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TURBOROUNDABOUTS IN URBAN AREAS – A CASE STUDY FROM CROATIA

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Abstract

In this study, a preliminary design of three-legged egg-shaped turboroundabout in the city of Šibenik in Croatia was made. The traffic situation before 2014 was analysed when there was a classic three-legged at-grade intersection, as well as the situation after 2014 when the aforementioned intersection was reconstructed into a four-legged intersection with traffic lights (current situation). All above-mentioned traffic solutions were compared, and their main advantages and shortcomings were described.

Keywords: turboroundabout, urban areas, classic at-grade intersections, comparison

1 Introduction

Turboroundabouts are specially designed multi-lane roundabouts with spiral circulatory roadway, where the traffic flows at the entrance, circulatory roadway, and exit are physically separated by raised mountable lane dividers [1]. This roundabout layout was developed by a Dutch researcher dr.ir. L.G.H. Fortuijn in the late nineties of the last century to increase the traffic safety and capacity at classic multilane roundabouts [2-3]. Turboroundabouts are usually planned outside of or on the edges of settlements [4]. They are rarely built in urban areas because of their large diameters and wide multi-lane approaches, i.e. the spatial limitations and frequent traffic accidents that are involving cyclists who have right of way over the vehicles approaching and leaving a turboroundabout [5]. As stated in [6], when deciding on the construction of a turboroundabout in an urban area following parameters should be taken into account: structure of the traffic flow (share of motorized and non-motorized traffic participants), required capacity, traffic safety, spatial constraints, and construction and maintenance costs.
Within the scope of this study, a preliminary design of a three-legged egg-shaped turboroundabout at the road intersection between the Stjepan Radić and Bosanska Street in the city of Šibenik was made. In the year 2014, a former classic three-legged at-grade intersection was reconstructed into a four-legged intersection with traffic lights at this particular location. However, it should be noted that the aforementioned four-legged intersection with traffic lights was not the only design solution at that time. A conceptual design of a knee-shaped turboroundabout, which received a lot of criticism from traffic experts in Croatia, was also made and presented to the public.

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2 Description of analysed road intersection

Stjepan Radić and Bosanska Street road intersection is located in Šibenik narrower city center, near the General Hospital Šibenik. In the vicinity of this intersection, there are mainly residential buildings, two elementary schools, and a kindergarten.

2.1 Traffic situation before 2014

Stjepan Radić and Bosanska Street road intersection was a critical point in the city of Šibenik for many years due to frequent traffic congestions and poor traffic safety. This intersection formally had three approach legs: NW and SE approach legs in Stjepan Radić Street, which is one of the main city arterials with high traffic volumes, and NE approach leg in Bosanska Street (Fig. 1).

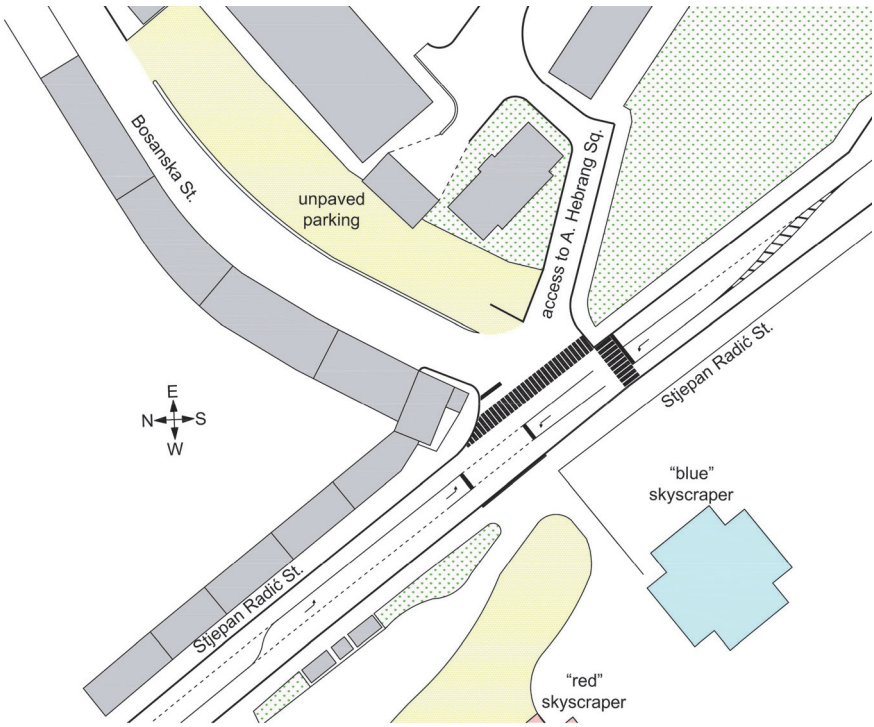

Figure 1 Stjepan Radić and Bosanska Street road intersection - traffic situation before 2014

