Roundabouts in Germany: State of the Art

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Traditional Roundabout

Münster / Westfalia
FGSV = private non-profit organization which develops and edits all standards for road traffic and highway construction

Cologne, Germany

Traffic rules

- 1st mentioning of roundabouts in the German highway code: 1953
  - priority to the traffic in the circle

- England: offside priority rule 1966
  - priority to the traffic in the circle
  - on the circle: priority for vehicles on the inner lanes

- Vienna-convention 1968
  - unified regulations for traffic rules and signs in Europe
  - no relative priority between vehicles on the circle;

  in practice: right before left, i.e. vehicles on the outside have priority (contrary to the British rules)
Types of roundabouts - according to FGSV 2006

- Mini-Roundabout
- Single-lane Roundabout
- 2-lane compact Roundabout
- Signalized Roundabout

Types of roundabouts - classified by size and daily capacity

- 1-lane urban
- 1-lane rural
- 2-lane compact
- Large 2-lane
Large multilane roundabouts

Europaplatz Aachen

Mini - Roundabouts

[Graph showing different types of roundabouts based on ADT and diameter]
Mini - Roundabouts

- Diameter: 13 – 22 m
- Traversable island: 4 cm curbs required
- Unexpected large capacity ($\Rightarrow \approx 20000$ veh/d)
- Very safe
- Well working, only urban

- 4.5 m wide asphalted ring
Rural Mini – Roundabouts?

Rural Mini-Roundabouts:

Some experiments
(4 locations)

→ not recommended
Standard = single-lane Roundabout: typical urban design

Standard = single-lane Roundabout: typical rural design
Single-lane Roundabout

**Characteristic design elements**
- urban and rural
- Diameter: 26 - 45 m
- circle width: 6 - 8 m
- circle crossfall with 2.5 % to the outside
- central apron
  - with min. curb height: 4 cm
- single lane entries + exits
- no flaring of entries
- entries as perpendicular as possible
- entry curb radius: 10-14 m (urban) 14-16m (rural)
- exit curb radius: 12-16 m (urban) 14-16m (rural)

Single-lane Roundabout: Design
• central apron
  with min. curb height: 4 cm ~ 1 inch
  (only urban and with small diameter)

Main characteristics:
• safest type of all intersections
• capacity up to 25 000 veh./day
**Single-lane Roundabout: Pedestrians**

**Pedestrians:**
- Pedestrians enjoy short or no delays and a high level of safety
- Zebra-Crossing as the standard solution

**Single-lane Roundabout: Pedestrians**

- Zebra-Crossings
Single-lane Roundabout: Pedestrians

Pedestrians:
- Also without Zebra-Crossing
  pedestrians have no problems

Single-lane Roundabout: Bicycles

Bicycles:
- Can be guided through the roundabout together with cars
  up to 15 000 veh/day (urban)
**Single-lane Roundabout: Bicycles**

**Bicycles:**
- Can be guided through the roundabout together with cars up to 15,000 veh/day (urban)

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**Bicycles at any type of roundabout**

Never guide cyclists on a cycle track through the roundabout very dangerous!
Bicycles:
A useful solution is also established by separated cycle tracks

- Separation of crossings from the circle by 5 m
- Urban: priority for cyclists

Separated cycle tracks ➔ “ghostdriver” cyclists
**Single-lane Roundabout: Bicycles**

**Bicycles:**
- Separate cycle tracks: Separation of crossing from the circle by 5 m

**Rural:** no priority for cyclists
**Single-lane Roundabout: Bicycles**

**Bicycles:**
- Separate cycle tracks: Separation of crossing from the circle by 5 m
- **Urban:** with priority for cyclists
- **Rural:** no priority for cyclists

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**Bypass lanes**

**Bypass = direct right turning lanes**
Bypass lanes

- A bypass is a good solution to increase capacity
- Separation from the circle by curbs and islands (not just road markings)

- Acceleration lane (no acute angled entries)

