TOMAŽ TOLLAZZI, Ph.D., B.Sc.C.E.
E-mail: tomaz.tollazzi@um.si
University of Maribor, Faculty of Civil Engineering
Smetanova 17, SI-2000 Maribor, Slovenia
GORAN JOVANOVIĆ, B.Sc.C.E.
E-mail: goran.jovanovic@appia.si
Appia Ltd.
Leskoškova 9e, SI-1000 Ljubljana, Slovenia
MARKO RENČELJ, Ph.D., B.Sc.C.E.
E-mail: marko.rencelj@um.si
University of Maribor, Faculty of Civil Engineering
Smetanova 17, SI-2000 Maribor, Slovenia

Traffic Infrastructure
Preliminary Communication
Accepted: Jan. 28, 2012
Approved: Sep. 24, 2013

NEW TYPE OF ROUNDABOUT: DUAL ONE-LANE ROUNDABOUTS ON TWO LEVELS WITH RIGHT-HAND TURNING BYPASSES – ''TARGET ROUNDABOUT''

ABSTRACT

The problems of low traffic safety level on multi-lane roundabouts have been resolved in various ways in different countries, usually by using alternative types of roundabouts that reduce the number of conflict points. Alternative types of roundabouts typically differ from "normal" or "standard" roundabouts in one or more design elements, as their implementation purposes could also be specific. Today, several different types of roundabouts are already in use ("mini", "double mini", "dumb-bell", those "with joint splitter islands" ("dog-bone"), those "with a spiralling circular carriageway" ("turbo"), those "with depressed lanes for right-hand turners" ("flower") etc.). This paper introduces a new type of roundabout, dual one-lane roundabouts on two levels with right-hand turning bypasses, namely the "target roundabout". This paper describes and analyses their design, traffic safety, and capacity characteristics, compared with the standard two–lane roundabouts.

KEY WORDS

roundabouts, alternative types of roundabouts, turbo roundabout, target roundabout

1. INTRODUCTION

As stated in the Abstract, there are several types of roundabouts in worldwide use today [1]. Some of the alternative types of roundabouts are more recent and have only been implemented in certain countries, but some of them are in frequent use all over the world. Both groups typically differ from the "standard" one- or two-lane roundabouts in one or more design elements, as their purposes for implementation are also specific.

The main reasons for their implementation are the particular disadvantages of "standard" one- or two-lane roundabouts under particular circumstances. Usually, these disadvantages are highlighted by low levels of traffic safety or capacity. Today, a growing number of foreign studies, as presented in the scientific and professional literature, have pointed out the poor traffic-safety characteristics of "standard" two-lane roundabouts, and their lower than expected capacities [2].

It is for these reasons that many countries are looking for solutions in order to provide a higher level of traffic safety and capacity. Different countries are tackling this problem in different ways; however, the most popular way is by decreasing the number of conflict points, which is usually one of the main characteristics for some alternative types of roundabouts. Two of them are the turbo and flower roundabouts.

2. BASIC CHARACTERISTICS OF TURBO AND FLOWER ROUNDABOUTS

A turbo roundabout, as developed by L.G.H. Fortuijn [3] is an innovative arrangement of a two-lane roundabout that has revolutionised the roundabout design in the Netherlands, and also in some other countries. A turbo roundabout is a special type of two-lane roundabout, where certain directional flows are separated or run alongside physically separated lanes (*Figure 1*).

Figure 1 - Turbo roundabout; City of Koper, Slovenia

In a turbo roundabout the traffic flows run separately even before actual entry into the roundabout, then occupy separate lanes throughout the roundabout, and also separate when exiting the roundabout. The physical separation of traffic lanes is only interrupted at places of entry into the inner circulatory carriageway (*Figure 2*).

Figure 2 - Physical separation of traffic lanes on a turbo roundabout; City of Maribor, Slovenia

Since weaving on the roundabout is no longer possible, drivers should be assisted by clear signposting and lane-marking – a special form of arrow-marking has been developed for turbo roundabouts, which ensures clearer lane selection [4].

The idea of a turbo roundabout was introduced very rapidly, over just a few years, into the Slovenian system (*Figure 3*). There were several reasons for this. One of the more important reasons was surely the fact that in the past, too small two-lane roundabouts had been constructed in Slovenia. Similar problems with the existing too small roundabouts have also been reported by Lithuania [5] and some other countries. The second of the more important reasons was that the inner circulatory lanes were not conductive for the younger and senior drivers because they felt insecure when changing lanes on a circulatory carriageway [6].

