Roundabouts: a State of the Art in Germany

by Werner Brilon[1]

Abstract

Modern roundabouts have become a common element in urban und rural traffic networks. The design standards as they have been developed over the times since 1985 have proven to be successful both regarding aspects of design and traffic performance. The toolbox contains

- compact single-lane roundabouts with diameters between 26 and 40 m,
- mini-roundabouts with a traversable island and diameters between 13 and 22 m,
- larger roundabouts (40 –60 m) with 2-lane access for cars and single-lane operation for trucks (semi-two-lane),
- turbo-roundabouts,
- signalized roundabouts.

All these types have turned out to be quite advantageous regarding traffic safety as well as traffic performance. Nevertheless, each of these types has its specific limitations in traffic capacity. The paper refers to the similar paper [1] from the recent Roundabout Conference. Both papers together document the experience gathered in practice and from a long series of research projects regarding traffic safety, capacity, and traffic performance estimation, as well as geometric design.

1. Introduction

In Germany modern roundabouts have become a rather usual solution for intersection design both in rural and within urban street networks. Meanwhile there may be several thousand circular intersections which have been built within the recent 30 years. A reliable statistic about the real number is not available. There were many new developments and alterations in design and general attitudes towards roundabouts in the early times of the 1980ies and 1990ies. Meanwhile, however, the standards have settled to a rather balanced status.

This fact is also the reason why this contribution to the International Conference on Roundabouts should be quite similar to the article by the same author submitted to the recent conference in Carmel [1]. Each of the statements and facts expressed in that earlier paper are still valid. Therefore in general, a state of the art report for Germany can mainly refer to that earlier paper. It should not repeat the same information. In consequence, the purpose of the present report is mainly to confirm positive experiences with roundabouts and the corresponding policy in Germany. It throws a light on the topic of roundabouts from a slightly different perspective. In addition, some more recent developments and research results which also go beyond the existing guidelines (see section 3) should be described in this paper.

Usually different types of roundabouts are distinguished. This is illustrated by fig. 1 which defines these types according to their size (measured by the inscribed diameter) and the range of traffic demand (measured by the ADT of the whole intersection) where this type could be applied.

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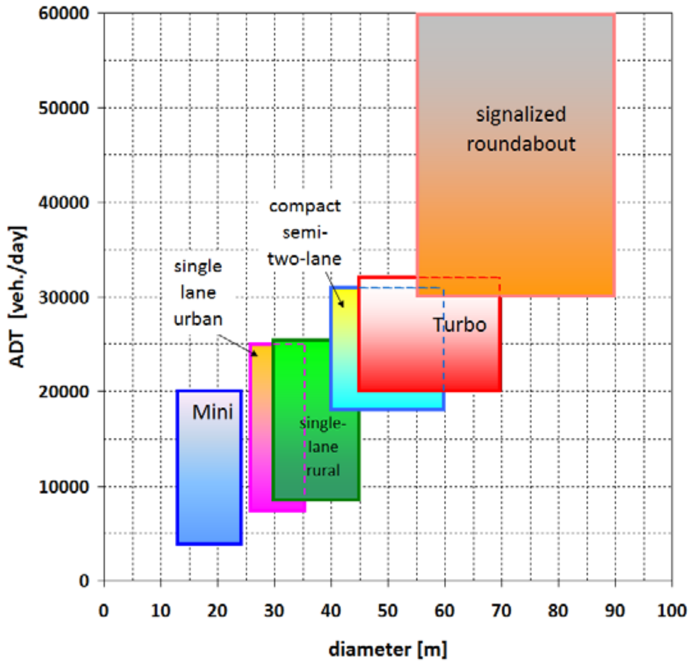


Figure 1 *Definition of types of roundabouts by their inscribed circle diameter and their potential range of applicability in terms of average daily traffic (ADT)*

2. Traffic rules

Traffic rules on the European continent are rather identical among the countries based on the Vienna convention [2] from 1968. Nevertheless, especially for roundabouts there are some national peculiarities between countries which, however, obey the rules from the Vienna convention.

