POSSIBLE RECONSTRUCTIONS OF INTERSECTIONS IN URBAN AREAS BY USING ROUNDABOUTS

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Abstract

Like other Croatian cities the city of Rijeka is trying to find optimal traffic solutions for complex problems of growing traffic volumes at existing non-appropriate road network. As a possible solution for the need to increase road and especially intersection capacity and in the same time calm the traffic the idea of reconstruction of the intersections in the form of roundabouts was implemented. In accordance with City authorities different locations were analysed in order to compare them by using common criteria and to define locations of the intersections that can be transformed in the roundabouts.

Keywords: city traffic, intersections, roundabouts

1 Introduction

In an european type of the city, which has been developing on the core of a historical settlement, traffic problems mostly arise due to the motor traffic overload of an insufficient transportation facilities grid. In the city of Rijeka this problem is accentuated by an extremely unfavorable geographical position on a narrow coastal area whose width is only 1.0km. This renders any extension of the existing longitudinal road grid in the town impossible. A prominent trend of the inhabitants to use individual means of transport and a minor role of the public transport in the city help aggravate the problem. The data show that the average daily traffic in the center of Rijeka is about 70.000 vehicles a day. [1] The optimal solution of the stated problem is an extension of the traffic grid. Such solution is feasible in long terms because, due to the insufficiency of the available space in the plain, it requires construction of tunnel sections and therefore considerable investments. The second possible solution, which is financially less demanding, would be a combined intervention into different traffic aspects: a quality reorganization of road traffic by improving the traffic regime and reconstructing the existing transportation facilities grid in order to achieve the optimal efficiency of traffic flow. The reconstruction of the existing road grid includes the reconstruction of the most critical grid parts at which traffic standstills occur – the intersections. The reconstruction of intersections by applying roundabouts is a possible solution which offers a lot of advantages. The specific quality of traffic areas and flows in Rijeka – the concentration of facilities and an abrupt increase in traffic amount in the high construction development zones, untypical longitudinal slopes in the very intersection zone and intersections of an elongated configuration ("Y") – have resulted in a more detailed analysis of constructing roundabouts in the City of Rijeka. This paper analyzes the two existing roundabouts (in Škurinje and in Radnička street) and several possible locations for constructing roundabouts as well as other available criteria and recommendations under given conditions. Based on the analysis of roundabout construction possibility, the aim of this paper is to assess the applicability of reconstructing the intersections by constructing roundabouts from the aspect of spatial, traffic and technical criteria.

2 Reconstruction of classical intersections in urban areas by using roundabouts

2.1 Roundabouts in urban areas

The reconstruction of classical intersections by using roundabouts is usually considered as adequate for intersections with larger number of approaches, intersections with a larger amount of traffic and intersections whose function is to slow the traffic down in a specific zone. Meeting of those stated and generally known requirements is not enough to make a decision to reconstruct the classical intersection by using a roundabout. When assessing the adequacy of roundabout construction the defined criteria can be used which were proposed by professor Tomaž Tollazzi in his book [2] or those criteria which are compatible with the stated ones and were proposed in Guidelines for Design and Equipment of Roundabouts [3]:

- spatial criterion which relates to the criterion of micro and macrolocation,
- traffic criterion which defines the cases in which the roundabout construction is adequate,
- traffic and safety criterion which defines criteria in relation to the traffic safety,
- capacity criterion which is tested by one of the standardized methods (in Croatia it is the Austrian method as a rule).

In both cases the following must be analyzed and tested in order to make a quality assessment of the solution:

- the significance and role of the road within the city road grid,
- the availability of area for roundabout construction,
- the configuration of the intersection (A, K, X, Y and H), number of approaches, justifiability of traffic lights,
- rate of traffic accidents according to gravity of consequences, velocities at intersection approaches, need for slowing the traffic down, location in relation to specific requirements of the users,
- amount and division of traffic at intersection.

