Chapter 8
State of the Art of Roundabout Performance for Promoting of Urban Safety

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8.1 Introduction

Town planning in the nineteenth century favoured large circular places as elements of agreeable city design. With increasing city traffic at the beginning of the twentieth century, these locations were the first where roundabouts (which just means one-way direction of traffic on the circle) were established like Columbus Circle in New York (1905) or Place Etoile in Paris (1907) (Todd 1988 and 1991). This happened in many countries around the world. In consequence, most of the large cities in the twentieth century had their monumental large traffic circles.

However, the traffic rules were quite different in various countries. In Germany, circulating traffic had priority; in other European countries, the entering traffic had the right-of-way with the consequence that under high traffic demand these intersections became gridlocked. In the USA, a variety of rules had been tested over the years. However, in 1966 the UK introduced the "off-site priority rule". This rule means: (a) the circular traffic has priority over the entering vehicles and (b) the vehicles on the inner lanes are privileged in a conflict over vehicles travelling further outside (GOV.UK). This rule is the background of the great success of roundabouts in the UK, and it is the reason for exceptionally high capacities at large roundabouts which can only be observed in the UK.

Meanwhile, outside the UK only part (a) of the "off-site priority rule" is valid in most countries, i.e. traffic on the circular roadway of the roundabout has priority over the approaching traffic. This rule, which has been valid in Germany since ever, has been adopted by the highway code in most countries of the Western Hemisphere during the last three decades.

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The acceptance and application of the valid traffic rules are the key for traffic safety of roundabouts. In the Western countries, the acceptance of these rules, usually, is quite good. Speaking about safety, thus, organization and acceptance of the traffic rules is a significant basic condition for all conclusions about traffic safety.

8.2 Classification of Roundabouts

Also the styles of roundabout design are specific to different countries. The traditional layout of roundabouts in the early twentieth century involved large multi-lane circles. These, however, were not successful regarding safety. Especially two-lane exits emerged as a major source of severe accidents. Thus, in the 1950s and the 1960s the larger circles were no longer favoured in most countries on the European continent or in the USA. Later in 1980, the big success of roundabouts in the UK incited planners and researchers in several European countries to study and experiment with roundabouts.

These studies unveiled unexpected gains in traffic performance and safety, however, only for the single-lane roundabouts. These compact intersections were found to be able to carry up to 25,000 veh/day combined with rather low delays for road users and with the highest potential to prevent accidents. They are still the most favoured type of roundabouts.

Later on, slightly larger—and also smaller—roundabouts were studied in many countries. As a consequence, we now have a whole toolbox of different types of roundabouts. Figure 8.1 tries to illustrate diameters and range of traffic demand for roundabouts for different sizes:

- mini-roundabout with a traversable central island and a diameter between 13 and 23 m
- single-lane roundabouts with a diameter between 26 m (minimum required for European trucks to make a full turn) and 35 m (urban) or 40 m (rural) and only single-lane entries and exits
- semi-two-lane roundabouts with a diameter of 45–60 m, a lane widths of 8–10 m (no lane marking on the circle) and single lane exits but 1- or 2-lane entries
- larger two-lane roundabouts (which are banned, e.g. by German guidelines due to their bad accident experience)
- turbo-roundabouts with 1- or two-lane segments on the circle. The entries and exits may have one or two lanes, where the two-lane solution needs a specific design to avoid undesired lane changes.

This is the kind of classification used in Germany. But in most countries on the European continent, the view on roundabouts is quite similar. It should be emphasized that all rules in design guidelines of the continental European countries are governed by a maximization of traffic safety as the first target. Capacity is only of secondary importance. Less safe roundabout constructions are not treated as state of the art.

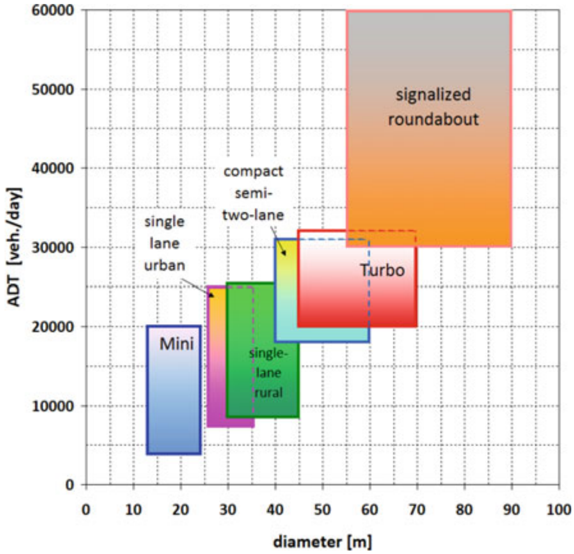

Fig. 8.1 Definition of types of roundabouts by their inscribed circle diameter and their potential range of applicability in terms of average daily traffic (ADT)

