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ROUNDABOUT WITH ”DEPRESSED” LANES FOR RIGHT TURNING – ”FLOWER ROUNDABOUT”

Abstract

Recently, many of the foreign traffic-safety analyses point out the low level of traffic safety in the multi-lane roundabouts. Weaving in the circulatory carriageway or changes of traffic lanes are particularly at issue, however they are essential for the exploitation of all circulatory traffic lanes, whereby the maximum capacity of the multi-lane roundabout can be achieved.
The problem of low traffic safety in the multi-lane roundabouts is resolved in more ways in different countries, however the solution, whereby the number of conflict points is diminished has proven to be the most successful. The roundabout with the spiral course of the circulatory carriageway or the turbo roundabout is a type of roundabout, which significantly diminishes the number of conflict points. However, the turbo roundabout also has its deficiencies. The fact is that if we want to implement the turbo roundabout instead of the existing two-lane roundabout, we have to tear down all the road curbs, transpose dividing islands and lightning..., which is financially extremely demanding. In addition, the turbo roundabout has crossing conflict points, where the consequences of traffic accidents are the worse.

This paper introduces the new type of roundabout, the roundabout with “depressed” lanes for the right turning or “the flower-roundabout.” Financially speaking, the main advantage of the new type of the roundabout is that it can be implemented within the dimensions of the already existing “normal” two-lane roundabout, which is very cost-efficient. From the traffic-safety point of view, the main advantage of the new type of roundabout is that it has no crossing conflict points.

Keywords: traffic safety, roundabout, turbo roundabout, roundabout with “depressed” lanes for the right turning – flower roundabout

1. INTRODUCTION

Lately, a growing number of foreign analysis point out to poor traffic - safety characteristics of "normal" multi-lane roundabouts and bad experiences related thereto [1]. For this reason, many countries are looking for a solution of what to do in these existing roundabouts, in order to improve the level of traffic safety [2, 3].
Different countries tackle this problem in different ways, which can be divided into four groups. A higher level of traffic safety in ”normal” multilane roundabouts can be achieved by:

- *decreasing the number of driving lanes in the circulatory carriageway*: not a good solution, because the roundabout's capacity is decreased,
- *decreasing the number of driving lanes at entries/exits:* not a good solution, because the roundabout's capacity is decreased,
- *increasing the outer roundabout’s diameter (whereby, the available length for weaving in the circulatory carriageway is increased):* financially very demanding,
- *decreasing the number of conflict points:* a good compromise between the finances on the one side and the increased capacity and traffic safety level on the other.

Lately, many countries are solving the problem of low traffic safety of ”normal” two-lane roundabouts by adopting the last of the above-mentioned methods – by decreasing the number of conflict points. One of the ways to decrease the number of conflict points is the turbo roundabout [4, 5].

2. RECENT SLOVENIAN EXPERIENCE WITH TURBO ROUNDABOUTS

All five of the Slovenian turbo roundabouts (figure 1 and 2) are subjected to monitoring and analyses of their operation, since they are still ”fresh” and we cannot yet guarantee that they shall be as successful as in the Netherlands, whereas certain dimensions of the Dutch typical roundabout were also changed in order to suit the Slovenian conditions. In addition, in Slovenia, we encounter specific problems because of the weather conditions (cleaning the snow from the turbo roundabout with a plough).

Figure 1 - The first Slovenian Turbo Roundabout; city Koper; 2008

However, in general, we can establish that turbo roundabouts in Slovenia have met the expectations as concerns the large capacity [6] and particularly the high level of traffic safety. We must stress at this point that traffic accidents in Slovenian turbo roundabouts are an exception and not a rule and these accidents normally result only in material damages.

Figure 2 - The second Slovenian Turbo Roundabout, city Maribor; 2008

However, a four-branch turbo roundabout has 6 merging conflict points, 4 diverging conflict points [7], unlike the "normal" two-lane roundabout it has no weaving conflict points; however, it does have 4 crossing conflict points, which is the bad side of this type of roundabout [8] (figure 3).

