

MODERN TYPES OF ROUNDABOUTS – TRENDS AND FUTURE EXPECTATIONS

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Abstract: Over the recent decades, roundabouts have been increasingly used when building new at-grade intersections and up-grade junctions all over the world, and also when rebuilding existing intersections. Modern roundabouts exist in all European countries and mainly worldwide, so we can say that today modern roundabouts are a world phenomenon.

No uniform guidelines exist in Europe for the geometric designing of roundabouts as specific circumstances (local customs, habits, traffic cultures ...) differ from country to country. Certain solutions that are safe in one country could be dangerous in another. Consequently, most countries have their own guidelines for the geometric designs of roundabouts that are, as far as possible, adapted to their circumstances in these countries and are therefore more acceptable within their surroundings.

Today, after many years of experience, there are different ideas about the "ideal roundabout", with some consensus on the crucial effect of rules how to negotiate intersections. There are several different types of roundabouts worldwide today, called the alternative types of roundabouts. Some of them are already in frequent use all over the world (hamburger, dumb-bell ...), and some of them are recent and have only been implemented within certain countries (turbo roundabout, dog-bone...) or are still at the development phases (turbo-square, flower, target, with segregated left-turn slip lanes...). 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. Therefore, it was decided that it would be useful to collate, in one article, some of the alternative types that are already in frequent use today in some countries and some of them that are "still coming".

1. INTRODUCTION

Analyse of literature show that "modern roundabouts" exist within all European countries, as well as in more than 60 countries elsewhere in the world, so we could say that they are a world phenomenon. Today in some European countries instead of the term "modern roundabout" they use "standard roundabout", which is understandable as the "modern" has already been a long time "standard", especially in countries within which "modern roundabouts" have been implemented over several decades.

Today, after many years of experience regarding roundabouts, there are still different ideas about the "ideal roundabout" with little consensus about the crucial effects of rules on how to negotiate an intersection. It needs to be stressed that the roundabout intersection has been "at the development phase" since 1902, and this development is still in progress. One of the results of this progress is the several types of roundabouts in worldwide usage today, called the "alternative types of roundabouts". Some of them are already in frequent use all over the world (hamburger, dumb-bell ...), and some of them are recent and have only been implemented within certain countries (turbo, dog-bone, compact semi-two-lane circle ...) or are still at the development phase (turbo-square, flower, target, with segregated left-turn slip-lanes...). Alternative types of roundabouts typically differ from "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 regarding actual specific circumstances. Usually, these disadvantages are highlighted by low-levels of traffic safety or capacities.

Some of them are presented in more detail in the continuation. However, it needs to be pointed out that roundabouts in different countries differ in their layouts. Certain solutions that would be safe in one country could be dangerous in another. So, there is no "only one truth" in the case of roundabouts.

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2. ALTERNATIVE TYPES OF ROUNDABOUTS THAT ARE ALREADY IN FREQUENT USE

It can be said that some of the alternative types of roundabouts today are already well-known and are in frequent use all over the world. Some of them are roundabouts with transitional central islands ("hamburger"), and also dumb-bell roundabouts.

The hamburger roundabout (Fig. 1) is a type of roundabout with a straight-through section of carriageway regarding of the major routes. It has a split central island with a splitter island between the two halves of the central island. The width of the intermediate splitter island is equal to the width of one heavy vehicle or bus (or more, but not less), with an inscribed circular diameter of about 60 m or more.

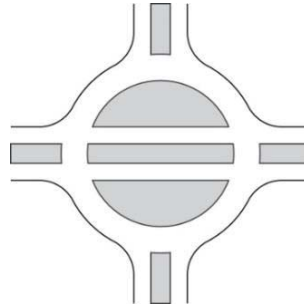


Fig. 1. Hamburger roundabout; sketch

It could be constructed as a one- or two-level roundabout. There are few variations of this type of one-level solution. One of them, which is in frequent use in the Canary Islands, also includes splitter islands on approaches and for right turners (Fig. 2).