In the UK the situation seems to be different. There the design is not so much oriented in lanes. Instead, if capacity makes it necessary, the lanes are flared out near the roundabout to increase capacity. This is supported by the results of capacity investigations (Kimber 1979). This leads to a design which can differ considerably from European continental solutions.

The USA started rather late in the 1990s with experiments in modern roundabouts. They discovered the benefits of this type of intersection, and meanwhile there are many of them. However, as with everything, the roundabouts in the USA are larger than in Europe (Fig. 8.2).

8.3 Some Words Regarding Accident Statistics

An international comparison of traffic safety leads to some complications regarding accident statistics. Already the identification of an accident differs from country to country. Some countries count all accidents (including property damage only) which were reported to the police. Other countries take account of only accidents with personal injuries. Another difference concerns fatalities, e.g. in Germany a fatality is classified as such if the victim dies within 30 days after the accident. Other countries apply completely different definitions.

Also the researchers use different methods of evaluation, e.g. the distance on the approaching arms where accidents are treated as intersection-related varies and is not

Fig. 8.2 Typical examples for an urban single-lane roundabout in Germany

Fig. 8.3 Examples for a mini-roundabout

explained in most of the publications. The most serious way in intersection accident analysis is to define relevant parameters to describe accident risk. The following variables seem to be most characteristic:

$$\text{accident rate} = \frac{\text{number of accidents}}{N_{\mathrm{T}}}$$

$$\text{accident } \cos t \text{ rate} = \frac{\text{damage by accidents}}{N_{\mathrm{T}}}$$

where N_{T} = no. of vehicles travelled through the intersection, usually estimated by the average daily traffic (ADT) damage by accidents: evaluated in currency units.

For the calculation of accident cost rates, the damage caused by accidents must be evaluated in currency units where the figures used are standardized on a national basis (e.g. in Germany: BASt 2014).

These measures of accident occurrence are relative to the exposure to risk as it is represented by the number of vehicles travelling through the intersection. These parameters allow a more meaningful interpretation than absolute figures.

Unfortunately, all the publications on traffic safety apply different methods of analysis. Therefore, a definitive comparison of the results from different investigations is not easy.

8.4 Some Early Findings for Traffic Safety

Starting modern roundabouts in the 1980, studies about safety effects generated by this type of intersection have been performed in many countries. Each of these studies revealed a large potential of safety emerging from modern roundabouts. Among these early studies, we see investigations from France. Gambard (1989) found in a before/after study where conventional intersections had been converted into roundabouts a reduction of fatalities by 88%. Alphand et al. (1991) studied more than 500 roundabouts. 90% of these remained without any personal injury for the year of investigation. Roundabouts experienced only half the number of accidents as signalized intersections. Also two-wheelers had 77% less accidents at roundabouts than at signalized intersections. These analyses are based on a report by CETE (1986). Here we can also find that large roundabouts had a significantly higher accident rate. The results also supported higher safety for circles with a cross-fall (slope) to the outside.

Also Switzerland started experiments with modern roundabouts in the 1980s. Several studies by Buehlmann and Huber (1994), Buehlmann and Spacek (1997) testified the high level of traffic safety at roundabouts. In a before/after study at 113 intersections, most of them in urban environments, he found significant improvements in safety by converting intersections into roundabouts—especially at single-lane roundabouts. Multi-lane roundabouts, however, did also lead to worse safety conditions compared with the previous situation. The most important effect was the

Table 8.1 Reduction in accident rates in Germany

Roundabouts				Conventional intersections			
Size	AR	ACR	MC		AR	ACR	MC
Large	6.6	24.9	3.8	With traffic signal	3.6	21.7	6.5
1-lane	1.2	4.7	3.8	Two-way-stop	1.0	12.0	12.0

Source Brilon and Stuwe (1993)
AR Accident rate in acc./10^6 veh; *ACR* accident cost rate in DM/10^3 veh; *DM* German mark = valid currency until 2002; *MC* mean costs per accident in 10^3 DM/acc.

significant reduction in accident severity. The largest gains in safety were achieved for pedestrians.