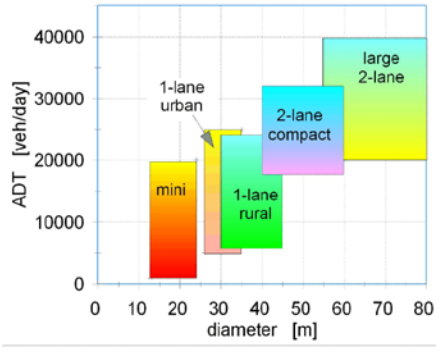

Figure 1 Classification of roundabouts according to size and maximum capacity expressed by ADT [4]

The analysis is based on the multi-criterion comparision of defined parameters and can be conducted through different grade scale. What needs to be discussed is to what extent could (or should) the specific criteria be of decisive character, that is, do some of the criteria, should they not have been met, actually exclude the whole option of constructing a roundabout at a certain location. This group of criteria definitely comprises those criteria relating to the geometrical intersection elements because by not satisfying those criteria the option of satisfying the criteria of intersection function and traffic safety come into question. Not meeting the criterion of level of service is the second element which is of decesive nature when deciding about the adequacy of the solution.

The roundabout function is determined by the intersection location within the urban structure. The intersections which are located on city roads of higher level (primary roads) function, as a rule, as means of slowing down the traffic in the zone. The geometrical elements of intersection also depend on its location. In the available references in Croatian language [2,3] or in foreign languages [4] the intersections are classified according to the inscribed circle diameter size, in this case, those which are applicable in urban areas. Figure 1 presents german classification of roundabouts.

2.2 Constructed roundabouts in Rijeka

As part of the transportation grid of Rijeka, several roundabouts were constructed in the past 5 years. Two of them are located on the extremely important traffic locations in the city where there has been a significant increase in the amount of traffic due to construction of new structures (commercial, housing, service structures). Those are the intersection in Škurinje and the intersection in Radnička street (next to the shopping mall – Tower center).

2.2.1 Roundabout "Radnička ulica" (Radnička street)

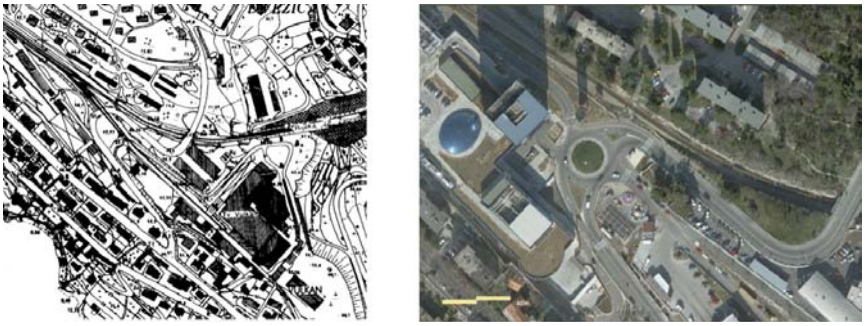

Figure 2 Previous and present situation

The shopping mall "Tower" in Rijeka is situated in Pećine part of town, on the east side of the city, in the location of warehouses directly to the south-east of the railway station "Pećine". The traffic connection of the location where the shopping mall was to be constructed could not meet the requirements of the planned facilities and the existing built-up zone restricted the possibilities of approaching the existing traffic infrastructure. (Figure 3). The junction road is situated in the sharp bend with a railroad crossing and an approach to the former factory. The traffic conception within the shopping mall had to meet standards of the final traffic solution, the needs for garage space (2000 parking places) and safety measures so that there is a one-way traffic regime with two-lane roads around the shopping mall. The roundabout is dimensioned for traffic of heavy trucks and the entrance and exit ramps in Radnička street were constructed almost tangentially. The minimum marginal radius of entrance and exit ramps are the consequence of limitations in space. The sidewalk for pedestrian traffic continuous all around the roundabout and has pedestrian crossings at all approaches.