At this moment (January 2013) in Slovenia, there are eleven existing turbo roundabouts, two under construction, and design documentation for four more turbo roundabouts are being processed, even though there are more expensive solutions. Generally, those layouts that provide higher levels of services are the more expensive ones [7].

Figure 3 - Typical Slovenian turbo roundabout; City of Maribor

The roundabout with "depressed" lanes for right-hand turning – namely, the "flower roundabout" – was invented at the Centre for Road Infrastructure at the Faculty of Civil Engineering, University of Maribor, Slovenia [6, 8], as a solution for achieving a higher level of traffic safety on the existing, less safe standard two-lane roundabouts. One of the basic characteristics of this type of two-lane roundabout is the same as for the turbo roundabout – physically separated lanes on the circulatory carriageway (*Figure 4*). The second characteristic of the flower roundabout is that all the right-hand turns have their own separated lanes – bypasses. Therefore, bypasses are not a novelty; as they are in frequent use all over the world and also in Slovenia (especially two types of bypasses). What is a novelty is that it is possible to adjust the existing "standard" (less safe) two-lane roundabout into (safer) flower roundabout without moving any of the outer road curbs. Therefore, a one-lane roundabout is obtained by physically separating the right-hand turning traffic

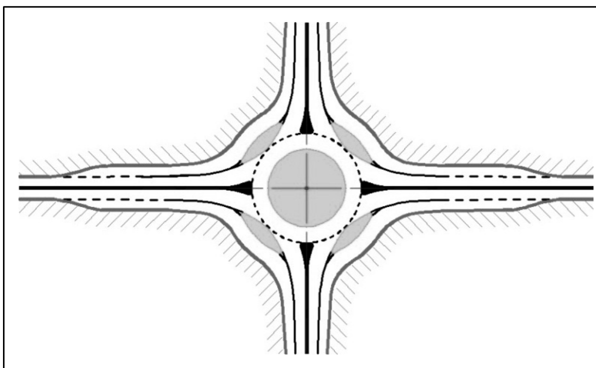

Figure 4 - Typical layout of a flower roundabout

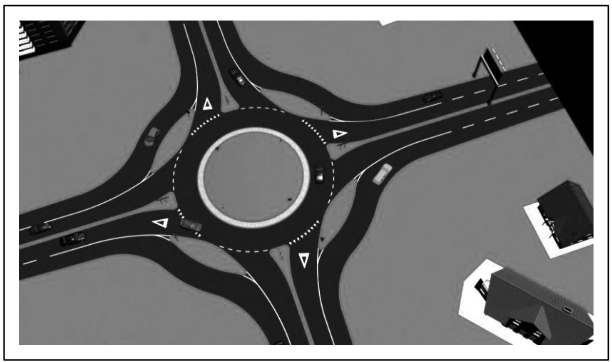

Figure 5 - Physical separation of the right-hand turnings in a flower roundabout

flow (*Figure 5*). This solution can be used on two- or four-lane roads.

The best design characteristic of a turbo roundabout (different from flower roundabout) is the existence of different types of turbo roundabouts. Selecting the type depends on the predominant direction of the main traffic flow. Namely, the predominant direction of the main traffic flow is the criterion for selecting the type of turbo roundabout.

The geometrical form of the turbo roundabout is rather complicated. It is formed by the so-called turbo block. This is a formation of all the necessary radii, which must be rotated in a certain way, thereby obtaining traffic lanes or driving lines. However, probably the best characteristic of the flower roundabout is that it is implemented within an existing “standard” two-lane roundabout, without any moving (unlike the turbo roundabout) of the outer road curbs.

Turbo is a more effective roundabout type than the “standard” two-lane roundabout from the traffic safety point of view. A typical turbo roundabout reduces the number of potential conflict points [9]. Theoretically, there are four crossing, four diverging, and six merging conflict points.

On a flower roundabout the traffic safety situation is slightly better. By physically separating the right-hand turning traffic flow, a one-lane roundabout is obtained, where (unlike the turbo roundabout) there are no crossing conflict points; however, (unlike the “standard” two-lane roundabout), there are also no weaving conflict points. The weaving conflict points are transferred from the circulatory carriageway (along the curve) to the road section before the roundabout (usually a straight line), which is a safer solution from the traffic safety point of view. In short: on a flower roundabout there are just four merging, and four diverging conflict points.

