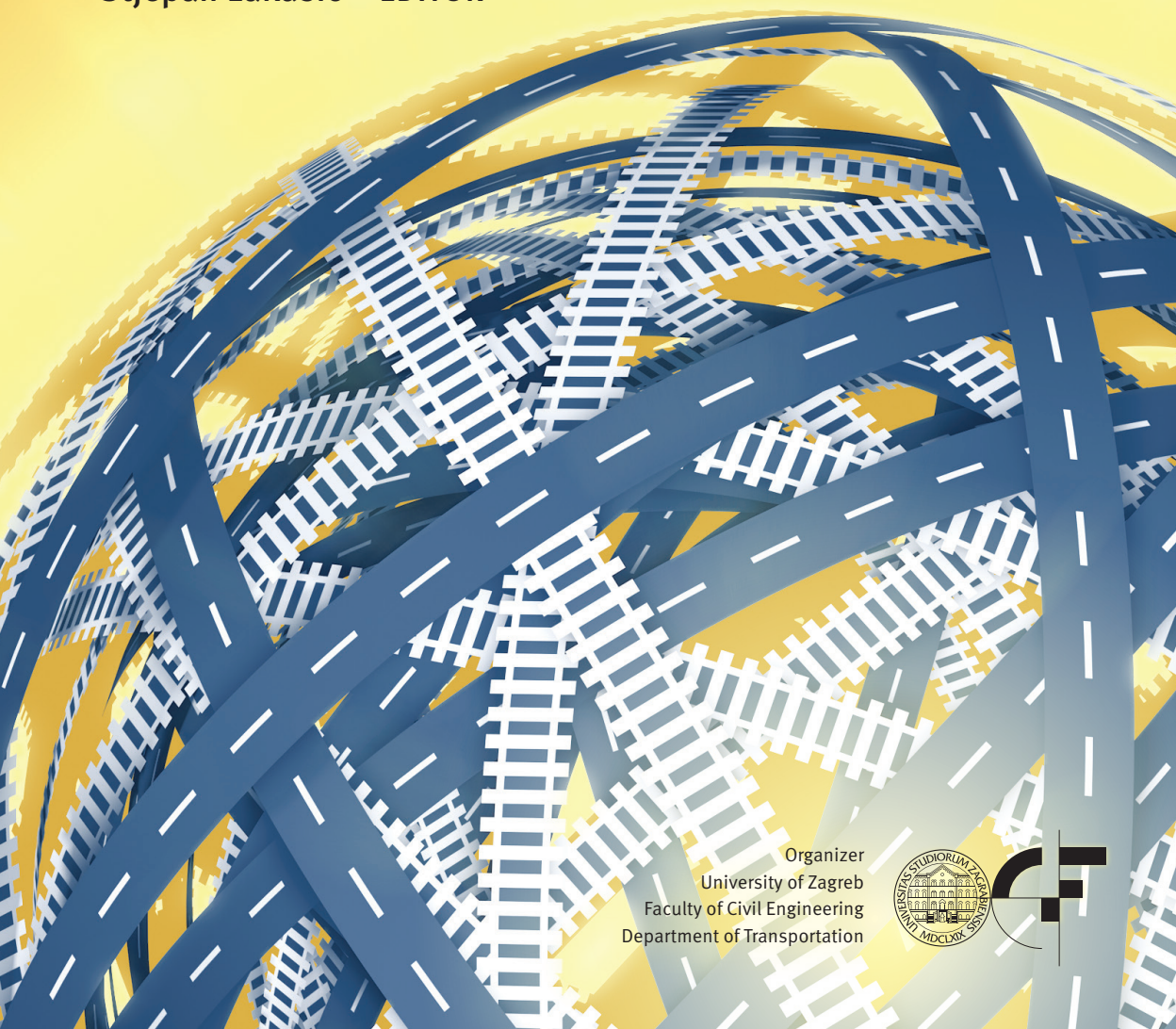
CETRA 2016

4th International Conference on Road and Rail Infrastructure
23-25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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CRITERIA FOR URBAN TRAFFIC INFRASTRUCTURE ANALYSES – CASE STUDY OF IMPLEMENTATION OF CROATIAN GUIDELINES FOR ROUNABOUTS ON STATE ROADS

