout, for years has been a source of problems for vehicle users or citizens whom for various reasons are obligated to pass through this segment of the infrastructure. Even though in the last years have been carried out some interventions to improve its condition they resulted being insufficient and have not solved the problem in hand. The last interventions were carried out by Municipality of Tirana in 2013. They consisted in adding travel lanes on the right side with 5 m width, increasing its geometrical parameters, building new 3-4 meters sidewalks, increasing the pedestrian safety by building protective banisters and also disciplining their movements on the white lines (pedestrians crossing), etc.

Fig. 1. Aerial photo of the roundabout "Shqiponja"

3. GEOMETRICAL PARAMETERS OF THE INTERSECTION

The roundabout has four branches, from which the north-west branch and the south-east branch have the heavier circulating flow. It is characterized by carriageways with four lines at the entrance and exit, while the north-east branch carriageway has one travel line as for the circulating ring, it has three lines.

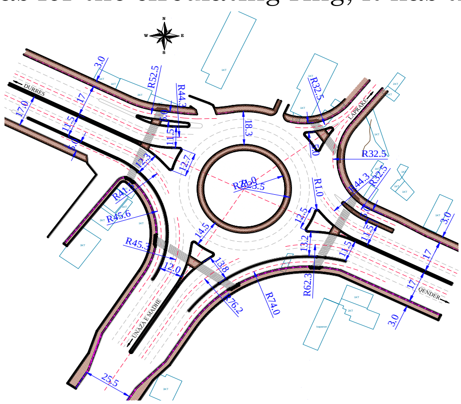

Fig. 2. "Shqiponja" roundabout plan

It stands out from other roundabouts for the large diameter of the circular outer ring and from the great size of the entrance-exit areas. The roundabout geometrical parameters are as follow:

- The central island diameter is 42 m, the length of the crossable line is 2.5m, while the outer circle diameter is 75m.
- The center is elevated (impassable), this area includes, proportional to the edge, an accessible line. The greenness or other elements, inside the central island are outside the visibility triangle so it guaranties a good perception of the central island.
- The entry-exit carriageway has four lanes, excluding one branch that has a single travel lane. Its three branches, including the right turn lanes, have a width of 5-5.7 m
- The radiuses at the entry of its branches are respectively: 44.3m (branch-Centre), 41.5m (branch-Rruga e Durrësit), 76.2m (branch-Unaza Re) and 32.5m (Branch-Laprake);
- The width of the entry branches are respectively: 11.5m (Branch-Rruga e Durrësit), 12.5m (Branch-Unaza Re), 11.5m (Branch-Qender) and 4.5m (Branch- Laprake);
- The width of the exit branches are respectively: 17m (Branch-Rr. Durrësi), 16.7m (Branch-Unaza Re), 17m (Branch-Qender) and 3.5m (Branch- Laprake);
- The splitter islands have a pseudo-triangular shape, with entry radius and exit radius of 50m.
- The sidewalks for each branch are 3 m of depth.

4. TRAFFIC ON THE MAIN BRANCHES

The used technique to measure traffic flow is through a camera monitoring system and partially manually. The surveys were undertaken in a time period of 15 days, taking advantage of the most suitable day intervals, according to the normative recommendation. The data recording was done using table modules (files) pre-prepared for each category of vehicles and for each time interval it were registered the number of vehicles passing for time unit.

For each vehicle category the equivalence with a unit equivalent was done, issuing even their hourly volumes. The gathered data present the daily average for each branch of the roundabout and will help with creating the matrix origin-destination [2], [5] shown below, which furthermore will help with carrying out the necessary verifications

Table 1. Matrix origin-destination

Matrix O/D	Branch 1	Branch 2	Branch 3	Branch 4	Unit
Branch 1	0	489	1890	97	Vehicle/h
Branch 2	1295	0	485	47	Vehicle/h
Branch 3	992	233	0	93	Vehicle/h
Branch 4	252	109	0	0	Vehicle/h

5. ASSESSMENT OF BRANCHES CAPACITY

The assessment of branches capacity for the roundabout was prepared using the Highway Capacity Manual (HCM) [1], [3] and the Cetur [4] method. According to the HCM method, the assessment of branches capacity is calculated by the expression below:

$$C = (Q_c * e^{-Qc*\frac{tc}{3600}})/(1 - e^{-Qc*\frac{tf}{3600}})$$

where:

- C - assessment of branches capacity (vehicle/hour);
- Q_c - circular traffic in conflict with the entry flow (vehicle/hour);
- t_c - critic interval (s);
- t_f - escalation time in the tail, end (s)
- Q_e- traffic at the entry for each branch(vehicle/hour);

In Table 2 are given the obtained results from the verifications according to the expression above.