Reports on roundabout safety in the Netherlands had been published by van Minnen (1992, 1995a, b). The study included 46 (1990) and 177 (1995) roundabouts—most of them in urban areas. Also here roundabouts turned out to be much safer than other types of intersections. After converting conventional intersections into roundabouts, the number of recorded accidents decreased by 47%, the number of victims by 71%. The biggest reduction was achieved for car passengers (−95%) and pedestrians (−89%), whereas cyclists benefited only by −30%. Accidents were considerably reduced by converting intersections into roundabouts. Similar results were reported by Schoon and van Minnen (1994) on the basis of 201 places which were converted into roundabouts. Here the number of accidents per intersection was cut into half, and the number of injury accidents was reduced by 70%.

Several studies—however with rather small samples—have also been made in Germany. Brilon and Stuwe (1993) report on their studies showing the advantage of single-lane roundabouts. Results from before/after studies are summarized in Table 8.1.

The before/after comparison showed a reduction of accident costs from 34.5 DM/10^3 veh to 5.1 DM/10^3 veh (i.e. −88%) as a consequence of intersection conversions into single-lane roundabouts. This effect is achieved by a strong reduction in the number of severe injuries. These results were a clear indication of an unexpectedly high level of traffic safety at small roundabouts.

Other reports provided very similar results come from Norway (Giaever 1992), Denmark (Jorgensen and Jorgensen 1994), USA (Flannery and Elefteriadou 1999), and Australia (Tudge 1990; Troutbeck 1993). A good international overview on roundabout safety in the earlier times is also given by Jaquemart (1998). Table 8.2 gives an overview of the published effects of roundabout implementation at street junctions from the earlier days obtained from various publications, e.g. also Rodegerdts et al. (2010, pp. 5–16).

Elvik (2003) has reviewed results from 28 roundabout safety studies in a meta-analysis. He concluded that, on average, roundabouts reduce injury accidents by 30–50% and the amount of fatal accidents by 50–70% whereas the results for property-damage-only accidents varied quite a lot. Overall, also this study underlines the significant improvement of traffic safety by roundabouts.

Table 8.2 Rough figures for the reduction of the number of accidents in various countries obtained from earlier publications

	All	Injury
	Crashes	Accidents
Netherlands	−47	−72
Australia	−41 up to −61	−45 up to −87
France		−57 up to −82
USA	−35	−76
Germany	+22	−75

All these former findings of positive safety effects obtained from roundabouts are the basis for the extreme dissemination of modern roundabouts in many countries of the world.

8.5 Current Research Results on Roundabout Safety

The number of roundabouts has exploded in many countries during the last three decades. Reports estimate the numbers in France to be above 30,000, in the UK above 30,000, in the USA 9000 (in 2021, cf. Kittelson 2021), in Denmark 1450 (in 2010; Underlien-Jensen 2013) and in Germany a count in the summer of 2014 revealed 12,500. As a consequence, against this broader background most countries have updated their experiences with modern roundabouts. Among the wide diversity of reports we concentrate only on some characteristic results.

8.5.1 USA

Bill and Khan (2014) report that accident research at 30 roundabouts in Wisconsin over 3–4 years each before and after a conversion of conventional intersections into roundabouts. Although the effects were not always as good as expected the general conclusion was positive, e.g. the total number of crashes increased by 12%. The crash severity, however, did significantly decrease. The number of accidents with personal injuries decreased by 38% and no fatality was reported. The best effects were achieved at unsignalized intersections.

An investigation about roundabout safety on a national platform had been performed by Rodegerdts et al. (2007) which is also documented in the second US roundabout guide (Rodegerdts et al. 2010). Fifty-five sites at different locations in the US had been investigated in a before and after study. The conversion into roundabouts achieved a reduction in the number of all accidents of 35% and for injury