The situation is slightly different from the capacity point of view. The results from micro-simulation show that there are no significant differences between the turbo and flower roundabouts for low traffic loads. Congestions and queue lengths are approximately the same. It is at higher traffic loads that the differences in favour of the flower roundabout occur, when the percentage of right-hand turners approaches 60% of the total number of vehicles along the main traffic direction [6, 10]. The flower roundabout becomes completely congested at that moment when the one-lane roundabout capacity is exceeded.

3. DUAL ONE-LANE ROUNDABOUTS ON TWO LEVELS WITH RIGHT-HAND TURNING BYPASSES – “TARGET ROUNDABOUT”

As written above, decreasing the number of conflict points is a very useful solution for providing higher levels of traffic safety and capacities, and also a good compromise between the finances, on the one hand, and the increased capacity and traffic safety levels, on the other. A lower number of conflict points is usually one of the characteristics of some alternative types of roundabouts. Most of them are two-lane roundabouts, but new layouts also exist. One of them is the dual one-lane roundabout on two levels with right-hand turning bypasses, namely, the “target roundabout”. Like the flower roundabout, the target roundabout was also invented at the Centre for Road Infrastructure at the Faculty of Civil Engineering, University of Maribor, Slovenia [11]. At this moment, this new type of roundabout is in the development phase.

3.1 Design elements

The target roundabout is designed as a two one-lane roundabout with different dimensions (outer diametres), located on dual levels (*Figure 6*), and all right-hand turners on both roundabouts have their own, separate right-hand turn bypass lanes. Dual one-lane roundabouts on two levels allow for driving from all directions to all directions, and this roundabout type “forgives errors”: if a driver mistakenly stays in the left-hand lane at the entry, it is still possible to turn right at the next exit (unlike the turbo roundabout).

Target roundabouts are useful in suburban areas, where there is plenty of space, and two-level interchanges (“diamond”, “diverging diamond” [12], “cloverleaf” interchange...) are possible solutions. However, this solution is also acceptable in urban areas because of its low dimensions.

3.2 Traffic safety characteristics

By physically separating the right-hand turning traffic flow, a one-lane roundabout is obtained, where (unlike in the case of a turbo roundabout) there are no crossing conflict points; however, (unlike in the case of normal two-lane roundabout), there are also no weaving conflict points. Any possible weaving conflict points when transferring from the circulatory carriageway

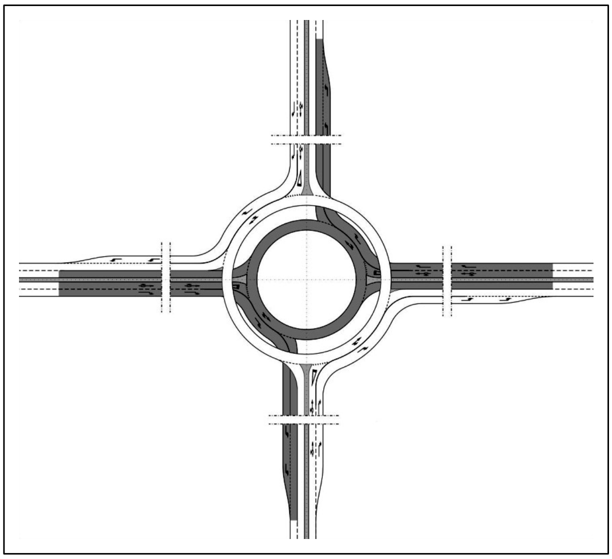

Figure 6 - Typical layout of a target roundabout

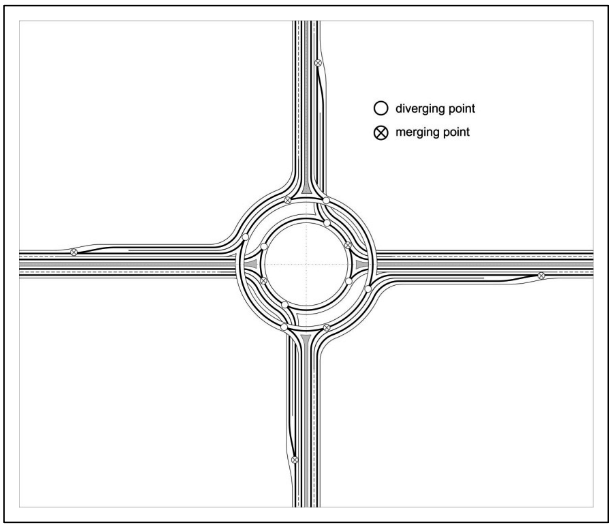

Figure 7 – Conflict points on a target roundabout

onto the road section are before the roundabout (as in the case of the turbo and flower roundabouts), which is a safer solution from the traffic safety point of view (*Figure 7*). On the target roundabout there are just eight merging, and eight diverging conflict points (as in the two one-lane roundabouts).