In Germany traffic rules are documented by federal law called "Strassenverkehrsordnung (StVO)" [3] (= highway code). On the one hand this is directed to the public by the StVO expressing rules how to use streets and highways. On the other hand there is an internal governmental advice VvV-StVO which tells the traffic administration how to use signs, markings, etc. This VvV-StVO is applied very strictly.

Figure 2 : *Traffic signs at the entry into a roundabout*

Since ever, in Germany at roundabouts, the circulating traffic has priority over the entering traffic which is indicated to the approaching drivers by a sign like in fig. 2 which is also the practice in many other continental European countries except France. Different from the British offside-priority rule (see: [4]) in Germany there is no advice which lane should be used by the drivers nor is their any regulation for conflicts within traffic on the circle. This means: on multilane roundabouts conflicts between vehicles on the inner side and vehicles near the exterior of the circle are not guided by specific rules. This results to problems, especially near the exits. In this way, at larger roundabouts with multi-lane exits, as they have been in operation in former times, crashes happened quite frequently. In consequence, large multilane roundabouts are now banned by the guidelines; i.e. they are not mentioned and, thus, are not state-of-the-art. Up to now there are no efforts to fill this gap in the traffic rules.

What the rules also say is that small vehicles are not allowed to overrun the low curbs on the inner side of the circle and even not lane markings (cf. fig. 6a). All these kinds of inner limitations of the circular carriageway may, however, be overrun by large trucks or busses who need this space for their swept-path kinematics.

3. Technical guidelines

Below the judicial level there are technical guidelines which are primarily addressing engineers. They establish the state of the art and in practice they are applied for design and operation of roundabouts. These guidelines are, in general, edited by the FGSV which is a private non-profit association, where a community of practitioners from administration, consultants, universities, and others develops these guidelines on a voluntary basis. Many of these guidelines are usually appointed by the federal DOT. That means they become mandatory to be applied for Federal highways.

For roundabouts the following guidelines are relevant:

1) RAL: Guidelines for the design of rural highways [5]
2) RASt: Guidelines for the design of urban streets [6]
3) Guidelines for roundabouts [7]
4) HBS: “German highway capacity manual” [8], [9]

No. 1) and 2) describe warrants for the application of different types of intersections plus rather general advice for design of roundabouts whereas 3) specifies a lot of details which are also described in [1]. 4) contains algorithms for capacity estimation at roundabouts.

According to the recently (in 2013) edited RAL [5], in a rural environment, roundabouts should mainly be applied to intersections within class-3 roads. This is by far the majority of rural highways (Class 1 and 2 are high-speed 3- and 2-lane long distance highways with grade-separated intersections whereas class-4 includes minor narrow local roads). On this background roundabouts are more and more becoming something like a standard type of intersection in the ordinary rural highway network.

The urban guideline [6] covers all kinds of intersections. For roundabouts it is mainly containing a short version of the guideline [7].

4. Mini-Roundabouts

Mini-roundabouts can only be applied in urban areas with a general speed limit of 50 km/h. They have an inscribed diameter between 13 m and 24 m. Compact vehicles like cars or vans have to follow the circular lane whereas larger vehicles like big trucks or busses are allowed to override the central island as far as necessitated by their kinematics. It is most important that the central island is elevated by curbs with at least 4 cm to 6 cm. It should also be paved by a material different from the circular lane; e.g. concrete block pavement. Otherwise the rule not to override the central reserve is not well accepted. Mini-roundabouts where the center island is just represented by some road marking have failed to achieve sufficient safety.

Of course, mini-roundabouts have only single-lane entries and exits without any flaring. The circular lane should have a width between 4 m and 6 m and it should be inclined to the outside by around 2.5 % relative to the approaching streets.

One more recent experience is that separate cycle tracks crossing the entries and exits adjacent to the pedestrian crosswalks fail to be a safe solution. That means: any markings of cycle facilities should be avoided at mini roundabouts. Cyclists can most safely be accommodated by driving on the circular lane.