Compact semi-2-lane Roundabout

[Bar chart showing ADT vs diameter for different types of roundabouts: mini, 1-lane urban, 1-lane rural, 2-lane compact, large 2-lane]
Compact semi-2-lane Roundabout
Compact semi-2-lane Roundabout

To be applied:
• No or few pedestrians and cyclists
• Therefore: mainly rural or peripheral urban

Design rules:
• Circular roadway 8 – 10 m wide
• No lane markings in the circle
• Diameter 40 – 60 m
• No cyclists admitted to the circle
• Only 1-lane exits
• 2-lane entries, only where required
• No priorities for pedestrians or cyclists (no Zebra!)

Turbo-Roundabout

What is a Turbo-Roundabout?

Roundabout with
• a variable number of lanes
• without lane changes on the circle
What is a Turbo-Roundabout?

Typical:
no driver must or should change lanes within the circle (except for turning, which is not encouraged)
Turbo-roundabout Netherlands

Netherlands

Characteristics:
• narrow curvature
• curbs in the middle of the roadway on the circle and in the approaches

Problems with application in Germany:
• curbs impede snow removal for winter maintenance
• risk for motor cyclists

⇒ no curbs on the roadway in Germany
Turbo-Roundabout in Baden-Baden (since 2006)

Utilisation of Entry Lanes

<table>
<thead>
<tr>
<th></th>
<th>left lane</th>
<th>right lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>24 – 40 %</td>
<td>60 - 76 %</td>
</tr>
<tr>
<td>Exit</td>
<td>23 – 40 %</td>
<td>60 - 77 %</td>
</tr>
</tbody>
</table>
Utilisation of Entry Lanes

Traffic volume on the entry
[pcu/h]

Traffic volume per lane [pcu/h]

Observation of Lane Marking
More Turbo-Roundabouts in Germany

Offenburg

More Turbo-Roundabouts in Germany

Typical design
Accident cost rates (UKR in €/1000 veh)

![Bar graph showing accident cost rates for different types of roads](image)

- Mini-Roundabout
- Single lane urban
- Single lane rural
- 2-lane, no marking

\[ G = 3600 \cdot \left(1 - \frac{t_{\text{min}} \cdot q_c}{n_k \cdot 3600}\right) \cdot \frac{n_z}{t_f} \cdot e^{-\frac{q_c}{3600} \left(\frac{t_f}{2} - t_{\text{min}}\right)} \]

**G** = entry capacity [pcu/h]
**q_c** = traffic volume on the circle [pcu/h]
**n_k** = no. of lanes in the circle [-]
**n_z** = no. of lanes in the entry [-]
**t_c** = critical gap [s]
**t_f** = follow-up time [s]
**t_{\text{min}}** = minimum gap in the circle [s]

**HBS 2001**

**Empirical Regression method**

- \[ G = A - B \cdot q_c \]
- \[ G = C \cdot e^{-D \cdot q_c} \]
**Capacity: Mini & 1-lane**

\[
G = 3600 \cdot \left(1 - \frac{t_{\text{min}} \cdot q_k}{n_k \cdot 3600}\right)^{n_e} \cdot n_e \cdot q_e \cdot e^{-\frac{q_e}{3600} \left(t_f - t_{\text{min}}\right)}
\]

**Critical Gap Theory**

(with parameters estimated by regression)

**G** = capacity of an entry [pcu/h]

<table>
<thead>
<tr>
<th></th>
<th>(n_e)</th>
<th>(n_k)</th>
<th>(t_c)</th>
<th>(t_f)</th>
<th>(t_{\text{min}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini</td>
<td>1</td>
<td>1</td>
<td>(t_c = 4.9 - \frac{0.4}{13} \cdot d)</td>
<td>(t_f = 3.1 - \frac{0.1}{13} \cdot d)</td>
<td>(t_{\text{min}} = 3.9 - \frac{0.9}{13} \cdot d)</td>
</tr>
<tr>
<td>compact 1-lane</td>
<td>1</td>
<td>1</td>
<td>(t_c = \frac{1}{14} \cdot (52.2 + 0.2 \cdot d))</td>
<td>(t_f = \frac{1}{14} \cdot (51 - 0.4 \cdot d))</td>
<td>(t_{\text{min}} = 6 - 0.15 \cdot d)</td>
</tr>
</tbody>
</table>