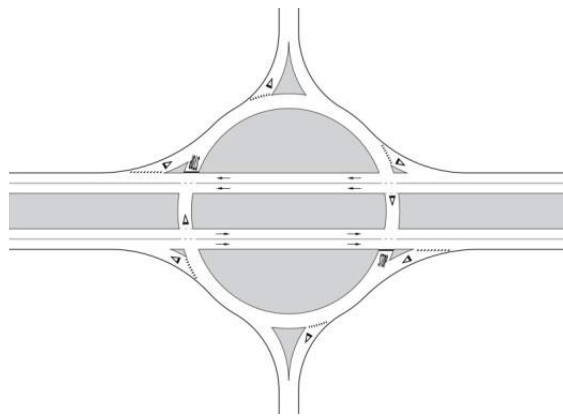


Fig. 2. Hamburger roundabout with splitter islands for right turners; sketch

The dumb-bell (Fig. 3) is a "hybrid" combining the diamond interchange and the roundabout, which makes it a very close relative of both, as one is a direct descendant of the other. In short, it combines the capacity benefits of a (usually) one-lane roundabout with the smaller footprint and single bridge of a standard diamond junction. It can generally handle traffic with fewer approach lanes than other intersection types. This type of roundabout reduces construction costs by eliminating the need for a wider bridge (diamond - minimum three (usually four lanes), dumb-bell - just two lanes), and less space. As a rule, drivers within a "standard diamond interchange" driving at high speeds and accordingly, approaching from ramps might be difficult. At a dumb-bell roundabout, speeds are significantly lower, as two roundabouts are a measure for traffic calming. A dumb-bell roundabout provides the possibility of completely eliminating the option of driving in the wrong direction, using the adequate deflection of a ramp. This configuration also allows for easy U-turns.

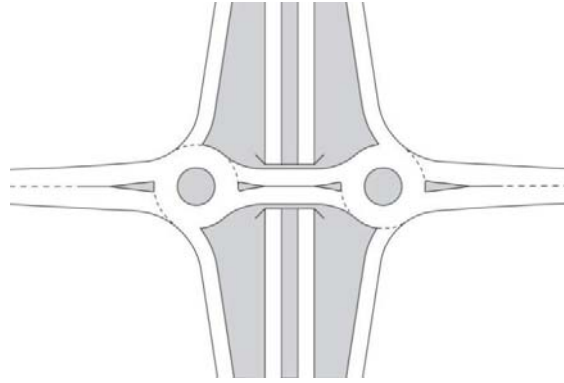


Fig. 3. Dumb-bell roundabout; sketch

This type of roundabout is very common in different European countries and elsewhere. It seems that the more numerous dumb-bell roundabouts are located on the Canary Islands, where virtually all ramp intersections are constructed as a dumb-bell roundabout.

3. RECENT ALTERNATIVE TYPES OF ROUNDABOUTS

Some of the alternative types of roundabouts are recent and have only been implemented within certain countries. These are e.g. turbo roundabout, dog-bone, and compact semi-two-lane roundabout.

There is no doubt that dr. Lambertus Fortuijn, a researcher from the University of Delft, the Netherlands, is the "father" of the turbo roundabout (Fig. 4). And there is also no doubt that this type of roundabout has been a more popular alternative type of roundabout over the last decade all over Europe. It seems the turbo roundabout is a kind of "fashion" nowadays.

The first turbo roundabouts were installed at the end of the 90's in The Netherlands; by the end of 2007 there were seventy turbo roundabouts [2], whilst at the end of 2013 there were more than two hundred turbo roundabouts in the Netherlands [3]. The idea was very rapidly (just over a few years) transposed into several European countries such as Slovenia [4] (Fig. 5), Germany [5], Denmark, and Czech Republic [6], as also Hungary, the FYR of Macedonia and also into the USA. According to a web page of Dirk de Baan, at the moment there are 320 turbo-roundabouts all over the world.

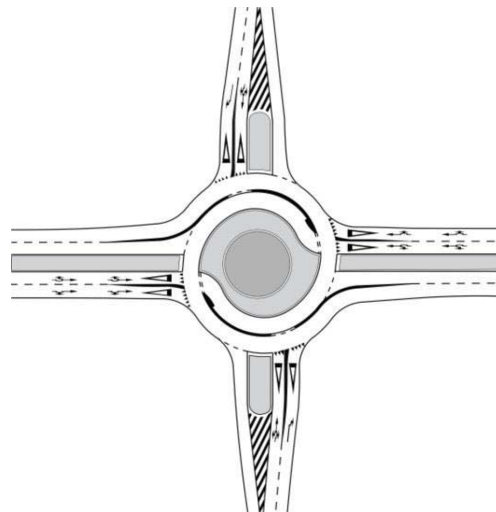


Fig. 4. Typical layout of turbo roundabout [1]

Experience provide good insight into the effects on road safety, capacity, and experience by road users in some countries but also less satisfactory experience in other countries, because of the already known reason: *Road marking (without divided curbs) does not prevent the change of traffic lanes at the turbo roundabout!*

It seems that today two groups of countries exist that have turbo roundabouts: countries having turbo-roundabouts with (The Netherlands, Slovenia, Hungary, and the Former Yugoslav Republic of Macedonia), and without divided curbs - with only road markings (Germany, Denmark, Czech Republic, and USA).