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Abstract

Implementation and reconstruction of urban traffic infrastructure has proved to be very complex task because of different reasons. Among the most important are those connected with negative influence of motorized traffic on urban environment (congestions, safety, environmental problems) and those connected with urban surrounding (lack of free space, ambientality). During last decades there was great increase of reconstruction of standard intersections into roundabouts all over the middle Europe (Slovenija, Croatia, Italy ect.). Because of that the need to have objective and comprehensive estimation of the implementation of roundabout at the place of standard three or four leg intersection was established. In different countries were set, we can conclude based on different national regulation, similar criteria. Croatian Guidelines for Roundabouts at State Roads were adopted by authorities for state roads Hrvatske ceste in 2014. They prescribe estimation and comparison of solutions in the case of new or reconstruction of existing intersection into roundabout. The goal of this paper is to discuss proposed criteria by comparing it with widely used criteria for traffic infrastructure planning and design commonly used for urban traffic infrastructure. The suitability and universality of proposed criteria will be tested on two case studies where guidelines were implemented: four leg signalised intersection and three leg non signalized intersection situated in different urban context.

Keywords: urban infrastructure, criteria, roundabout

1 Introduction

Implementation and reconstruction of urban traffic infrastructure has proved to be very complex task because of different reasons among which the most important are those connected with negative influence of motorized traffic on urban environment and on wider urban surroundings. This is why evaluation of urban infrastructure includes criteria connected with engineering solution and economics of the solution but also different social and environmental criteria too [1]. Overall used criteria for planning, design and construction of urban traffic infrastructure can be divided in four groups: traffic criteria, environmental criteria, social criteria and economic criteria.
Traffic criteria include different aspects of traffic efficiency of proposed solution and, if applicable, increase in traffic safety. Environmental criteria are connected with all of the negative effects of traffic, especially motorized traffic on air, water and land. Social criteria measure how many people and sometimes also which groups (with the emphasis of different vulnerable groups) will benefit (or not) from new infrastructure. Economic criteria takes into consideration the costs of construction and maintenance of traffic infrastructure.

During last decades there was great increase of reconstruction of standard intersections into roundabouts all over the middle Europe (meaning Slovenija, Croatia, Italy ect.). Because of that the need to have objective and comprehensive estimation of the implementation of roundabout at the place of standard three or four leg intersection was established [2, 3, 4]. Also in different countries were set, we can conclude based on different national regulation, similar criteria [5-10]. Croatian Guidelines for Roundabouts at State Roads (further in the text Croatian Guidelines) were adopted by authorities for state roads Hrvatske ceste in 2014 [5]. They prescribe estimation and comparison of solutions in the case of new or reconstruction of existing intersection into roundabout.
In this paper an analyses and comparison of criteria used in different national regulation is done in order to make an objective assessment of criteria and methodology proposed in Croatian Guidelines. Methodology for assessing roundabout design at different location, set in the Croatian Guidelines, are applied as case study on two different intersections. The aim was to test proposed criteria for different types of intersections (three and four leg, signalised and non signalised) and in different urban context (inside the city, on the border of the city) planned for reconstruction in roundabout.

2 Criteria for roundabout implementation

There is no uniform guidelines in Europe for geometric design of roundabouts as specific circumstances differ among countries. Design elements as well as criterion for acceptability of roundabouts are usually defined in national guidelines adapted to their circumstances [11].

2.1 Overview of usually used criteria for roundabout implementation

In the book "Kružne raskrsnice-Rotori", author Zoran Kenjić, mentions 4 main criteria that should be considered when making decisions on the justification of the construction a certain type of the intersection [8]. Similar, 8 criteria acceptable for standard one or two lane roundabouts suggestes the author of the book "Alternative Types of Roundabouts" [11]. The suggested criterion are: functional, spatial, capacity, design, traffic-safety, front-and-rear, economical and environmental. Analyses of different available guidelines from European countries and USA use many common criteria although some differences, due to different traffic culture, can be recognised. In Table 1 comparison of criterion in different guidelines is shown.