Figure 3 : Mini-Roundabout in Koblenz with a design according to guidelines.

Figure 4 : Critical design for a Mini-Roundabout: The central island built of concrete is on the same level as the circular lane (lack of a delta of 4 – 6 cm). This reduces the acceptance of a correct driving on the circular lane. The direct access from the circle to private parking positions (left side) gives reason for several conflicts.

Another surprising experience is that mini-roundabouts are often favored especially by truck operators and transit bus companies. They prefer mini-roundabouts since ease of handling for the large vehicles is advantageous in comparison to normal roundabouts.

One – primarily unexpected – aspect was that at mini-roundabouts special attention must be paid to sight distances. At each entry there must be good visibility especially into the next upstream entry (on the left side). If this visibility is obstructed by buildings or plantations then priority accidents must be suspected.

A rather comprehensive study of mini-roundabouts has been finished recently by Baier e.a. [10]. Here one outstanding result was, that the mini-roundabouts were extremely safe. Their accident cost rate was in a range of 2 to 5.7 €/1000 veh which is even much lower than reported accident cost rates at single-lane roundabouts with around 6-8 €/1000 veh (cf. [1]). What is even more important is the fact that mini-roundabouts proof to be much safer than conventional types of intersections (cf. table 1).

This study [10] proposed also a new algorithm for capacity calculation of entries to mini-roundabouts. The new aspect is that the influence of traffic exiting into the same arm should be included into the calculations. This is described below in Section 10. This new method will be part of the future HBS [9].

Table 1: Accident cost rates for mini-roundabouts compared to conventional urban intersections (obtained from[10], p. 40, table 19).

	3-arm	4-arm
mini-roundabouts	2.02	5.66
unsignalized intersections	4.68	13.39
signalized intersections	6.60	8.40
	€/1000 veh	€/1000 veh

Figure 5: Example for a rather large mini-Roundabout in Bonn.

In summary: mini-roundabouts – if designed according to the standard rules [7] – are a very safe solution – may be the safest of all types of intersections. They are also rather well accepted by the public and they are quite efficient from the investment point of view. As a consequence, they enjoy great popularity – both in general public as well as in community administrations.

5. Compact Single-Lane Roundabouts

In Germany the single-lane roundabout is still the reference type to which all other types are compared. This basic type of a roundabout is applied on rural roads and for urban streets as well. However, recommendations for design are slightly different. This standard type has an inscribed diameter between 26 m (better: 30 m) and 45 m in an urban environment and 30 m to 50 m at a rural intersection. The characteristic feature is that all entries and exits as well as the circulating carriageway have only one single lane.


a)


b)


c)


e)

d)

Figure 6*:*
Examples for compact single-lane urban roundabouts

The minimum value is derived from the European standardized truck which must be able to make a full turn within a circle of 25 m (measured over the most external points of the vehicle, with a width of the covered ring of maximum 7.5 m), so that the smallest allowed roundabout still offers some clearance for the large vehicles. In consequence the smallest roundabout requires a circular lane width of 8 m. With that a passenger car usually can pass through the roundabout without any deflection. To avoid too high speeds under these circumstances, in such small roundabouts the circulating roadway can be divided into an outer paved area (≈ 6 – 7 m wide) to accommodate smaller vehicles plus an inner paved apron to provide space for the swept-path of larger vehicles. This paved apron prevents also the overtaking of cyclists by cars. For larger roundabouts the truck apron can also be waived. It should never be built on rural intersections since with larger diameters it is not required. The truck aprons are not well regarded by the city authorities due to their additional costs and significant problems with maintenance.

For details in design the reader is referred to [7] or even [1]. The pictures in fig. 6 provide some impressions for the typical design of this standard type of roundabouts.

Initially in Germany the style of design was directed on reducing speeds of motor-vehicles. In this sense entries were directed perpendicular towards the circle and the exits and entries had rather narrow curb radii. Meanwhile – as the pictures demonstrate – there is an increasing tendency to make driving through a roundabout easier for truck drivers by using more generous alignments of entries and exits. One accident study from the state of Bavaria has shown that this is not causing additional risks.