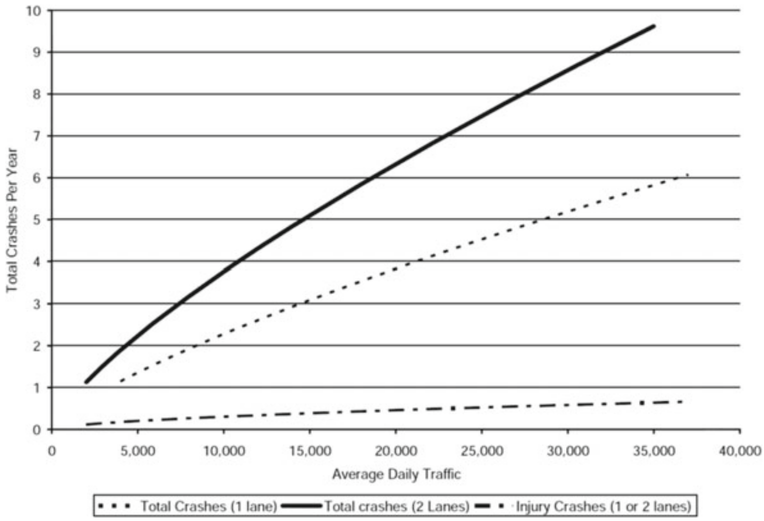

Fig. 8.4 Expected number of crashes per year for one- and two-lane roundabouts (Rodegerdts et al. 2010)

accidents of 77%—which again provides an indication that especially severe accidents are avoided by roundabouts. The study did also demonstrate that the single-lane accidents provide a better level in safety than the two-lane circles (Fig. 8.4).

8.5.2 Denmark

One rather careful investigation on roundabout safety has been performed in Denmark (Underlien-Jensen 2015). He has analysed 332 sites which were converted from conventional intersections into roundabouts during a period from 1995 until 2009. Empirical data were collected for general trends and for "regression to the mean". The number of injury crashes reduced by 47% with a decrease of injuries by 60%. The estimate is that the conversions prevented 20 fatalities. The improvements, regarding all accidents, were better at single-lane roundabouts than at multi-lane circles. Safety effects were the largest at 4-arm intersections, for a large percentage of left-turning traffic, and when the approach speeds were high. However, at 3-arm intersections under urban speed conditions, the accident number did increase. Special attention was directed on bicycles. The number of cycle accidents increased from 113 to 246% when the new roundabout had a cycle lane at the outer margin of the roundabout—a clear indication that this facility is extremely dangerous—this has also been found in other countries several years ago. On the other side, roundabouts with separate cycle paths and no priority to cyclists at the crossings lead to a reduction in the number of accidents by −81%. The study could also demonstrate that the long-term improvement effects were even better than the improvements in the first years. The problem with this study is that all investigated roundabouts were treated the same regardless of whether they were designed in line with the valid guidelines or they suffered from known errors in design (e.g. bicycle lanes).

8.5.3 Germany

The general situation regarding roundabouts in Germany has been described by Brilon (2014). Moreover, recently a rather well-sophisticated accident analysis at roundabouts was published in Germany (Bondzio et al. 2012). The investigation is concentrated on 100 single-lane urban roundabouts which comply with the current design guidelines. These sites were distributed over ten German states in towns and cities of all sizes. The traffic volumes were between 5000 and 25,000 veh/day, 0 to 800 pedestrians/2 h, and 0 to 7000 cycles/day. The research considered accident data from the police records from 2008 until 2010. Figure 8.5 as an example shows a plan from one of the investigated roundabouts with an inscribed diameter of 35 m, 24,000 veh/day, 720 cycles/day, and 120 ped/2 h. The circular roadway consists of a 4.5-m-wide asphalted roadway and an inner 3-m-wide truck apron. Bicycles run on the circular roadway.