The aforementioned capacity and traffic safety problems at this particular location arose due to the following reasons:

- access to Andrija Hebrang Square, and (unformal) entrance to unpaved parking in Bosanska Street, were located in the immediate vicinity of the intersection;
- vehicles that were entering the parking of so-called "blue" and "red" skyscrapers had to drive across the sidewalk in Stjepan Radić Street;
- sight distance at the entrance to the intersection in Bosanska Street was not adequate because of an acute angle between the Bosanska and Stjepan Radić Street (approx. 60º) and a three-floor corner building;
- path of vehicles that were driving from Bosanska Street to the parking of "blue" and "red" skyscrapers across the intersection was distorted;

- there were no sidewalks in Bosanska Street;
- traffic signalization was generally poor (horizontal signalization in the intersection area was not properly marked, there was no center line between the traffic lanes in Bosanska Street, there was no crosswalk on NW approach leg in Stjepan Radić Street).

2.2 Traffic situation after the reconstruction

The previously described three-legged intersection was reconstructed into a four-legged intersection with traffic lights in the year 2014. As it can be seen from Fig. 2, a former entrance to the parking of "blue" and "red" skyscrapers has been moved several meters to the south-east, and now represents a fourth approach leg of the intersection.

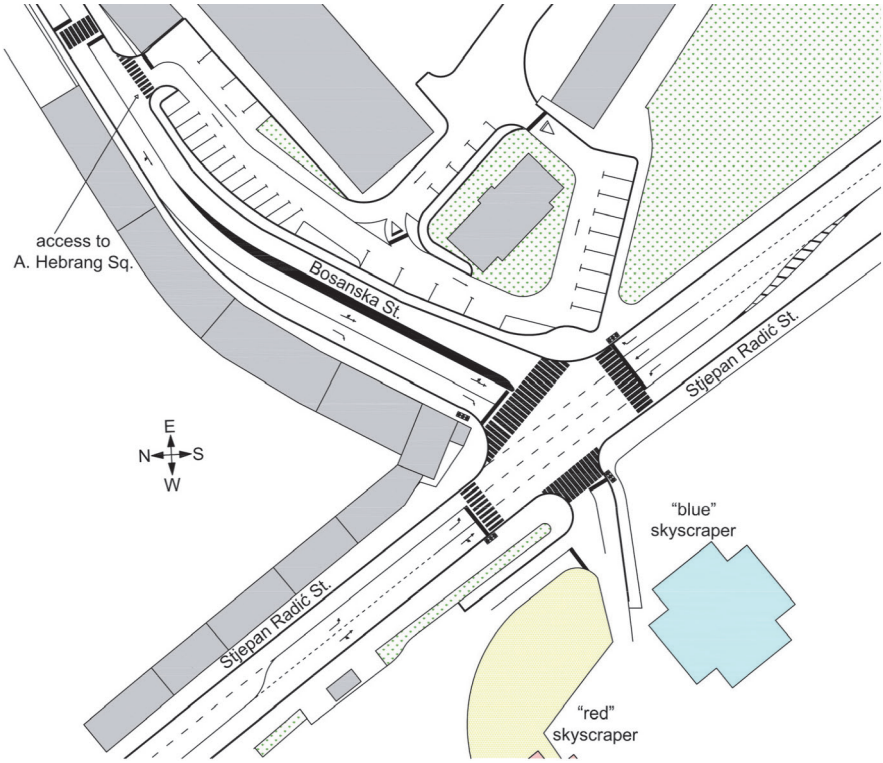

Figure 2 Stjepan Radić and Bosanska Street road intersection - current traffic situation

Apart from that, the following changes have been made:

- Bosanska Street is notably wider and now contains two entry and one exit lane, a splitter island between these lanes, and sidewalks on both sides of the street;
- the parking in Bosanska Street is now paved and has properly marked parking spaces, and the (unformal) entrance to it no longer exists;
- the access to Andrija Hebrang Square was moved away from the intersection and relocated to the entrance of parking in Bosanska Street (four detached garages were removed for this purpose);
- an additional right-turn lane at the SE approach leg in Stjepan Radić Street, which leads to Bosanska Street, was constructed;
- with this new layout, the angle between the approach leg in Bosanska Street and NW approach leg in Stjepan Radić Street is less acute (approx. 66º);

- new horizontal traffic signalization is significantly better;
- the intersection now has two new crosswalks - one on the NW approach leg in Stjepan Radić Street, and one on the new fourth approach leg near the "blue" and "red" skyscrapers.

Overall, it was concluded that this four-legged intersection with traffic lights works well, and that the previously described capacity and traffic safety problems at this location are resolved.