Fig. 5. Typical Slovenian turbo-roundabout (with divided curbs)

The dog-bone roundabout (Fig. 6) (due to its aerial resemblance to a toy dog bone), reputedly invented in The Netherlands, is a variation of the dumb-bell roundabout. The dog-bone is, like a dumb-bell, also a "hybrid" combining the diamond interchange and the roundabout. Dog-bone occurs when the roundabouts do not form a complete circle but instead have a "raindrop" or "teardrop" shape. These two roundabouts are fused together, forming a single "squashed" roundabout. The interior of the roundabout is closed, and parallel roadways are used between the ramp terminals. At a dog-bone roundabout speeds are significantly lower than at the standard diamond interchange, as two roundabouts are a measure for traffic calming. At a "standard diamond interchange" drivers might make a mistake and turn towards the wrong direction at the ramp, and at a dog-bone roundabout, such an option is significantly lower.

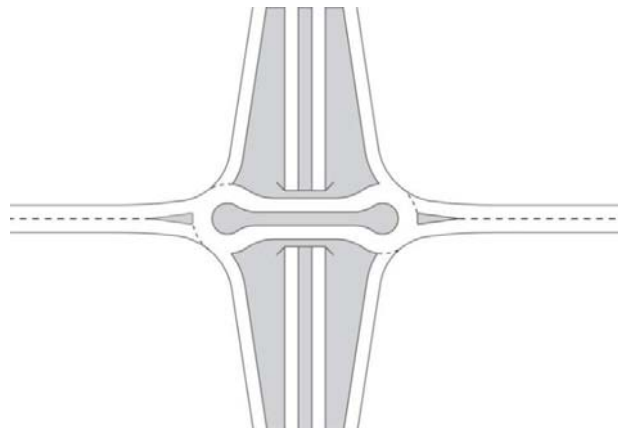


Fig. 6. Dog-bone roundabout; sketch

This configuration reduces conflicts between vehicles entering the dog-bone roundabouts from the ramps, increasing the roundabouts' capacities, and reducing queuing and delays, compared with the dumb-bell roundabout. A dog-bone roundabout, like the dumb-bell, even provides the possibility for completely eliminating the option of driving in the wrong direction, using adequate deflection of a ramp. A dog-bone roundabout can generally handle traffic with fewer approach lanes than other intersection types. Direct U-turns are impossible, although movement can be made by circulating around both roundabouts. This type of roundabout is slightly more expensive than the dumb-bell roundabout because three lanes (instead of

two lanes in the case of the dumb-bell) on a bridge, but still cheaper than the diamond interchange. It could be constructed by two "standard" one-lane roundabouts or by two turbo-roundabouts. This type of roundabout has started to be very common in different European countries, especially in The Netherlands and the United Kingdom, and the idea is very rapidly transposing also into other European countries.

As is stated by Brilon [5], the compact semi-two-lane roundabout (Fig. 7) is already the state-of-the-art solution in Germany, but it seems to be only there. The design of compact semi-two-lane roundabouts is similar to the concept of single-lane roundabouts. The main difference is the width of the circular lane. It is wide enough for passenger cars to drive side by side, if required. However, the circle lane has no lane marking. Large trucks and busses are forced to use the whole width of the circulatory roadway when making their way through the intersection [4]. Their outer diameter is from 40 to 60 m, circulatory carriageway width is from 8 to 10 m (and is without lane marking - to prevent drivers from overtaking), and it could be one- or two-lane entries, according to traffic volumes.

As reported by Brilon [5], this type of design does not aim for the avoidance of vehicle path overlap. Different from the US approach, there is not the concept of the natural "trajectory" of vehicles within the German sophistication. The basic consideration is: The geometry of the roadway must provide space for all vehicles to drive through the intersection! If however, several vehicles compete for space then the drivers must take care of each other. Thus, at a compact two-lane roundabout a large vehicle can claim the whole width of the circular roadway. Car drivers must avoid interfering with them. Also the parallel driving of cars is unusual. The wider space, however, allows for some kind of staggered driving. This style of design is aiming for an improved safety since it requires lower speeds as well as mutual attention and care of users [5].