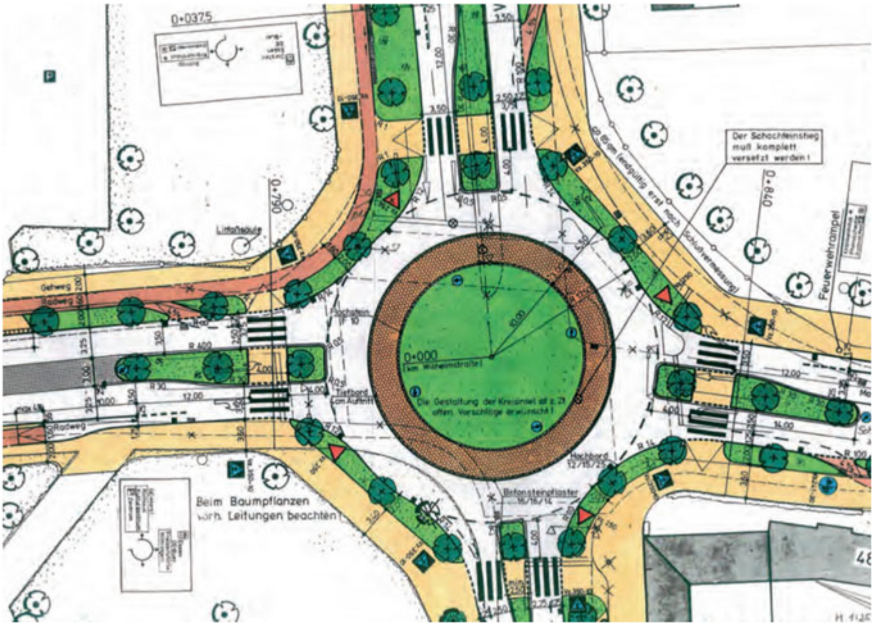

Fig. 8.5 Plan of one of the roundabouts

There was no fatality in the sample, 8 hospitalized injured (5 were pedestrians) and 92 slightly injured persons. Cars were mostly involved in the accidents (80%), cyclists with 10%, and pedestrians only with 1% (see Fig. 8.7). The picture of involvement becomes different if we analyse the traffic involvement of different road users only for accidents with personal injuries. Then we see the higher vulnerability of motor cyclists, bicycle users, and pedestrians. From the rather low involvement of pedestrians, we can obtain the high degree of safety of all roundabouts for pedestrians. Here it should also be noted that of a total of 15 accidents involving pedestrians 5 were severely injured persons and 11 had slight injuries, 9 from 11 accidents on crosswalks happened on zebra crossings (zebra crossing gives an absolute priority to pedestrians).

The average accident cost rate was 6.3 €/1000 veh which is much lower than the 10 €/1000 veh which are treated as a good result for an intersection. Therefore, on average these roundabouts proved to be a very safe solution for an intersection. The accident cost rate as it is distributed from extremely low to rather high values is illustrated in Fig. 8.6. We see that the average of 6.3 included points with an extremely low figure, but also roundabouts with intolerable severe accident occurrence. This picture of a concentration of severe accidents on few sites was even worse when focusing on bicycle accidents. The reasons for these differences have not been analysed.

Looking on the influence of design parameters: In a range from 25 m until 50 m the diameter did not influence the accident risk. However, a number of arms larger than 4 had a negative effect on safety (Fig. 8.7).

Table 8.3 provides a view on the distribution by types of accidents. We see that the most frequent type was a collision of an entering vehicle with a circulation road user (31%). Looking on accident severity, we see, however, the important role of bicycle accidents.

A special focus was set on bicycles at these roundabouts. The designs under test were: (A) cycles mixed with other traffic on the circle (e.g. Fig. 8.5), (B1) bicycle paths with priority to cyclists at the crossings (e.g. Fig. 8.8), (B2) bicycle paths together with pedestrian facilities, (B3) bicycle paths with no priority to cyclists

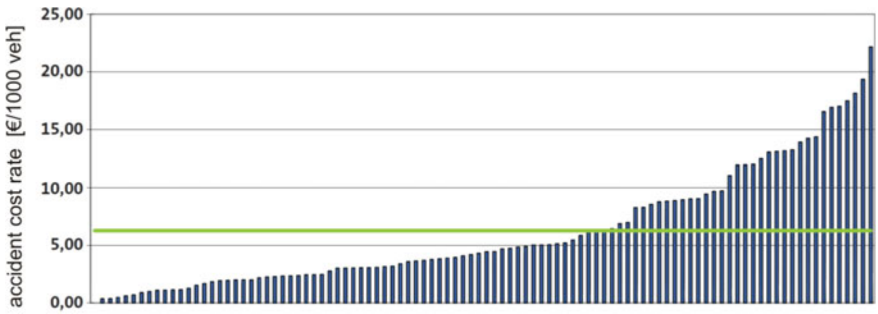

Fig. 8.6 Distribution of accident cost rate over the 100 roundabouts under investigation (Bondzio et al. 2012) (vertical lines: individual values of accident cost rate at the 100 sites in the study; horizontal green line: average)