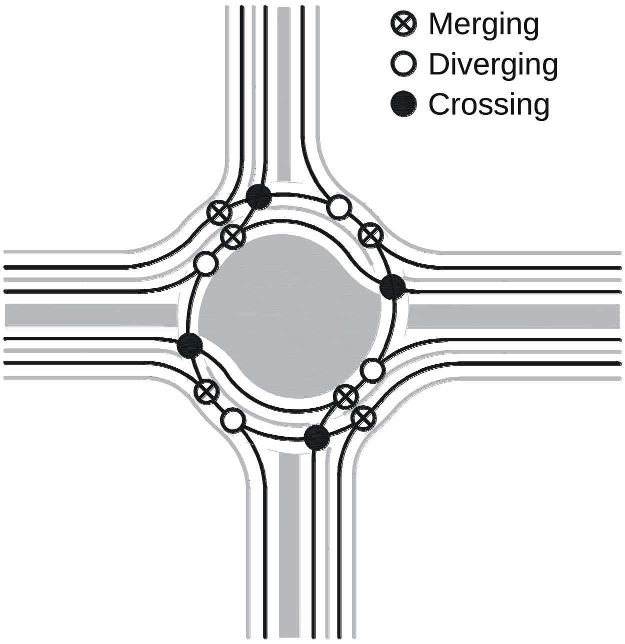

Figure 3 - Conflict points in four – branch turbo roundabout

In two out of five Slovenian turbo roundabouts we notice hesitance (fear, confusion, insecurity) of drivers, when they enter the turbo roundabout on the inner circulatory carriageway (figure 4).

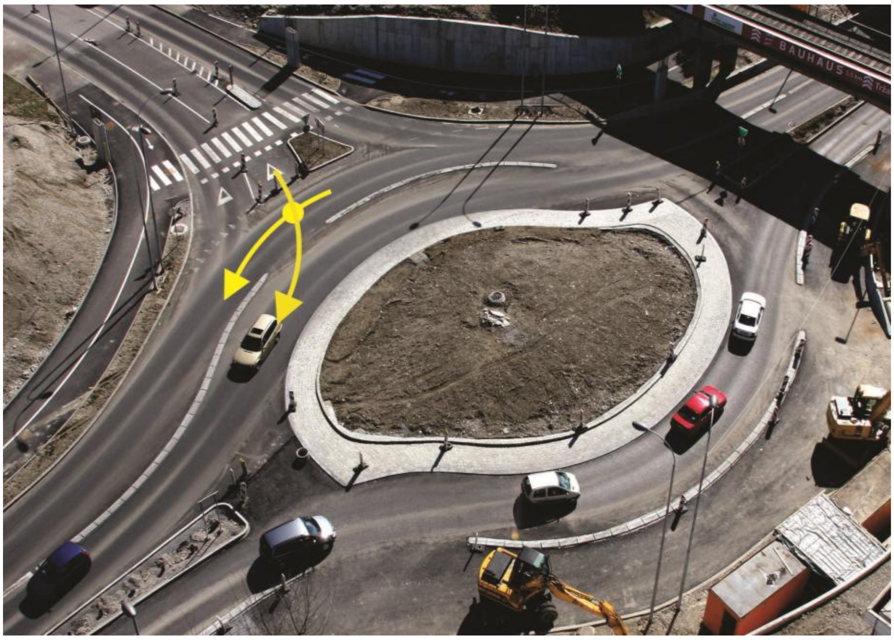

Figure 4 - Crossing conflict point at the entry on the turbo roundabout

The fact is that in both cases, the vehicle at this traffic maneuver crosses a very strong traffic flow and enters the second, equally strong traffic flow, which causes a sense of insecurity and danger with the driver (figure 5). Therefore, these drivers enter the turbo roundabout very slowly or only when the vehicles in the roundabout are at a great distance from them.
Therefore, the crossing conflict points in the turbo roundabout have a significantly larger negative effect than was expected (at least at the beginning of the introduction).