Table 2. Branch capacity

Branch 1 (Rr. Durresit)			Branch 2 (Unaza e re)			Branch 3 (Qender)			Branch 4 (Laprake)		
C=	**855**	vehicle/h	**C=**	**518**	vehicle/h	**C=**	**202**	vehicle/h	**C=**	**116**	vehicle/h
Q_c=	426	vehicle/h	Q_c=	1015	vehicle/h	Q_c=	2068	vehicle/h	Q_c=	2662	vehicle/h
t_c=	4.3	sec	t_c=	4.3	sec	t_c=	4.3	sec	t_c=	4.3	sec
t_f=	2.9	sec	t_f=	2.9	sec	t_f=	2.9	sec	t_f=	2.9	sec
e=	2.78		e=	2.78		e=	2.78		e=	2.78	
Q_e=	2476	vehicle/h	Q_e=	1827	vehicle/h	Q_e=	1318	vehicle/h	Q_e=	361	vehicle/h

Using the HCM method [3], the spare capacity (given in %) is derived from the formula:

$$R_c = (C - Q_e)/Q_e$$

In Table 3 are given the results derived from the analysis using the above formula.

Table 3. Spare capacity for each branch

Branch 1 (Rr. Durresit)			Branch 2 (Unaza e re)			Branch 3 (Qender)			Branch 4 (Laprake)		
Rc=	-1620	vehicle/h	Rc=	-1308	vehicle/h	Rc=	-1115	vehicle/h	Rc=	-245	vehicle/h
Rc=	-65	%	Rc=	-71.6	%	Rc=	-84	%	Rc=	-68	%
Test			Test			Test			Test		
Critical			*Critical*			*Critical*			*Critical*		

The stopping delay is the time the driver loses while sanding in queue to enter the circular flow. To define the delay and the degree of saturation we refer to the formula:

$$d = \frac{3600}{C} + 900T\left[(x-1) + \sqrt{(x-1) + \frac{3600x}{450CT}}\right]; \qquad x = \frac{Q_i}{C}$$

where:

- C - branch capacity (vehicle/hour);
- d – average delay for one travel line (seconds/vehicle)
- x - degree of saturation for the branch;

- T – study period (h), (T = 0.25 for a period of 15 minutes);
- Q_i –entry flow (vehicle/hour).

If we carry out the calculation for the above expression, we derive the conclusions below:

Table 4. Degree of saturation for each branch

Branch 1 (Rr. Durresit)			Branch 2 (Unaza e re)			Branch 3 (Qender)			Branch 4 (Laprake)		
C=	855	vehicle/h	C=	518	vehicle/h	C=	202	vehicle/h	C=	116	vehicle/h
T=	1	h	T=	1	h	T=	1	h	T=	1	h
x=	2.89		x=	3.52		x=	6.51		x=	3.11	

If we carry out the calculation according to the Cetur [4] method, which is very reliable for urban roundabouts as in our case, to define the flow will be used the following expression

$$C = \gamma(1500 - \frac{5Q_d}{6})$$

where:

- C - branch capacity (vehicle/hour);
- Q_d - heavy flow (vehicle/hour);

Where γ =1, for the entrance to a lane, and γ = 1.5 for entrance to two or more lanes. In our case, for heavy traffic the formula Q_d is:

$$Q_d = bQ_c + 0.2Q_u,$$

where:

- b - 1 for (ring lengh) L_c < 8 m; b = 0.9 for $L_c \geq 8$ m and R_i (internal radius) < 20 m; b = 0.7 for ring length L_c > 8 m and R_i < 20 m;
- Q_c - traffic at the ring (vehicle/hour);
- Q_u - traffic at the branch exit (vehicle/hour);

If we calculate according to the formula above we derive the following result in the table:

Table 5. Branch capacity using CETUR method

Branch 1 (Rr. Durresit)			Branch 2 (Unaza e re)			Branch 3 (Qender)			Branch 4 (Laprake)		
C=	1189	vehicle/h	C=	770	vehicle/h	C=	201	vehicle/h	C=	-534	vehicle/h
Q_c=	426	vehicle/h	Q_c=	1015	vehicle/h	Q_c=	2068	vehicle/h	Q_c=	2662	vehicle/h
Q_d=	848	vehicle/h	Q_d=	1183	vehicle/h	Q_d=	1639	vehicle/h	Q_d=	2227	vehicle/h
x=	2.08		x=	2.37		x=	6.54		x=	-0.67	

Saturation degree for one lane estimated using "Cetur" method is two, and as a result the time the driver loses queuing is greater.