Table 1 Comparison of usually used criteria for roundabout

Countries	Criteria	Application	Year of publication
Croatia [5]	1) functional criterion 2) spatially-urbanistic criterion 3) traffic flow criterion 4) design and technical criterion 5) traffic safety criterion 6) capacity criterion 7) environmental criterion 8) economic criterion	State roads	2014.
Slovenia [6] Serbia [7]	1) functional criterion 2) capacity criterion 3) spatial criterion 4) design and technical criterion 5) traffic safety criterion 6) economic criterion	State roads	2011. 2012.

Table 1 Comparison of usually used criteria for roundabout (continued)

Countries	Criteria	Application	Year of publication
Netherland [9]	1) road function criterion 2) capacity criterion 3) road safety criterion 4) policy of traffic management; 5) spatial possibilities or limitations; 6) capital and maintenance costs.	N/A	2009.
USA [10]	1) considerations of context 2) potential applications 3) planning-level sizing and space requirements 4) economic evaluation 5) public involvement	N/A	2010.

Some of criteria are very common. In all of analysed guidelines we can find economical, traffic and design criterion. As specific can be seen criteria "policy of traffic management" in Netherlands Guidelines which emphasises the importance of consistent traffic policy when some parts of road network is analysed. In the USA Guidelines specific criteria is "public involvement" which, in developed countries such as USA, has great importance when some new infrastructural objects are planned or constructed.

2.2 Croatian guidelines for roundabouts at state roads

First Croatian guidelines for roundabouts were adopted in 2002. [12] and they made important step in standardisation of roundabout design practice. However, after more than 10 years of intensive implementation of roundabouts in Croatia there was a need to revise and upgrade the Guidelines. Upgrade done in Guidelines from 2014. [5] are mainly connected with more detailed explanation of the design principles, introduction of some new types of roundabouts and introduction of obligatory procedure for estimation of roundabout projects.
In this new guidelines estimation and comparison of solutions for roundabouts with those for standard intersection became obligatory for all state roads. The suggested methodology proposes 8 criteria through which the solutions are analysed and compared. Comparison can be made between non-signalised intersection and roundabout and between signalised intersection and roundabout. Proposed criteria are:

- **Functional criterion:** analyses the primary role of the intersection under consideration in the road network and in general;
- **Spatially-urbanistic criterion:** analyses potential roundabout location and sensitivity of certain zones to the planned changes;
- **Traffic flow criterion:** comprises the verification of the circumstances of the present intersection, relating to the overall level of traffic flow, and to the – direction of traffic flow at the intersection;
- **Design and technical criterion:** analyses the circumstances on the subject intersection that are related to the geometry of the intersection, to the position, number and angle of intersection approaches;
- **Traffic safety criterion:** analyses if the roundabout, in the existing conditions, is the solution that guarantees the safety for all road users.
- **Capacity criterion:** analyzes possible traffic capacity and quality of traffic flow (level of service) for certain types of intersection;
- **Environmental criterion:** analyses whether and how much implementation of roundabout contributes to the improvement of the intersections environment and wider;
- **Economic criterion:** analyses the cost-effectiveness of roundabout implementation at the particular location.

The criteria can be grouped as commonly used criteria for urban infrastructure (Table 2). Some of the criteria can be connected with one and some with more than one standard groups which points that they cover the problem well.