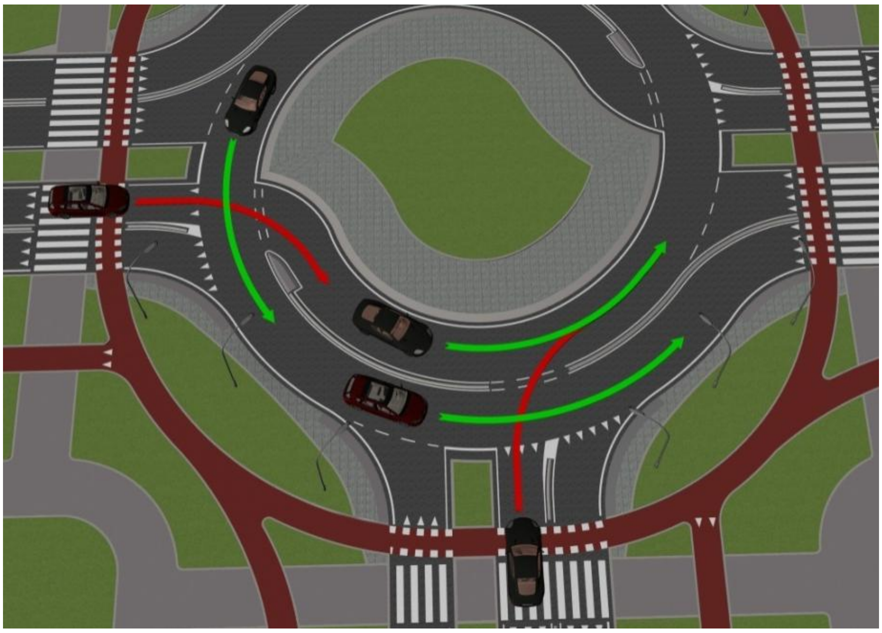

Figure 5 - Crossing conflict point at the entry on the inner circulatory carriageway from the inner lane at the entry

Notwithstanding the good experience with the turbo roundabouts in Slovenia, the question is:

What to do with the existing, less safe, ''normal'' multi-lane roundabouts?

It would be an illusion to expect (mostly for financial reasons) that they could all be reconstructed into the turbo roundabouts!
There is a question, whether it is possible to combine positive characteristics of different types of roundabouts, while at the same time eliminate their negative characteristics or:

Is it possible to eliminate crossing and weaving conflict points in the existing "normal" roundabouts and thereby achieving a high level of traffic safety without decreasing the roundabout's capacity?

The solution is the roundabout with ”depressed” lanes for right-turners. Because of the long term and because it seems like flower, we called it ''the flower roundabout''.

The idea came to life at the Centre for Road Construction of the Faculty of Civil Engineering, University of Maribor, Slovenia, while contemplating, how to turn an existing dangerous two-lane roundabout into a more traffic-safe solution.

3. ROUNDABOUT WITH ”DEPRESSED” LANES FOR RIGHT-TURNING

3.1 Basic characteristics

One of the basic characteristics of the roundabout with ”depressed” lanes for right turning is the same as in the turbo roundabout – physically separated traffic lanes in the circulatory carriageway [9, 10]. The second characteristic of the roundabout with ”depressed” lanes for right turning is that the right-turners have their own separated traffic surfaces (figure 6). This causes that the inner circulatory carriageway is used only by vehicles, which drive straight through the roundabout (180°) or turn for three quarters of a circle (270°).

Figure 6 - The roundabout with ”depressed” lanes for right-turners

By physically separating the right turning traffic flow, we get a one-lane roundabout, where (unlike in the case of the turbo roundabout) there are no crossing conflict points; however, (unlike in the case of the "normal" two-lane roundabout) there are also no weaving conflict points.

Weaving conflict points transfer from the circulatory carriageway (in 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.