Fig. 7. Typical German compact semi-two-lane roundabout; Oberhausen (source: Werner Brilon)

4. ALTERNATIVE TYPES OF ROUNDABOUTS AT DEVELOPMENT PHASES

As mentioned before, the roundabout intersection has been "at the development phase" since 1902, and this development is still in progress.

Today, after many years of experience, there are different ideas about the "ideal roundabout", with only slight consensus on the crucial effects on the rules of how to negotiate an intersection. The development of design rules and advice from an extensive body of research should allow civil and traffic engineers to produce more effective forms of roundabout.

Some of them that are at the development phase at the moment are: turbo-square, flower-roundabout, target-roundabout, and a roundabout with segregated left-turn slip-lanes ("four bridges roundabout").

In 2000, the Province of Zuid-Holland introduced the signalized multi-lane "turbo-square" (in original "turbo-plein") as a new intersection layout and has installed two of them [7] near Delft. The turbo-square (Fig. 8) is an at-level intersection solution with a large traffic throughput capacity, based on the principle of a turbo roundabout with signalized traffic control. The idea is that it fulfils the pre-conditions of a roundabout, namely the approach lanes are radially connected (this reduces the entering speed) and the traffic on the square has the right of way. Besides, at a turbo-square there is sufficient space at the roundabout segments to buffer the left-turning and through-going traffic [8].



Fig. 8. Turbo-square [8]

The three alternative types of roundabouts in the continuation of this article were invented at the Centre for Road Infrastructure at the Faculty of Civil Engineering, University of Maribor, and are still at the development phase.

A roundabout with "depressed" lanes for right turning (slip-lanes) - in short a "flower roundabout" [9] was invented as a solution for achieving a high level of traffic safety on existing, less safe two-lane roundabouts. Therefore, bypasses (slip-lanes) are not a novelty; they are in frequent use all over the world. What is indicated as a novelty is that it is possible to adjust the existing "standard" (less safe) two-lane roundabout into a (safer) flower roundabout without any moving of the outer road curbs. One of the basic characteristics of the flower roundabout is the same as for the turbo roundabout – physically separated traffic lanes within the circulatory carriageway. This means that the inner circulatory carriageway is only used by vehicles that drive straight through the roundabout (180°), turn for three quarters of a circle (270°) or turn semi-circular (360°). By physically separating the right turning traffic flow, we get a one-lane roundabout where (unlike in the turbo roundabout) there are no crossing conflict points; however, there are also no weaving conflict points. They transfer from the circulatory carriageway (on the curve) to the road section before the roundabout (usually a straight line), which is a safer solution.

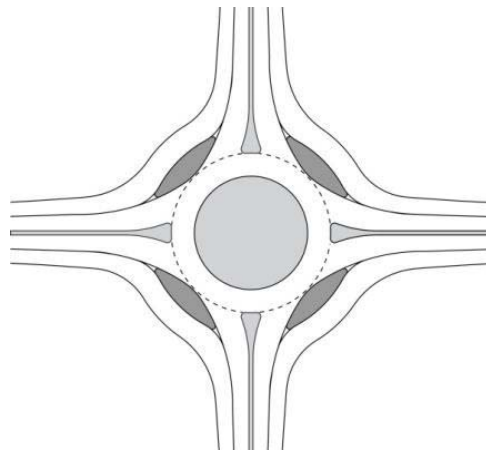


Fig. 9. Typical layout of a flower roundabout; sketch

The "target roundabout" [10] is designed as a two one-lane roundabout with different outer diameters, located on dual levels (Fig. 10), and all right-hand turners on both roundabouts have their own, separate right-hand turn bypass lanes.