2.3 Rejected conceptual solution of knee-shaped turboroundabout

As mentioned in the introduction, the four-legged intersection with traffic lights was not the only design solution at that time - a conceptual design of a knee-shaped turboroundabout was also made. However, traffic experts thought that such a new type of intersection, which had just been introduced into Croatian design practise, would not solve the capacity and traffic safety problems at this location and that it would create several additional problems [7]:

- the parking of the "blue" and "red" skyscrapers could no longer be accessed from the intersection;
- this roundabout would interrupt the main pedestrian corridor along Stjepan Radić Street and move it about 30 metres further down the Bosanska Street, which could result in pedestrians running across the intersection;
- almost all parking spaces in the former unpaved parking in Bosanska Street, which are absolutely necessary for tenants, would be lost.

They also said that this roundabout was marketed as a turboroundabout and was not designed according to the design guidelines.
In view of the above, a preliminary design of egg-shaped turboroundabout according to the specifications of the Croatian guidelines for the design of turboroundabouts was made [8]. The main objective was to determine whether this specially designed multi-lane roundabout could be implemented at this particular location while respecting all project rules.
3 Preliminary design of egg-shaped turboroundabout
Egg-shaped turboroundabout is recommended for use when one of the traffic flows is dominant [8]. In this case, a road with dominant traffic flow is Stjepan Radić Street. A fourth approach leg at the entrance to the parking of the "blue" and "red" skyscrapers could not be adequately designed due to lack of space, so this turboroundabout was designed as a three-legged intersection (Fig. 3). The access to Andrija Hebrang Square was moved away from the intersection and relocated to the entrance of the parking in Bosanska Street and a number of parking spaces at this parking had to be reduced.
The first step in this design process was to create a "mini" turbo block recommended by the Croatian guidelines [8] (Fig. 4, Table 1). As can be seen in Fig. 4, the centre of this turbo block could not be aligned with the geometric center (GC) of the intersection. Its size and position were determined as follows: that the occupation of the surrounding area is as low as possible; that as many parking spaces as possible are preserved in the vicinity of adjacent residential buildings; that sidewalks along the intersection are at least 1.6 m wide; that the visibility on the entrance to the intersection from the NW approach leg in Stjepan Radić Street is as good as possible.