However, probably the best characteristic of the roundabout with ”depressed” lanes for right-turners is that it is implemented within the existing ”normal” two-lane roundabout. Unlike the turbo roundabout, there is no need to move the outer curbs of the circulatory carriageway, therefore no additional buying of the surrounding land is required. At the reconstruction of the ”normal” two-lane roundabout into the roundabout with ”depressed” lanes for right turning, all the curbs of the circulatory carriageway, splitter islands and access roads remain on the same position.

Speaking shortly, the basic characteristics of the roundabout with ”depressed” lanes for right-turners are:

- implementation in dimensions (extension) of existing two-lane roundabout,
- traffic lanes in circulatory carriageway are separated,
- all right-turnings have separate lane,
- inner circulatory lane is used only by traffic flows for driving 180^o, 270^o or 360^o,
- from inner circulatory lane semicircle turning is possible,
- in circulatory carriageway there are no conflict points of crossing or weaving (4 merging and 4 diverging),
- driving through flower roundabout is like in classic two-lane roundabouts
- this roundabout type is ’’errors forgiving’’,
- the best role in situations where on major and minor road traffic flow is similar and in situations with a strong right - turning traffic flow.

3.2 Conditions and locations of appropriate use of the ’’flower roundabout’’

The flower roundabout on locations in the urban area is an appropriate solution.
On locations outside the urban areas, when there is normally one main and one side road, regarding the intensity of the traffic flows, flower roundabout is just a conditionally appropriate solution.

The flower roundabout is an appropriate solution in the case of:

- existing traffic-overloaded one-lane roundabouts, the size of which (outer radius) enables the implementation of an additional circulatory lane inwards (better solution) or there is space for the implementation of another circulatory lane outwards (somewhat less appealing and more expensive solution),
- existing traffic-overloaded two-lane roundabouts,
- existing traffic less safe two-lane roundabouts,
- reconstruction of the classic intersection with a situation where on major and minor road traffic flow is similar,
- a rather large diameter must be given to enable this solution (inside diameter greater than 39 m).

3.3 Traffic Safety on Flower Roundabout

3.3.1 Traffic safety of motorized participants

Flower roundabout:

- all traffic is not "compressed" into the roundabout (the roundabout is less occupied by traffic, reduced possibility of conflicts as consequence),
- all vehicles turning right have own, separate lanes, therefore roundabout is one-lane (elimination of the conflict points of crossing and weaving),
- there are just 4 merging and 4 diverging conflict points.

3.3.2 Traffic safety of non-motorized participants

The high level of traffic safety of non-motorized participants in flower roundabout is tackled in different ways, particularly by:

- speed control at the entries and exits (during design) (fig. 7),
- separation of entry traffic lanes with intermediate splitter island,
- deviated position of the pedestrian and cycle crossing at the entry and exit and/or
- leading non-motorised traffic participants in different level.

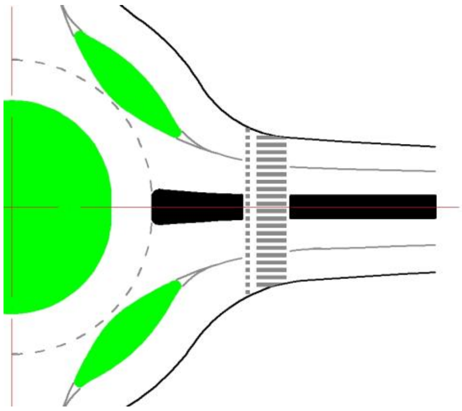

Figure 7 – Pedestrian crossing in flower roundabout

3.4 Construction of the Flower roundabout within the Existing ”Normal” Two-Lane roundabout

In order to transform the existing ”normal” two-lane roundabout into the flower roundabout, another circulatory carriageway towards the centre of the roundabout must be implemented and splitter islands must be prolonged towards the central island [10].