If we look on pedestrians there are usually no significant problems with safety and comfort. The guideline [7] says that in urban environments usually zebra-crossings should be arranged offering a full priority to pedestrians when crossing the entries and exits. But also without zebra crossings there are usually no safety problems – just the opposite: zebra crossings do frequently lead to conflicts. At the moment there is a discussion between engineers (who want to comply with the guidelines) and legal opinions who are oriented along a DOT guideline RFG-Ü [11] which demands for a minimum volume of pedestrians to warrant a zebra crossing.

a)

b)

Figure 7: *Examples for cycle tracks crossing the entry and exit of an urban roundabout.*
a) good design
b) Many cyclists use cycle tracks in the wrong direction which is a cause for accidents.

The more severe problem is still constituted by the cyclists. Especially here the rules for design must be strictly obeyed to achieve a maximum of safety – or better: a minimum of risk. For lower traffic volumes in urban motorized traffic (i.e. < 15000 veh/d) the safest solution is to guide the cyclists on the circular lane. For higher volumes separate bicycle tracks should be provided. In urban environments cyclists should be prioritized and this should be clearly indicated by colored road markings. Here it is very important for safety to separate the crossing points by 4, better 5 m from the exterior of the circle. Otherwise the drivers of vans and trucks, at the exits, have not sufficient sight on the cyclists on their right. The risks are mainly caused by the cyclists themselves: e.g. they use the cycle tracks in the wrong direction (see fig. 7b), they use zebra crossings without knowing that they neither are allowed nor that cyclists do not have any kind of priority on zebras, or they use the cross points without any caution relying on their right of way.

Along rural roads – in most cases – there is only a cycle track on one side of the road to be used for both directions. These cycle tracks must be guided across the arms of a roundabout. Of course, outside built-up areas the cyclists get a yield sign; i.e. they should not have priority. In practice this does not cause any problem to the cyclists since in most cases car drivers treat cyclist with caution. The positive effect of this priority regulation is that the cyclists can not rely on their right of way and, thus, are forced to care about their own safety.

One rather severe problem is that in many cases the designers do not follow the standardized rules. E.g. in fig 6d) both roundabouts can be used with rather high speed – in the upper case in a rather extreme way. Also the cycle crossing on the left side (bottom of the picture) is too close to the circle. Both mistakes must be regarded as rather serious.

6. Compact two-lane roundabouts

In the German terminology there is still an intermediate type of roundabout which could be called – loosely translated – compact semi-two-lane roundabout. Roundabouts of this type have a diameter between 40 and 60 m and a circular carriageway between 8 and 10 m wide without lane marking on the circle. Beside these measures they are very much designed like a single-lane roundabout and in the US they would be even treated like single-lane.

Figure 8: Examples for semi-two-lane roundabouts in peripheral urban situations.

These types could have two lane entries if required. But two-lane exits are strictly forbidden due to safety reasons. On these roundabouts passenger cars could drive side by side. Most drivers, however, prefer to drive in a staggered manner. Larger vehicles are forced to use the whole width of the circular carriageway. This may cause some path overlap between vehicles entering on the same approach. This is, however, not a real problem in practice.

This type of roundabout becomes problematic in connection with pedestrians or cyclists. Cyclists on the circle must be strictly prohibited. It is recommended that for these non-motorized road users facilities separated from the roundabout should be provided. Especially at the cross-points within two-lane entries, crosswalks of any kind are strictly discouraged due to safety reasons. Thus, this type can mainly be used in rural environments and in peripheral urban areas where no pedestrians or cyclists must be expected.

Despite of these limitations many roundabouts of this type have been built at many places and they are operated quite successfully.