Table 2 Criteria for urban infrastructure

Standard group of criteria for urban traffic infrastructure	Criteria from Croatian guidelines for roundabouts
Traffic	Capacity, traffic flow, functional criteria, design (technical) criteria
Social	Traffic safety, functional criteria, spatial criteria
Environmental	Environmental criteria, spatial criteria
Economical	Design criteria, economical criteria

3 Case study

The methodology and criteria proposed in Croatian Guidelines were applied on two different standard intersections in urban part of Rijeka City [13]. Urban in this case means area close to city centre with road network used by motorised and non-motorised users, pedestrians and possibly also cyclists.
Case study 1 was three leg non-signalised intersection situated at the east entrance to Rijeka City and case study 2 was four-leg signalised intersection situated inside city network.
For both intersections deep analyses based on criteria defined in Croatian Guidelines for roundabouts at state roads was done. In order to make the analyses it was necessary to: make design of roundabout with all geometric elements, test horizontal and vertical alignment of new roundabout design with existing road network, analyse data about traffic accidents, make capacity analyses for roundabout and existing intersection, make analyses of level of air pollution for both solutions [13].

3.1 Case study 1: Three-leg non signalized intersection [13]

Analysed three-leg non signalized intersection is situated on crossing of XIII divizije Street and Janka Polić Kamova Street. The intersection serves as an east entrance/exit for Rijeka City and connects Rijeka as primary center with close secondary center Kostrena, Bakar and Kraljevica. The intersection lost it's role as an important transit point after Rijeka ring was opened few years ago so present traffic volumes are smaller than they were. In near surrounding of the intersection there are city beaches so during summer season there is intensive pedestrian traffic in the intersection zone.
Because of the shape and open space around existing intersection it was not a problem to design roundabout of medium size with the radii of 18 m and with all standard dimensions, circulatory lane with width of 6,5 m and approaching lanes with width of 3,25 – 5,73 m. The control of turning path was done for all of possible driving directions for design vehicle as well as the control of visibility from all approaches, shown in the Figure 2.
For design purposes the traffic volume counting and capacity estimation was done. For capacity of roundabout approaches the commercial computer program Sidra Intersection was used. That computer program is based on non-linear Australian method and on the basis of geometry and load volumes gives output on average delay, saturation of approach lane and finally level of service. For analysed location results of capacity calculation for standard three-leg intersection and for designed roundabout show that both solutions can satisfy present level of traffic at the intersection as well as the projected traffic for next years. The average level of service (LOS) for present solution is B and for roundabout is A. The estimated CO emissions happened to be much favorable at roundabout than on standard intersection presently in function (Figure 3).

Figure 1 Present situation at intersection Case study 1 (left) and roundabout design at the same location (right) [13]

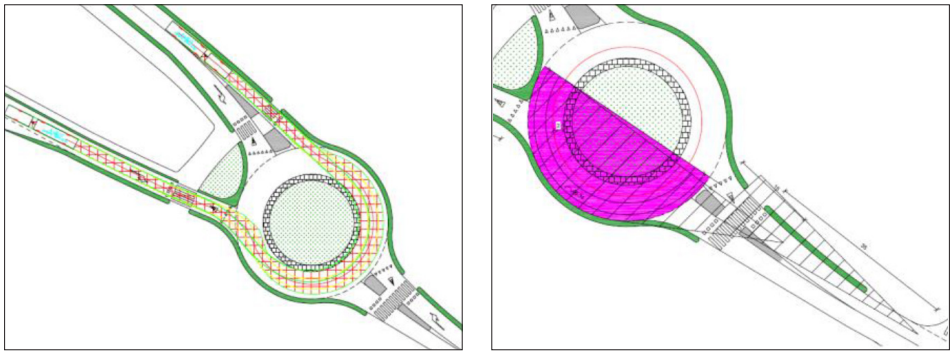

Figure 2 Turning paths for design vehicle (left) and visibility control (right) – examples [13]

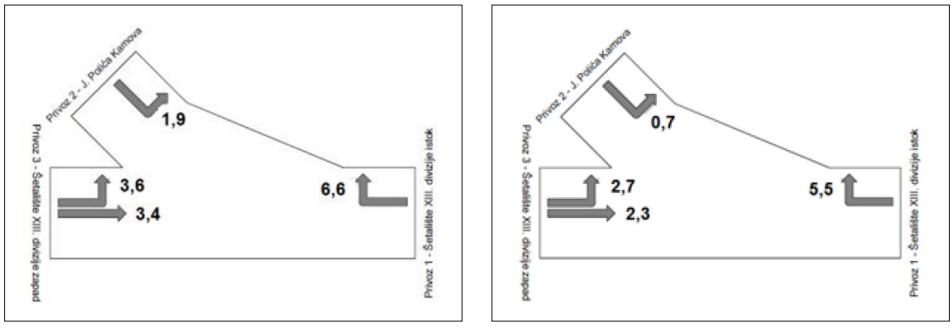

Figure 3 Pollution – CO emissions for standard intersection (left) and roundabout (right) [13]