The reconstruction of the existing ”normal” two-lane roundabout into the flower roundabout is performed in four steps (figure 8):

step 1: additional circulatory carriageway towards the centre of the roundabout is implemented
step 2: construction lines of entries and exits are prolonged
step 3: splitter islands are prolonged for one circulatory traffic lane towards the centre of the roundabout
step 4: redundant surfaces are rearranged into green areas

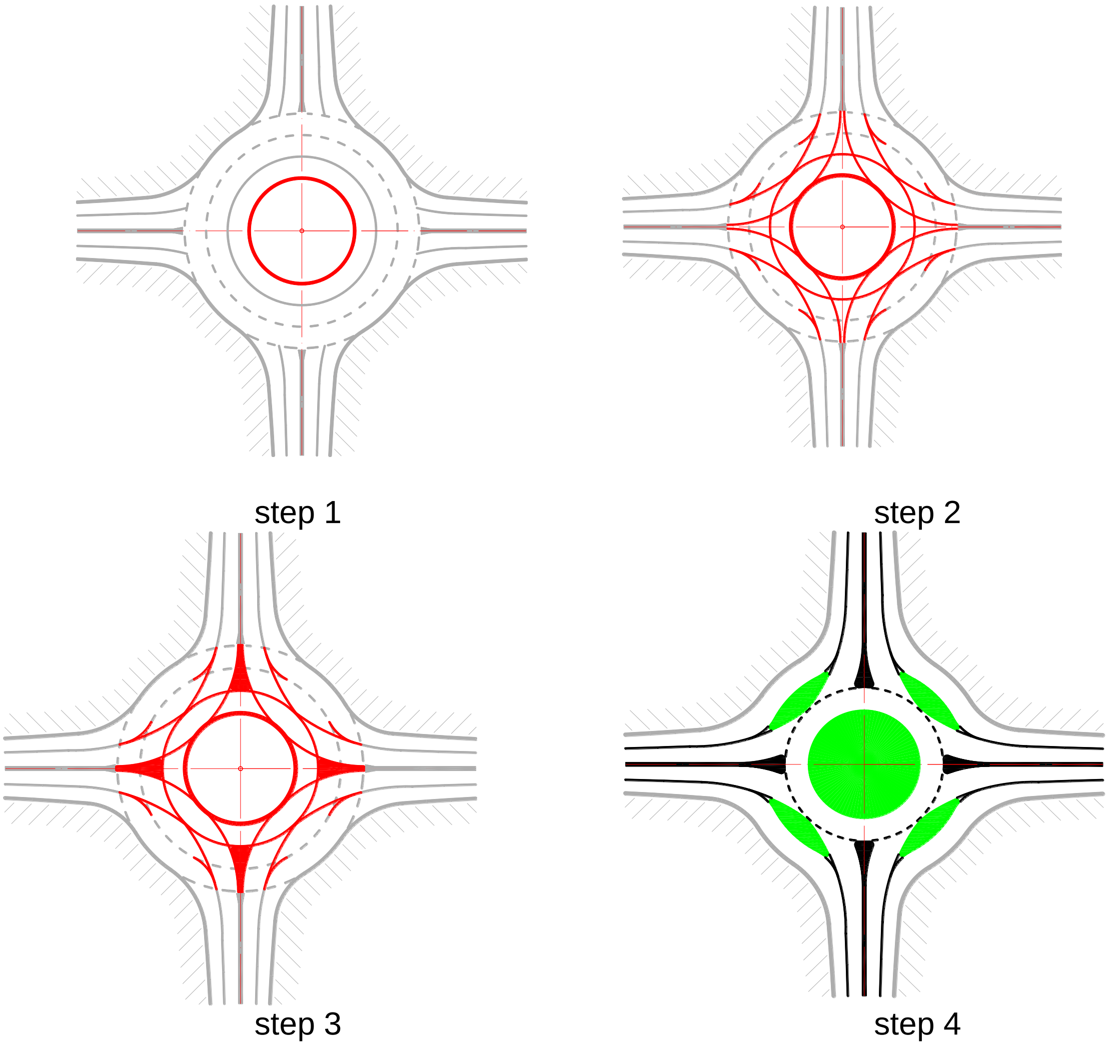

Figure 8 - Procedure of reconstruction of the existing ”normal” two-lane roundabout into the flower roundabout

This solution is possible in four-lane as well as in two-lane roads. In the case of the two-lane road, an additional, sufficiently long traffic lane is implemented, directly before the entry/exit.