7. Turbo-Roundabouts

Turbo-roundabout is a term which goes back to engineers in Netherlands, especially Bertus Fortuijn. Independently from that source Turbos had also been developed in Germany. A prototype is the intersection in Baden-Baden (cf. [1]). A Turbo-roundabout is a roundabout with alternating numbers of lanes on the circle (in Germany only 1 or 2 lanes). The characteristic properties are, that the addition of a lane is only achieved by adjoining the lane on the inner side opposite from an entry. Subtracting of a lane can be either performed as a normal lane drop or by a two-lane exit where the right lane must leave into the exit. Thus, the typical arrangements are type-1 exits and entries (table 2). Using only the types mentioned in table 2 there is no need for drivers to change lanes on the circle. In consequence it could also be defined: A Turbo-roundabout is a kind of circular intersection where lane changes on the circular roadway are completely avoided.

For the US-reader it may be strange that this type of a roundabout is treated with such notice as a type of its own since in the US roundabouts like these are implemented without giving them a special name.

Table 2 Set of arrangements of lanes at the entries and exits of Turbo-roundabouts

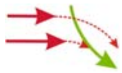
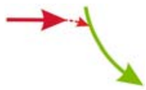
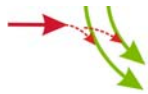
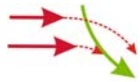
	Type			
	1	2	3	4
entry				
exit				

Figure 9: Examples for Turbo-roundabouts

In Netherlands, at Turbo-roundabouts, the lanes on the entries and exits are diverted by vertical elements which can not be overrun by cars. This concept is not transferred to Germany. Due to considerations of motorcycle safety and winter service, but also costs and maintenance requirements, the vertical elements in the middle of the intersection are not accepted. They are also not required. Research showed that – even if the discipline of drivers keeping within their lane is not perfect – it is not a risk to abstain from vertical lane dividers.

There was a series of evaluations of Turbo-roundabouts in recent years. They are documented in a report [13] which – unfortunately – is not yet published. There are results about safety, useful design, correct signing, and capacity.

The experience regarding safety is very good. The Turbos which were included in the study performed as much safer that the other types of roundabouts. To achieve such a good safety level it is important to keep pedestrians and cyclist away from a Turbo-roundabout.

Regarding capacity, a special algorithm for turbo-roundabouts has been developed (it can not be described here in detail due to limited space). Application of the method to real cases shows, that Turbos – regarding their total capacity – work with sufficient quality up to a total traffic volume of 30000 to 35000 veh/day. The entries of type 1 (see table 1) can carry up to 1500 veh/h. The total possible traffic volume is not really larger than the maximum load of a semi-two-lane roundabout. The difference is that a Turbo provides higher quality if specific movements dominate at the intersection whereas the semi-two-lane type provides higher performance if the total volume is well distributed over all of the movements.

Overall the Turbo-roundabout combines high safety level with rather large capacity – especially in the case of single predominant movements. They are more and more used in practice as new installations. To guide engineers in practice a short guideline [14] for Turbo-roundabouts has been drafted which is going to be published in 2014.

8. Signalized Roundabouts

What many people would not expect is that a combination of traffic signals arranged at a circular intersection can be an excellent solution for larger traffic volumes. There are some examples which have proven, that this combination can be capable to carry up to 50000 or even 60000 veh/day on a two-lane circular carriageway with a diameter beyond 50 m.

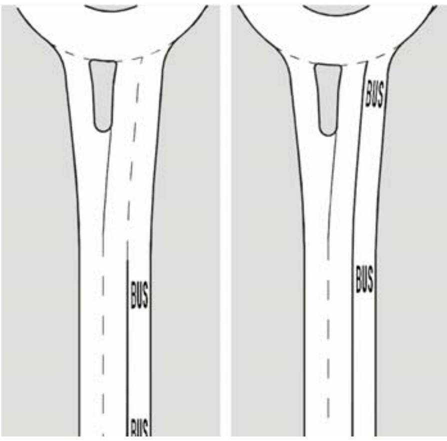
Some people think that roundabouts and signals are a contradiction in itself. But this opinion is wrong. There are, however, some tricky ways of signalization which are required to achieve a high capacity. These ideas have first been formulated in the UK [15]. An overview about the methodology and a report on German experience has been given in [16]. With the application of these methods a rather high capacity on a limited area of land can be achieved. In the city of Hannover several such examples are operated with success. But in specific cases the potential may also be limited depending on the pattern of movements at the intersection.