6. ANALYSIS OF THE GEOMETRICAL PARAMETERS

Below is presented in a summarized way the analysis of the geometrical parameters for the roundabout:

- The outer diameter of the central ring is D = 75 m, while the diameter of the central island is d = 42m, classifying it as a urban roundabout with triple carriageway. The diameter for the outer circle ring for urban roundabouts of standard dimensions is at maximum 45-55 m, as a result this roundabout, for the dimension of the central ring, is off standard.
- The circulatory roadway is B = 14.5-18.3m. This width is approximately as the entry width. This brings uniformity to the circulation but it is not efficient because of the geometrical irregulatory of the roundabout. It exist a connection between the width of the circulatory roadway and the diameter of the outer ring but in our case this proportionality has not been achieved.
- The choice of radius for the turning is a very important parameter in the assessment of a roundabout, for it is directly connected to the capacity and the safety. The exit turn shout have a greater radius than the entry turn. At the roundabout in case, this condition is not fulfilled. As you can see, with the exception of the fourth

branch, no one of the other roundabouts branches is conforming to the standard. The second branch, has an excessive entry radius, that allows the vehicle to enter with speed the roundabout and is a possible source of accidents.

- The width of the entry and exit lane should be equal to the width of the circulatory lane. The lane for right-turn poses a design artifice that distorts the functioning mechanism of the roundabouts. They are used only in cases where the flow of vehicle that turns right is high as it happens at branch 1 and 2. The solution for these two branches is correct. The solution for branches 3 and 4 it is not correct even though the vehicle flow that turn right it is not high, meaning it is not a necessity to have a tuning lane. These lanes have a width of 5m, sufficient for the vehicles.
- The central island is elevated, so that the driver has a good perception. The island is 0.5m high and conform the norms recommendations.
- The splitter islands are positioned at the branches 1-2-3 of the roundabout, while it is not clear the shape of the fourth branch. This last one only gives an idea of an island as it doesn't fulfill any of it requirements. Since the ring radius is $Rg > 15$; the triangle for designing splitter islands must not be equilateral. From this we can conclude that to design splitter island symmetrically it is not correct. The islands are cleared from elements and object that might become an obstacle.
- The width for the pedestrian walkway is 4m, which fulfills the requirements for urban areas. In the roundabout in case, the distance for placing the white stripes from the centre ring to the respective branch is equal to the entry branch, this is not correct according to the normative recommendations.

7. CONCLUSIONS

From the analysis of the branches capacity and the geometrical parameters of the roundabout incase, were derived the following conclusions:

- The roundabout it is not in good functioning conditions as the saturation degree for the entry carriageway (x) is greater than 0.8-0.9. For the roundabout being studied the saturation is above 2, as a result the driver loses time staying in long queues.
- The roundabout at study is in critical exploitation conditions and as such very often it is face with blocking the vehicle flow.
- The interventions of the last years to improve the functioning of the intersection resulted being insufficient and ineffective.
- As a result of the given study we can conclude that further emergency intervention must be carried out to give a new technical solution, the most suitable solution would be an out of grade intersection (junction).

REFERENCES

[1] "Design of roundabout", Designing and verifying the intersections with round circulations. Eng Artur Sulce, Eng Edmond Kazazi

[2] Report n. FHWA-RD-00.067. *"Roundabouts: an informational guide".* U.S. Departament of Transportation. Federal Highway Administration. June 2000

[3] "*Transportation Research Board, Highway Capacity Manual"* (H.C.M) 2000, TRB, NRC, Washington, DC, 2000.

[4] CETUR. *"Conception des Carrefours a sens Giratoire Implantes en Milieu Urban".* Centre d'Etudes des Transports Urbains (CETUR) 1998

[5] "*Republic of Albania Road Code 1998"*, v.k.m 153 prill 2000