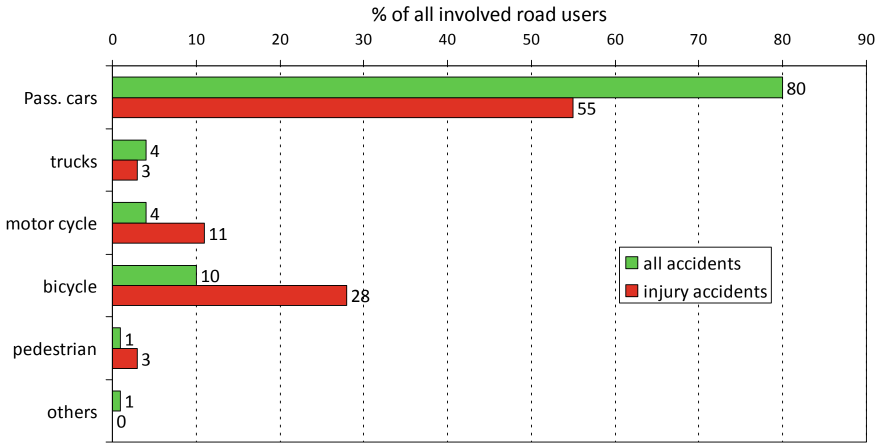

Fig. 8.7 Involvement of different road users in all accidents and in injury accidents (in %)

Table 8.3 Frequency of different types of accidents

	All Accidents	Injury Accidents
Collision of approaching with circulation vehicle	34	31
Single vehicle accident	13	10
Rear end collision on the approach	17	7
Rear end collision on the circle	19	8
Collision of an entering vehicle and a bicycle (on the cycle path crossing) at the entry	7	10
Collision of an existing vehicle and a bicycle (on the cycle path crossing) at the exit	5	15

at the crossings. In Fig. 8.9, we see that the safest solution is to provide separate paths guiding cyclists around the roundabout where the cyclist have to care for the priority of motor vehicles at the crossings. The two solutions with priority to cyclists were associated with a larger accident cost rate. The answer was the same when the exposure of the intersection to cyclists was taken into account. This result is well in line with results from other countries like Denmark (see above).

A comparison with other types of intersections or with prior situations was not a topic in this investigation. It was, however, complimented by an observation of road user behaviour at some of the analysed intersections. Here, among others it was found that at cycle paths (see e.g. Fig. 8.8), the bicyclists up to 50% use the crossings in the wrong direction which imposes a significant risk.

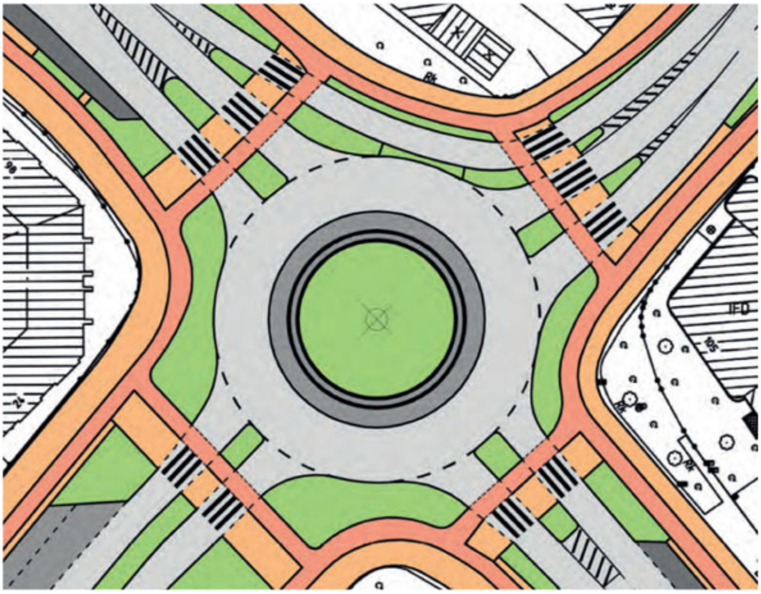

Fig. 8.8 Sketch of a roundabout with cycle paths which cross the entries and exits next to the pedestrian crossings (here with zebra marking). This site also has a bypass lane (on the top of the picture)

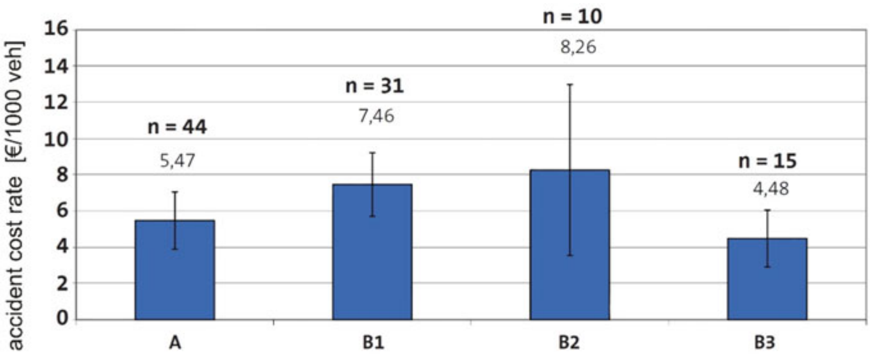

Fig. 8.9 Accident cost rates for the various designs for cyclists (Bondzio et al. 2012; types A, B1, … see text)