9. Public Transit and Roundabouts

In many cases roundabouts carry also public transit vehicles like busses and light rail (tram). Here several solutions can be recommended – also in conjunction with bus stops and holding positions.

Bus stops on the entrance and on the exits of roundabouts can equally be good solutions (fig. 10). The exact position depends mainly on those points which create the major demand by passengers.

If trams or other light rail lines are crossing through the roundabout or crossing over one entrance then the remaining traffic must be controlled by signals. For trams there is the alternative between two solutions (fig. 11): in case a) the whole roundabout is closed when the tram is arriving and running through the intersection. This solution is mainly used for smaller roundabouts. It offers also good access by pedestrians to a station next to the roundabout. In case b) the signals (only amber and red) do just close the circular lanes next to the tracks on the arrival of a tram. This solution can also be associated with severe accidents. What proved to enhance safety is to put additional signals in a height 1.5 m above the ground (on the level of driver's eye) on the left side.



a)


b)

Figure 10: useful solutions for bus stops (examples):
a) ahead of the roundabouts in combination with a bus lane for acceleration of transit busses
b) at the exit from a roundabout (Hamburg).

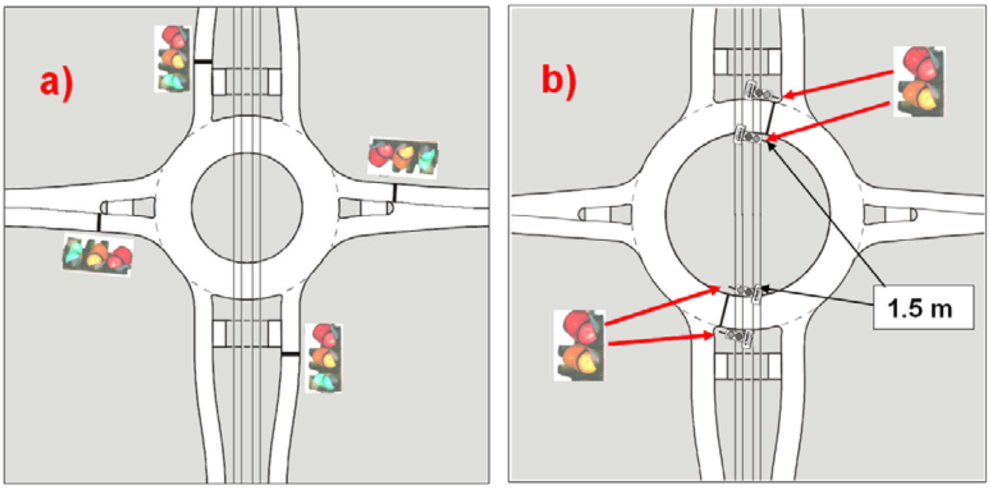


Figure 11: Two solutions for guiding trams through the roundabout:
a) closing all entries for the approaching train
b) closing only the circle at the crossing points with an additional signal in a height of 1.5 m on the left side.

10. Capacity

For Germany the standards for estimating the capacity of roundabouts and to evaluate measures for the quality of traffic flow as they are established in [7] and documented in [1] have proven to quite realistic. The equations described in [1] which are based on a paper by Brilon and Wu [12] will also be included into the future German HCM [9]. Meanwhile some minor modifications of the capacity parameters are recommended.