Driving in the target roundabout is the same as on the turbo roundabout (the same philosophy of sign-posting and lane-marking).

3.3 Capacity characteristics

Practical evaluation data are presently unavailable for modern types of roundabouts. Only in the Netherlands have a number of turbo roundabouts been constructed and very few of those are operating at or near capacity. Therefore, different possibilities remain open for determining the capacities of turbo roundabouts and even other alternative types of roundabouts (for those roundabouts with right-hand turn bypass lanes. Capacity models have already been created in [13] and [14]).

Mauro and Branco [2] found, using their analytical model that the capacities of turbo roundabout secondary entries were higher than the roundabout capacities when the traffic flow within the inner lane of the circle was high and the traffic flow in the outer lane of the circle was within the low to lower-middle range. On the contrary, the capacities of the main entries to roundabouts are always higher than the capacities of the main entries to the turbo roundabouts.

Tollazzi et al. [6] conducted a comparative analysis of the capacities of "standard" two-lane, turbo and flower roundabouts, using a PTV VISSIM micro-simulation program. The right-of-way conflicting movements in VISSIM were modelled using the so-called "Priority Rules", which are almost unique within the software industry.

Instead of testing and calibrating the positions and parameters (minimum gap time, minimum headway) for flower roundabouts, we decided to use the standard parameters that have been tried and tested under Slovenian conditions and also for capacity estimation of the target roundabout.

The congestion and queue lengths covering three traffic load scenarios were measured. The typical target roundabouts could be installed at urban interchanges with 4-lane urban arterial roads. Arterial roads are high-capacity roads (from 35,000 AADT up to 65,000 AADT) delivering the traffic from city feeder roads to the motorways, and the speed limits are between 50-70 km/h.

At these intersections signalised intersections could be used, thus causing capacity reduction. In the suburban areas, where there is plenty of space, two-level interchanges would be possible solutions, instead of signalised intersections. "Diamond", "diverging diamond", roundabout or "cloverleaf" interchanges could be used. There are also several other possible solutions as well, but for our comparisons we focused on the widely used standard two-lane roundabout (*Figure 8*). Our model represents a simple two-lane roundabout with diametre D=75 m, with both roads having four lanes.

We tested the target roundabout for three different load scenarios (1,000, 1,250 and 1,500 veh./leg/h). The traffic flows represented the intersection of two roads with overall 40,000-60,000 AADT. All the scenarios presumed that both roads had equal traffic loads, the through traffic flow was 50% of the approach input, and the left-hand and right-hand turning flows were 25% each of the approach input traffic load. We did not change the relationship between the through and turning traffic, which could be done during further research. In order to obtain the basic impression of the differences in capacity estimations, we have included