Roundabout solution has the advantage that in the case of good LOS the cars are not forced to stop at the approach, the traffic flow is continuous and the level of pollution in that case lower than on the standards intersection in similar conditions.

Finally, the traffic safety indicators were analysed. The data about traffic accident during last 5 years were collected from authorities and potential conflict spots were analysed too. In number of potential conflict points roundabout has general advantage not to have conflict point of crossing type so it is almost always better solution than any type of standard intersection on which crossings of traffic directions cannot be avoided. As for the traffic accidents the analyses show that most frequent type of accident is impact from the back. As it is type of

accident that is very common on roundabouts in this case proposed solution cannot improve the traffic safety significantly.

3.2 Case study 2: Four-leg signalized intersection [13]

Analysed four-leg signalized intersection (Figure 4) is situated on the crossing of street coming from the direction of center part of the Rijeka City – 1. Maja Street (approach 4), street coming from residential as well as very developed commercial city zone around Osječka Street (approach 2) and two streets coming from mostly residential areas Tizianova Street (approach 1) and Kresnikova Street (approach 3). The main direction is the one connecting city center and residential-commercial zone around Osječka Street not only because of it's traffic role as commercial street but also because of the transit role that Osječka Street has in city road network. It is a two-lane corridor (Osječka – 1. Maja) with significant traffic volumes, the statistics collected by city transportation firm Rijekapromet shows an average ADT on that corridor of 5500 / per lane during week days.

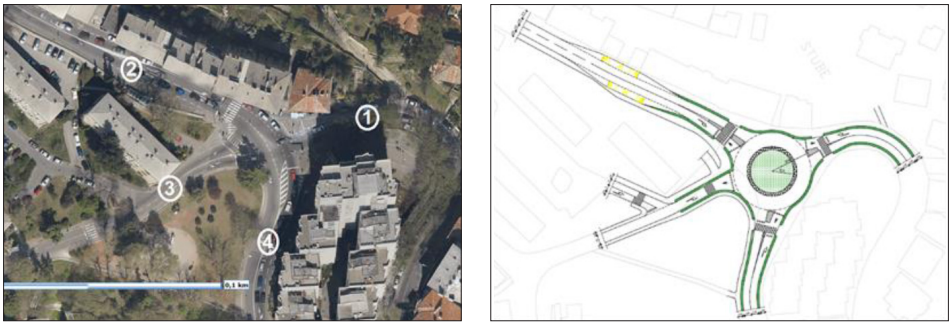

Figure 4 Present situation at intersection Case study 2 (left) and roundabout design at location (right) [13]

Because of the densely built-up area on the eastern side of the intersection, present intersection located in curve and on slope, it was not an easy task to implement roundabout with standard geometric elements on the location. The designed solution is medium size roundabout with radii of 18 m and with all standard dimensions, circulatory lane with width of 6,5 m and approaching lanes with width of 3,25 – 5,73 m. The control of turning path was done for all of possible driving directions for design vehicle as well as the control of visibility from all approaches, shown in the Figure 5.