The basic capacity of an entry into a roundabout is calculated by

$$C = 3600 \cdot \left(1 - \frac{t_{min} \cdot q_k}{n_c \cdot 3600}\right)^{n_c} \cdot \frac{n_e}{t_f} \cdot e^{-\frac{q_k}{3600} \cdot \left(t_g - \frac{t_f}{2} - t_{min}\right)} \qquad (1)$$

where

C	=	basic capacity of one entry	[pcu/h]
q_k	=	traffic volume on the circle	[pcu/h]
n_c	=	number of circulating lanes	[-]
n_e	=	number of entry lanes	[-]
t_g	=	critical gap	[s]
t_f	=	follow-up time	[s]
t_{min}	=	minimum gap between succeeding vehicles on the circle	[s]

Values for the parameters are indicated in Table 3. Compared to the parameters given in [1] some changes have been performed based on recent research reports. However, the consequences of the new parameters are very limited.

Table 3 Parameters for capacity calculations

Type of roundabout		n_e	n_c	t_g [s]	t_f [s]	t_{min} [s]
				eq. 1 with the following parameters:		
single-lane:						
Mini-roundabout [10] 13 ≤ d ≤ 24 m 1) 4)				4.7	3.1	2.5
single-lane [12] 26 ≤ d ≤ 40 m 1) 2)				$t_g = 3{,}86 + \frac{8{,}27}{d}$	$t_f = 2{,}84 + \frac{2{,}07}{d}$	$t_{min} = 1{,}57 + \frac{18{,}6}{d}$
semi-two-lane: [13]						
1/2 40 ≤ d ≤ 60 m 1) 3)		1	2	4.0	2.5	2.0
2/2 40 ≤ d ≤ 60 m 1) 3)		2	2	3 arms $C = 1826 \cdot e^{-\frac{q_k}{1667}}$		> 3 arms $C = 1642 \cdot e^{-\frac{q_k}{1180}}$
large two-lane: [18]						
2/2 large d >> 60 m 1) 5)		2	2	$C = 1926 \cdot e^{-\frac{q_k}{1405}}$		

1) : d = inscribed circle diameter [m]
2) : for d > 40 m: d = 40 m has to be used
3) : If d > 60 m but all other characteristics of a compact two-lane roundabout according to the guideline *[7]* are fulfilled, then d = 60 m should be assumed.
4) : q_k is the traffic volume of the circulating traffic minus 0.15 times the exiting traffic.
5) : in connection with 2 complete and separate lanes (with lane marking) plus full-capacity exits

Investigations on mini-roundabouts [10] proved that the traffic exiting into the same arm (as the entry under consideration) should be taken into account. Thus, the circulating traffic is reduced by o.15 times the volume of the exiting traffic (in pcu/h).

For the compact 2-lane roundabouts the parameters and the equations given in Table 2 have to be used. They are based on [13]. The numerical results are nearly identical with the former parameters [1], [12]. There is only one significant difference: for the two-lane entry into the semi-two-lane roundabout significantly larger capacities have been observed if the intersection has only three arms. In that case the left entry lane is increasingly accepted by the drivers. Here a presorting of traffic as it is directed into the other two arms takes place which contributes to a more balanced utilization of the left lane. For the equation it is, however, assumed that the proportion of left turning traffic on the entry is in a range between 0.4 and 0.7. For other cases a more complex procedure has been developed in [13].

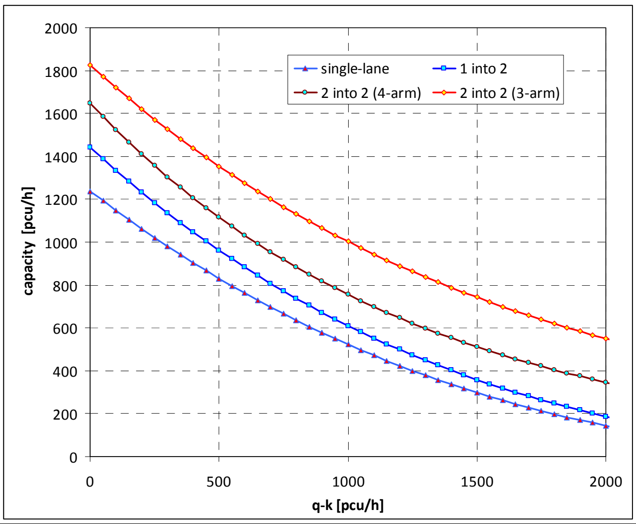


Figure 12*:*
Entry capacity depending on circular traffic volume for 4 configurations

For the evaluation of traffic flow quality by average delay and by queue lengths still the methods described in [1] are recommended which are also part of the HCM [17].