3.5. Capacity Comparison Between the "Flower-Roundabout”, ”Normal” Two-Lane Roundabout and Turbo Roundabout

Due to lack of analytical methods for capacity estimation concerning turbo and flower roundabouts, we have decided to use micro simulation tools. In the period of very first start there were just a few turbo roundabouts in Europe and plenty of single and double lanes roundabouts in Slovenia as well. First simulation was implemented with standard-sized parameters, offered by PTV VISSIM (figure 9) for single and double lane roundabouts. From previous researches we can consider that that parameter fits well and the model was calibrated. In the next step a two-lane turbo-roundabout and finally flower roundabout was treated. In an equal simulation model, equal construction elements, equal vehicle types, equal driver types and equal simulation parameters have been used.

There is scientific research currently running in the University of Maribor on the calibration of those parameters from field observation on turbo roundabouts in Slovenia.

Figure 9 - The mathematical model and 3D simulation of ”depressed” roundabout with PTV VISSIM 5.20

VISSIM presents a stochastic, discrete, time oriented microscopic simulation model. It uses psycho-physical characteristic of a so-called "car following" model for longitudinal movements of vehicles and algorithms based on the rules of driving for vehicles joining from the side directions. A mathematical model is designed according to the idea derived from Wiedemann's theory. The basic idea of Wiedemann's model is presented under the assumption, that every driver can find themselves in one of the following situations:

- driving in a free traffic flow (no influence of other vehicles),
- approach drive (a process of adapting to the velocity of the vehicle in front),
- pursuing drive (driver keeps a constant distance to the vehicle in front, with no accelerating or braking),
- braking (applied when the safety distance drops under the lower limit).

A characteristic of the VISSIM program package is that it does not use a conventional *link/node* module system, but a *link/connector* system, which enables modeling of very complex geometries.

We analyzed congestions and the queue lengths for four variants of traffic loads (750, 1000, 1250 and 1500 vehicles in the main traffic direction in the peak hour) and for four variants of right-turners (40%, 60% and 80% right-turners on the main traffic direction). In all scenarios we add 10% of the main traffic stream on minor streams [9].

Results of the micro simulation shows that there are no significant differences between the flower roundabout, normal and turbo roundabout, at a low traffic loads. Congestions and queue lengths are approximately the same.
At higher traffic loads, the differences in favor of the flower roundabout occur, when the percentages of right-turners approach 80% of the total value of vehicles in the main traffic direction (figures 10 and 11).