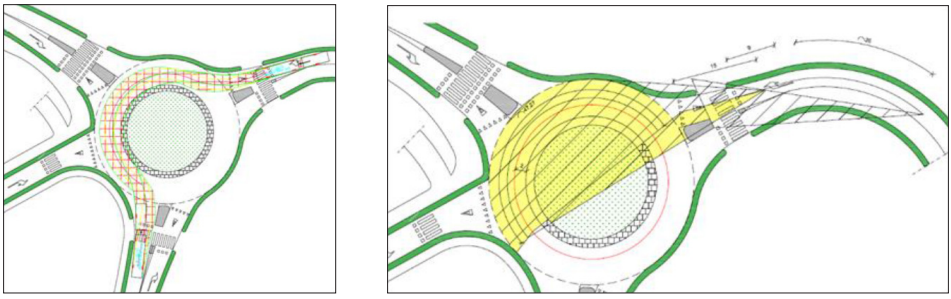

Figure 5 Turning paths for design vehicle (left) and visibility control (right) – examples for approach 1 [13]

For design purpose the traffic volume counting and capacity estimation was done. For capacity of roundabout approaches the commercial computer program Sidra Intersection was used. For analysed location results of capacity calculation for signalised four-leg intersection and

for designed roundabout show that both solutions have unsatisfactorily LOS for some of the directions. With roundabout solution great problem is approach 4 (1. Maja) which is one of the main directions with great traffic volumes and which, in this case, has LOS D. This is why the conclusion is that roundabout cannot satisfy traffic volumes at the location.

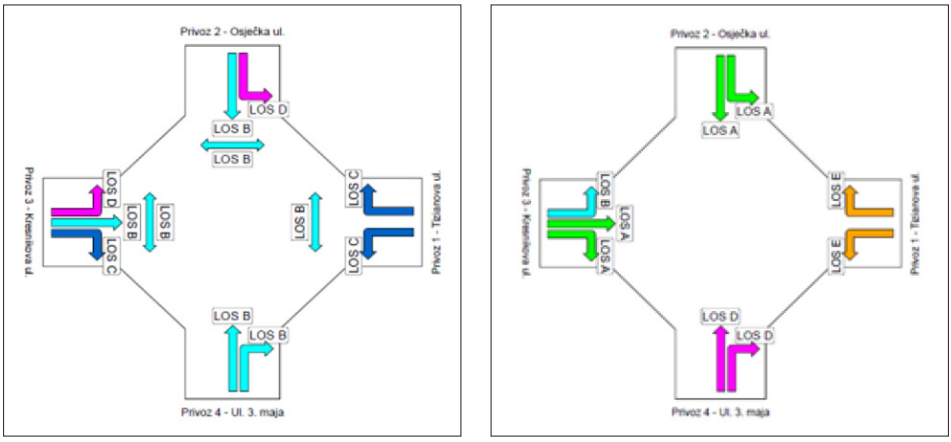

Figure 6 Level of service for present intersection (left) and for roundabout (right) [13]

The estimated CO emissions happened to be much favorable for all approaches at present signalized intersection than on the roundabout. The result have to do with greater LOS and calculated stops at the approaches for roundabout solution (Figure 6).

3.3 Case study – conclusion

Case study showed that proposed criteria can be easily and with high level of reliability implemented for estimation of roundabouts in the case of reconstruction of existing standard intersection. As lots of data can be collected directly on the site it is possible to make objective analyses and assessment of proposed solution as well as the comparison with existing intersection.

4 Conclusion

Analyses of literature as well as of the existing national guidelines for roundabouts show that analyses of the acceptability of roundabout is necessary step in their application at the location of new or reconstructed intersection. The need was recognized in Croatian guidelines in which 8 criteria, comparable with those used widely in Europe and in USA, were defined.
Criteria set in Croatian Guidelines were tested on two different case studies. They proved to be sensitive enough for application on the location of signalized and non-signalized existing intersection. In both cases analyzes of criteria pointed that roundabout is not an optimal solution for analyzed location but because of different reasons. In case study 1 (non-signalized intersection on the border of the city) the roundabout solution proved to be expensive and not justified by the traffic need. In case study 2 (signalized intersection with high traffic volumes) roundabout wasn't able to satisfy capacity and it proved to have more negative impact to the environment than exiting standard four leg signalized intersection.
In both cases positive was that for all of the measurable criteria there was possibility to collect data on the site (number of traffic accidents, traffic volumes) which made positive effect on the quality of comparison of the solutions. In next step the methodology has to be tested for estimating application of planed roundabout without possibility to collect data on the site, as it is the case when planning a completely new intersection.

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