\(t_c\) = critical headway [s]
\(t_f\) = follow-up time [s]
\(t_{\text{min}}\) = minimum headway on the circle [s]
\(d\) = diameter [m]

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**Capacity: 2-lane**

\[
G = C \cdot e^{-D \cdot q_c}
\]

**Empirical regression Theory**

<table>
<thead>
<tr>
<th></th>
<th>(n_e)</th>
<th>(n_k)</th>
<th>(q_{e,\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>compact 2-lane 40 ≤ (d) ≤ 60 m</td>
<td>1</td>
<td>2</td>
<td>(1440 \cdot e^{-\frac{q_k}{1180}})</td>
</tr>
<tr>
<td>compact 2-lane 40 ≤ (d) ≤ 60 m</td>
<td>2</td>
<td>2</td>
<td>(1642 \cdot e^{-\frac{q_k}{1180}})</td>
</tr>
<tr>
<td>large 2-lane (d \gg 60) m</td>
<td>2</td>
<td>2</td>
<td>(1926 \cdot e^{-\frac{q_k}{1405}})</td>
</tr>
</tbody>
</table>
Capacity:

Traffic volume on the circle [pcu/h]

Entry capacity [pcu/h]

- Mini 13 m
- Mini 18 m
- 1/1 26 m
- 1/1 30 m
- 1/2 40 m
- 2/2 60 m
- 2/2 large (not recommended)
- 1/2 & 2/2 - compact
- 1/1 (30 m)

Capacity: Software

KREISEL 7.1
(German English Italian)

Models from
USA
Germany
UK
France
Swiss
Austria
...

www.bps-verkehr.de
### Capacity:

<table>
<thead>
<tr>
<th>No. of lanes Entry / circle :</th>
<th>1/1 compact 2/2</th>
<th>large 2/2</th>
<th>With signals 2/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No calculations required →</td>
<td>15 000</td>
<td>16 000</td>
<td>20 000</td>
</tr>
<tr>
<td>Maximum capacity →</td>
<td>25 000</td>
<td>32 000</td>
<td>35 000 - 40 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 000 - 60 000</td>
</tr>
</tbody>
</table>

veh/day

### General remarks

Roundabout and Trams: only with traffic signals
• Roundabout is always circular (not oval)

• No dangerous obstacles on the central island (like trees, monuments, walls, high kerbs)

• Visibility during darkness may be a problem
• Urban: always illuminated
• Rural: reflecting chevrons

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• Landscaping and architectural design is important for public acceptance

Leinfelden near Stuttgart
General remarks

- Landscaping and architectural design is important for public acceptance

Bad Herrenalb near Karlsruhe

Curiosities:

- Gasoline station in the center of a roundabout

Singen near Konstanz
### General aspects:

- Roundabouts cause less energy consumption and emissions
- Roundabout reduces noise emission by 3 – 5% (compared to a signal)
- Roundabout is cheaper than a traffic signal
- Roundabouts are highly appreciated by citizens and politicians

### Conclusions

- **single-lane roundabouts** are among the safest types of all kinds of intersections
- design should be speed-reducing
- capacity is unexpectedly large - but limited
- **single-lane roundabouts** are a very favorable type of intersection under all possible aspects

- **larger roundabouts** are treated with care in Germany
- compact-2-lane can be recommended
- larger than the compact 2-lanes are not favored due to safety reasons
- 2-lane exits are banned
- cyclists are banned on multilane roundabouts

- **Turbo-Roundabouts** combine high safety standards with larger capacities

- larger **signalized** roundabouts can be a useful solution under rather specific circumstances