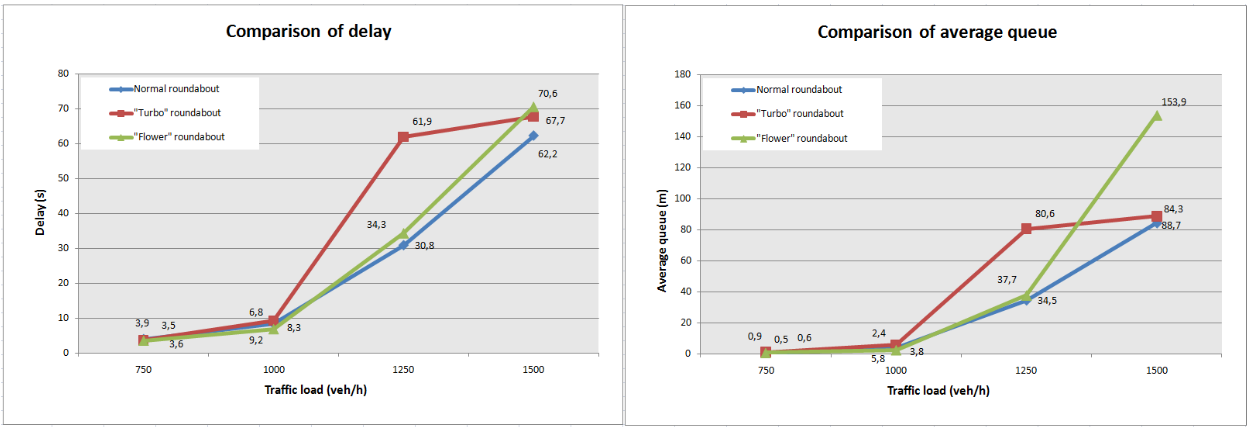

Figure 10 - Scenario with 60% of right-turners

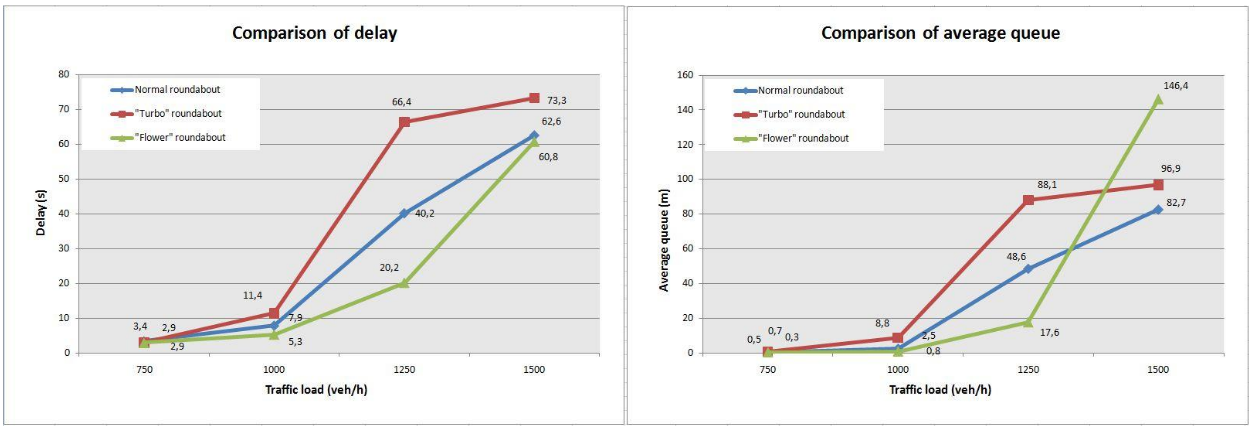

Figure 11 - Scenario with 80% of right-turners

Compared to the ”normal” two-lane and turbo roundabout, the flower roundabout shows its advantages, when the larger part of the traffic on the main traffic direction, is the direction of right-turners. Delays in the scenario "80%" and loads of "1250" are 20.02 s in flower roundabout (level of service; LOS = C), in ”normal” roundabout are 40.2 s (LOS = D), and turbo roundabout 66.4 s (LOS = D).
The flower roundabout ”burns-out” at the moment, when the one-lane roundabout capacity is exceeded.

4. CONCLUSION

The problem of low traffic safety in the multi-lane roundabouts is resolved in more ways in different countries, however the solution, whereby the number of conflict points is diminished has proven to be the most successful. The roundabout with the spiral course of the circulatory carriageway or the turbo roundabout is a type of roundabout, which significantly diminishes the number of conflict points.

However, the turbo roundabout also has its deficiencies. The fact is that if we want to implement the turbo roundabout instead of the existing two-lane roundabout, we have to tear town all the road curbs, transpose dividing islands and lightning ..., which is financially extremely demanding. In addition, the turbo roundabout has conflict crossing points, where the consequences of traffic accidents are the worse.

This paper introduces the new type of roundabout, the roundabout with ”depressed” lanes for the right turning. This type of roundabout combines the positive properties of the ”normal” two-lane roundabout and the ”turbo” roundabout.

The flower roundabout turns out to be a good solution, when we are dealing with a situation where on major and minor road traffic flow is near similar and in situations with a high percentage of vehicles, turning right. The bigger the percentage of right-turners, the more sensible is the use of the roundabout of this type.

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