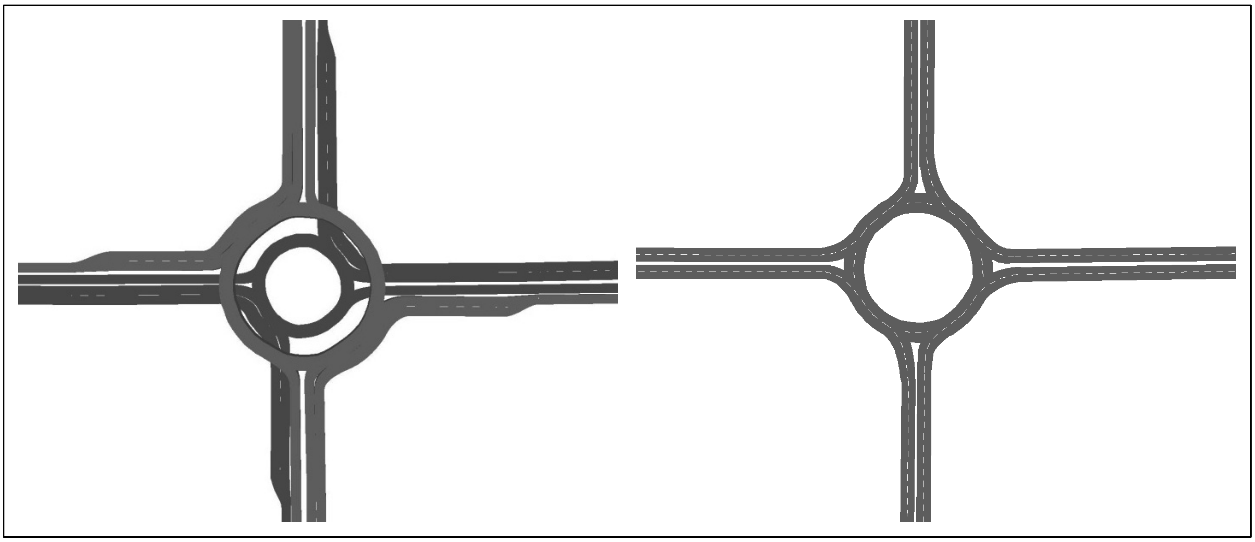

Figure 8 – Mathematical model of the target and standard two-lane roundabout, modelled in PTV VISSIM 5.40

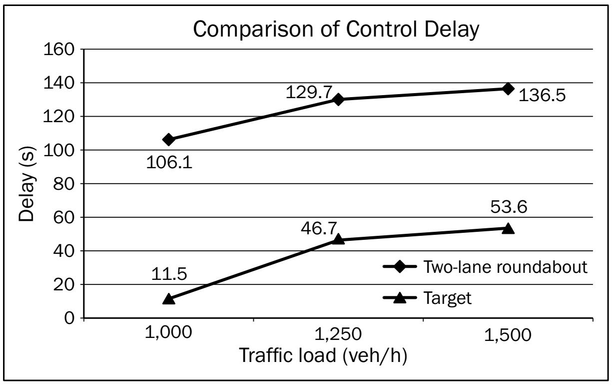

Figure 9 – Comparison between control delays

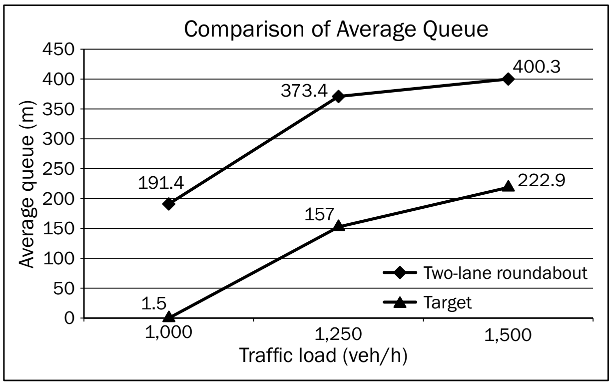

Figure 10 – Comparison between average queues

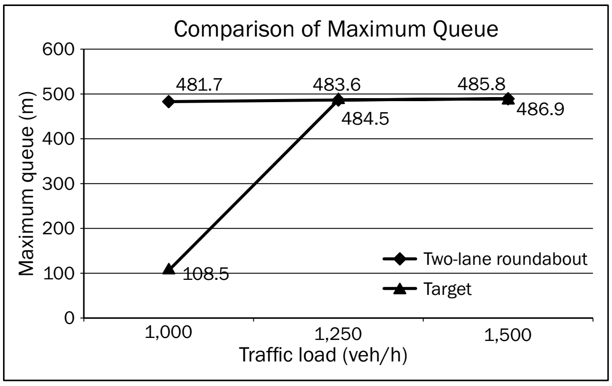

Figure 11 – Comparison between maximum queues

the results for two-lane roundabouts in the following graphs (Figures 9 – 11) as well.

Following the results of micro simulation it can be summarised that the target roundabout would serve an interchange with 50,000 AADT. Within a scenario of 1,500 veh./h/leg (60,000 AADT) there would be an overall delay of 53.6 s, which is still acceptable due to HCM criteria (LOS=E), but in regard to queue lengths (average 223 m) and visual perception of simulation, we could not recommend such a solution for that amount of traffic. Still an acceptable capacity was reached at 1,250 veh./h/leg (50,000 AADT) with LOS=E (46.7 s), but it would be necessary to deal with the queue lengths.