2.2.2 Roundabout "Osiječka ulica" (Osiječka street)

Škurinjska draga, the location where the roundabout is located, goes from the north-west suburbs to the center of the city crossing a longitudinally positioned street – the Osiječka street. The low-lying part of Draga is foreseen for business and commercial facilities while the east slope is covered by a densely built residential structures. Numerous commercial centers which were build in the past decade close to the once four-armed intersection and the solution which did not include traffic lights or any separate lanes for those vehicles which turn left

often caused traffic standstills and required organization of a more effective traffic solution. A detailed urban development plan of the area provided main guidelines for the solution which was finally performed as a two-lane roundabout with a number of unconventional solutions:

- Inside the roundabout there is a retarding basin with an absorption area and a wastewater purification facility.
- Due to the unfavorable altitude differences in the existing approaches the roundabout was constructed with a longitudinal grade of 4.50%.
- The roundabout pavement is bent around the inner shoulder for +/- 2.50 % according to the requirements of the intersection approach.

The main technical characteristics of the roundabout are given in Table 1.

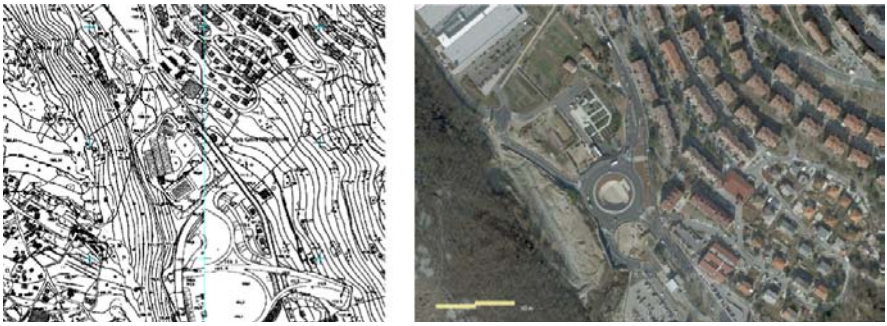

Figure 3 Previous and present situation

3 Analysis of possible reconstruction of classical intersections by using roundabouts – City of Rijeka example

As part of the scientific project "Correlation between shaping and safety of roundabouts" financed by the Ministry of Science, Education and Sports a cooperation with the Department of Urban Development of City of Rijeka was established and the potential locations for roundabout construction in City of Rijeka were determined. Five locations of existing intersections (four-arm and three-arm intersections) were analyzed in order to justify their reconstruction by constructing roundabouts. The intersections are located on the primary grid. The purpose of their reconstruction into roundabouts would be to increase the level of service on the intersection or to solve the problem of insufficient level of service for specific approaches (in rule, of those where the left turn is made).

3.1 Analysis of the present state

The analysis of the present state was conducted on the following locations:

- Antuna Barca street (A) – roadway connection of primary city grid and the motorway ring
- Zametska / Liburnijska / Zvonimirova streets (B) – intersection of two major city roads
- Janka Polić Kamova / Šetalište XIII. divizije (C) streets – primary traffic grid, eastern city gateway (connection to the state road)
- Grobnička cesta / Franje Račkoga / motorway ring / Kačjak streets (D) – primary traffic grid, gateway form the motorway Rijeka – Zagreb
- Tome Strižića / Vjekoslava Dukića streets (E) – primary traffic grid, connection to the future University Hospital and University Campus area.

3.1.1 Description of the analyzed intersections

Figure 4 Location (A):

Figure 5 Location (B): the intersection of Y type.

The intersection is a three-armed one of "T" type, all the approaches are two-way ones and have the same traffic load. In the close vicinity there are unoccupied public areas (a park and a parking lot), which enables a certain amount of freedom when selecting the geometrical elements of the intersection. The utility level of equipment is of average character for urban areas.

Figure 6 Location (C):

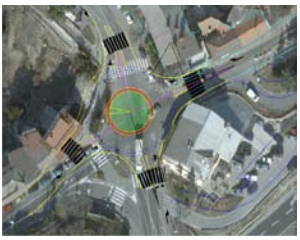

Figure 7 Location (D):

The intersection is a three-armed one, of "Y" type, with a very unfavorable angle of approach intersections and an extremely large ADT (rush hour › 3000 vehicles). The residential structures on the north and the south-east intersection margin render the optimization of the intersection location impossible. From the point of view of pedestrian traffic, the location is unfavorable due to the several entrances to the residential houses in the very intersection zone.
The intersection is a three-armed one of "Y" type. The residential structures with house lots on the eastern side of the intersection give the lot development an unfavorable mark. In the intersection zone there are bus stations and drive and pedestrian approaches. One of the approaches is a one-way one, which is favourable.
The intersection is a four-armed one of "X" type. The residential structures with house lots as well as the bus stop and the drive and pedestrian approaches in the intersection zone make the location unfavorable. The intersection has a significant role in slowing the traffic down at the city gateway from the direction of the motorway.