8.5.4 Mini Roundabouts

Mini-roundabouts are small circular junctions with a traversable central island (see Fig. 8.3). Small cars, have to drive around the central island, whereas trucks are forced to cross this island with their rear wheels. These types have first been introduced in the

Table 8.4 Effect of the conversion into mini-roundabouts

	Before (conventional intersection)	After (mini roundabout)
Average accident rate (acc./10^6 veh)	0.8	0.4
Average accident cost rate (DM/1000 veh)	29.3	3.5

Table 8.5 Accident cost rates (€/1000 veh) of mini-roundabouts compared to other types of junctions

	Mini roundabout	Unsignalized intersection	Signalized intersection
3 arms	2.02	4.68	6.60
4 arms	5.66	13.39	8.40

UK under the leadership of Frank Blackmore in 1968. Other countries have imitated this example rather late, e.g. Germany started to experiment with this form in 1997 (see Brilon and Bondzio 1999).

The safety of mini roundabouts in Germany has been studied first by Brilon and Bondzio (1999) and recently by Baier et al. (2014). Brilon and Bondzio report on the pioneering (for Germany) experiment of a conversion of 10 intersections into mini-roundabouts. As a result, the accident risk was significantly reduced (see Table 8.4). The accident cost rate was much lower than at a very safe conventional intersection (i.e. ≈10 DM/1000 veh in 1999).

Also the analysis by Baier et al. of 26 mini-roundabouts and 309 conventional intersections confirmed an extraordinary low accident cost rate (see Table 8.5).

Of course, mini-roundabouts are only allowed in urban areas with a general speed limit of 50 km/h. Details of a reasonable design are described in the guidelines (FGSV 2006) and in the report by Baier et al. (2014). The most important aspect is that the central island should consist of a paved circle which must be elevated by 4 or 5 cm above the asphalted circle.

8.5.5 Turbo-Roundabouts

A turbo-roundabout is a kind of circular intersection where the number of lanes on the circle varies between 1 and 2 and where the traffic through the intersection is strictly channelized by lanes (Fig. 8.10). This type does also allow a safe operation of two-lane exits. Usually, such a roundabout has a diameter of 50 or more meters. Application is useful if one or two of the movements have periods with very large traffic volumes. In Germany, traffic guidance is achieved just by lane markings, whereas in the Netherlands vertical lane dividers (similar to kerbs in the middle of

(a)

(b)

Fig. 8.10 Typical exit (**a**) and entry (**b**) of a turbo-roundabout in Germany

the roadway) are in use. Even if these circles are quite space-consuming their capacity is limited to around 35,000 veh/day.

Traffic safety of turbo-roundabouts has recently been investigated by Brilon and Geppert (2015), based on a limited sample size. The accident rate on average was 1.0 acc/10^6 veh, and the accident cost rate was 7.7 €/1000 veh which corresponds to the level of single-lane roundabouts and is better that the risk at conventional intersections.

Therefore, this type of roundabout provides an adequate level of traffic safety and, thus, is a useful instrument of traffic design in urban areas. However, it is not compatible with any kind of bicycle operation which means that for bicycles other kinds of traffic guidance (e.g. bridges) must be applied at the relevant sites.

8.6 Accident Prediction

Accident prediction at roundabouts has first been proposed by Maycock and Hall (1984). Based on the analysis of 84 4-arm at-grade roundabouts, they developed a linear model to predict the number of accidents (frequency of all crashes + pedestrian accidents) based on the entry path curvature, the roundabout diameter, entry width, angle of the approach relative to the circle, and traffic volumes. The equations can primarily be used to compare alternative designs according to the British style of roundabout design.