In comparison with the two-lane roundabout there was a big advantage due to capacity criteria. The two-lane roundabout could not handle even 1,000 veh/h; based on LOS=F estimation.

4. CONCLUSION

Many foreign traffic safety analyses point out the low level of traffic safety and capacity regarding the "standard" multi-lane roundabouts, and this problem is resolved in several different ways in different countries, usually with alternative types of roundabouts at which the number of conflict points are reduced. Today, several different types of roundabouts are already known, and two of them, though relatively new, are turbo and flower roundabouts.

This paper introduced a completely new type of roundabout, dual one-lane roundabouts on two levels with right-hand turning bypasses, namely a "target roundabout" with its design, traffic safety and capacity characteristics, being compared with the "standard" two-lane roundabouts.

The target roundabout is designed as two one-lane roundabouts, located on two levels, with all the right-hand turners at both roundabouts having their own, separate right-hand turn bypass lanes.

At the target roundabout, there would be two one-lane roundabouts where (unlike in the case of the turbo roundabout) there are no crossing conflict points. The target roundabout would have just eight merging, and eight diverging conflict points (as in the two one-lane roundabouts), with the weaving conflict points transferred from the circulatory carriageway to the road section before the roundabout, which is a better solution from the traffic safety point of view.

However, in accordance with the results of micro simulation, we can summarise that the target roundabout could serve as an interchange with 50,000 AADT. Compared with the cloverleaf this would be a big disadvantage due to capacity criteria, but in the case of urban space limitation, the possible target roundabout would need to be taken into consideration and analyse using forecasted traffic.

All alternative types of roundabouts have their advantages and deficiencies, which makes sense, since they are intended for solving particular problems. In the near future, we can expect further developments of alternative types of roundabouts, intended for solving specific problems, which will certainly represent a challenge for our branch of science.

ACKNOWLEDGEMENT

We would like to thank Mr. George Yeoman for proofreading this article.

NOTES:

The turbo roundabouts, as presented in the figures, were designed by BPI d.o.o., LINEAL d.o.o. and PS PROSTOR d.o.o., Slovenia.

All the technical drawings were compiled by Sašo Turnšek, B.Sc.

Dr. **TOMAŽ TOLLAZZI**
E-mail: tomaz.tollazzi@uni-mb.si
Univerza v Mariboru, Fakulteta za gradbeništvo
Smetanova 17, SI-2000 Maribor, Slovenija
GORAN JOVANOVIĆ, univ.dipl.inž.gr.
E-mail: goran.jovanovic@appia.si
Appia doo
Leskoškova 9e, SI-1000 Ljubljana, Slovenija
Dr. **MARKO RENČELJ**
E-mail: marko.rencelj@uni-mb.si
Univerza v Mariboru, Fakulteta za gradbeništvo
Smetanova 17, SI-2000 Maribor, Slovenija

POVZETEK

NOVI TIP KROŽNEGA KRIŽIŠČA: DVONIVOJSKI ENOPASOVNI KROŽNI KRIŽIŠČI S PASOVI ZA DESNE ZAVIJALCE – "TARGET ROUNDABOUT"

Problem nizke ravni prometne varnosti v obstoječih večpasovnih krožnih križiščih se v različnih državah rešuje na različne načine, običajno z uvedbo alternativnih tipov krožnih križišč, v katerih je število konfliktnih točk praviloma manjše.

Za alternativne tipe krožnih križišč je tipično, da se od "normalnih" oz. "standardnih" krožnih križišč razlikujejo v enem ali več projektno – tehničnih elementov, specifični pa so lahko tudi pogoji njihove izvedbe.

Danes je že znanih veliko različnih tipov krožnih križišč ("mini", "dvojni mini", "dumb – bell", "s povezanima ločilnima otokoma" ("dog-bone"), "s spiralnim potekom krožnega vozišča" ("turbo"), "s pritisnjenimi pasovi za desne zavijalce" ("flower"), ...) in njihov razvoj bo zagotovo potekal tudi v prihodnosti.

Prispevek prikazuje novi tip krožnega križišča, dvonivojski enopasovni krožni križišči s pasovi za desne zavijalce, krajše "target roundabout". V prispevku so predstavljene njegove projektno – tehnične, prometno – varnostne in kapacitetne lastnosti, primerjaje z običajnim dvopasovnim krožnim križiščem.

KLJUČNE BESEDE

krožna križišča, alternativni tipi krožnih križišč, turbo krožno križišče, target krožno križišče

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