Figure 8 Location (E):

The intersection is a four-armed one of K type. At present, two of the approaches are more loaded than the other. However, the intersection will be changing its function in time due to the planned facilities (University Campus) on its north side. The non-existing lot development on the west side is a favorable factor because it enables widening of the intersection. One of the approaches (the north one) has an extremely unfavorable longitudinal grade of approach. A superficial assessment of suitability of the described locations makes clear that, according to the lot development criterion, location (A) is suitable for transformation into a roundabout ulike the location (D) where the existing lot development significantly limits the design elements. Significant interventions can be expected at location (E) due to its unfavorable approach relations. A low assessment grade of traffic areas on locations (B), (C) and (D) is the result of numerous secondary facilities (bus stations, approaches) but also an indicator of a location overload by disturbances which influence their capacity and traffic safety, resulting in the need to reconstruct the intersection. This indicator predictably corresponds with the lot development indicator of the location.

4 The achieved design and shaping elements for present and planned roundabouts in the City of Rijeka

4.1 Present roundabouts

The roundabout in Škurinje (I) (Figure 3) is by all its characteristics a medium-size urban intersection which enables velocities of up to 40km/h, traffic of articulated buses (which is very important because of the vicinity of residential buildings) and, in theory, a relatively large capacity (ADT of up to 20.000 vehicles). The expected traffic load required a construction of a two-lane roundabout with a 11.50m wide pavement. It is supposed that, due to the small roundabout radius and, consequently, short overlap length, the expected redistribution of traffic into the inside lane did not occur. The analysis of the capacity in the rush hour confirms the successfulness of this solution within the given circumstances.
The roundabout in Radnička street (II) (Figure 2) can be classified as a mini roundabout which successfully contributes to the traffic flow, which is confirmed by the level of service data. This solution offers a very untypical situation in which one of the approaches is constructed as a two-lane road while the very roundabout is one-lane construction. Low speeds and non-existence of standardized traffic solutions which the public is used to help the roundabout perform its function with a satisfactory traffic safety level despite to this design lack of logic. The achieved geometrical elements for the present roundabouts in Rijeka City are shown in Table 5.

4.2 Planned roundabouts

In order to examine the possibility of roundabout construction at defined locations a conceptual design was made based on the maximum exploitation of the available public areas, on usage of the existing facilities along with the effective construction work on the site (Figures 4-8). The achieved geometrical elements for the analyzed locations are shown in Table 5. It must be pointed out that the examined levels of service of the locations, calculated according the Austrian method, were adequate for all of them except for the levels of service of the intersection B. In case of a specific analysis of roundabout applicability, any further analysis of the intersection (B) would not be recommendable because the level of service is one of the decisive criteria for roundabout application.
The data from Table 5 show that the only solution for all the locations, in regard to the spatial availability, are the mono-lane urban roundabouts of middle size (categorization according to Guidelines) with the inscribed circle radius diameter of 15, that is, of 20 m. The circulatory roadway has the adequate width of 6 – 7m on all the intersections, which by itself does not

guarantee the intersection capacity – the capacity should be examined gradually by taking into consideration a relevant vehicle for each intersection. Due to the narrowness of the area, the entry and exit lanes of the intersection D are of minimal width while on all the other intersections they are of adequate width. One of the constructed roundabouts in Radnička street (Table 4) shows that the minimum width of entry lanes is not an obstacle to reaching a certain level of service on the intersection so that this solution can be considered as adequate.
Another very important element of the solutions was examined – the longitudinal grade of approach outside the intersection zone, that is, the possibility of intersection zone design (the entry and the very rotor) under the appropriate grade. Out of five potential locations two have single approaches with >/-10% grade. Considering the conditions in Rijeka, all the solutions reached the adequate grade of entries and rotors of up to 4%. The problem that occurs in such situations is the alignment inclusion zone length of the proposed solution, that is, the amount (and the price) of reconstruction of the wider intersection zone.