For the USA, an accident prediction model has been formulated by the NCHRP 572-report (Rodegerdts et al. 2007) which is also mentioned in the US roundabout guide (Rodegerdts et al. 2010; Exhibit 5-19, 5-20). Here the expected number of crashes per year is estimated by an exponential function of the ADT (annual average daily traffic), e.g.

$$\text{crashes/year} = 0.0038 \cdot ADT^{0.749} \quad \text{for a 2-lane 4-arm round about}$$
(see cited literature for other parameters)

Other parts of the model concern accident prediction for each approach. Here the ADTs of the approach, of the circle, and of the exit are of predominant importance. In addition, geometric parameters like entry radius, entry width, diameter, and others are used for accident prediction. These models estimate the number of accidents on the approach, entering-circulating, and exiting-circulating separately. These equations have the potential to compare several alternatives for the geometric design regarding safety. It must, however, be mentioned that the equations have a relatively small empirical background and that they are only based on the US background (e.g. definition of crashes, design style).

8.7 Cyclists at Roundabouts

All investigations underline the fact that cyclists at roundabouts constitute a specific problem. Usually, they also get some improvement in safety by a roundabout. However, these improvements are not as significant for them as they are for the other road users like car passengers or pedestrians. As a consequence, cyclists at roundabouts face the largest risks.

All the studies come to very similar conclusions. They distinguish between the following kinds of bicycle treatment. Moreover, the reports propose the following actions. These points apply only to single lane roundabouts.

- Bicycles in mixed traffic on the circular roadway together with cars: this is a very safe solution for lower traffic volumes. It should be favoured up to a total traffic volume of 15,000 veh/day (Germany, FGSV 2006; Haller et al. 2000) or 8000 veh/day (Netherlands, van Minnen 1995a, b).

- Bicycling lane on the outer margin of the circular roadway. This is the most dangerous solution. It must be absolutely banned (see, e.g., Brilon and Stuwe 1993; Schoon and van Minnen 1994; Daniels et al. 2009; Underlien-Jensen 2013).
- Bicycle paths separated from the roundabout. This is the recommended solution for larger traffic volumes. The crossings of the exits and the entries must be separated from the circle by 4 m, better by 1 car length, i.e. 5 m. The cycle paths should approach the crossings vertical to the direction of the roadway. It is evident that a priority for cyclists at these cross points induces a higher risk than a regulation where cyclist have to yield to motor vehicles (Bondzio et al. 2012; Underlien-Jensen 2013).

These recommendations apply for single-lane roundabouts. At multi-lane roundabouts, cyclists cannot be allowed on the same roadway as motor vehicles. Also bicycle crossings at multi-lane entries—and especially exits—are a significant risk. Thus, multi-lane roundabouts should only be implemented where the occurrence of cyclists can be completely excluded. Tunnels or bridges for cyclists are a must at these larger roundabouts.

For the mini-roundabouts, separate cycle facilities are not recommended. Here, if cyclists cannot be operated on the roundabout itself, then a mini is not a good solution for the relevant situation.

8.8 Conclusion

The paper tries to provide an overview about research results on safety at roundabouts with a focus on urban intersections. Even if it is written from a German perspective, it includes results from several other countries.

As a conclusion from all studies, there is no doubt that roundabouts are the safest type of intersection. Especially the single-lane roundabouts reveal the highest level of safety. Also mini-roundabouts have an extraordinary good safety record. Turbo-roundabouts—regarding safety—are on the same level as the single-laned. This high degree of traffic safety depends on the speed-reducing design of the whole intersection.

In comparison to conventional types of intersections like signalized or two-way-stop intersections, the car occupants and the pedestrians enjoy the highest gains from roundabout safety. On the other hand, bicyclists can become a problem for traffic safety at roundabouts. However, also cyclists can be accommodated with a sufficient degree of safety—but only if the requirements for design are strictly obeyed.

It should be emphasized that the high degree of safety is coherent to road user discipline and to the acceptance of the existing traffic rules. This acceptance should be strengthened by an adequate intersection design. Therefore, the favourable safety effects of roundabouts can only be achieved if the rules for modern roundabout design, as they are documented in many national design guidelines, are strictly applied.

It must also be ascertained that roundabouts are not the optimal solution in each situation. Following the continental European guidelines, there are limits in capacity (cf. Fig. 8.1) which in detail have to be figured out for each single case by adequate capacity models (see, e.g., Brilon 2014). Beyond these limits, signalized intersections remain to be useful solutions to manage traffic at urban intersections with a very large traffic demand. Also due to limited space, alternatives to roundabouts must be applied in many cases.

Overall, it can clearly be stated that the adequate use of roundabouts may be a real boon for traffic safety—especially in urban areas.

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