11. Landscaping

Most of the points mentioned above are meanwhile standard know-how and are not treated to be too exciting. What however leads to an enormous amount of public discussion recently is the aspect of landscaping. Many communities have decorated their roundabouts with different kinds of monuments. Even on roundabouts within the federal and state networks the adjacent communities – in many cases – have spent a lot of money to emblaze the roundabouts in their neighborhood by artwork. Doing this the artists – in most cases - did not obey the rule that dangerous objects should not be placed on the central island of a roundabout. This topic became virulent by a severe accident where the driver lost control over his car at quite a distance before he arrived at the roundabout. The vehicle was catapulted against the monument in the center with the consequence of two fatalities and two severely injured occupants (see fig. 13a). One surprising but important aspect was that an obstacle which was not placed in the direct projection of the arriving lane could cause such severe damage.

As a consequence most of the state highway administrations checked systematically the safety aspects of their roundabouts. By these investigations e.g. the authorities in Baden-Wuerttemberg became aware of quite a large number of severe accidents where cars have hit dangerous obstacles in the area of a roundabout. In consequence they ordered to remove all kinds of monuments from the central islands of roundabouts. This lead to rather significant rumors in the public and, thus, in the political arena. In consequence, now, most of the states have started a systematic program to abandon dangerous objects, like all vertical elements (walls, monuments, trees, rocks, etc.) from their roundabouts. Meanwhile this is, however, limited to intersections outside urban areas. In urban areas these dangerous elements are now more and more tolerated. Several of the German states have edited guidelines how to treat problems with pieces of artwork at roundabouts. This discussion, however, made it obvious that around the country there are numerous amazing and unbelievable examples of extremely dangerous installations around roundabouts. Apparently this kind of intersection triggers the imagination and creativity both of citizens and politicians.

a)

b)

more examples see:
http://www.kunstimkreisverkehr.de

c)

Figure 13*: Problems of landscaping*

a) *Crash of a car into a monument on the central island with 2 fatalities and 2 severely injured persons*
b) *Three massive stone pillars plus a beam with a globe on top have been placed in the center of a roundabout with bad visibility one the approaches.*
c) *Huge steel construction on the central island of a roundabout*

12. Conclusion

Roundabouts, in our days, have become a kind of standard solution for intersection design in urban and in rural environments. They are favored in a sometimes enthusiastic way by the public. Car drivers and also pedestrians enjoy the absent of delays as they are suffered at traffic signals. In consequence politicians support the transition to more and more roundabouts. Here they treat this topic sometimes in an overwhelming way. In many cases the expectation regarding capacities exceeds realistic values and the flexibility of design standards is overstressed in many cases with the consequence that also bad solutions might be implemented. To combat this source of errors better education of engineers might be required.

From the technical point of view: the rules for roundabout design (e.g. *[7]*) have proven to be a good standard. The concept of geometric design is still aiming for a speed-reducing layout which should contribute to a high safety standard. Thus, the compact single-lane roundabout is still the standard solution for a roundabout. This type usually provides a better traffic performance than a signalized intersection of similar size also in peak periods.

Also the capacity of standardized types of roundabouts can rather well be described. On the background of the German traffic rules and driver behavior also the larger types of roundabouts do not exceed a total capacity beyond 40,000 veh/day. Thus, for larger traffic demand the signalized intersection still is a well accepted solution.

The most significant benefit of roundabouts is still their high level of safety. Also the mini-roundabouts and the Turbo-roundabouts enjoy exceptional low accident cost rates. In this sense roundabouts may have contributed to the rather significant decrease of nationwide figures of traffic fatalities which Germany enjoyed over the last decade [19].

13. References

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