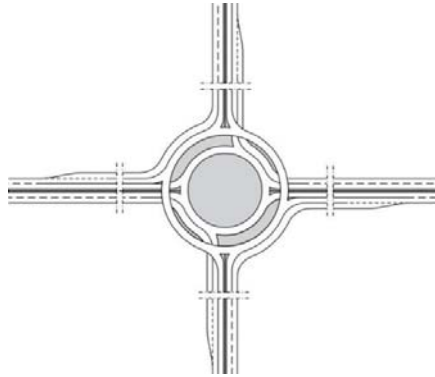


Fig. 10. Typical layout of a target-roundabout; sketch

Dual one lane roundabouts on two levels allow for driving from all directions to all directions, and this roundabout type also "forgives errors": if a driver mistakenly stays in the left-hand lane at the entrance, as it is still possible to turn right at the next exit (different to the turbo roundabout). By physically separating the right-hand turning traffic flow, a one-lane roundabout is obtained, where (unlike in the case of the turbo roundabout) there are no crossing conflict spots; however (unlike in the case of the normal two-lane roundabout), there are also no weaving conflict spots. Any possible weaving conflict spots when transferring from the circulatory carriageway 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. The target roundabout is useful in suburban areas, where we have plenty of space, and two - level interchanges ("diamond", "diverging diamond", "cloverleaf" interchange, dog-bone and dumb-bell) are possible solutions. However, this solution is also acceptable in urban areas because of its low dimensions.

A roundabout with segregated left-turn slip-lanes on the major roads – the "four bridges roundabout" (Fig. 11) is designed as a large one-lane roundabout on one level, and both left-hand turners on the major roads have their own, separate left-hand turn bypass lanes, located on another, lower level. Left-hand turners are located as on standard intersection – at the left lane on the approach.

By physically separating the left-hand turning traffic flow on the major road, we get a one-lane roundabout, where (unlike at the turbo roundabout) there are no crossing conflict spots; however (unlike at the "standard" two-lane roundabout) there are also no weaving conflict points. On the four bridges roundabout there are just 6 merging, and 6 diverging conflict spots.

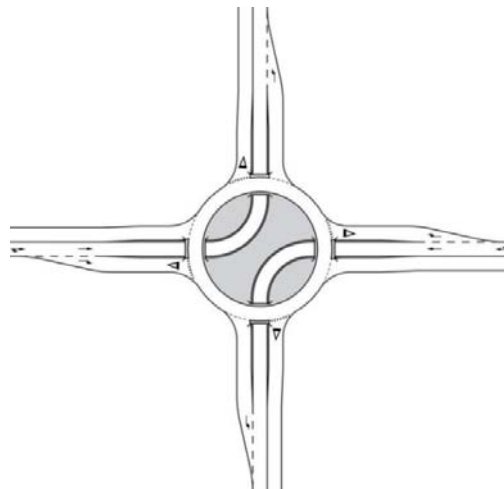


Fig. 11. Roundabout with segregated left-turn slip-lanes on the major road – "four bridges roundabout"; sketch

5. CONCLUSION

In many European countries (Germany, The Netherlands, France, Switzerland, Slovenia ...), and especially in Great Britain, research into the various aspects and various types of roundabouts as useful types of road junctions has spanned many decades. During this long period the numbers of vehicles, their sizes and speeds and in particular their acceleration capabilities, have radically changed. The same situation also exists regarding drivers' experiences and their expectations of the highway infrastructure. Also, with increased traffic there may be more concern about matters of public safety and liability. These changes have had a strong influence on the evolution of modern roundabouts, especially over the last two decades. There is now a good level of understanding regarding the requirements for capacity and safety at roundabouts. The major elements of predictive design geometry have been dealt with by research into empirical formulae, micro simulations, and by some case studies (pilot projects) in real life, and these have been further developed and refined over the last two decades.

In Europe (the same applies for the rest of the world), different countries are at different stages of development concerning roundabouts. If we disregard the UK (which has always traditionally been at the top), over the past two decades there has been intensive roundabout developments in some other European countries (Austria, Slovenia, Croatia, Czech Republic, the Former Yugoslav Republic of Macedonia ...) besides France, Netherlands and Germany. At the moment there is an intensive roundabout development in Italy and Lithuania as well. As mentioned before different countries are at different stages of roundabouts' development. But, this is perfectly in order because roundabouts in each country develop according what is acceptable for their own particular environments – end users. However, it can be noticed that the biggest progress in the field of roundabout developments has been in the USA. A European observer might think that roundabouts in the USA have simply "exploded" lately.

At the moment, several research aspects are running on the development on different layouts of roundabouts for different circumstances or problems. The benefits of maximum success from research can possibly be estimated, but it should be obvious that any expectation of future benefits from a particular item of research, as sometimes implied in funding requirements, cannot be guaranteed.

Disappointing results must sometimes be expected and negative results also have value!

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