Table 1 Geometrical elements of present (I and II) and planned roundabouts (A-E)

(I)	(II)	Desing and shaping element	Sign.	(A)	(B)	(C)	(D)	(E)
35	17	Inscribed circle radius	Rv	20m	15m	22m	15m	20m
2 x 5.75	5	Circulary roadway width	u	7m	7,25m	7m	7m	6m
3.5 – 7.0	3.5 – 6.0	Approach width	v	3,5m	3,25-3,5m	3,5-3,75m	3,5m	3,5-4m
4.5 – 7.5	3.5 – 6.0	Entry width	e	4,5m	4-5,45m	5m	3,5-3,78m	4,5m
18 – 22.5	6.0 -12.0	Entry radius	Rul	13m	8-14m	14m	12-14m	10m
4.0 – 4.60	3.1 – 4.3	Exit width	x	4,5m	4-4,4m	5-6m	3,84-4,26m	4,5m
20 - 22.5	10	Exit radius	Riz	15m	10-16m	16m	14m	12m
10 %	12.0 %	Longitudinal grade of approach outside the intersection zone (max)	ip	0,2-10%	4,5-7%	1,5-7%	0,8-5,4%	6,5-12%
4.0 %	4.0 %	Longitudinal grade of entry within the intersection zones	iu	1-4%	4%	1,5-4%	4%	4%

5 Conclusion

Design of roundabouts is a very demanding and complicated task because there are no unambiguously defined solutions but only frames within which the best possible solution for specific conditions must be found. The City of Rijeka is a very specific area from the spatial and traffic point of view. From the traffic point of view, the City of Rijeka has the problems similar to those of all the larger Croatian cities – a growing traffic load which is not accompanied by the adequate investment into the traffic grid, that is, the traffic system as a whole. From the spatial point of view, the City of Rijeka has very specific problems caused by the city terrain configuration which has determined the way of its development. Today, the city area is densely built and has a traffic grid of insufficient geometrical characteristics and capacities within which every intervention poses a challenge. Under the stated conditions, the reconstruction of the existing classical intersections by constructing roundabouts is a challenge from different points of view: the first roundabout was constructed in the city only in 2007. So far, only two were constructed (and a prefabricated one in the city vicinity) and the drivers are still getting used to driving on such kind of intersections. The typization of "Rijeka's" roundabouts, if it is possible at all, is yet to be made because the two constructed roundabouts are completely

different according to their geometrical characteristics. The analysis of the five potential locations shows that the solutions applicable on the primary city grid are possible, should all the previously stated restrictions be respected, if design elements for small or middle size mono-lane roundabouts are used. The average terrain grade conditions the approaches and roundabouts also to have a 4% grade. Should this grade be made, the alignment inclusion at lengths over 40m must be performed. The examination of levels of service and possible geometrical elements is an important step in assessing the roundabout solution applicability on locations where there are classical intersections. However, it is not sufficient. The construction assessment criteria must also be analyzed in order to assess the challenging levels of roundabout construction under the stated more complicated city conditions. A detailed analysis of pedestrian traffic on roundabouts must also be performed.

An experienced design engineer recognizes the majority of the described indicators of the present state already by analyzing the presentation of the situation and by observing the traffic flows. By introducing the criteria and assessing the state the intention of the paper was to uniformly quantify the present state in order to avoid any subjective assessments about the suitability and necessity of present intersection reconstruction. By assessing the proposed solution the purpose-serving quality of roundabouts can be determined more objectively.

The way of assessing the specific criteria, the range of grades and the necessity of introducing new criteria should be examined in the same way also on locations with different spatial and traffic conditions. By doing so, the objective criteria for assessing the present state and the optimality of single solutions would be defined primarily from the traffic, but also from the spatial (construction) point of view while the limit conditions of the present state would not be neglected.

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