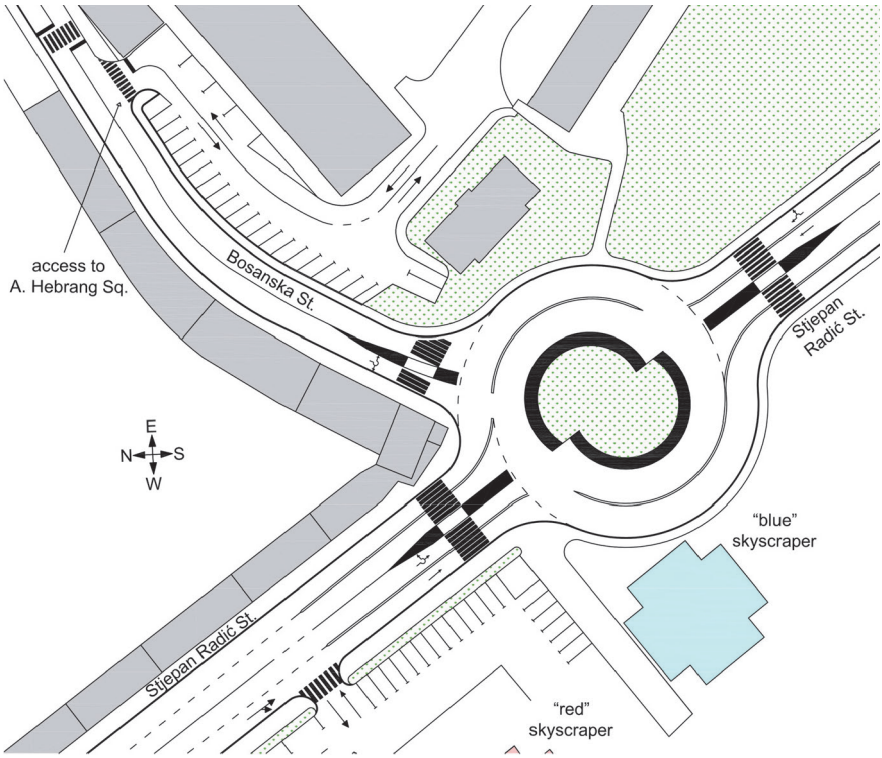

Figure 3 Preliminary design of egg-shaped turboroundabout

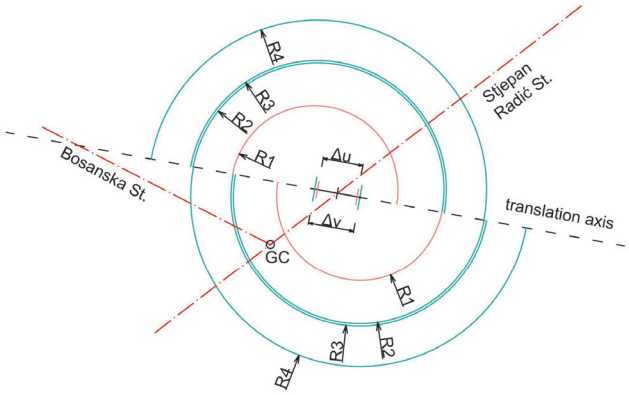

Figure 4 The design of turbo block of the egg-shaped turboroundabout

Table 1 Dimensions of mini turbo block [8]

Parameter	R1	R2	R3	R4	Δu	Δv	D
Dimensions [m]	10.45	15.85	16.15	21.20	5.05	5.75	46.55

After the creation of a turbo block, the remaining elements of the egg-shaped turboroundabout were designed: the central island, the circulatory lanes, the raised mountable lane dividers, and the elements of roundabout approach leg.
The central island had a 2 m wide truck apron, and the width of the circulatory lanes was determined by the dimensions of the turbo block (Table 1). The 30 cm wide raised mountable lane dividers were placed between the lanes at the entry to the roundabout, the circulatory roadway, and the exit. The 2.75 m wide entry and exit lanes at roundabout approach legs were divided by 2 m wide splitter islands. The crosswalks were installed at all roundabout approach legs at a distance of 5 m from the outer edge of the circulatory roadway. All entry and exit curves were designed with the minimum recommended radii: 12 m for roundabout entries and 15 m for exits. The only exception was the curve for the right turn from Bosanska Street to NW approach leg in Stjepan Radić Street, which could not be designed according to the design guidelines due to the limited space (the radius of this curve was 6 m). The diameter (D) of this egg-shaped turboroundabout amounted 46.55 m.
Finally, two performance checks were carried out at the end of the design process: horizontal swept path analyses for all driving directions using a three-axle truck with a three-axle semitrailer (in accordance with the specifications of Annex D of the Croatian guidelines [9]); speed analyses for all driving directions using a Dutch calculation model (in accordance with the specifications of Annex C of the Croatian guidelines [10]). The results of the above performance checks have shown the following:

- the designed egg-shaped turboroundabout did not met the swept path requirements recommended in the guidelines for the relevant design vehicle;
- the vehicle fastest paths for right turns could not be constructed due to the lane dividers between the traffic lanes at roundabout approach legs and circulatory roadway, i.e. because of the specific alignment of the approach leg in Bosanska Street.

4 Conclusions

For many years, the Stjepan Radić and Bosanska Street road intersection was a critical point in the city of Šibenik due to frequent traffic congestions and poor traffic safety. In order to solve the above-mentioned problems, a former classic three-legged intersection was reconstructed into a four-legged intersection with traffic lights in 2014. The main objective of this study was to determine whether the egg-shaped turboroundabout could be built at this site while complying with all the project rules set out in the Croatian guidelines. Accordingly, the following problems arose during this design process, mainly due to the limited space:

- the intersection approach legs could not be aligned at the recommended 90° angles;
- the centre of the turbo block could not be aligned with the geometric centre of the intersection;
- the curve for the right turn from Bosanska Street into the NW approach leg in Stjepan Radić Street could not be designed according to the project rules;
- the applied roundabout elements did not meet the swept path and speed requirements,
- the problem of poor visibility between the Bosanska Street and NW approach leg in Stjepan Radić Street was not solved;
- the number of parking spaces near the adjacent residential buildings was significantly reduced;
- the entrance to the parking of the “blue” and “red” skyscrapers, which has been moved to the NW approach leg in Stjepan Radić Street, may lead to additional traffic conflicts and potential traffic accidents in this area;
- the diameter of this roundabout is quite large, i.e. its circulatory roadway has been aligned close to the surrounding buildings, which may cause noise nuisance to the residents.

In the light of the above considerations, it can be concluded that a four-legged intersection with traffic lights is probably the best traffic solution for this particular location and that turboroundabouts (even with the smallest dimensions) can hardly be designed appropriately in urban areas. As stated in the introduction, these roundabouts should be planned outside or at the edge of settlements where the number of non-motorised road users in a traffic network is low and spatial constraints are less frequent. Finally, it is questionable whether this existing four-legged intersection with traffic lights would also meet the horizontal swept path requirements for the relevant design vehicle that is common in tourist locations such as the city of Šibenik - an intercity bus.
It should be emphasized that these conclusions were mainly made from perspective of intersection design and construction requirements, and that other parameters such as capacity and traffic safety of motorized and non-motorized road users were not analysed in detail.

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